Apache Cassandra™ 1.2

Documentation

December 13, 2013

Contents

What's new

Key features

Cassandra 1.2 introduced many improvements, which are described briefly in this section.

- Cassandra 1.2.2 and later support CQL3-based implementations of IAuthenticator and IAuthorizer for use with these security features, which were introduced a little earlier:
  - Internal authentication based on Cassandra-controlled login accounts and passwords.
  - Object permission management using internal authorization to grant or revoke permissions for accessing Cassandra data through the familiar relational database GRANT/REVOKE paradigm.
  - Client-to-node-encryption that protects data in flight from client machines to a database cluster was also released in Cassandra 1.2.
- Virtual nodes

  Prior to this release, Cassandra assigned one token per node, and each node owned exactly one contiguous range within the cluster. Virtual nodes (vnodes) change this paradigm from one token and range per node to many tokens per node. This allows each node to own a large number of small ranges distributed throughout the ring, which has a number of important advantages.
- The shuffle tool upgrades a cluster to use vnodes.
- Murmur3Partitioner

  This new default partitioner provides faster hashing and improved performance.
- Faster startup times

  The release provides faster startup/bootup times for each node in a cluster, with internal tests performed at DataStax showing up to 80% less time needed to start primary indexes. The startup reductions were realized through more efficient sampling and loading of indexes into memory caches. The index load time is improved dramatically by eliminating the need to scan the partition index.
- Improved handling of disk failures

  In previous versions, a single unavailable disk had the potential to make the whole node unresponsive (while still technically alive and part of the cluster). Memtables were not flushed and the node eventually ran out of memory. If the disk contained the commitlog, data could no longer be appended to the commitlog. Thus, the recommended configuration was to deploy Cassandra on top of RAID 10, but this resulted in using 50% more disk space. New disk management solves these problems and eliminates the need for RAID as described in the hardware recommendations.
- Multiple independent leveled compactions

  Increases the performance of leveled compaction. Cassandra's leveled compaction strategy creates data files of a fixed, relatively small size that are grouped into levels.
- Configurable and more frequent tombstone eviction

  Tombstones are evicted more often and automatically in Cassandra 1.2 and are easier to manage. Configuring tombstone eviction instead of manually performing compaction can save users time, effort, and disk space.
- Support for concurrent schema changes

  Support for concurrent schema changes: Cassandra 1.1 introduced modifying schema objects in a concurrent fashion across a cluster, but did not support programmatically and concurrently creating and dropping tables (permanent or temporary). Version 1.2 includes this support, so multiple users can add/drop tables, including temporary tables, in this way.

Key CQL features

CQL 3, which was previewed in Beta form in Cassandra 1.1, has been released in Cassandra 1.2. CQL 3 is now the default mode for cqlsh. CQL 3 supports schema that map Cassandra storage engine cells to a more powerful and natural row-column representation than earlier CQL versions and the Thrift API. CQL3 transposes data partitions into familiar row-based resultsets, dramatically simplifying data modeling. New features in Cassandra 1.2 include:

- Collections.

  Collections provide easier methods for inserting and manipulating data that consists of multiple items that you want to store in a single column; for example, multiple email addresses for a single employee. There are three different types of collections: set, list, and map. Common tasks that required creating a multiple columns or a separate table can now be accomplished intuitively using a single collection.
- Query profiling/request tracing.

  This cqlsh feature includes performance diagnostic utilities aimed at helping you understand, diagnose, and troubleshoot CQL statements sent to a Cassandra cluster. You can interrogate individual CQL statements in an ad-hoc manner, or perform a system-wide collection of all queries/commands sent to a cluster. The new nodetool utility adds probabilistic tracing for collecting all statements sent to a database to isolate and tune most resource intensive statements.
- System information.

  You can easily retrieve details about your cluster configuration and database objects by querying tables in the system keyspace using CQL.
- Atomic batches.

  Prior versions of Cassandra allowed for batch operations for grouping related updates into a single statement. If some of the replicas for the batch failed mid-operation, the coordinator would hint those rows automatically. However, if the coordinator itself failed in mid operation, you could end up with partially applied batches. In version 1.2 of Cassandra, batch operations are guaranteed by default to be atomic, and are handled differently than in earlier versions of the database.
- Flat file loader/export utility.

  A new cqlsh utility facilitates importing and exporting flat file data to/from Cassandra tables. Although initially introduced in Cassandra 1.1.3, the new load utility wasn't formally announced until now. The utility mirrors the COPY command from the PostgreSQL RDBMS. A variety of file formats are supported including comma-separated value (CSV), tab-delimited, and more, with CSV being the default.

Other CQL 3 enhancements

Cassandra 1.2 introduced many enhancements in addition to the key CQL features.

- New statement for altering the replication strategy: ALTER KEYSPACE.
- Querying ordered data using additional operators such as >=
- Compound keys and clustering.
- Composite partition keys.
- Safeguard against running risky queries.
- Retrieve more information about cluster topology.
- Increased query efficiency by using the clustering order.
- Easy access to column timestamps.
- Improved index updates.
- A table can now consist of only a primary key definition.
- New inet data type.

- New syntax for setting the replication strategy using a map collection.
- Capability to query legacy tables.
- Capability to rename a CQL 3 column.
- Consistent case-sensitivity rules for keyspace, table, and column names.
- Configurable tombstone eviction by setting a CQL table property.

Other changes

- Support for legacy tables.
- Option used to start cqlsh in CQL 2 mode.
- CLI command to query CQL 3 table.
- New syntax for setting compression and compaction.
- New compaction sub-properties for configuing the size-tiered bucketing process.
- Change to the default consistency level, now set in the driver instead of CQL or globally using cqlsh.
- Capability to drop a column from a table temporarily removed.
- Removal of The WITH CONSISTENCY LEVEL clause from CQL commands. Programmatically, you now set the consistency level in the driver. On the command line, you can use a new cqlsh CONSISTENCY command.
- As of Cassandra 1.2.3, CQL 3 supports blob constants.
- As of Cassandra 1.2.3, new functions convert native types to blobs and perform timeuuid conversions.

CQL

Cassandra Query Language (CQL) is the default and primary interface into the Cassandra DBMS. Using CQL is similar to using SQL (Structured Query Language). The concept of a table having rows and columns is almost the same in CQL and SQL. The main difference is that Cassandra does not support joins or subqueries, except for batch analysis through Hive. Instead, Cassandra emphasizes denormalization through CQL features like collections and clustering specified at the schema level.

CQL is the recommended way to interact with Cassandra. The simplicity of reading and using CQL is an advantage over older Cassandra APIs.

The CQL documentation contains a data modeling section, examples, and reference information for each CQL command.

Understanding the architecture

Architecture in brief

An overview of Cassandra's structure.

Cassandra is designed to handle big data workloads across multiple nodes with no single point of failure. Its architecture is based in the understanding that system and hardware failure can and do occur. Cassandra addresses the problem of failures by employing a peer-to-peer distributed system where all nodes are the same and data is distributed among all nodes in the cluster. Each node exchanges information across the cluster every second. A commit log on each node captures write activity to ensure data durability. Data is also written to an in-memory structure, called a memtable, and then written to a data file called an SSTable on disk once the memory structure is full. All writes are automatically partitioned and replicated throughout the cluster.

Cassandra is a row-oriented database. Cassandra's architecture allows any authorized user to connect to any node in any data center and access data using the CQL language. For ease of use, CQL uses a similar syntax to SQL. From the CQL perspective the database consists of tables. Typically, a cluster has one keyspace per application. Developers can access CQL through cqlsh as well as via drivers for application languages.

Client read or write requests can go to any node in the cluster. When a client connects to a node with a request, that node serves as the coordinator for that particular client operation. The coordinator acts as a proxy between the client application and the nodes that own the data being requested. The coordinator determines which nodes in the ring should get the request based on how the cluster is configured. For more information, see Client requests on page 21.

Key components for configuring Cassandra

- Gossip: A peer-to-peer communication protocol to discover and share location and state information about the other nodes in a Cassandra cluster.

  Gossip information is also persisted locally by each node to use immediately when a node restarts. You may want to purge gossip history on node restart for various reasons, such as when the node's IP addresses has changed.
- Partitioner: A partitioner determines how to distribute the data across the nodes in the cluster. Choosing a partitioner determines which node to place the first copy of data on.

  You must set the partitioner type and assign the node a num_tokens value for each node. If not using virtual nodes (vnodes), use the initial_token setting instead.
- Replica placement strategy: Cassandra stores copies (replicas) of data on multiple nodes to ensure reliability and fault tolerance. A replication strategy determines which nodes to place replicas on. The first replica of data is simply the first copy; it is not unique in any sense.

  When you create a keyspace, you must define the replica placement strategy and the number of replicas you want.
- Snitch: A snitch defines the topology information that the replication strategy uses to place replicas and route requests efficiently.

  You need to configure a snitch when you create a cluster. The snitch is responsible for knowing the location of nodes within your network topology and distributing replicas by grouping machines into data centers and racks.
- The cassandra.yaml file is the main configuration file for Cassandra. In this file, you set the initialization properties for a cluster, caching parameters for tables, properties for tuning and resource utilization, timeout settings, client connections, backups, and security.

- Cassandra stores keyspace attributes in the system keyspace. You set keyspace or table attributes on a per-keyspace or per-table basis programmatically or using a client application, such as CQL.

  By default, a node is configured to store the data it manages in the `/var/lib/cassandra` directory. In a production cluster deployment, you change the commitlog-directory to a different disk drive from the data_file_directories.

Internode communications (gossip)

Cassandra uses a protocol called gossip to discover location and state information about the other nodes participating in a Cassandra cluster.

Gossip is a peer-to-peer communication protocol in which nodes periodically exchange state information about themselves and about other nodes they know about. The gossip process runs every second and exchanges state messages with up to three other nodes in the cluster. The nodes exchange information about themselves and about the other nodes that they have gossiped about, so all nodes quickly learn about all other nodes in the cluster. A gossip message has a version associated with it, so that during a gossip exchange, older information is overwritten with the most current state for a particular node.

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To prevent partitions in gossip communications, use the same list of seed nodes in all nodes in a cluster. This is most critical the first time a node starts up. By default, a node remembers other nodes it has gossiped with between subsequent restarts.

Note: The seed node designation has no purpose other than bootstrapping the gossip process for new nodes joining the cluster. Seed nodes are *not* a single point of failure, nor do they have any other special purpose in cluster operations beyond the bootstrapping of nodes.

Configuring gossip settings

When a node first starts up, it looks at its `cassandra.yaml` configuration file to determine the name of the Cassandra cluster it belongs to; which nodes (called *seeds*) to contact to obtain information about the other nodes in the cluster; and other parameters for determining port and range information.

In the `cassandra.yaml` file, set the following parameters:

Property	Description
cluster_name	Name of the cluster that this node is joining. Must be the same for every node in the cluster.
listen_address	The IP address or hostname that other Cassandra nodes use to connect to this node. Should be changed from localhost to the public address for the host.
seed_provider	A -seeds list is comma-delimited list of hosts (IP addresses) that gossip uses to learn the topology of the ring. Every node should have the same list of seeds. In multiple data-center clusters, the seed list should include a node from each data center.
storage_port	The intra-node communication port (default is 7000). Must be the same for every node in the cluster.

Property	Description
initial_token	Used in the single-node-per-token architecture, where a node owns exactly one contiguous range in the ringspace.
num_tokens	Used for virtual nodes (vnodes). Defines the number of tokens randomly assigned to this node on the ring.

Purging gossip state on a node

Gossip information is persisted locally by each node to use immediately on node restart without having to wait for gossip communications.

You may want to clear gossip history on node restart in certain cases, such as when node IP addresses have changed.

1. Edit the `cassandra-env.sh` file:
   - Packaged installs: `/usr/share/cassandra`
   - Tarball installs: `<install_location>/conf`
2. Add the following line to the `cassandra-env.sh` file:

```
-Dcassandra.load_ring_state= false
```

Failure detection and recovery

Failure detection is a method for locally determining, from gossip state and history, if another node in the system is up or down. Cassandra uses this information to avoid routing client requests to unreachable nodes whenever possible. (Cassandra can also avoid routing requests to nodes that are alive, but performing poorly, through the dynamic snitch.)

The gossip process tracks state from other nodes both directly (nodes gossiping directly to it) and indirectly (nodes communicated about secondhand, thirdhand, and so on). Rather than have a fixed threshold for marking failing nodes, Cassandra uses an accrual detection mechanism to calculate a per-node threshold that takes into account network performance, workload, or other conditions. During gossip exchanges, every node maintains a sliding window of inter-arrival times of gossip messages from other nodes in the cluster. In Cassandra, configuring the phi_convict_threshold property adjusts the sensitivity of the failure detector. Use default value for most situations, but increase it to 12 for Amazon EC2 (due to the frequently experienced network congestion).

Node failures can result from various causes such as hardware failures and network outages. Node outages are often transient but can last for extended intervals. A node outage rarely signifies a permanent departure from the cluster, and therefore does not automatically result in permanent removal of the node from the ring. Other nodes will periodically try to initiate gossip contact with failed nodes to see if they are back up. To permanently change a node's membership in a cluster, administrators must explicitly add or remove nodes from a Cassandra cluster using the nodetool utility.

When a node comes back online after an outage, it may have missed writes for the replica data it maintains. Once the failure detector marks a node as down, missed writes are stored by other replicas for a period of time providing hinted handoff is enabled. If a node is down for longer than max_hint_window_in_ms (3 hours by default), hints are no longer saved. Because nodes that die may have stored undelivered hints, you should run a repair after recovering a node that has been down for an extended period. Moreover, you should routinely run nodetool repair on all nodes to ensure they have consistent data.

For more explanation about recovery, see Modern hinted handoff.

Data distribution and replication

In Cassandra, data distribution and replication go together. This is because Cassandra is designed as a peer-to-peer system that makes copies of the data and distributes the copies among a group of nodes. Data is organized by table and identified by a primary key. The primary key determines which node the data is stored on. Copies of rows are called replicas. When data is first written, it is also referred to as a replica.

When your create a cluster, you must specify the following:

- Virtual nodes: assigns data ownership to physical machines.
- Partitioner: partitions the data across the cluster.
- Replication strategy: determines the replicas for each row of data.
- Snitch: defines the topology information that the replication strategy uses to place replicas.

Consistent hashing

Details about how the consistent hashing mechanism distributes data across a cluster in Cassandra.

Consistent hashing partitions data based on the primary key. For example, if you have the following data:

jim	age: 36	car: camaro	gender: M
carol	age: 37	car: bmw	gender: F
johnny	age: 12	gender: M	
suzy	age: 10	gender: F	

Cassandra assigns a hash value to each primary key:

Primary key	Murmur3 hash value
jim	-2245462676723223822
carol	7723358927203680754
johnny	-6723372854036780875
suzy	1168604627387940318

Each node in the cluster is responsible for a range of data based on the hash value:

Node	Murmur3 start range	Murmur3 end range
A	-9223372036854775808	-4611686018427387903
B	-4611686018427387904	-1
C	0	4611686018427387903
D	4611686018427387904	9223372036854775807

Cassandra places the data on each node according to the value of the primary key and the range that the node is responsible for. For example, in a four node cluster, the data in this example is distributed as follows:

Node	Start range	End range	Primary key	Hash value
A	-9223372036854775808	-4611686018427387903	johnny	-6723372854036780875

Node	Start range	End range	Primary key	Hash value
B	-4611686018427387904	0	jim	-2245462676723223822
C	0	4611686018427387903	suzy	116860462738794 0318
D	4611686018427387904	9223372036854775807	carol	772335892720368 0754

Virtual nodes

Overview of virtual nodes (vnodes).

Vnodes simplify many tasks in Cassandra:

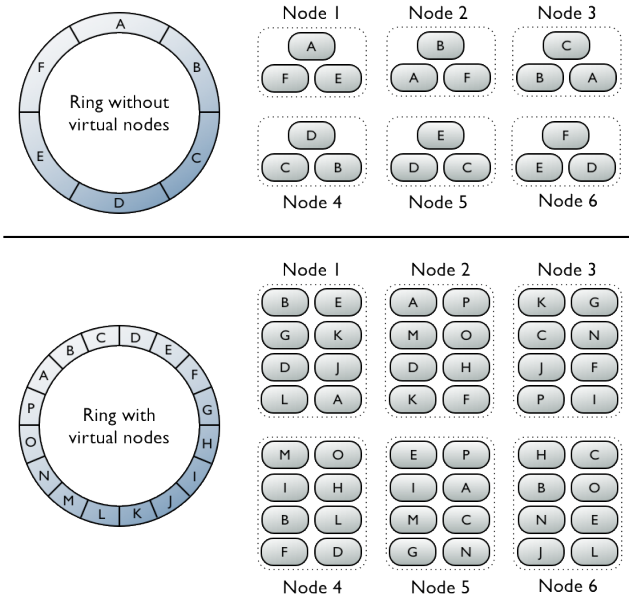
- You no longer have to calculate and assign tokens to each node.
- Rebalancing a cluster is no longer necessary when adding or removing nodes. When a node joins the cluster, it assumes responsibility for an even portion of data from the other nodes in the cluster. If a node fails, the load is spread evenly across other nodes in the cluster.
- Rebuilding a dead node is faster because it involves every other node in the cluster and because data is sent to the replacement node incrementally instead of waiting until the end of the validation phase.
- Improves the use of heterogeneous machines in a cluster. You can assign a proportional number of vnodes to smaller and larger machines.

For more information, see the article Virtual nodes in Cassandra 1.2 and Enabling virtual nodes on an existing production cluster on page 76.

How data is distributed across a cluster (using virtual nodes)

Prior to version 1.2, you had to calculate and assign a single token to each node in a cluster. Each token determined the node's position in the ring and its portion of data according to its hash value. Although the design of consistent hashing used prior to version 1.2 (compared to other distribution designs), allowed moving a single node's worth of data when adding or removing nodes from the cluster, it still required substantial effort to do so.

Starting in version 1.2, Cassandra changes this paradigm from one token and range per node to many tokens per node. The new paradigm is called virtual nodes (vnodes). Vnodes allow each node to own a large number of small partition ranges distributed throughout the cluster. Vnodes also use consistent hashing to distribute data but using them doesn't require token generation and assignment.



The top portion of the graphic shows a cluster without vnodes. In this paradigm, each node is assigned a single token that represents a location in the ring. Each node stores data determined by mapping the row key to a token value within a range from the previous node to its assigned value. Each node also contains copies of each row from other nodes in the cluster. For example, range E replicates to nodes 5, 6, and 1. Notice that a node owns exactly one contiguous partition range in the ring space.

The bottom portion of the graphic shows a ring with vnodes. Within a cluster, virtual nodes are randomly selected and non-contiguous. The placement of a row is determined by the hash of the row key within many smaller partition ranges belonging to each node.

Data replication

Cassandra stores replicas on multiple nodes to ensure reliability and fault tolerance. A replication strategy determines the nodes where replicas are placed.

The total number of replicas across the cluster is referred to as the replication factor. A replication factor of 1 means that there is only one copy of each row on one node. A replication factor of 2 means two copies of each row, where each copy is on a different node. All replicas are equally important; there is no primary or master replica. As a general rule, the replication factor should not exceed the number of nodes in the cluster. However, you can increase the replication factor and then add the desired number of nodes later. When replication factor exceeds the number of nodes, writes are rejected, but reads are served as long as the desired consistency level can be met.

Two replication strategies are available:

- SimpleStrategy: Use for a single data center only. If you ever intend more than one data center, use the NetworkTopologyStrategy.
- NetworkTopologyStrategy: Highly recommended for most deployments because it is much easier to expand to multiple data centers when required by future expansion.

SimpleStrategy

Use only for a single data center. SimpleStrategy places the first replica on a node determined by the partitioner. Additional replicas are placed on the next nodes clockwise in the ring without considering topology (rack or data center location).

NetworkTopologyStrategy

Use NetworkTopologyStrategy when you have (or plan to have) your cluster deployed across multiple data centers. This strategy specify how many replicas you want in each data center.

NetworkTopologyStrategy places replicas in the same data center by walking the ring clockwise until reaching the first node in another rack. NetworkTopologyStrategy attempts to place replicas on distinct racks because nodes in the same rack (or similar physical grouping) often fail at the same time due to power, cooling, or network issues.

When deciding how many replicas to configure in each data center, the two primary considerations are (1) being able to satisfy reads locally, without incurring cross data-center latency, and (2) failure scenarios. The two most common ways to configure multiple data center clusters are:

- Two replicas in each data center: This configuration tolerates the failure of a single node per replication group and still allows local reads at a consistency level of ONE.
- Three replicas in each data center: This configuration tolerates either the failure of a one node per replication group at a strong consistency level of LOCAL_QUORUM or multiple node failures per data center using consistency level ONE.

Asymmetrical replication groupings are also possible. For example, you can have three replicas per data center to serve real-time application requests and use a single replica for running analytics.

Choosing keyspace replication options

To set the replication strategy for a keyspace, see CREATE KEYSPACE.

When you use NetworkToplogyStrategy, during creation of the keyspace, you use the data center names defined for the snitch used by the cluster. To place replicas in the correct location, Cassandra requires a keyspace definition that uses the snitch-aware data center names. For example, if the cluster uses the PropertyFileSnitch, create the keyspace using the user-defined data center and rack names in the `cassandra-topologies.properties` file. If the cluster uses the EC2Snitch, create the keyspace using EC2 data center and rack names.

Partitioners

A partitioner determines how data is distributed across the nodes in the cluster (including replicas). Basically, a partitioner is a hash function for computing the token (it's hash) of a row key. Each row of data is uniquely identified by a row key and distributed across the cluster by the value of the token.

Both the Murmur3Partitioner and RandomPartitioner use tokens to help assign equal portions of data to each node and evenly distribute data from all the tables throughout the ring or other grouping, such as a keyspace. This is true even if the tables use different row keys, such as usernames or timestamps. Moreover, the read and write requests to the cluster are also evenly distributed and load balancing is simplified because each part of the hash range receives an equal number of rows on average. For more detailed information, see Consistent hashing on page 14.

Cassandra offers the following partitioners:

- Murmur3Partitioner (default): uniformly distributes data across the cluster based on `MurmurHash` hash values.
- RandomPartitioner: uniformly distributes data across the cluster based on `MD5` hash values.
- ByteOrderedPartitioner: keeps an ordered distribution of data lexically by key bytes

The Murmur3Partitioner is the default partitioning strategy for new Cassandra clusters and the right choice for new clusters in almost all cases.

Set the partitioner in the cassandra.yaml file:

- Murmur3Partitioner: `org.apache.cassandra.dht.Murmur3Partitioner`
- RandomPartitioner: `org.apache.cassandra.dht.RandomPartitioner`
- ByteOrderedPartitioner: `org.apache.cassandra.dht.ByteOrderedPartitioner`

Note: If using virtual nodes (vnodes), you do **not** need to calculate the tokens. If not using vnodes, you **must** calculate the tokens to assign to the initial_token parameter in the `cassandra.yaml` file. See Generating tokens on page 75 and use the method for the type of partitioner you are using.

Murmur3Partitioner

The Murmur3Partitioner provides faster hashing and improved performance than the previous default partitioner (RandomPartitioner).

You can only use Murmur3Partitioner for new clusters; you cannot change the partitioner in existing clusters. If you are switching to the 1.2 `cassandra.yaml` be sure to change the partitioner setting to match the previous partitioner.

The Murmur3Partitioner uses the `MurmurHash` function. This hashing function creates a 64-bit hash value of the row key. The possible range of hash values is from -2^{63} to $+2^{63}$.

When using the Murmur3Partitioner, you can page through all rows using the token function in a CQL 3 query.

RandomPartitioner

The default partitioner prior to Cassandra 1.2.

Although no longer the default partitioner, you can use the RandomPartitioner in version 1.2, even when using virtual nodes (vnodes). However, if you don't use vnodes, you must calculate the tokens, as described in Generating tokens.

The RandomPartition distributes data evenly across the nodes using an MD5 hash value of the row key. The possible range of hash values is from 0 to 2^{127} -1.

When using the RandomPartitioner, you can page through all rows using the token function in a CQL 3 query.

ByteOrderedPartitioner

Use for ordered partitioning

Cassandra provides the ByteOrderedPartitioner for ordered partitioning. This partitioner orders rows lexically by key bytes. You calculate tokens by looking at the actual values of your row key data and using a hexadecimal representation of the leading character(s) in a key. For example, if you wanted to partition rows alphabetically, you could assign an A token using its hexadecimal representation of 41.

Using the ordered partitioner allows ordered scans by primary key. This means you can scan rows as though you were moving a cursor through a traditional index. For example, if your application has user names as the row key, you can scan rows for users whose names fall between Jake and Joe. This type of query is not possible using randomly partitioned row keys because the keys are stored in the order of their `MD5` hash (not sequentially).

Although having the capability to do range scans on rows sounds like a desirable feature of ordered partitioners, there are ways to achieve the same functionality using table indexes.

Using an ordered partitioner is not recommended for the following reasons:

Difficult load balancing

More administrative overhead is required to load balance the cluster. An ordered partitioner requires administrators to manually calculate partition ranges (formerly token ranges) based on their estimates of the row key distribution. In practice, this requires actively moving node tokens around to accommodate the actual distribution of data once it is loaded.

Sequential writes can cause hot spots

If your application tends to write or update a sequential block of rows at a time, then the writes are not be distributed across the cluster; they all go to one node. This is frequently a problem for applications dealing with timestamped data.

Uneven load balancing for multiple tables

If your application has multiple tables, chances are that those tables have different row keys and different distributions of data. An ordered partitioner that is balanced for one table may cause hot spots and uneven distribution for another table in the same cluster.

Snitches

A snitch determines which data centers and racks are written to and read from.

Snitches inform Cassandra about the network topology so that requests are routed efficiently and allows Cassandra to distribute replicas by grouping machines into data centers and racks. All nodes must have exactly the same snitch configuration. Cassandra does its best not to have more than one replica on the same rack (which is not necessarily a physical location).

Note: If you change the snitch after data is inserted into the cluster, you must run a full repair, since the snitch affects where replicas are placed.

Dynamic snitching

Monitors the performance of reads from the various replicas and chooses the best replica based on this history.

By default, all snitches also use a dynamic snitch layer that monitors read latency and, when possible, routes requests away from poorly-performing nodes. The dynamic snitch is enabled by default and is recommended for use in most deployments. For information on how this works, see Dynamic snitching in Cassandra: past, present, and future. Configure dynamic snitch thresholds for each node in the cassandra.yaml configuration file.

For more information, see the properties listed under Failure detection and recovery on page 13.

SimpleSnitch

The SimpleSnitch (the default) does not recognize data center or rack information. Use it for single-data center deployments (or single-zone in public clouds).

Using a SimpleSnitch, the only keyspace strategy option you specify is a replication factor.

RackInferringSnitch

The RackInferringSnitch determines the location of nodes by rack and data center, which are assumed to correspond to the 3rd and 2nd octet of the node's IP address, respectively. Use this snitch as an example of writing a custom Snitch class.

PropertyFileSnitch

Determines the location of nodes by rack and data center.

This snitch uses a user-defined description of the network details located in the `cassandra-topology.properties` file. Use this snitch when your node IPs are not uniform or if you have complex replication grouping requirements. When using this snitch, you can define your data center names to be whatever you want. Make sure that the data center names you define correlate to the name of your data centers in your keyspace strategy_options. Every node in the cluster should be described in the `cassandra-topology.properties` file, and this file should be exactly the same on every node in the cluster.

The location of the `cassandra-topology.properties` file depends on the type of installation; see Locations of the configuration files on page 129 or DataStax Enterprise File Locations

If you had non-uniform IPs and two physical data centers with two racks in each, and a third logical data center for replicating analytics data, the `cassandra-topology.properties` file might look like this:

```
# Data Center One

175.56.12.105 =DC1:RAC1
175.50.13.200 =DC1:RAC1
175.54.35.197 =DC1:RAC1

120.53.24.101 =DC1:RAC2
120.55.16.200 =DC1:RAC2
120.57.102.103 =DC1:RAC2

# Data Center Two

110.56.12.120 =DC2:RAC1
```

```
110.50.13.201 =DC2:RAC1
110.54.35.184 =DC2:RAC1

50.33.23.120 =DC2:RAC2
50.45.14.220 =DC2:RAC2
50.17.10.203 =DC2:RAC2

# Analytics Replication Group

172.106.12.120 =DC3:RAC1
172.106.12.121 =DC3:RAC1
172.106.12.122 =DC3:RAC1

# default for unknown nodes default =DC3:RAC1
```

GossipingPropertyFileSnitch

The GossipingPropertyFileSnitch defines a local node's data center and rack; it uses gossip for propagating this information to other nodes. The `conf/cassandra-rackdc.properties` file defines the default data center and rack used by this snitch:

```
dc =DC1
 rack =RAC1
```

The location of the `conf` directory depends on the type of installation; see Locations of the configuration files on page 129 or DataStax Enterprise File Locations.

To migrate from the PropertyFileSnitch to the GossipingPropertyFileSnitch, update one node at a time to allow gossip time to propagate. The PropertyFileSnitch is used as a fallback when `cassandra-topologies.properties` is present.

EC2Snitch

Use the EC2Snitch for simple cluster deployments on Amazon EC2 where all nodes in the cluster are within a single region. The region is treated as the data center and the availability zones are treated as racks within the data center. For example, if a node is in us-east-1a, us-east is the data center name and 1a is the rack location. Because private IPs are used, this snitch does not work across multiple Regions.

When defining your keyspace strategy option, use the EC2 region name (for example,``us-east``) as your data center name.

EC2MultiRegionSnitch

Use the EC2MultiRegionSnitch for deployments on Amazon EC2 where the cluster spans multiple regions. As with the EC2Snitch, regions are treated as data centers and availability zones are treated as racks within a data center. For example, if a node is in us-east-1a, us-east is the data center name and 1a is the rack location.

This snitch uses public IPs as broadcast_address to allow cross-region connectivity. This means that you must configure each Cassandra node so that the listen_address is set to the *private* IP address of the node, and the broadcast_address is set to the *public* IP address of the node. This allows Cassandra nodes in one EC2 region to bind to nodes in another region, thus enabling multiple data center support. (For intra-region traffic, Cassandra switches to the private IP after establishing a connection.)

Additionally, you must set the addresses of the seed nodes in the `cassandra.yaml` file to that of the *public* IPs because private IPs are not routable between networks. For example:

```
seeds: 50.34.16.33, 60.247.70.52
```

To find the public IP address, run this command from each of the seed nodes in EC2:

```
curl http://instance-data/latest/meta-data/public-ipv4
```

Finally, be sure that the storage_port or ssl_storage_port is open on the public IP firewall.

When defining your keyspace strategy option, use the EC2 region name, such as ``us-east``, as your data center names.

Client requests

Client read or write requests can go to any node in the cluster because all nodes in Cassandra are peers.

When a client connects to a node and issues a read or write request, that node serves as the coordinator for that particular client operation.

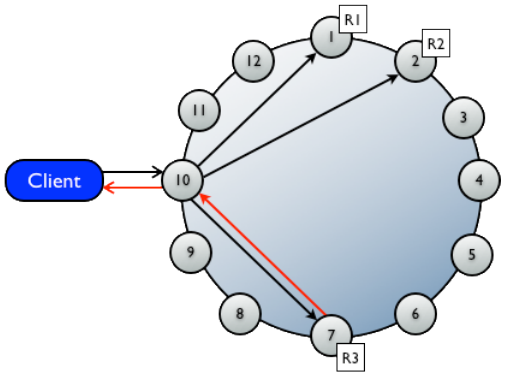
The job of the coordinator is to act as a proxy between the client application and the nodes (or replicas) that own the data being requested. The coordinator determines which nodes in the ring should get the request based on the cluster configured partitioner and replica placement strategy.

Write requests

The coordinator sends a write request to *all* replicas that own the row being written. As long as all replica nodes are up and available, they will get the write regardless of the consistency level specified by the client. The write consistency level determines how many replica nodes must respond with a success acknowledgment in order for the write to be considered successful. Success means that the data was written to the commit log and the memtable as described in About writes.

For example, in a single data center 10 node cluster with a replication factor of 3, an incoming write will go to all 3 nodes that own the requested row. If the write consistency level specified by the client is ONE, the first node to complete the write responds back to the coordinator, which then proxies the success message back to the client. A consistency level of ONE means that it is possible that 2 of the 3 replicas could miss the write if they happened to be down at the time the request was made. If a replica misses a write, Cassandra will make the row consistent later using one of its built-in repair mechanisms: hinted handoff, read repair, or anti-entropy node repair.

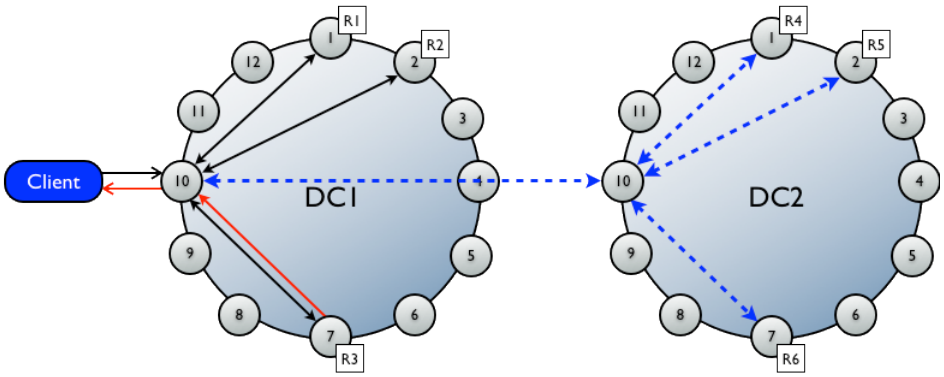
That node forwards the write to all replicas of that row. It will respond back to the client once it receives a write acknowledgment from the number of nodes specified by the consistency level. when a node writes and responds, that means it has written to the commit log and puts the mutation into a memtable.



Multiple data center write requests

In multiple data center deployments, Cassandra optimizes write performance by choosing one coordinator node in each remote data center to handle the requests to replicas within that data center. The coordinator node contacted by the client application only needs to forward the write request to one node in each remote data center.

If using a consistency level of ONE or LOCAL_QUORUM, only the nodes in the same data center as the coordinator node must respond to the client request in order for the request to succeed. This way, geographical latency does not impact client request response times.



Read requests

There are two types of read requests that a coordinator can send to a replica:

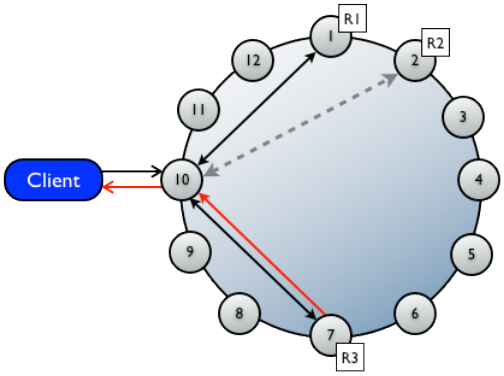
- A direct read request
- A background read repair request

The number of replicas contacted by a direct read request is determined by the consistency level specified by the client. Background read repair requests are sent to any additional replicas that did not receive a direct request. Read repair requests ensure that the requested row is made consistent on all replicas.

Thus, the coordinator first contacts the replicas specified by the consistency level. The coordinator sends these requests to the replicas that are currently responding the fastest. The nodes contacted respond with the requested data; if multiple nodes are contacted, the rows from each replica are compared in memory to see if they are consistent. If they are not, then the replica that has the most recent data (based on the timestamp) is used by the coordinator to forward the result back to the client.

To ensure that all replicas have the most recent version of frequently-read data, the coordinator also contacts and compares the data from all the remaining replicas that own the row in the background. If the replicas are inconsistent, the coordinator issues writes to the out-of-date replicas to update the row to the most recent values. This process is known as read repair. Read repair can be configured per table (using read_repair_chance), and is enabled by default.

For example, in a cluster with a replication factor of 3, and a read consistency level of QUORUM, 2 of the 3 replicas for the given row are contacted to fulfill the read request. Supposing the contacted replicas had different versions of the row, the replica with the most recent version would return the requested data. In the background, the third replica is checked for consistency with the first two, and if needed, the most recent replica issues a write to the out-of-date replicas.



Planning a cluster deployment

When planning a Cassandra cluster deployment, you should have a good idea of the initial volume of data you plan to store and a good estimate of your typical application workload.

The following topics provide information for planning your cluster:

Selecting hardware for enterprise implementations

Choosing appropriate hardware depends on selecting the right balance of the following resources: memory, CPU, disks, number of nodes, and network.

Memory

The more memory a Cassandra node has, the better read performance. More RAM allows for larger cache sizes and reduces disk I/O for reads. More RAM also allows memory tables (memtables) to hold more recently written data. Larger memtables lead to a fewer number of SSTables being flushed to disk and fewer files to scan during a read. The ideal amount of RAM depends on the anticipated size of your hot data.

- For dedicated hardware, the optimal price-performance sweet spot is 16GB to 64GB; the minimum is 8GB.
- For a virtual environments, the optimal range may be 8GB to 16GB; the minimum is 4GB.
- For testing light workloads, Cassandra can run on a virtual machine as small as 256MB.
- For setting Java heap space, see Tuning Java resources.

CPU

Insert-heavy workloads are CPU-bound in Cassandra before becoming memory-bound. (All writes go to the commit log, but Cassandra is so efficient in writing that the CPU is the limiting factor.) Cassandra is highly concurrent and uses as many CPU cores as available:

- For dedicated hardware, 8-core processors are the current price-performance sweet spot.
- For virtual environments, consider using a provider that allows CPU bursting, such as Rackspace Cloud Servers.

Disk

Disk space depends a lot on usage, so it's important to understand the mechanism. Cassandra writes data to disk when appending data to the commit log on page 141 for durability and when flushing memtable on page 143 to SSTable on page 144 data files for persistent storage. SSTables are periodically compacted. Compaction improves performance by merging and rewriting data and discarding old data. However, depending on the type of compaction_strategy and size of the compactions, compaction can substantially increase disk utilization and data directory volume. For this reason,

you should leave an adequate amount of free disk space available on a node: 50% (worst case) for SizeTieredCompactionStrategy and large compactions, and 10% for LeveledCompactionStrategy. The following links provide information about compaction:

- Configuring compaction and compression
- The Apache Cassandra storage engine
- Leveled Compaction in Apache Cassandra
- When to Use Leveled Compaction

For information on calculating disk size, see Calculating usable disk capacity.

Recommendations:

Capacity per node

Ideal capacity for Cassandra 1.2 and later is 3-5TB per node. For Cassandra 1.1, it is 500-800GB per node.

Capacity and I/O

When choosing disks, consider both capacity (how much data you plan to store) and I/O (the write/read throughput rate). Some workloads are best served by using less expensive SATA disks and scaling disk capacity and I/O by adding more nodes (with more RAM).

Solid-state drives

SSDs are the recommended choice for Cassandra. Cassandra's sequential, streaming write patterns minimize the undesirable effects of write amplification associated with SSDs. This means that Cassandra deployments can take advantage of inexpensive consumer-grade SSDs. Enterprise level SSDs are not necessary because Cassandra's SSD access wears out consumer-grade SSDs in the same time frame as more expensive enterprise SSDs.

Note: For SSDs it is recommended that both commit logs and SSTables are on the same mount point.

Number of disks - SATA

Ideally Cassandra needs at least two disks, one for the commit log and the other for the data directories. At a minimum the commit log should be on its own partition.

Commit log disk - SATA

The disk not need to be large, but it should be fast enough to receive all of your writes as appends (sequential I/O).

Data disks

Use one or more disks and make sure they are large enough for the data volume and fast enough to both satisfy reads that are not cached in memory and to keep up with compaction.

RAID on data disks

It is generally not necessary to use RAID for the following reasons:

- Data is replicated across the cluster based on the replication factor you've chosen.
- Starting in version 1.2, Cassandra includes a JBOD (Just a bunch of disks) feature to take care of disk management. Because Cassandra properly reacts to a disk failure either by stopping the affected node or by blacklisting the failed drive, you can deploy Cassandra nodes with large disk arrays without the overhead of RAID 10. You can configure Cassandra to stop the affected node or blacklist the drive according to your availability/consistency requirements.

RAID on the commit log disk

Generally RAID is not needed for the commit log disk. Replication adequately prevents data loss. If you need the extra redundancy, use RAID 1.

Extended file systems

DataStax recommends deploying Cassandra on XFS. On ext2 or ext3, the maximum file size is 2TB even using a 64-bit kernel. On ext4 it is 16TB.

Because Cassandra can use almost half your disk space for a single file, use XFS when using large disks, particularly if using a 32-bit kernel. XFS file size limits are 16TB max on a 32-bit kernel, and essentially unlimited on 64-bit.

Number of nodes

Prior to version 1.2, the recommended size of disk space per node was 300 to 500GB. Improvement to Cassandra 1.2, such as JBOD support, virtual nodes (vnodes), off-heap Bloom filters, and parallel leveled compaction (SSD nodes only), allow you to use few machines with multiple terabytes of disk space.

Network

Since Cassandra is a distributed data store, it puts load on the network to handle read/write requests and replication of data across nodes. Be sure that your network can handle traffic between nodes without bottlenecks. You should bind your interfaces to separate Network Interface Cards (NIC). You can use public or private depending on your requirements.

- Recommended bandwidth is 1000 Mbit/s (gigabit) or greater.
- Thrift/native protocols use the rpc_address.
- Cassandra's internal storage protocol uses the listen_address.

Cassandra efficiently routes requests to replicas that are geographically closest to the coordinator node and chooses a replica in the same rack if possible; it always chooses replicas located in the same data center over replicas in a remote data center.

Firewall

If using a firewall, make sure that nodes within a cluster can reach each other. See Configuring firewall port access on page 50.

Generally, when you have firewalls between machines, it is difficult to run JMX across a network and maintain security. This is because JMX connects on port 7199, handshakes, and then uses any port within the 1024+ range. Instead use SSH to execute commands remotely connect to JMX locally or use the DataStax OpsCenter.

Planning an Amazon EC2 cluster

DataStax provides an Amazon Machine Image (AMI) to allow you to quickly deploy a multi-node Cassandra cluster on Amazon EC2.

The DataStax AMI initializes all nodes in one availability zone using the SimpleSnitch.

If you want an EC2 cluster that spans multiple regions and availability zones, do not use the DataStax AMI. Instead, install Cassandra on your EC2 instances as described in Installing Cassandra Debian packages, and then configure the cluster as a multiple data center cluster.

Use the following guidelines when setting up your cluster:

- Only use known AMI's from a trusted source. Random AMI's pose a security risk and may perform levels slower than expected due to the way the install is configured for EC2. For example:
  - Ubuntu Amazon EC2 AMI Locator
  - Debian AmazonEC2Image
  - CentOS-6 images on Amazon's EC2 Cloud
- For production Cassandra clusters on EC2, use Large or Extra Large instances with local storage.

  Amazon Web Service has reduced the number of default ephemeral disks attached to the image from four to two. Performance will be slower for new nodes unless you manually attach the additional two disks; see Amazon EC2 Instance Store.
- RAID 0 the ephemeral disks, and put both the data directory and the commit log on that volume. This has proved to be better in practice than putting the commit log on the root volume (which is also

a shared resource). For more data redundancy, consider deploying your Cassandra cluster across multiple availability zones or using EBS volumes to store your Cassandra backup files.

- Cassandra JBOD support allows you to use standard disks, but you may get better throughput with RAID0. RAID0 splits every block to be on another device so that writes are written in parallel fashion instead of written serially on disk.
- EBS volumes are not recommended for Cassandra data volumes for the following reasons:
  - EBS volumes contend directly for network throughput with standard packets. This means that EBS throughput is likely to fail if you saturate a network link.
  - EBS volumes have unreliable performance. I/O performance can be exceptionally slow, causing the system to back load reads and writes until the entire cluster becomes unresponsive.
  - Adding capacity by increasing the number of EBS volumes per host does not scale. You can easily surpass the ability of the system to keep effective buffer caches and concurrently serve requests for all of the data it is responsible for managing.

  For more information and graphs related to ephemeral versus EBS performance, see the blog article Systematic Look at EC2 I/O.

Calculating usable disk capacity

Determining how much data your Cassandra nodes can hold.

To calculate how much data your Cassandra nodes can hold, calculate the usable disk capacity per node and then multiply that by the number of nodes in your cluster. Remember that in a production cluster, you will typically have your commit log and data directories on different disks.

1. Start with the raw capacity of the physical disks:

   ```
   raw_capacity = disk_size * number_of_data_disks
   ```

2. Calculate the usable disk space as follows:

   ```
   ( raw_capacity * 0.9 ) = formatted_disk_space
   ```

   During normal operations, Cassandra routinely requires disk capacity for compaction and repair operations. For optimal performance and cluster health, DataStax recommends not filling your disks to capacity, but running at 50% to 80% capacity depending on the compaction_strategy and size of the compactions.

3. Account for file system formatting overhead (roughly 10 percent):

   ```
   formatted_disk_space * (0.5 to 0.8) = usable_disk_space
   ```

Calculating user data size

Accounting for storage overhead in determining user data size.

As with all data storage systems, the size of your raw data will be larger once it is loaded into Cassandra due to storage overhead. On average, raw data is about two times larger on disk after it is loaded into the database, but could be much smaller or larger depending on the characteristics of your data and tables. The following calculations account for data persisted to disk, not for data stored in memory.

- Determine column overhead:

  ```
  regular_total_column_size = column_name_size + column_value_size + 15
  ```

  ```
  counter - expiring_total_column_size = column_name_size + column_value_size
   + 23
  ```

  Every column in Cassandra incurs 15 bytes of overhead. Since each row in a table can have different column names as well as differing numbers of columns, metadata is stored for each column. For counter columns and expiring columns, you should add an additional 8 bytes (23 bytes total).
- Account for row overhead.

  Every row in Cassandra incurs 23 bytes of overhead.
- Estimate primary key index size:

```
primary_key_index = number_of_rows * ( 32 + average_key_size )
```

Every table also maintains a partition index. This estimation is in bytes.

- Determine replication overhead:

```
replication_overhead = total_data_size * ( replication_factor - 1 )
```

The replication factor plays a role in how much disk capacity is used. For a replication factor of 1, there is no overhead for replicas (as only one copy of data is stored in the cluster). If replication factor is greater than 1, then your total data storage requirement will include replication overhead.

Anti-patterns in Cassandra

Implementation or design patterns that are ineffective and/or counterproductive in Cassandra production installations. Correct patterns are suggested in most cases.

Network attached storage

Storing SSTables on a network attached storage (NAS) device is of limited use. Using a NAS device often results in network related bottlenecks resulting from high levels of I/O wait time on both reads and writes. The causes of these bottlenecks include:

- Router latency.
- The Network Interface Card (NIC) in the node.
- The NIC in the NAS device.

There are exceptions to this pattern. If you use NAS, ensure that each drive is accessed only by one machine and each drive is physically close to the node.

Shared network file systems

Shared network file systems (NFS) have the same limitations as NAS. The temptation with NFS implementations is to place all SSTables in a node into one NFS. Doing this deprecates one of Cassandra's strongest features: No Single Point of Failure (SPOF). When all SSTables from all nodes are stored onto a single NFS, the NFS becomes a SPOF. To best use Cassandra, avoid using NFS.

Excessive heap space size

DataStax recommends using the default heap space size for most use cases. Exceeding this size can impair the Java virtual machine's (JVM) ability to perform fluid garbage collections (GC). The following table shows a comparison of heap space performances reported by a Cassandra user:

Heap	CPU utilization	Queries per second	Latency
40 GB	50%	750	1 second
8 GB	5%	8500 (not maxed out)	10 ms

For information on heap sizing, see Tuning Java resources on page 97.

Cassandra's rack feature

Defining one rack for the entire cluster is the simplest and most common implementation. Multiple racks should be avoided for the following reasons:

- Most users tend to ignore or forget rack requirements that racks should be organized in an alternating order. This order allows the data to get distributed safely and appropriately.
- Many users are not using the rack information effectively. For example, setting up with as many racks as nodes (or similar non-beneficial scenarios).

- Expanding a cluster when using racks can be tedious. The procedure typically involves several node moves and must ensure that racks are distributing data correctly and evenly. When clusters need immediate expansion, racks should be the last concern.

To use racks correctly:

- Use the same number of nodes in each rack.
- Use one rack and place the nodes in different racks in an alternating pattern. This allows you to still get the benefits of Cassandra's rack feature, and allows for quick and fully functional expansions. Once the cluster is stable, you can swap nodes and make the appropriate moves to ensure that nodes are placed in the ring in an alternating fashion with respect to the racks.

Multiple-gets

Multiple-gets may cause problems. One sure way to kill a node is to buffer 300MB of data, timeout, and then try again from 50 different clients.

You should architect your application using many single requests for different rows. This method ensures that if a read fails on a node, due to a backlog of pending requests, an unmet consistency, or other error, only the failed request needs to be retried.

Ideally, use the same key reading for the entire key or slices. Be sure to keep the row sizes in mind to prevent out-of-memory (OOM) errors by reading too many entire ultra-wide rows in parallel.

Using the Byte Ordered Partitioner

The Byte Ordered Partitioner (BOP) is not recommended.

Use virtual nodes (vnodes) and use either the Murmur3Partitioner (default) or the RandomPartitioner. Vnodes allow each node to own a large number of small ranges distributed throughout the cluster. Using vnodes saves you the effort of generating tokens and assigning tokens to your nodes. If not using vnodes, these partitioners are recommended because all writes occur on the hash of the key and are therefore spread out throughout the ring amongst tokens range. These partitioners ensure that your cluster evenly distributes data by placing the key at the correct token using the key's hash value. Even if data becomes stale and needs to be deleted, this ensures that data removal also takes place while evenly distributing data around the cluster.

Reading before writing

Reads take time for every request, as they typically have multiple disk hits for uncached reads. In work flows requiring reads before writes, this small amount of latency can affect overall throughput. All write I/O in Cassandra is sequential so there is very little performance difference regardless of data size or key distribution.

Load balancers

Cassandra was designed to avoid the need for load balancers. Putting load balancers between Cassandra and Cassandra clients is harmful to performance, cost, availability, debugging, testing, and scaling. All high-level clients, such as Astyanax and pycassa, implement load balancing directly.

Insufficient testing

Be sure to test at scale and production loads. This the best way to ensure your system will function properly when your application goes live. The information you gather from testing is the best indicator of what throughput per node is needed for future expansion calculations.

To properly test, set up a small cluster with production loads. There will be a maximum throughput associated with each node count before the cluster can no longer increase performance. Take the maximum throughput at this cluster size and apply it linearly to a cluster size of a different size. Next extrapolate (graph) your results to predict the correct cluster sizes for required throughputs for your

production cluster. This allows you to predict the correct cluster sizes for required throughputs in the future. The Netflix case study shows an excellent example for testing.

Lack of familiarity with Linux

Linux has a great collection of tools. Become familiar with the Linux built-in tools. It will help you greatly and ease operation and management costs in normal, routine functions. The essential list of tools and techniques to learn are:

- Parallel SSH and Cluster SSH: The pssh and cssh tools allow SSH access to multiple nodes. This is useful for inspections and cluster wide changes.
- Passwordless SSH: SSH authentication is carried out by using public and private keys. This allows SSH connections to easily hop from node to node without password access. In cases where more security is required, you can implement a password Jump Box and/or VPN.
- Useful common command-line tools include:
    - top: Provides an ongoing look at processor activity in real time.
    - System performance tools: Tools such as iostat, mpstat, iftop, sar, lsof, netstat, htop, vmstat, and similar can collect and report a variety of metrics about the operation of the system.
    - vmstat: Reports information about processes, memory, paging, block I/O, traps, and CPU activity.
    - iftop: Shows a list of network connections. Connections are ordered by bandwidth usage, with the pair of hosts responsible for the most traffic at the top of list. This tool makes it easier to identify the hosts causing network congestion.

Running without the recommended settings

Be sure to use the recommended settings in the Cassandra documentation.

Also be sure to consult the Planning a Cassandra cluster deployment documentation, which discusses hardware and other recommendations before making your final hardware purchases.

More anti-patterns

For more about anti-patterns, visit Matt Dennis` slideshare.

Installing DataStax Community

Installing DataStax Community on RHEL-based systems

Install using Yum repositories on RHEL, CentOS, and Oracle Linux.

Note: To install on SUSE, use the Cassandra binary tarball distribution.

For a complete list of supported platforms, see DataStax Community – Supported Platforms.

- Yum Package Management application installed.
- Root or sudo access to the install machine.
- Install the latest version of Oracle Java SE Runtime Environment (JRE) 6 or 7. See Installing Oracle JRE on RHEL-based Systems on page 33.
- Java Native Access (JNA) is required for production installations. See Installing the JNA on RHEL or CentOS Systems on page 34.

The packaged releases create a `cassandra` user. When starting Cassandra as a service, the service runs as this user.

In a terminal window:

1. Check which version of Java is installed by running the following command:

   ```
   java -version
   ```

   Use the latest version of Java 6 or 7 on all nodes.
2. Add the DataStax Community repository to the `/etc/yum.repos.d/datastax.repo`:

   ```
   [datastax]
   name = DataStax Repo for Apache Cassandra
   baseurl = http://rpm.datastax.com/community
   enabled = 1
   gpgcheck = 0
   ```
3. Install the latest package:

   ```
   $ sudo yum install dsc12-1.2.10-1 cassandra12-1.2.10-1
   ```

   Note: To install prior versions of 1.2, use this format: `$ sudo yum install dsc12-1.2.x-1 cassandra12-1.2.x-1`.

The DataStax Community distribution of Cassandra is ready for configuration.

- Initializing a multiple node cluster (single data center) on page 41
- Initializing a multiple node cluster (multiple data centers) on page 42
- Recommended production settings on page 35
- Installing OpsCenter
- Key components for configuring Cassandra

Installing DataStax Community on Debian-based systems

Install using APT repositories on Debian and Ubuntu.

For a complete list of supported platforms, see DataStax Community – Supported Platforms.

- Advanced Package Tool is installed.
- Root or sudo access to the install machine.

- Install the latest version of Oracle Java SE Runtime Environment (JRE) 6 or 7. See Installing Oracle JRE on Debian or Ubuntu Systems on page 33.
- Java Native Access (JNA) is required for production installations. Installing the JNA on Debian or Ubuntu Systems on page 35.

Note: If you are using Ubuntu 10.04 LTS, you must update to JNA 3.4, as described in Installing the JNA using the binary tarball on page 35.

The packaged releases create a `cassandra` user. When starting Cassandra as a service, the service runs as this user.

In a terminal window:

1. Check which version of Java is installed by running the following command:

   ```
   java -version
   ```

   Use the latest version of Java 6 or 7 on all nodes.
2. Add the DataStax Community repository to the `/etc/apt/sources.list.d/cassandra.sources.list`

   ```
   deb http://debian.datastax.com/community stable main
   ```
3. Debian systems only:
   a) In `/etc/apt/sources.list`, find the line that describes your source repository for Debian and add `contrib non-free` to the end of the line. For example:

      ```
      deb http://some.debian.mirror/debian/ $distro main contrib non-free
      ```

      This allows installation of the Oracle JVM instead of the OpenJDK JVM.
   b) Save and close the file when you are done adding/editing your sources.
4. Add the DataStax repository key to your aptitude trusted keys.

   ```
   $ curl -L http://debian.datastax.com/debian/repo_key | sudo apt-key add -
   ```
5. Install the latest package.

   ```
   $ sudo apt-get update
   $ sudo apt-get install dsc12=1.2.10-1 cassandra=1.2.10
   ```

   Note: To install prior versions of 1.2, use this format: `$ sudo apt-get install dsc12=1.2.x-1 cassandra=1.2.x`.

   This installs the DataStax Community distribution of Cassandra. By default, the Debian packages start the Cassandra service automatically.
6. To stop the service and clear the initial gossip history that gets populated by this initial start:

   ```
   $ sudo service cassandra stop
   $ sudo rm -rf /var/lib/cassandra/data/system/*
   ```

The DataStax Community distribution of Cassandra is ready for configuration.

- Initializing a multiple node cluster (single data center) on page 41
- Initializing a multiple node cluster (multiple data centers) on page 42
- Recommended production settings on page 35
- Installing OpsCenter
- Key components for configuring Cassandra

Installing DataStax Community on any Linux-based platform

Install on all Linux-based platforms, including Mac OSX and platforms without package support, or if you do not have or want a root installation.

For a complete list of supported platforms, see DataStax Community – Supported Platforms.

- The latest version of Oracle Java SE Runtime Environment (JRE) 6 or 7. See Installing the JRE.
- Java Native Access (JNA) is required for production installations. See Installing the JNA.

Note: If you are using Ubuntu 10.04 LTS, you must update to JNA 3.4, as described in Installing the JNA using the binary tarball on page 35.

The binary tarball runs as a stand-alone process.

In a terminal window:

1. Check which version of Java is installed by running the following command:

   ```
   java -version
   ```

   Use the latest version of Java 6 or 7 on all nodes.
2. Download the DataStax Community tarball:

   ```
   $ curl -OL http://downloads.datastax.com/community/dsc.tar.gz
   ```

   You can also download from Planet Cassandra.
3. Unpack the distribution:

   ```
   $ tar -xvzf dsc.tar.gz
   $ rm *.tar.gz
   ```
4. Go to the install directory:

   ```
   cd dsc-cassandra-1.2.x
   ```
5. By default, Cassandra installs files into the `/var/lib/cassandra` and `/var/log/cassandra` directories. If you do not have root access to the default directories, ensure you have write access:

   ```
   $ sudo mkdir /var/lib/cassandra
   $ sudo mkdir /var/log/cassandra
   $ sudo chown -R  $USER: $GROUP /var/lib/cassandra
   $ sudo chown -R  $USER: $GROUP /var/log/cassandra
   ```

The DataStax Community distribution of Cassandra is installed and ready for configuration.

- Initializing a multiple node cluster (single data center) on page 41
- Initializing a multiple node cluster (multiple data centers) on page 42
- Recommended production settings on page 35
- Installing OpsCenter
- Key components for configuring Cassandra

Installing DataStax Community on Windows

Install DataStax Community and OpsCenter on 32- or 64-bit Windows 7 or Windows Server 2008.

Please see the Getting Started with Cassandra and DataStax Enterprise.

Installing a Cassandra cluster on Amazon EC2

A step-by-step guide for installing the DataStax Community AMI (Amazon Machine Image).

For instructions on installing the DataStax AMI (Amazon Machine Image), see the latest AMI documentation.

Installing the Oracle JRE and the JNA

Instructions for various platforms.

Installing Oracle JRE on RHEL-based Systems

You must configure your operating system to use the Oracle JRE, not the OpenJDK. The latest 64-bit version of Java 6 or 7 is recommended. The minimum supported versions are 1.6.0_29 and 1.7.0_25.

Note: After installing the JRE, you may need to set *JAVA_HOME*:

```
$ export JAVA_HOME =<path_to_java>
```

1. Check which version of the JRE your system is using:

   ```
   java -version
   ```

   If Oracle Java is used, the results should look like:

   ```
   java version "1.7.0_25"
   Java(TM) SE Runtime Environment (build 1.7.0_25-b15)
   Java HotSpot(TM) 64-Bit Server VM (build 23.25-b01, mixed mode)
   ```

2. If necessary, go to Oracle Java SE Downloads, accept the license agreement, and download the installer for your distribution.

   Note: If installing the Oracle JRE in a cloud environment, accept the license agreement, download the installer to your local client, and then use `scp` (secure copy) to transfer the file to your cloud machines.

3. From the directory where you downloaded the pacage, run the install:

   ```
   $ sudo rpm -ivh jre-7u<version>-linux-x64.rpm
   ```

   The RPM installs the JRE into the `/usr/java/` directory.

4. Use the `alternatives` command to add a symbolic link to the Oracle JRE installation so that your system uses the Oracle JRE instead of the OpenJDK JRE:

   ```
   $ sudo alternatives --install /usr/bin/java java /usr/java/
   jre1.7.0_<version>/bin/java 20000
   ```

5. Make sure your system is now using the correct JRE. For example:

   ```
   $ java -version
   ```

   ```
   java version "1.7.0_25"
   Java(TM) SE Runtime Environment (build 1.7.0_25-b15)
   Java HotSpot(TM) 64-Bit Server VM (build 23.25-b01, mixed mode)
   ```

6. If the OpenJDK JRE is still being used, use the `alternatives` command to switch it. For example:

   ```
   $ sudo alternatives --config java
   ```

   ```
   There are 2 programs which provide java.

     Selection      Command
   -----------------------------------------------------------
      1             /usr/lib/jvm/jre-1.7.0-openjdk.x86_64/bin/java
   *+ 2             /usr/java/jre1.7.0_25/bin/java

   Enter to keep the current selection [+ ], or type selection number:
   ```

Installing Oracle JRE on Debian or Ubuntu Systems

You must configure your operating system to use the Oracle JRE, not the OpenJDK. The latest 64-bit version of Java 6 or 7 is recommended. The minimum supported versions are 1.6.0_29 and 1.7.0_25.

Note: After installing the JRE, you may need to set *JAVA_HOME*:

```
$ export JAVA_HOME =<path_to_java>
```

The Oracle Java Runtime Environment (JRE) has been removed from the official software repositories of Ubuntu and only provides a binary (`.bin`) version. You can get the JRE from the Java SE Downloads.

1. Check which version of the JRE your system is using:

```
java -version
```

If Oracle Java is used, the results should look like:

```
java version "1.7.0_25"
Java(TM) SE Runtime Environment (build 1.7.0_25-b15)
Java HotSpot(TM) 64-Bit Server VM (build 23.25-b01, mixed mode)
```

2. If necessary, go to Oracle Java SE Downloads, accept the license agreement, and download the installer for your distribution.

   Note: If installing the Oracle JRE in a cloud environment, accept the license agreement, download the installer to your local client, and then use `scp` (secure copy) to transfer the file to your cloud machines.
3. Place the downloaded file in the `/usr/java/latest` directory.
4. From the `/usr/java/latest` directory, unpack the tarball and install the JRE:

   ```
   $ sudo tar zxvf jre-7u<version>-linux-x64.tar.gz
   ```

   The JRE files are installed into a directory called `jre-7u_<version>`.
5. Tell the system that there's a new Java version available:

   ```
   $ sudo update-alternatives --install "/usr/bin/java" "java" "/usr/java/
   latest/jre1.7.0_<version>/bin/java" 1
   ```

   If updating from a previous version that was removed manually, execute the above command twice, because you'll get an error message the first time.
6. Set the new JRE as the default:

   ```
   $ sudo update-alternatives --set java /usr/java/latest/jre1.7.0_<version>/
   bin/java
   ```
7. Make sure your system is now using the correct JRE. For example:

   ```
   $ java -version
   ```

   ```
   java version "1.7.0_25"
   Java(TM) SE Runtime Environment (build 1.7.0_25-b15)
   Java HotSpot(TM) 64-Bit Server VM (build 23.25-b01, mixed mode)
   ```

Installing the JNA on RHEL or CentOS Systems

Installing JNA can improve Cassandra memory usage. When installed and configured, Linux does not swap out the JVM, and thus avoids related performance issues.

Install with the following command:

```
$ sudo yum install jna
```

Installing the JNA on SUSE Systems

Installing JNA can improve Cassandra memory usage. When installed and configured, Linux does not swap out the JVM, and thus avoids related performance issues.

Install with the following commands:

```
# curl -o jna.jar -L
# https://github.com/twall/jna/blob/3.4.1/dist/jna.jar?raw=true
# curl -o platform.jar -L https://github.com/twall/jna/blob/3.4.1/dist/
platform.jar?raw=true
# mv jna.jar /usr/share/java
# mv platform.jar /usr/share/java
```

Installing the JNA on Debian or Ubuntu Systems

Installing JNA can improve Cassandra memory usage. When installed and configured, Linux does not swap out the JVM, and thus avoids related performance issues.

Install the JNA with the following command:

```
$ sudo apt-get install libjna-java
```

For Ubuntu 10.04 LTS, update to JNA 3.4 as follows:

1. Download the `jna.jar` from https://github.com/twall/jna.
2. Remove older versions of the JNA from the `/usr/share/java/` directory.
3. Place the new `jna.jar` file in `/usr/share/java/` directory.
4. Create a symbolic link to the file:

```
ln -s /usr/share/java/jna.jar <install_location>/lib
```

Installing the JNA using the binary tarball

Installing JNA can improve Cassandra memory usage. When installed and configured, Linux does not swap out the JVM, and thus avoids related performance issues.

1. Download jna.jar from https://github.com/twall/jna.
2. Add `jna.jar` to *`install_location`*`/resources/dse/lib` (or place it in the CLASSPATH).
3. Add the following lines in the `/etc/security/limits.conf` file for the user/group that runs Cassandra:

```
$USER soft memlock unlimited
$USER hard memlock unlimited
```

Recommended production settings

Recommendations for production environments; adjust them accordingly for your implementation.

User resource limits

You can view the current limits using the `ulimit -a` command. Although limits can also be temporarily set using this command, DataStax recommends making the changes permanent:

Packaged installs: Ensure that the following settings are included in the `/etc/security/limits.d/cassandra.conf` file:

```
cassandra - memlock unlimited
cassandra - nofile 100000
cassandra - nproc 32768
cassandra - as unlimited
```

Tarball installs: Ensure that the following settings are included in the `/etc/security/limits.conf` file:

```
* - memlock unlimited
* - nofile 100000
* - nproc 32768
* - as unlimited
```

If you run Cassandra as root, some Linux distributions such as Ubuntu, require setting the limits for root explicitly instead of using `*`:

```
root - memlock unlimited
root - nofile 100000
root - nproc 32768
root - as unlimited
```

For CentOS, RHEL, OEL systems, also set the nproc limits in `/etc/security/limits.d/90-nproc.conf`:

```
* - nproc 32768
```

For all installations, add the following line to `/etc/sysctl.conf`:

```
vm.max_map_count = 131072
```

To make the changes take effect, reboot the server or run the following command:

```
$ sudo sysctl -p
```

To confirm the limits are applied to the Cassandra process, run the following command where *<pid>* is the process ID of the currently running Cassandra process:

```
$ cat /proc/<pid>/limits
```

For more information, see Insufficient user resource limits errors.

Disable swap

Disable swap entirely. This prevents the Java Virtual Machine (JVM) from responding poorly because it is buried in swap and ensures that the OS OutOfMemory (OOM) killer does not kill Cassandra.

```
sudo swapoff --all
```

To make this change permanent, remove all swap file entries from `/etc/fstab`.

For more information, see Nodes seem to freeze after some period of time.

Synchronize clocks

The clocks on all nodes should be synchronized. You can use NTP (Network Time Protocol) or other methods.

This is required because columns are only overwritten if the timestamp in the new version of the column is more recent than the existing column.

Optimum blockdev --setra settings for RAID

Typically, a setra of 512 is recommended, especially on Amazon EC2 RAID0 devices.

Check to ensure setra is not set to 65536:

```
sudo blockdev --report /dev/<device>
```

To set setra:

```
sudo blockdev --setra 512 /dev/<device>
```

Java Virtual Machine

The latest 64-bit version of Java 6 or 7 is recommended, not the OpenJDK.

Java Native Access

Java Native Access (JNA) is required for production installations.

Upgrading Cassandra

Upgrading to DataStax Community 1.2.10

To upgrade an earlier version of Cassandra or DataStax Community Edition to DataStax Community 1.2.10, follow the best practices and pre-requisite steps before upgrading, and then follow step-by-step procedures for your operating system to upgrade.

Best practices

Follow these best practices before upgrading Cassandra:

- Take a snapshot before the upgrade.

  This allows you to rollback to the previous version if necessary. Cassandra is able to read data files created by the previous version, but the inverse is not always true. Taking a snapshot is fast, especially if you have JNA installed, and takes effectively zero disk space until you start compacting the live data files again.
- Check NEWS.txt for any new information about upgrading.

  News.txt is on the Apache Cassandra github site.
- Familiarize yourself with changes and fixes in this release.

  A complete list is available in CHANGES.txt.

Prerequisites

Before upgrading, a data type change may require modification of your queries. Pre-1.0 versions cannot be upgraded directly to the latest release. Dead nodes must be removed before upgrading.

- Modify queries.

  Date strings (and timestamps) are no longer accepted as valid timeuuid values. This change requires modifying queries that use these values. New methods have been added for working with timeuuid values. see Timeuuid functions in CQL data types.
- Upgrade to 1.0.1 or 1.1.x before upgrading to the latest release.

  DataStax Community 1.2.10 is not network-compatible with versions older than 1.0. If you want to perform a rolling restart, first upgrade the cluster to 1.0.x or 1.1.x, and then to 1.2.10, as described in the Cassandra 1.1 documentation. Data files from Cassandra 0.6 and later are compatible with Cassandra 1.2 and later. If it's practical to shut down cluster instead of performing a rolling restart, you can skip upgrading to an interim release and upgrade from Cassandra 0.6 or later to 1.2.3.
- Remove dead nodes.

  Do not upgrade if nodes in the cluster are down. The hints schema changed from 1.1 to 1.2.10. Cassandra automatically snapshots and then truncates the hints table as part of starting up 1.2.10 for the first time. Additionally, upgraded nodes will not store new hints destined for older (pre-1.2) nodes. Use the nodetool removetoken command to remove dead nodes.
- If you decommissioned a node, wait at least 72 hours after decommissioning the node before upgrading.

  Confirm that the node was deleted by running nodetool gossipinfo. If the STATUS line in the output shows

  ```
  removed, <token of decommissioned node>
  ```

the decommissioned node has not been deleted. If the STATUS line in the output shows only partition ranges of other nodes, the decommissioned node has been deleted. If the node was not deleted, wait longer or restart the entire cluster.

Debian or Ubuntu

Follow these steps to get the new version, merge your customizations of the old cassandra.yaml file to the new one, and then complete the upgrade.

1. Save the cassandra.yaml file from the old installation to a safe place.
2. On each of your Cassandra nodes, install the new version.

   ```
   sudo apt-get install dsc12
   ```
3. Open the old and new cassandra.yaml files and diff them.
4. Merge the diffs by hand, including the partitioner setting, from the old file into the new one.

   Do not use the default partitioner setting in the new cassandra.yaml because it has changed in this release to the Murmur3Partitioner. The Murmur3Partitioner can be used only for new clusters. After data has been added to the cluster, you cannot change the partitioner without reworking tables, which is not practical. Use your old partitioner setting in the new cassandra.yaml file.
5. Save the file as cassandra.yaml.
6. Follow steps for completing the upgrade.

RHEL or CentOS

Follow these steps to remove the old installation, merge your customizations of the old cassandra.yaml file to the new one, and then complete the upgrade.

1. On each Cassandra node, remove the old installation.

   ```
   sudo yum remove apache-cassandra11
   ```
2. Install the new version.

   ```
   sudo yum install dsc12
   ```

   The installer creates the file cassandra.yaml.rpmnew in /etc/cassandra/default.conf/.
3. Open the old and new cassandra.yaml files and diff them.
4. Merge the diffs by hand, including the partitioner setting, from the old file into the new one.

   Do not use the default partitioner setting in the new cassandra.yaml because it has changed in this release to the Murmur3Partitioner. The Murmur3Partitioner can be used only for new clusters. After data has been added to the cluster, you cannot change the partitioner without reworking tables, which is not practical. Use your old partitioner setting in the new cassandra.yaml file.
5. Save the file as cassandra.yaml.
6. Follow steps for completing the upgrade.

Tarball

Follow these steps to download and unpack the binary tarball, merge your customizations of the old cassandra.yaml file into the new one, and then complete the upgrade.

1. Save the cassandra.yaml file from the old installation to a safe place.
2. On each node, download and unpack the binary tarball package from the downloads section of the Cassandra website.

3. In the new installation, open the cassandra.yaml for writing.
4. In the old installation, open the cassandra.yaml.
5. Diff the new and old cassandra.yaml files.
6. Merge the diffs, including the partitioner setting, by hand from the old file into the new one.

   Do not use the default partitioner setting in the new cassandra.yaml because it has changed in this release to the Murmur3Partitioner. The Murmur3Partitioner can be used only for new clusters. After data has been added to the cluster, you cannot change the partitioner without reworking tables, which is not practical. Use your old partitioner setting in the new cassandra.yaml file.
7. Follow steps for completing the upgrade.

Completing the upgrade

Regardless of your operating system, you perform these steps to complete the upgrade process.

1. Account for new parameters in cassandra.yaml.
2. Make sure any client drivers, such as Hector or Pycassa clients, are compatible with the new version.
3. Run nodetool drain before shutting down the existing Cassandra service. This prevents overcounts of counter data, and will also speed up restart post-upgrade.
4. Stop the old Cassandra process, then start the new binary process.
5. Monitor the log files for any issues.
6. If you are upgrading to Cassandra DataStax Community from 1.1.x or earlier or if you use counter tables, run nodetool upgradesstables before doing any move, repair, or bootstrap operation.

   Because these operations copy SSTables within the cluster and the on-disk format sometimes changes between major versions, upgrade SSTables now to prevent possible SSTable incompatibilities.
7. After upgrading all nodes in the cluster, consider upgrading existing nodes to vnodes.

   Upgrading to vnodes is optional but has a number of important advantages. See Enabling virtual nodes on an existing production cluster on page 76.

Changes impacting upgrade

Changes that can affect upgrading to Cassandra 1.2.10 are:

- The nodetool upgradesstables command now only upgrades/rewrites sstables that are not on the current version, which is usually what you want.

  Use the new -a flag to recover the old behavior of rewriting all sstables.
- Tables using LeveledCompactionStrategy do not create a row-level bloom filter by default.

  In versions of Cassandra before 1.2 the default value differs from the current value. Manually set the false positive rate to 1.0 (to disable) or 0.01 (to enable, if you make many requests for rows that do not exist).
- The default version of CQL (and cqlsh) is CQL 3.0.

  CQL 2 is still available.
- In CQL 3, the DROP behavior has been removed temporarily from ALTER TABLE because it was not correctly implemented.
- Use lowercase property map keys in ALTER and CREATE statements.

  In earlier releases, CQL3 property map keys used in ALTER and CREATE statements were case-insensitive. For example, CLASS or class and REPLICATION_FACTOR or replication_factor were permitted. The case-sensitivity of the property map keys was inconsistent with the treatment of

other string literals and incompatible with formatting of NetworkTopologyStrategy property maps, which have case-sensitive data center names. In this release property map keys, such as class and replication_factor are case-sensitive. Lowercase property map keys are shown in this example:

```
CREATE KEYSPACE test WITH replication =
  { 'class' : 'SimpleStrategy', 'replication_factor' : '1' };
```

- You might need to fix queries having loose type validation of CQL 3 constants that now have strong validation.

  See the changelog section of http://cassandra.apache.org/doc/cql3/CQL.html. Using blobs as strings constants is now deprecated in favor of blob constants.

Initializing a cluster

Initializing a multiple node cluster (single data center)

You can use initialize a Cassandra cluster with a single data center.

Each node must be correctly configured before starting the cluster. You must determine or perform the following before starting the cluster:

- Install Cassandra on each node.
- Choose a name for the cluster.
- Get the IP address of each node.
- Determine which nodes will be seed nodes. (Cassandra nodes use the seed node list for finding each other and learning the topology of the ring.)
- Determine the snitch.
- If using multiple data centers, determine a naming convention for each data center and rack, for example: DC1, DC2 or 100, 200 and RAC1, RAC2 or R101, R102.
- Other possible configuration settings are described in The cassandra.yaml configuration file on page 64.

This example describes installing a six node cluster spanning two racks in a single data center. Each node is configured to use the RackInferringSnitch (multiple rack aware) and 256 virtual nodes (vnodes). It is recommended to have more than one seed node per data center.

In Cassandra, the term data center is a grouping of nodes. Data center is synonymous with replication group, that is, a grouping of nodes configured together for replication purposes.

1. Suppose you install Cassandra on these nodes:

   ```
   node0 110.82.155.0 (seed1)
   node1 110.82.155.1
   node2 110.82.155.2
   node3 110.82.156.3 (seed2)
   node4 110.82.156.4
   node5 110.82.156.5
   ```

   It is a best practice to have more than one seed node per data center.
2. If you have a firewall running on the nodes in your cluster, you must open certain ports to allow communication between the nodes. See Configuring firewall port access on page 50.
3. If Cassandra is running:

   Packaged installs:

   a) Stop Cassandra:

   ```
   $ sudo service cassandra stop
   ```

   b) Clear the data:

   ```
   $ sudo rm -rf /var/lib/cassandra/*
   ```

   Tarball installs:

   a) Stop Cassandra:

   ```
   $ ps auwx | grep cassandra
   $ sudo  kill <pid>
   ```

   b) Clear the data:

   ```
   $ cd <install_location>
   $ sudo rm -rf /var/lib/cassandra/*
   ```

4. Modify the following property settings in the `cassandra.yaml` file for each node:
   - num_tokens: <recommended value: 256>
   - -seeds: <internal IP address of each seed node>
   - listen_address: <localhost IP address>
   - endpoint_snitch: <name of snitch> (See endpoint_snitch.)
   - auto_bootstrap: false (Add this setting **only** when initializing a fresh cluster with no data.)

   node0

   ```
   cluster_name: 'MyDemoCluster'
   num_tokens: 256
   seed_provider:
     - class_name: org.apache.cassandra.locator.SimpleSeedProvider
       parameters:
            - seeds:  "110.82.155.0,110.82.155.3"
   listen_address: 110.82.155.0
   rpc_address: 0.0.0.0
   endpoint_snitch: RackInferringSnitch
   ```

   node1 to node5

   The properties for these nodes are the same as **node0** except for the listen_address.
5. After you have installed and configured Cassandra on all nodes, start the seed nodes one at a time, and then start the rest of the nodes.

   If the node has restarted because of automatic restart, you must stop the node and clear the data directories, as described above.

   For packaged installs, run the following command:

   ```
   $ sudo service cassandra start
   ```

   For binary installs, run the following commands:

   ```
   $ cd <install_location>
   $ bin/cassandra
   ```
6. To check that the ring is up and running, run the `nodetool status` command.

```
paul@ubuntu:~/cassandra-1.2.0$ bin/nodetool status
Datacenter: datacenter1
=======================
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address          Load       Tokens  Owns   Host ID                               Rack
UN  10.194.171.160   53.98 KB   256     0.8%   a9fa31c7-f3c0-44d1-b8e7-a2628867840c  rack1
UN  10.196.14.48     93.62 KB   256     9.9%   f5bb146c-db51-475c-a44f-9facf2f1ad6e  rack1
DN  10.196.14.239    ?          256     8.2%   null                                  rack1
```

Initializing a multiple node cluster (multiple data centers)

You can use initialize a Cassandra cluster with multiple data centers.

Data replicates across the data centers automatically and transparently; no ETL work is necessary to move data between different systems or servers. You can configure the number of copies of the data in each data center and Cassandra handles the rest, replicating the data for you.

In Cassandra, the term data center is a grouping of nodes. Data center is synonymous with replication group, that is, a grouping of nodes configured together for replication purposes.

Each node must be correctly configured before starting the cluster. You must determine or perform the following before starting the cluster:

- Install Cassandra on each node.

- Choose a name for the cluster.
- Get the IP address of each node.
- Determine which nodes will be seed nodes. (Cassandra nodes use the seed node list for finding each other and learning the topology of the ring.)
- Determine the snitch.
- If using multiple data centers, determine a naming convention for each data center and rack, for example: DC1, DC2 or 100, 200 and RAC1, RAC2 or R101, R102.
- Other possible configuration settings are described in The cassandra.yaml configuration file on page 64.

1. Suppose you install Cassandra on these nodes:

```
node0 10.168.66.41 (seed1)
node1 10.176.43.66
node2 10.168.247.41
node3 10.176.170.59 (seed2)
node4 10.169.61.170
node5 10.169.30.138
```

2. If you have a firewall running on the nodes in your cluster, you must open certain ports to allow communication between the nodes. See Configuring firewall port access on page 50.
3. If Cassandra is running:

   Packaged installs:

   a) Stop Cassandra:

   ```
   $ sudo service cassandra stop
   ```

   b) Clear the data:

   ```
   $ sudo rm -rf /var/lib/cassandra/*
   ```

   Tarball installs:

   a) Stop Cassandra:

   ```
   $ ps auwx | grep cassandra
   $ sudo  kill <pid>
   ```

   b) Clear the data:

   ```
   $ cd <install_location>
   $ sudo rm -rf /var/lib/cassandra/*
   ```

4. Modify the following property settings in the `cassandra.yaml` file for each node:

   - num_tokens: <recommended value: 256>
   - -seeds: <internal IP address of each seed node>
   - listen_address: <localhost IP address>
   - endpoint_snitch: <name of snitch> (See endpoint_snitch.)
   - auto_bootstrap: false (Add this setting **only** when initializing a fresh cluster with no data.)

   node0

```
cluster_name: 'MyDemoCluster'
num_tokens: 256
seed_provider:
  - class_name: org.apache.cassandra.locator.SimpleSeedProvider
    parameters:
         - seeds:  "10.168.66.41,10.176.170.59"
listen_address: 10.168.66.41
endpoint_snitch: PropertyFileSnitch
```

   Note: Include at least one node from *each* data center.

   node1 to node5

The properties for these nodes are the same as **node0** except for the listen_address.

5. In the cassandra-topology.properties file, assign the data center and rack names you determined in the Prerequisites to the IP addresses of each node. For example:

```
# Cassandra Node IP=Data Center:Rack
10.168.66.41=DC1:RAC1
10.176.43.66=DC2:RAC1
10.168.247.41=DC1:RAC1
10.176.170.59=DC2:RAC1
10.169.61.170=DC1:RAC1
10.169.30.138=DC2:RAC1
```

6. Also, in the cassandra-topologies.properties file, assign a default data center name and rack name for unknown nodes.

```
# default for unknown nodes
default=DC1:RAC1
```

7. After you have installed and configured Cassandra on all nodes, start the seed nodes one at a time, and then start the rest of the nodes.

   If the node has restarted because of automatic restart, you must stop the node and clear the data directories, as described above.

   For packaged installs, run the following command:

```
$ sudo service cassandra start
```

   For binary installs, run the following commands:

```
$ cd <install_location>
$ bin/cassandra
```

8. To check that the ring is up and running, run the `nodetool status` command.

```
paul@ubuntu:~/cassandra-1.2.0$ bin/nodetool status
Datacenter: datacenter1
=======================
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address          Load       Tokens  Owns   Host ID                               Rack
UN  10.194.171.160   53.98 KB   256     0.8%   a9fa31c7-f3c0-44d1-b8e7-a2628867840c  rack1
UN  10.196.14.48     93.62 KB   256     9.9%   f5bb146c-db51-475c-a44f-9facf2f1ad6e  rack1
DN  10.196.14.239    ?          256     8.2%   null                                  rack1
```

Security

Securing Cassandra

Cassandra provides these security features to the open source community.

- Client-to-node encryption

  Cassandra includes an optional, secure form of communication from a client machine to a database cluster. Client to server SSL ensures data in flight is not compromised and is securely transferred back/forth from client machines.
- Authentication based on internally controlled login accounts/passwords

  Administrators can create users who can be authenticated to Cassandra database clusters using the CREATE USER command. Internally, Cassandra manages user accounts and access to the database cluster using passwords. User accounts may be altered and dropped using the Cassandra Query Language (CQL).
- Object permission management

  Once authenticated into a database cluster using either internal authentication, the next security issue to be tackled is permission management. What can the user do inside the database? Authorization capabilities for Cassandra use the familiar GRANT/REVOKE security paradigm to manage object permissions.

SSL encryption

Client-to-node encryption

Client-to-node encryption protects data in flight from client machines to a database cluster using SSL (Secure Sockets Layer). It establishes a secure channel between the client and the coordinator node.

All nodes must have all the relevant SSL certificates on all nodes. See Preparing server certificates on page 47.

To enable client-to-node SSL, you must set the client_encryption_options in the `cassandra.yaml` file.

On each node under client_encryption_options:

- Enable encryption.
- Set the appropriate paths to your `.keystore` and `.truststore` files.
- Provide the required passwords. The passwords must match the passwords used when generating the keystore and truststore.
- To enable client certificate authentication, set require_client_auth to true. (Available starting with Cassandra 1.2.3.)

```
client_encryption_options:
enabled: true
keystore: conf/.keystore ## The path to your .keystore file
keystore_password: <keystore password> ## The password you used
 when generating the keystore.
truststore: conf/.truststore
truststore_password: <truststore password>
require_client_auth: <true or false>
```

Node-to-node encryption

Node-to-node encryption protects data transferred between nodes in a cluster using SSL (Secure Sockets Layer).

All nodes must have all the relevant SSL certificates on all nodes. See Preparing server certificates on page 47.

To enable node-to-node SSL, you must set the server_encryption_options in the `cassandra.yaml` file.

On each node under sever_encryption_options:

- Enable internode_encryption.

  The available options are:

  - all
  - none
  - dc: Cassandra encrypts the traffic between the data centers.
  - rack: Cassandra encrypts the traffic between the racks.
- Set the appropriate paths to your `.keystore` and `.truststore` files.
- Provide the required passwords. The passwords must match the passwords used when generating the keystore and truststore.
- To enable client certificate authentication, set require_client_auth to true. (Available starting with Cassandra 1.2.3.)

```
server_encryption_options:
   internode_encryption: <internode_option>
   keystore: resources/dse/conf/.keystore
   keystore_password: <keystore password>
   truststore: resources/dse/conf/.truststore
   truststore_password: <truststore password>
   require_client_auth: <true or false>
```

Using cqlsh with SSL encryption

Using a `.cqlshrc` file, or `cqlshrc` file in Cassandra 1.2.9 and later, means you don't have to override the SSL_CERTFILE environmental variables every time.

To run cqlsh, you must create a `.cqlshrc` or `cqlshrc` file in your home or client program directory. In Cassandra 1.2.9 and later, create the `cqlshrc` file in your `~/.cassandra` directory. You cannot use cqlsh when client certificate authentication is enabled (require_client_auth=true). Sample files are available in the following directories:

- Packaged installs: `/etc/cassandra`
- Binary installs: `<install_location>/conf`

```
[authentication]
username = fred
password = !!bang!!$

[connection]
hostname = 127.0.0.1
port = 9160
factory = cqlshlib.ssl.ssl_transport_factory

[ssl]
certfile = ~/keys/cassandra.cert
validate = true ## Optional, true by default.

[certfiles] ## Optional section, overrides the default certfile in
 the [ssl] section.
```

```
192.168.1.3 = ~/keys/cassandra01.cert
192.168.1.4 = ~/keys/cassandra02.cert
```

Note:

When validate is enabled, the host in the certificate is compared to the host of the machine that it is connected to. The SSL certificate must be provided either in the configuration file or as an environment variable. The environment variables (*SSL_CERTFILE* and *SSL_VALIDATE*) override any options set in this file.

Preparing server certificates

Generate SSL certificates for client-to-node encryption or node-to-node encryption.

If you generate the certificates for one type of encryption, you do not need to generate them again for the other: the same certificates are used for both.

All nodes must have all the relevant SSL certificates on all nodes. A keystore contains private keys. The truststore contains SSL certificates for each node and doesn't require signing by a trusted and recognized public certification authority.

1. Generate the private and public key pair for the nodes of the cluster leaving the key password the same as the keystore password:

   ```
   keytool -genkey -alias <cassandra_node0> -keyalg RSA -keystore .keystore
   ```
2. Repeat the previous step on each node using a different alias for each one.
3. Export the public part of the certificate to a separate file and copy these certificates to all other nodes.

   ```
   keytool -export -alias cassandra -file cassandranode0.cer -
   keystore .keystore
   ```
4. Add the certificate of each node to the truststore of each node, so nodes can verify the identity of other nodes.

   ```
   keytool -import -v -trustcacerts -alias <cassandra_node0> -file
    <cassandra_node0>.cer -keystore .truststore
   keytool -import -v -trustcacerts -alias <cassandra_node1> -file
    <cassandra_node1>.cer -keystore .truststore
   . . .
   ```
5. Make sure `.keystore` is readable only to the Cassandra daemon and not by any user of the system.

Adding new trusted users

Add new users when client certificate authentication is enabled.

The client certificate authentication must be enabled (require_client_auth=true).

1. Generate the certificate as described in Client-to-node encryption on page 45.
2. Import the user's certificate into every node's truststore using keytool:

   ```
   keytool -import -v -trustcacerts -alias <username> -file <certificate file>
    -keystore .truststore
   ```

Internal authentication

Internal authentication

Like object permission management using internal authorization, internal authentication is based on Cassandra-controlled login accounts and passwords. Internal authentication works for the following clients when you provide a user name and password to start up the client:

- Astyanax
- cassandra-cli
- cqlsh
- DataStax Java and C# drivers
- Hector
- pycassa

Internal authentication stores usernames and bcrypt-hashed passwords in the system_auth.credentials table.

PasswordAuthenticator is an IAuthorizer implementation, available in Cassandra 1.2.2 and later, that you can use to configure Cassandra for internal authentication out-of-the-box.

Limitations

The dsetool and Hadoop utilities are not supported by internal authentication.

Configuring authentication

To configure Cassandra to use internal authentication, first make a change to the cassandra.yaml file and increase the replication factor of the system_auth keyspace, as described in this procedure. Next, start up Cassandra using the default user name and password (cassandra/cassandra), and start cqlsh using the same credentials. Finally, use these CQL 3 statements to set up user accounts to authorize users to access the database objects:

- ALTER USER
- CREATE USER
- DROP USER
- LIST USERS

1. Change the authenticator option in the cassandra.yaml to PasswordAuthenticator.

   By default, the authenticator option is set to AllowAllAuthenticator.

   ```
   authenticator: PasswordAuthenticator
   ```
2. Increase the replication factor for the system_auth keyspace.
3. Restart the Cassandra client.

   The default superuser name and password that you use to start the client is stored in Cassandra.

   ```
   <client startup string> -u cassandra -p cassandra
   ```
4. Start cqlsh using the superuser name and password (cassandra).

   ```
   ./cqlsh -u cassandra -p cassandra
   ```
5. Create another superuser, not named cassandra. This step is optional but highly recommended.
6. Log in as that new superuser.
7. Change the cassandra user password to something long and incomprehensible, and then forget about it. It won't be used again.
8. Take away the cassandra user's superuser status.
9. Use the CQL 3 statements listed previously to set up user accounts and then grant permissions to access the database objects.

Logging in using cqlsh

To avoid having to pass credentials for every login using cqlsh, you can create a `.cqlshrc` file, or `cqlshrc` file in Cassandra 1.2.9 and later. Create this file in your home directory, or in `~/.cassandra` in Cassandra 1.2.9 and later. When present, this file passes default login information to cqlsh.

1. Open a text editor and create a file that specifies a user name and password.

```
[authentication]
username = fred
password = !!bang!!$
```

2. Save the file in your home directory or `~/.cassandra` directory and name it .cqlshrc or cqlshrc, as previously discussed.
3. Set permissions on the file.

   To protect database login information, ensure that the file is secure from unauthorized access.

   Note: Sample .cqlshrc files are available in:

   - Packaged installs

     /usr/share/doc/dse-libcassandra
   - Binary installs

     <install_location>/conf

Internal authorization

Object permissions

You use familiar relational database GRANT/REVOKE paradigm to grant or revoke permissions to access Cassandra data. A superuser grants initial permissions, and subsequently a user may or may not be given the permission to grant/revoke permissions. Object permission management is based on internal authorization.

Read access to these system tables is implicitly given to every authenticated user because the tables are used by most Cassandra tools:

- system.schema_keyspace
- system.schema_columns
- system.schema_columnfamilies
- system.local
- system.peers

Configuring internal authorization

CassandraAuthorizer is one of many possible IAuthorizer implementations, and the one that stores permissions in the system_auth.permissions table to support all authorization-related CQL 3 statements. Configuration consists mainly of changing the authorizer option in the cassandra.yaml to use the CassandraAuthorizer.

1. In the cassandra.yaml, comment out the default AllowAllAuthorizer and add the CassandraAuthorizer.

   ```
   #authorizer: org.apache.cassandra.auth.AllowAllAuthorizer
   authorizer: org.apache.cassandra.auth.CassandraAuthorizer
   ```

   You can use any authenticator except AllowAll.
2. Configure the replication factor for the system_auth keyspace.
3. Adjust the validity period for permissions caching by setting the permissions_validity_in_ms option in the cassandra.yaml.

   Alternatively, disable permission caching by setting this option to 0.

CQL 3 will now support these authorization statements:

- GRANT
- LIST PERMISSIONS
- REVOKE

Configuring firewall port access

Which ports to open when nodes are protected by a firewall.

If you have a firewall running on the nodes in your Cassandra cluster, you must open up the following ports to allow communication between the nodes, including certain Cassandra ports. If this isn't done, when you start Cassandra on a node, the node acts as a standalone database server rather than joining the database cluster.

Table 1: Public ports

Port number	Description
22	SSH port
8888	OpsCenter website. The opscenterd daemon listens on this port for HTTP requests coming directly from the browser.

Table 2: Cassandra internode ports

Port number	Description
1024+	JMX reconnection/loopback ports. See description for port 7199.
7000	Cassandra inter-node cluster communication.
7199	Cassandra JMX monitoring port. After the initial handshake, the JMX protocol requires that the client reconnects on a randomly chosen port (1024+).
9160	Cassandra client port (Thrift).

Table 3: Cassandra OpsCenter ports

Port number	Description
61620	OpsCenter monitoring port. The opscenterd daemon listens on this port for TCP traffic coming from the agent.
61621	OpsCenter agent port. The agents listen on this port for SSL traffic initiated by OpsCenter.

Database internals

Managing data

Cassandra uses a storage structure similar to a Log-Structured Merge Tree, unlike a typical relational database that uses a B-Tree. The storage engine writes sequentially to disk in append mode and stores data contiguously. Operations are parallel within cross nodes and within an individual machine. Because Cassandra does not use a B-tree, concurrency control is unnecessary. Nothing needs to be updated when writing.

Cassandra accommodates modern solid-state disks (SSDs) extremely well. Inexpensive, consumer SSDs are fine for use with Cassandra because Cassandra minimizes wear and tear on an SSD. The disk I/O performed by Cassandra is minimal.

Throughput and latency

Throughput and latency are key factors affecting Cassandra performance in managing data on disk.

- Throughput is operations per second.
- Latency is the round trip time to complete a request.

When database operations are serial, throughput and latency are interchangeable. Cassandra operations are performed in parallel, so throughput and latency are independent. Unlike most databases, Cassandra achieves excellent throughput and latency.

Writes are very efficient in Cassandra and very inefficient in storage engines that scatter random writes around while making in-place updates. When you're doing many random writes of small amounts of data, Cassandra reads in the SSD sector. No random seeking occurs as it does in relational databases. Cassandra's log-structured design obviates the need for disk seeks. As database updates are received, Cassandra does not overwrite rows in place. In-place updates would require doing random I/O. Cassandra updates the bytes and rewrites the entire sector back out instead of modifying the data on disk. Eliminating on-disk data modification and erase-block cycles prolongs the life of the SSD and saves time: one or two milliseconds.

Cassandra does not lock the fast write request path that would negatively affect throughput. Because there is no modification of data on disk, locking for concurrency control of data on disk is unnecessary. The operational design integrates nicely with the operating system page cache. Because Cassandra does not modify the data, dirty pages that would have to be flushed are not even generated.

Using SSDs instead of rotational disks is necessary for achieving low latency. Cassandra runs the same code on every node and has no master node and no single point of failure, which also helps achieve high throughput.

Separate table directories

Cassandra 1.1 and later releases provide fine-grained control of table storage on disk, writing tables to disk using separate table directories within each keyspace directory. Data files are stored using this directory and file naming format:

/var/lib/cassandra/data/ks1/cf1/ks1-cf1-hc-1-Data.db

The new file name format includes the keyspace name to distinguish which keyspace and table the file contains when streaming or bulk loading data. Cassandra creates a subdirectory for each table, which allows you to symlink a table to a chosen physical drive or data volume. This provides the capability to move very active tables to faster media, such as SSD's for better performance, and also divvy up tables across all attached storage devices for better I/O balance at the storage layer.

About writes

To manage and access data in Cassandra, it is important to understand how Casssandra writes and reads data, the hinted handoff feature, areas of conformance and non-conformance to the ACID (atomic, consistent, isolated, durable) database properties. In Cassandra, consistency refers to how up-to-date and synchronized a row of data is on all of its replicas.

Cassandra includes client utilities and application programming interfaces (APIs) for developing applications for data storage and retrieval.

The role of replication

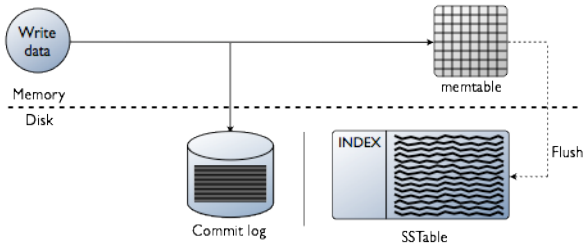
Cassandra delivers high availability for writing through its data replication strategy. Cassandra duplicates data on multiple peer nodes to ensure reliability and fault tolerance. Relational databases, on the other hand, typically structure tables to keep data duplication at a minimum. The relational database server has to do additional work to ensure data integrity across the tables. In Cassandra, maintaining integrity between related tables is not an issue. Cassandra tables are not related. Usually, Cassandra performs better on writes than relational databases.

About the write path

When a write occurs, Cassandra stores the data in a structure in memory, the memtable, and also appends writes to the commit log on disk, providing configurable durability.

The commit log receives every write made to a Cassandra node, and these durable writes survive permanently even after hardware failure.

The more a table is used, the larger its memtable needs to be. Cassandra can dynamically allocate the right amount of memory for the memtable or you can manage the amount of memory being utilized yourself. When memtable contents exceed a configurable threshold, the memtable data, which includes indexes, is put in a queue to be flushed to disk. You can configure the length of the queue by changing memtable_flush_queue_size in the cassandra.yaml. If the data to be flushed exceeds the queue size, Cassandra blocks writes. The memtable data is flushed to SSTables on disk using sequential I/O. Data in the commit log is purged after its corresponding data in the memtable is flushed to the SSTable.



Memtables and SSTables are maintained per table. SSTables are immutable, not written to again after the memtable is flushed. Consequently, a row is typically stored across multiple SSTable files.

For each SSTable, Cassandra creates these in-memory structures:

- Partition index

  A list of primary keys and the start position of rows in the data file.
- Partition summary

  A subset of the partition index. By default 1 primary key out of every 128 is sampled.

How Cassandra stores data

In the memtable, data is organized in sorted order.

For efficiency, Cassandra does not repeat the names of the columns in memory or in the SSTable. For example, the following writes occur:

```
write (k1, c1:v1)
write (k2, c1:v1 C2:v2)
write (k1, c1:v4 c3:v3 c2:v2)
```

In the memtable, Cassandra stores this data after receiving the writes:

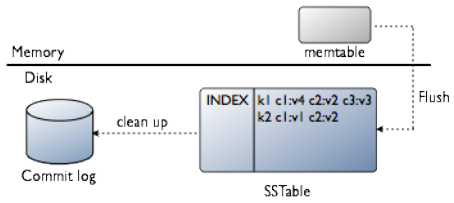
```
k1 c1:v4 c2:v2 c3:v3
k2 c1:v1 c2:v2
```

In the commit log on disk, Cassandra stores this data after receiving the writes:

```
k1, c1:v1
k2, c1:v1 C2:v2
k1, c1:v4 c3:v3 c2:v2
```

In the SSTable on disk, Cassandra stores this data after flushing the memtable:

```
k1 c1:v4 c2:v2 c3:v3
k2 c1:v1 c2:v2
```



About index updates

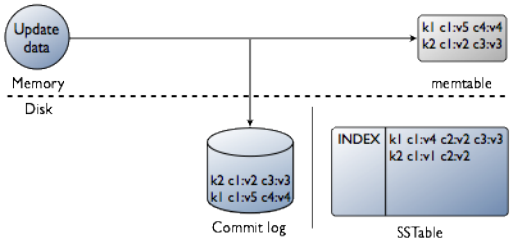
To update an index Cassandra appends data to the commit log, updates the memtable, and updates the index. Writing to a table having an index involves more work than writing to a table without an index, but the update process has been improved in Cassandra 1.2. The need for a synchronization lock to prevent concurrency issues for heavy insert loads has been removed.

When a column is updated, the index is updated. If the old column value was still in the memtable, which typically occurs when updating a small set of rows repeatedly, Cassandra removes the index entry; otherwise, the old entry remains to be purged by compaction. If a read sees a stale index entry before compaction purges it, the reader thread invalidates it.

As with relational databases, keeping indexes up to date is not free, so unnecessary indexes should be avoided.

About inserts and updates

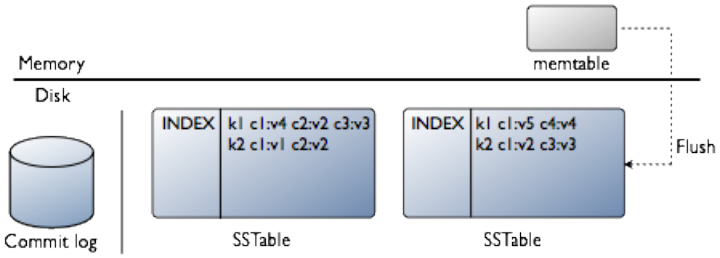
Insert and update operations are identical. As inserts/updates come in, Cassandra does not overwrite the rows in place, but instead groups inserts/updates in the memtable.



Any number of columns may be inserted/updated at the same time. When inserting or updating columns in a table, the client application identifies which column records to change.

The write path of an update

Inserting a duplicate primary key is treated as an upsert. Eventually, the updates are streamed to disk using sequential I/O and stored in a new SSTable.



Columns are overwritten only if the timestamp in the new version of the column is more recent than the existing column, so precise timestamps are necessary if updates (overwrites) are frequent. The timestamp is provided by the client, so the clocks of all client machines should be synchronized using NTP (network time protocol), for example.

About deletes

Cassandra deletes data in a different way from a traditional, relational database. A relational database might spend time scanning through data looking for expired data and throwing it away or an administrator might have to partition expired data by month, for example, to clear it out faster. In Cassandra, you do not have to manually remove expired data. Two facts about deleted Cassandra data to keep in mind are:

- Cassandra does not immediately remove deleted data from disk.
- A deleted column can reappear if you do not run node repair routinely.

After an SSTable is written, it is immutable (the file is not updated by further DML operations). Consequently, a deleted column is not removed immediately. Instead a tombstone is written to indicate the new column status. Columns marked with a tombstone exist for a configured time period (defined by the gc_grace_seconds value set on the table). When the grace period expires, the compaction process permanently deletes the column.

Marking a deleted column with a tombstone signals Cassandra to retry sending a delete request to a replica that was down at the time of delete. If the replica comes back up within the grace period of time, it eventually receives the delete request. However, if a node is down longer than the grace period, then the node can possibly miss the delete altogether, and replicate deleted data once it comes back up again. To prevent deleted data from reappearing, administrators must run regular node repair on every node in the cluster (by default, every 10 days).

About hinted handoff writes

Hinted handoff is a Cassandra feature that ensures high write availability when consistency is not required. Hinted handoff dramatically improves response consistency after temporary outages such as network failures. You enable or disable hinted handoff in the cassandra.yaml file.

How hinted handoff works

When a write is performed and a replica node for the row is either known to be down ahead of time, or does not respond to the write request, the coordinator will store a hint locally in the system.hints table. This hint indicates that the write needs to be replayed to the unavailable node(s).

The hint consists of:

- The location of the replica that is down
- The row that requires a replay
- The actual data being written

By default, hints are saved for three hours after a replica fails because if the replica is down longer than that, it is likely permanently dead. In this case, run a repair to re-replicate the data before the failure occurred. You can configure this interval of time using the max_hint_window_in_ms property in the cassandra.yaml file.

After a node discovers from gossip that a node for which it holds hints has recovered, the node sends the data row corresponding to each hint to the target. Additionally, the node checks every ten minutes for any hints for writes that timed out during an outage too brief for the failure detector to notice through gossip.

A hinted write does not count toward consistency level requirements of ONE, QUORUM, or ALL.
The coordinator node stores hints for dead replicas regardless of consistency level unless hinted handoff is disabled. If insufficient replica targets are alive to satisfy a requested consistency level, an UnavailableException is thrown with or without hinted handoff. This is an important difference from Dynamo's replication model; Cassandra does not default to sloppy quorum.

For example, in a cluster of two nodes, A and B, having a replication factor (RF) of 1: each row is stored on one node. Suppose node A is down while we write row K to it with consistency level of one. The write fails because reads always reflect the most recent write when:

W-nodes + R > replication factor

where W is the number of nodes to block for writes and R is the number of nodes to block for reads. Cassandra does not write a hint to B and call the write good because Cassandra cannot read the data at any consistency level until A comes back up and B forwards the data to A.

Extreme write availability

For applications that want Cassandra to accept writes even when all the normal replicas are down, when not even consistency level ONE can be satisfied, Cassandra provides consistency level ANY. ANY guarantees that the write is durable and will be readable after an appropriate replica target becomes available and receives the hint replay.

Performance

By design, hinted handoff inherently forces Cassandra to continue performing the same number of writes even when the cluster is operating at reduced capacity. Pushing your cluster to maximum capacity with no allowance for failures is a bad idea. Hinted handoff is designed to minimize the extra load on the cluster.

All hints for a given replica are stored under a single partition key, so replaying hints is a simple sequential read with minimal performance impact.

If a replica node is overloaded or unavailable, and the failure detector has not yet marked it down, then expect most or all writes to that node to fail after the timeout triggered by write_request_timeout_in_ms, which defaults to 10 seconds. During that time, Cassandra writes the hint when the timeout is reached.

If this happens on many nodes at once this could become substantial memory pressure on the coordinator. So the coordinator tracks how many hints it is currently writing, and if this number gets too high it will temporarily refuse writes (withUnavailableException) whose replicas include the misbehaving nodes.

Removal of hints

When removing a node from the cluster by decommissioning the node or by using the nodetool removenode command, Cassandra automatically removes hints targeting the node that no longer exists. Cassandra also removes hints for dropped tables.

Scheduling repair weekly

At first glance, it may appear that hinted handoff lets you safely get away without needing repair. This is only true if you never have hardware failure. Hardware failure has the following ramifications:

- Loss of historical data about which writes have finished. The is no information about what data has gone missing to convey to the rest of the cluster.
- Loss of hints-not-yet-replayed from requests that the failed node coordinated.

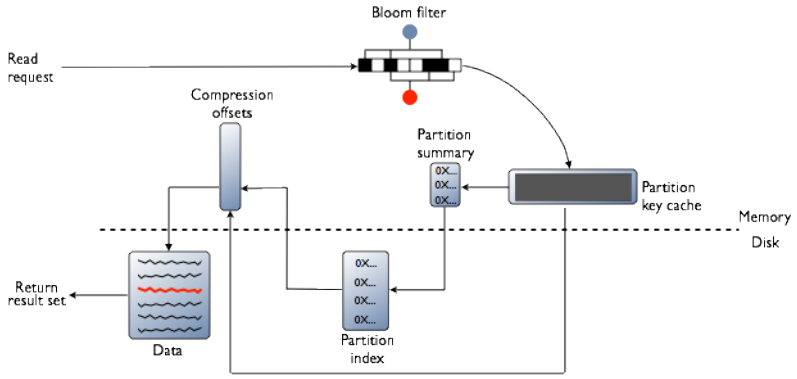
About reads

Cassandra performs random reads from SSD in parallel with extremely low latency, unlike most databases. Rotational disks are not recommended. Cassandra reads, as well as writes, data by partition key, eliminating complex queries required by a relational database.

First, Cassandra checks the Bloom filter. Each SSTable has a Bloom filter associated with it that checks the probability of having any data for the requested partition key in the SSTable before doing any disk I/O.

If the probability is good, Cassandra checks the partition key cache and takes one of these courses of action:

- If an index entry is found in the cache:
  - Cassandra goes to the compression offset map to find the compressed block having the data.
  - Fetches the compressed data on disk and returns the result set.
- If an index entry is not found in the cache:
  - Cassandra searches the partition summary to determine the approximate location on disk of the index entry.
  - Next, to fetch the index entry, Cassandra hits the disk for the first time, performing a single seek and a sequential read of columns (a range read) in the SSTable if the columns are contiguous.
  - Cassandra goes to the compression offset map to find the compressed block having the data.
  - Fetches the compressed data on disk and returns the result set.



In Cassandra 1.2 and later, the Bloom filter and compression offset map are off-heap, which greatly increases the data handling capacity per node. Of the components in memory, only the partition key cache is a fixed size. Other components grow as the data set grows.

- The Bloom filter grows to approximately 1-2 GB per billion partitions. In the extreme case, you can have one partition per row, so you can easily have billions of these entries on a single machine. The Bloom filter is tunable if you want to trade memory for performance.
- By default, the partition summary is a sample of the partition index. You configure sample frequency by changing the index_interval property in the cassandra.yaml file. You can probably increase the index_interval to 512 without seeing degradation. Cassandra 1.2.5 reduced the size of the partition summary by using raw longs instead of boxed numbers inside jvm.
- The compression offset map grows to 1-3 GB per terabyte compressed. The more you compress data, the greater number of compressed blocks you have and the larger the compression offset table.

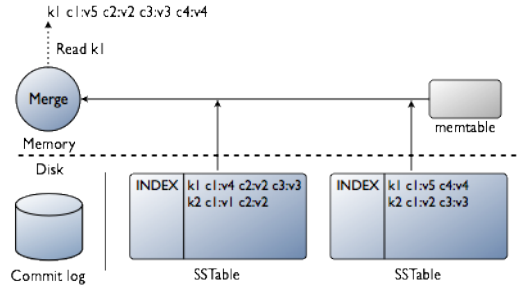
Compression is enabled by default even though going through the compression offset map consumes CPU resources. Having compression enabled makes the page cache more effective, and typically, almost always pays off.

Reading a clustered row

Using a CQL 3 schema, Cassandra's storage engine uses compound columns to store clustered rows. All the logical rows with the same partition key get stored as a single, physical row. Within a partition, all rows are not equally expensive to query. The very beginning of the partition -- the first rows, clustered by your key definition -- is slightly less expensive to query because there is no need to consult the partition-level index. For more information about clustered rows, see Compound keys and clustering in Data Modeling.

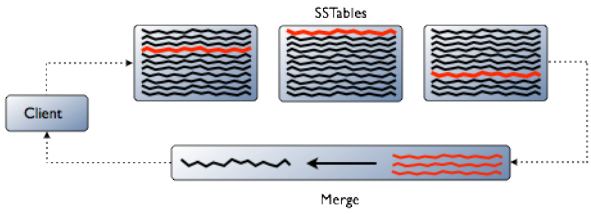
About the read path

When a read request for a row comes in to a node, the row must be combined from all SSTables on that node that contain columns from the row in question, as well as from any unflushed memtables, to produce the requested data. This diagram depicts the read path of a read request, continuing the example in The write path of an update on page 54:



For example, you have a row of user data and need to update the user email address. Cassandra doesn't rewrite the entire row into a new data file, but just puts new email address in the new data file. The user name and password are still in the old data file.

The red lines in the SSTables in this diagram are fragments of a row that Cassandra needs to combine to give the user the requested results. Cassandra caches the merged value, not the raw row fragments. That saves some CPU and disk I/O.



The row cache is a write-through cache, so if you have a cached row and you update that row, it will be updated in the cache and you still won't have to merge that again.

For a detailed explanation of how client read and write requests are handled in Cassandra, also see Client requests on page 21.

How write patterns affect reads

The type of compaction strategy Cassandra performs on your data is configurable and can significantly affect read performance. Using the SizeTieredCompactionStrategy tends to cause data fragmentation when rows are frequently updated. The LeveledCompactionStrategy (LCS) was designed to prevent fragmentation under this condition. For more information about LCS, see the article Leveled Compaction in Apache Cassandra.

How the row cache affects reads

Typical of any database, reads are fastest when the most in-demand data (or *hot* working set) fits into memory. Although all modern storage systems rely on some form of caching to allow for fast access to hot data, not all of them degrade gracefully when the cache capacity is exceeded and disk I/O is required. Cassandra's read performance benefits from built-in caching. For rows that are accessed frequently, Cassandra has a built-in key cache and an optional row cache.

How compaction and compression affect reads

To prevent read speed from deteriorating, compaction runs in the background without random I/O. Compression maximizes the storage capacity of nodes and reduces disk I/O, particularly for read-dominated workloads.

When I/O activity starts to increase in Cassandra due to increased read load, typically the remedy is to add more nodes to the cluster. Cassandra avoids decompressing data in the middle of reading a data file, making its compression application-transparent.

About transactions and concurrency control

Cassandra does not offer fully ACID-compliant transactions, the standard for transactional behavior in a relational database systems:

- Atomic

  Everything in a transaction succeeds or the entire transaction is rolled back.
- Consistent

  A transaction cannot leave the database in an inconsistent state.
- Isolated

  Transactions cannot interfere with each other.
- Durable

  Completed transactions persist in the event of crashes or server failure.

As a non-relational database, Cassandra does not support joins or foreign keys, and consequently does not offer consistency in the ACID sense. For example, when moving money from account A to B the total in the accounts does not change. Cassandra supports atomicity and isolation at the row-level, but trades transactional isolation and atomicity for high availability and fast write performance. Cassandra writes are durable.

Atomicity

In Cassandra, a write is atomic at the row-level, meaning inserting or updating columns in a row is treated as one write operation. Cassandra does not support transactions in the sense of bundling multiple row updates into one all-or-nothing operation. Nor does it roll back when a write succeeds on one replica, but

fails on other replicas. It is possible in Cassandra to have a write operation report a failure to the client, but still actually persist the write to a replica.

For example, if using a write consistency level of QUORUM with a replication factor of 3, Cassandra will replicate the write to all nodes in the cluster and wait for acknowledgement from two nodes. If the write fails on one of the nodes but succeeds on the other, Cassandra reports a failure to replicate the write on that node. However, the replicated write that succeeds on the other node is not automatically rolled back.

Cassandra uses timestamps to determine the most recent update to a column. The timestamp is provided by the client application. The latest timestamp always wins when requesting data, so if multiple client sessions update the same columns in a row concurrently, the most recent update is the one that will eventually persist.

Tunable consistency

There are no locking or transactional dependencies when concurrently updating multiple rows or tables. Cassandra supports tuning availability and consistency, and always gives you partition tolerance. Cassandra can be tuned to give you strong consistency in the CAP sense where data is made consistent across all the nodes in a distributed database cluster. A user can pick and choose on a per operation basis how many nodes must receive a DML command or respond to a SELECT query.

Isolation

Prior to Cassandra 1.1, it was possible to see partial updates in a row when one user was updating the row while another user was reading that same row. For example, if one user was writing a row with two thousand columns, another user could potentially read that same row and see some of the columns, but not all of them if the write was still in progress.

Full row-level isolation is now in place so that writes to a row are isolated to the client performing the write and are not visible to any other user until they are complete.

From a transactional ACID (atomic, consistent, isolated, durable) standpoint, this enhancement now gives Cassandra transactional AID support. A write is isolated at the row-level in the storage engine.

Durability

Writes in Cassandra are durable. All writes to a replica node are recorded both in memory and in a commit log on disk before they are acknowledged as a success. If a crash or server failure occurs before the memory tables are flushed to disk, the commit log is replayed on restart to recover any lost writes. In addition to the local durability (data immediately written to disk), the replication of data on other nodes strengthens durability.

Configuring data consistency

Consistency refers to how up-to-date and synchronized a row of Cassandra data is on all of its replicas. Cassandra extends the concept of eventual consistency by offering tunable consistency—for any given read or write operation, the client application decides how consistent the requested data should be.

In addition to tunable consistency, Cassandra has a number of built-in repair mechanisms to ensure that data remains consistent across replicas.

Note: You may find this tool useful when determining consistency levels. This site is not run by DataStax.

Tunable consistency for client requests

Consistency levels in Cassandra can be configured to manage response time versus data accuracy. You can configure consistency on a cluster, data center, or individual I/O operation basis. Very strong

or eventual consistency among participating nodes can be set globally and also controlled on a per-operation basis (for example insert or update) using Cassandra's drivers and client libraries.

About write consistency

The consistency level specifies the number of replicas on which the write must succeed before returning an acknowledgment to the client application.

Table 4: Write Consistency Levels

Level	Description	Usage
ANY	A write must be written to at least one node. If all replica nodes for the given row key are down, the write can still succeed after a hinted handoff has been written. If all replica nodes are down at write time, an ANY write is not readable until the replica nodes for that row have recovered.	Provides low latency and a guarantee that a write never fails. Delivers the lowest consistency and highest availability compared to other levels.
ONE	A write must be written to the commit log and memory table of at least one replica node.	Satisfies the needs of most users because consistency requirements are not stringent. The replica node closest to the coordinator node that received the request serves the request (unless the dynamic snitch determines that the node is performing poorly and routes it elsewhere).
TWO	A write must be written to the commit log and memory table of at least two replica nodes.	Similar to ONE.
THREE	A write must be written to the commit log and memory table of at least three replica nodes.	Similar to TWO.
QUORUM	A write must be written to the commit log and memory table on a quorum of replica nodes.	Provides strong consistency if you can tolerate some level of failure.
LOCAL_ONE	Available in Cassandra 1.2.11 and later. A write must be sent to, and successfully acknowledged by, at least one replica node in the local datacenter.	In a multiple data center clusters, a consistency level of ONE is often desirable, but cross-DC traffic is not. LOCAL_ONE accomplishes this. For security and quality reasons, you can use this consistency level in an offline datacenter to prevent automatic connection to online nodes in other data centers if an offline node goes down.
LOCAL_QUORUM	A write must be written to the commit log and memory table	Used in multiple data center clusters with a rack-aware

Level	Description	Usage
	on a quorum of replica nodes in the same data center as the coordinator node. Avoids latency of inter-data center communication.	replica placement strategy (NetworkTopologyStrategy) and a properly configured snitch. Fails when using SimpleStrategy. Use to maintain consistency at locally (within the single data center) .
EACH_QUORUM	A write must be written to the commit log and memory table on a quorum of replica nodes in *all* data centers.	Used in multiple data center clusters to strictly maintain consistency at the same level in each data center. For example, choose this level if you want a read to fail when a data center is down and the QUORUM cannot be reached on that data center.
ALL	A write must be written to the commit log and memory table on all replica nodes in the cluster for that row.	Provides the highest consistency and the lowest availability of any other level.

Even at consistency level ONE or LOCAL_QUORUM, the write is still sent to all replicas for the written key, even replicas in other data centers. The consistency level just determines how many replicas are required to respond that they received the write.

About read consistency

The consistency level specifies how many replicas must respond to a read request before returning data to the client application.

Cassandra checks the specified number of replicas for the most recent data, based on the timestamp, to satisfy the read request.

Table 5: Read Consistency Levels

Level	Description	Usage
ONE	Returns a response from the closest replica, as determined by the snitch. By default, a read repair runs in the background to make the other replicas consistent.	Provides the highest availability of all the levels if you can tolerate a comparatively high probability of stale data being read. The replicas contacted for reads may not always have the most recent write.
TWO	Returns the most recent data from two of the closest replicas.	Similar to ONE.
THREE	Returns the most recent data from three of the closest replicas.	Similar to TWO.
QUORUM	Returns the record with the most recent timestamp after a quorum of replicas has responded.	Ensures strong consistency if you can tolerate some level of failure.

Level	Description	Usage
LOCAL_ONE	Available in Cassandra 1.2.11 and later. Returns a response from the closest replica, as determined by the snitch, but only if the replica is within the local data center.	Same usage as described in the table about write consistency levels.
LOCAL_QUORUM	Returns the record with the most recent timestamp once a quorum of replicas in the current data center as the coordinator node has reported. Avoids latency of inter-data center communication.	Used in multiple data center clusters with a rack-aware replica placement strategy (NetworkTopologyStrategy) and a properly configured snitch. Fails when using SimpleStrategy.
EACH_QUORUM	Returns the record with the most recent timestamp once a quorum of replicas in each data center of the cluster has responded.	Same as LOCAL_QUORUM
ALL	Returns the record with the most recent timestamp after all replicas have responded. The read operation will fail if a replica does not respond.	Provides the highest consistency of all levels and the lowest availability of all levels.

About the QUORUM levels

The QUORUM level writes to the number of nodes that make up a quorum. A quorum is calculated, and then rounded down to a whole number, as follows:

(replication_factor / 2) + 1

For example, using a replication factor of 3, a quorum is 2 nodes—the cluster can tolerate 1 replica down. Using a replication factor of 6, a quorum is 4—the cluster can tolerate 2 replicas down.

If consistency is top priority, you can ensure that a read always reflects the most recent write by using the following formula:

(nodes_written + nodes_read) > replication_factor

For example, if your application is using the QUORUM consistency level for both write and read operations and you are using a replication factor of 3, then this ensures that 2 nodes are always written and 2 nodes are always read. The combination of nodes written and read (4) being greater than the replication factor (3) ensures strong read consistency.

Configuring client consistency levels

You can use a new cqlsh command, CONSISTENCY, to set the consistency level for the keyspace. The WITH CONSISTENCY clause has been removed from CQL 3 commands in the release version of CQL 3. Programmatically, set the consistency level at the driver level. For example, call execute_cql3_query with the required binary query, the compression settings, and consistency level. The consistency level defaults to ONE for all write and read operations.

About built-in consistency repair features

You can use these built-in repair utilities to ensure that data remains consistent across replicas.

- Read repair
- Hinted handoff

- Anti-entropy node repair

About schema changes

In Cassandra 1.2 and later, large numbers of schema changes can simultaneously take place in a cluster without any schema disagreement among nodes. For example, if one client sets a column to an integer and another client sets the column to text, one or the another action will be instantly agreed upon. Which action is agreed upon is unpredictable.

The new schema resolution design eliminates delays caused by schema changes when a new node joins the cluster. As soon as the node joins the cluster, it receives the current schema with instantaneous reconciliation of changes.

Handling schema disagreements

In the event that a schema disagreement occurs, check for and resolve schema disagreements as follows:

1. Using the Command Line Interface (CLI), run the DESCRIBE CLUSTER command.

   ```
   $ cassandra-cli -host localhost -port 9160

      [default@unknown] DESCRIBE cluster;
   ```

   If any node is UNREACHABLE, you see output something like this:

   ```
   [default@unknown] describe cluster;
   Cluster Information:
   Snitch: com.datastax.bdp.snitch.DseDelegateSnitch
   Partitioner: org.apache.cassandra.dht.RandomPartitioner
   Schema versions:
   UNREACHABLE: [10.202.205.203, 10.80.207.102, 10.116.138.23]
   ```
2. Restart unreachable nodes.
3. Repeat steps 1 and 2 until the DESCRIBE cluster command shows that all nodes have the same schema version number—only one schema version appears in the output of DESCRIBE cluster.

Configuration

The cassandra.yaml configuration file

The `cassandra.yaml` file is the main configuration file for Cassandra.

Note: ** Some default values are set at the class level and may be missing or commented out in the `cassandra.yaml` file. Additionally, values in commented out options may not match the default value: they are the recommended value when changing from the default.

After changing properties in the `cassandra.yaml` file, you must restart the node for the changes to take effect. It is located in the following directories:

- Cassandra Packaged installs: `/etc/cassandra/conf`
- Cassandra Binary installs: `<install_location>/conf`
- DataStax Enterprise Packaged installs: `/etc/dse/cassandra`
- DataStax Enterprise Binary installs: `<install_location>/resources/cassandra/conf`

The configuration properties are grouped into the following sections:

- Initialization properties: Controls how a node is configured within a cluster, including inter-node communication, data partitioning, and replica placement.
- Global row and key caches properties : Caching parameters for tables.
- Performance tuning properties: Tuning performance and system resource utilization, including memory, disk I/O, CPU, reads, and writes.
- Binary and RPC protocol timeout properties: Timeout settings for the binary protocol.
- Remote procedure call tuning (RPC) properties: Settings for configuring and tuning RPCs (client connections).
- Fault detection properties: Settings to handle poorly performing or failing nodes.
- Automatic backup properties: Automatic backup settings.
- Security properties: Server and client security settings.

Initialization properties

Controls how a node is configured within a cluster, including inter-node communication, data partitioning, and replica placement.

Note: It is recommended that you carefully evaluate your requirements and make any changes before starting a node for the first time.

auto_bootstrap

(Default: true) This setting has been removed from default configuration. It makes new (non-seed) nodes automatically migrate the right data to themselves. When initializing a fresh cluster with no data, add auto_bootstrap: false.

broadcast_address

(Default: listen_address**) If your Cassandra cluster is deployed across multiple Amazon EC2 regions and you use the `EC2MultiRegionSnitch`, set the broadcast_address to public IP address of the node and the listen_address to the private IP.

cluster_name

(Default: Test Cluster) The name of the cluster; used to prevent machines in one logical cluster from joining another. All nodes participating in a cluster must have the same value.

commitlog_directory

(Default: `/var/lib/cassandra/commitlog`) The directory where the commit log is stored. For optimal write performance, it is recommended the commit log be on a separate disk partition (ideally, a separate physical device) from the data file directories.

data_file_directories

(Default:`/var/lib/cassandra/data`) The directory location where table data (SSTables) is stored.

disk_failure_policy

(Default: stop) Sets how Cassandra responds to disk failure.

- stop: Shuts down gossip and Thrift, leaving the node effectively dead, but it can still be inspected using JMX.
- best_effort: Cassandra does its best in the event of disk errors. If it cannot write to a disk, the disk is blacklisted for writes and the node continues writing elsewhere. If Cassandra cannot read from the disk, those SSTables are marked unreadable, and the node continues serving data from readable SSTables. This means you will see obsolete data at consistency level of ONE.
- ignore: Use for upgrading. Cassandra acts as in versions prior to 1.2. Ignores fatal errors and lets the requests fail; all file system errors are logged but otherwise ignored. It is recommended using stop or best_effort.

endpoint_snitch

(Default: `org.apache.cassandra.locator.SimpleSnitch`) Sets which snitch Cassandra uses for locating nodes and routing requests. It must be set to a class that implements `IEndpointSnitch`. For descriptions of the snitches, see Snitches on page 18.

initial_token

(Default: N/A) Used in the single-node-per-token architecture, where a node owns exactly one contiguous range in the ringspace. If you haven't specified num_tokens or have set it to the default value of 1, you should always specify this parameter when setting up a production cluster for the first time and when adding capacity. For more information, see this parameter in the Cassandra 1.1 Node and Cluster Configuration documentation.

listen_address

(Default: localhost) The IP address or hostname that other Cassandra nodes use to connect to this node. If left unset, the hostname must resolve to the IP address of this node using`/etc/hostname`, `/etc/hosts`, or DNS. Do not specify 0.0.0.0.

num_tokens

(Default: 1**) Used for virtual nodes (vnodes). Defines the number of tokens randomly assigned to this node on the ring. The more tokens, relative to other nodes, the larger the proportion of data that the node stores. Generally all nodes should have the same number of tokens assuming they have equal hardware capability. Specifying the initial_token overrides this setting. The recommended value is 256. If left unspecified, Cassandra uses the default value of 1 token (for legacy compatibility) and uses the initial_token. If you already have a cluster with one token per node, and wish to migrate to multiple tokens per node, see The cassandra-shuffle utility on page 117.

partitioner

(Default: `org.apache.cassandra.dht.Murmur3Partitioner`) Distributes rows (by key) across nodes in the cluster. Any `IPartitioner` may be used, including your own as long as it is on the classpath. Cassandra provides the following partitioners:

- `org.apache.cassandra.dht.Murmur3Partitioner`
- `org.apache.cassandra.dht.RandomPartitioner`
- `org.apache.cassandra.dht.ByteOrderedPartitioner`
- `org.apache.cassandra.dht.OrderPreservingPartitioner` (deprecated)
- `org.apache.cassandra.dht.CollatingOrderPreservingPartitioner` (deprecated)

rpc_address

(Default: localhost) The listen address for client connections (Thrift remote procedure calls). Valid values are:

- 0.0.0.0: Listens on all configured interfaces.
- IP address
- hostname
- unset: Resolves the address using the hostname configuration of the node. If left unset, the hostname must resolve to the IP address of this node using `/etc/hostname`, `/etc/hosts`, or DNS.

rpc_port

(Default: 9160) The port for the Thrift RPC service, which is used for client connections.

start_rpc

(Default: true) Starts the Thrift RPC server.

saved_caches_directory

(Default: `/var/lib/cassandra/saved_caches`) The directory location where table key and row caches are stored.

seed_provider

(Default: `org.apache.cassandra.locator.SimpleSeedProvider`) A list of comma-delimited hosts (IP addresses) to use as contact points when a node joins a cluster. Cassandra also uses this list to learn the topology of the ring. When running multiple nodes, you must change the - seeds list from the default value (127.0.0.1). In multiple data-center clusters, the - seeds list should include at least one node from each data center (replication group). See Initializing a multiple node cluster (single data center) on page 41 and Initializing a multiple node cluster (multiple data centers) on page 42.

start_native_transport

(Default: false) Enable or disable the native transport server. Currently, only the Thrift server is started by default because the native transport is considered beta. Note that the address on which the native transport is bound is the same as the rpc_address. However, the port is different from the rpc_port and specified in native_transport_port.

native_transport_port

(Default: 9042) Port on which the CQL native transport listens for clients.

native_transport_min_threads

(Default: 16**) The minimum number of thread handling requests. The meaning is the same as rpc_min_threads.

native_transport_max_threads

(Default: unlimited**) The maximum number of thread handling requests. The meaning is the same as rpc_max_threads.

storage_port

(Default: 7000) The port for inter-node communication.

Global row and key caches properties

Caching parameters for tables.

When creating or modifying tables, you enable or disable the key or row caches for that table by setting the caching parameter. Other row and key cache tuning and configuration options are set at the global (node) level. Cassandra uses these settings to automatically distribute memory for each table on the node based on the overall workload and specific table usage. You can also configure the save periods for these caches globally. For more information, see Configuring caches.

key_cache_keys_to_save

(Default: disabled - all keys are saved**) Number of keys from the key cache to save.

key_cache_save_period

(Default: 14400 - 4 hours) Duration in seconds that keys are saved in cache. Caches are saved to saved_caches_directory. Saved caches greatly improve cold-start speeds and has relatively little effect on I/O.

key_cache_size_in_mb

(Default: empty, which automatically sets it to the smaller of 5% of the available heap, or 100MB) A global cache setting for tables. It is the maximum size of the key cache in memory. To disable set to 0.

row_cache_keys_to_save

(Default: disabled - all keys are saved**) Number of keys from the row cache to save.

row_cache_size_in_mb

(Default: 0 - disabled) A global cache setting for tables.

row_cache_save_period

(Default: 0 - disabled) Duration in seconds that rows are saved in cache. Caches are saved to saved_caches_directory.

row_cache_provider

(Default: `SerializingCacheProvider`) Specifies what kind of implementation to use for the row cache.

- `SerializingCacheProvider`: Serializes the contents of the row and stores it in native memory, that is, off the JVM Heap. Serialized rows take significantly less memory than live rows in the JVM, so you can cache more rows in a given memory footprint. Storing the cache off-heap means you can use smaller heap sizes, which reduces the impact of garbage collection pauses. It is valid to specify the fully-qualified class name to a class that implements `org.apache.cassandra.cache.IRowCacheProvider`.
- `ConcurrentLinkedHashCacheProvider`: Rows are cached using the JVM heap, providing the same row cache behavior as Cassandra versions prior to 0.8.

The `SerializingCacheProvider` is 5 to 10 times more memory-efficient than `ConcurrentLinkedHashCacheProvider` for applications that are not blob-intensive. However, `SerializingCacheProvider` may perform worse in update-heavy workload situations because it invalidates cached rows on update instead of updating them in place as `ConcurrentLinkedHashCacheProvider` does.

Performance tuning properties

Tuning performance and system resource utilization, including memory, disk I/O, CPU, reads, and writes.

column_index_size_in_kb

(Default: 64) Add column indexes to a row when the data reaches this size. This value defines how much row data must be deserialized to read the column. Increase this setting if your column values are large or if you have a very large number of columns. If consistently reading only a few columns from each row or doing many partial-row reads, keep it small. All index data is read for each access, so take that into consideration when setting the index size.

commitlog_segment_size_in_mb

(Default: 32 for 32-bit JVMs, 1024 for 64-bit JVMs) Sets the size of the individual commitlog file segments. A commitlog segment may be archived, deleted, or recycled after all its data has been flushed to SSTables. This amount of data can potentially include commitlog segments from every table in the system. The default size is usually suitable for most commitlog archiving, but if you want a finer granularity, 8 or 16 MB is reasonable. See Commit log archive configuration on page 78.

commitlog_sync

(Default: periodic) The method that Cassandra uses to acknowledge writes in milliseconds:

- periodic: Used with commitlog_sync_period_in_ms (Default: 10000 - 10 seconds) to control how often the commit log is synchronized to disk. Periodic syncs are acknowledged immediately.
- batch: Used with commitlog_sync_batch_window_in_ms (Default: disabled**) to control how long Cassandra waits for other writes before performing a sync. When using this method, writes are not acknowledged until fsynced to disk.

commitlog_total_space_in_mb

(Default: 32 for 32-bit JVMs, 1024 for 64-bit JVMs**) Total space used for commitlogs. If the used space goes above this value, Cassandra rounds up to the next nearest segment multiple and flushes memtables to disk for the oldest commitlog segments, removing those log segments. This reduces the amount of data to replay on startup, and prevents infrequently-updated tables from indefinitely keeping commitlog segments. A small total commitlog space tends to cause more flush activity on less-active tables.

compaction_preheat_key_cache

(Default: true) When set to true, cached row keys are tracked during compaction, and re-cached to their new positions in the compacted SSTable. If you have extremely large key caches for tables, set the value to false; see Global row and key caches properties.

compaction_throughput_mb_per_sec

(Default: 16) Throttles compaction to the specified total throughput across the entire system. The faster you insert data, the faster you need to compact in order to keep the SSTable count down. The recommended Value is 16 to 32 times the rate of write throughput (in MBs/second). Setting the value to 0 disables compaction throttling.

concurrent_compactors

(Default: 1 per CPU core**) Sets the number of concurrent compaction processes allowed to run simultaneously on a node, not including validation compactions for anti-entropy repair. Simultaneous compactions help preserve read performance in a mixed read-write workload by mitigating the tendency of small SSTables to accumulate during a single long-running compaction. If compactions run too slowly or too fast, change compaction_throughput_mb_per_sec first.

concurrent_reads

(Default: 32) For workloads with more data than can fit in memory, the bottleneck is reads fetching data from disk. Setting to (16 × number_of_drives) allows operations to queue low enough in the stack so that the OS and drives can reorder them.

concurrent_writes

(Default: 32) Writes in Cassandra are rarely I/O bound, so the ideal number of concurrent writes depends on the number of CPU cores in your system. The recommended value is (8 x number_of_cpu_cores).

cross_node_timeout

(Default: false) Enable or disable operation timeout information exchange between nodes (to accurately measure request timeouts). If disabled Cassandra assumes the request was forwarded to the replica instantly by the coordinator.

Caution: Before enabling this property make sure NTP (network time protocol) is installed and the times are synchronized between the nodes.

flush_largest_memtables_at

(Default: 0.75) When Java heap usage (after a full concurrent mark sweep (CMS) garbage collection) exceeds the set value, Cassandra flushes the largest memtables to disk to free memory. This parameter is an emergency measure to prevent sudden out-of-memory (OOM) errors. Do not use it as a tuning mechanism. It is most effective under light to moderate loads or read-heavy workloads; it will fail under massive write loads. A value of 0.75 flushes memtables when Java heap usage is above 75% total heap size. Set to 1.0 to disable. Other emergency measures are reduce_cache_capacity_to and reduce_cache_sizes_at.

in_memory_compaction_limit_in_mb

(Default: 64) Size limit for rows being compacted in memory. Larger rows spill to disk and use a slower two-pass compaction process. When this occurs, a message is logged specifying the row key. The recommended value is 5 to 10 percent of the available Java heap size.

index_interval

(Default: 128) Controls the sampling of entries from the primary row index. The interval corresponds to the number of index entries that are skipped between taking each sample. By default Cassandra samples one row key out of every 128. The larger the interval, the smaller and less effective the sampling. The larger the sampling, the more effective the index, but with increased memory usage. Generally, the best trade off between memory usage and performance is a value between 128 and 512 in combination with a large table

key cache. However, if you have small rows (many to an OS page), you may want to increase the sample size, which often lowers memory usage without an impact on performance. For large rows, decreasing the sample size may improve read performance.

memtable_flush_queue_size

(Default: 4) The number of full memtables to allow pending flush (memtables waiting for a write thread). At a minimum, set to the maximum number of indexes created on a single table.

memtable_flush_writers

(Default: 1 per data directory**) Sets the number of memtable flush writer threads. These threads are blocked by disk I/O, and each one holds a memtable in memory while blocked. If you have a large Java heap size and many data directories, you can increase the value for better flush performance.

memtable_total_space_in_mb

(Default: 1/3 of the heap**) Specifies the total memory used for all memtables on a node. This replaces the per-table storage settings memtable_operations_in_millions and memtable_throughput_in_mb.

multithreaded_compaction

(Default: false) When set to true, each compaction operation uses one thread per core and one thread per SSTable being merged. This is typically useful only on nodes with SSD hardware. With HDD hardware, the goal is to limit the disk I/O for compaction (see compaction_throughput_mb_per_sec).

populate_io_cache_on_flush

(Default: false**) Populates the page cache on memtable flush and compaction. Enable this setting only when the whole node's data fits in memory.

reduce_cache_capacity_to

(Default: 0.6) Sets the size percentage to which maximum cache capacity is reduced when Java heap usage reaches the threshold defined by reduce_cache_sizes_at. Together with flush_largest_memtables_at, these properties constitute an emergency measure for preventing sudden out-of-memory (OOM) errors.

reduce_cache_sizes_at

(Default: 0.85) When Java heap usage (after a full concurrent mark sweep (CMS) garbage collection) exceeds this percentage, Cassandra reduces the cache capacity to the fraction of the current size as specified by reduce_cache_capacity_to. To disable, set the value to 1.0.

stream_throughput_outbound_megabits_per_sec

(Default: 400**) Throttles all outbound streaming file transfers on a node to the specified throughput. Cassandra does mostly sequential I/O when streaming data during bootstrap or repair, which can lead to saturating the network connection and degrading client (RPC) performance.

trickle_fsync

(Default: false) When doing sequential writing, enabling this option tells fsync to force the operating system to flush the dirty buffers at a set interval trickle_fsync_interval_in_kb. Enable this parameter to avoid sudden dirty buffer flushing from impacting read latencies. Recommended to use on SSDs, but not on HDDs.

trickle_fsync_interval_in_kb

(Default: 10240]). Sets the size of the fsync in kilobytes.

Binary and RPC protocol timeout properties

Timeout settings for the binary protocol.

read_request_timeout_in_ms

(Default: 10000) The time in milliseconds that the coordinator waits for read operations to complete.

range_request_timeout_in_ms

(Default: 10000) The time in milliseconds that the coordinator waits for sequential or index scans to complete.

truncate_request_timeout_in_ms

(Default: 60000) The time in milliseconds that the coordinator waits for truncates to complete. The long default value allows for flushing of all tables, which ensures that anything in the commitlog is removed that could cause truncated data to reappear. If auto_snapshot is disabled, you can reduce this time.

write_request_timeout_in_ms

(Default: 10000) The time in milliseconds that the coordinator waits for write operations to complete.

request_timeout_in_ms

(Default: 10000) The default timeout for other, miscellaneous operations.

Remote procedure call tuning (RPC) properties

Settings for configuring and tuning RPCs (client connections).

request_scheduler

(Default: `org.apache.cassandra.scheduler.NoScheduler`) Defines a scheduler to handle incoming client requests according to a defined policy. This scheduler is useful for throttling client requests in single clusters containing multiple keyspaces. Valid values are:

- `org.apache.cassandra.scheduler.NoScheduler`: No scheduling takes place and does not have any options.
- `org.apache.cassandra.scheduler.RoundRobinScheduler`: See request_scheduler_options properties.
- A Java class that implements the `RequestScheduler` interface.

request_scheduler_id

(Default: keyspace**) An identifier on which to perform request scheduling. Currently the only valid value is keyspace.

request_scheduler_options

(Default: disabled) Contains a list of properties that define configuration options for request_scheduler:

- throttle_limit: (Default: 80) The number of active requests per client. Requests beyond this limit are queued up until running requests complete. Recommended value is ((concurrent_reads + concurrent_writes) × 2).
- default_weight: (Default: 1**) How many requests are handled during each turn of the `RoundRobin`.
- weights: (Default: 1 or default_weight) How many requests are handled during each turn of the `RoundRobin`, based on the request_scheduler_id. Takes a list of keyspaces: weights.

rpc_keepalive

(Default: true) Enable or disable keepalive on client connections.

rpc_max_threads

(Default: unlimited**) Regardless of your choice of RPC server (rpc_server_type), the number of maximum requests in the RPC thread pool dictates how many concurrent requests are possible. However, if you are using the parameter sync in the rpc_server_type, it also dictates the number of clients that can be connected. For a large number of client connections, this could cause excessive memory usage for the thread stack. Connection pooling on the client side is highly recommended. Setting a maximum thread pool size acts as a safeguard against misbehaved clients. If the maximum is reached, Cassandra blocks additional connections until a client disconnects.

rpc_min_threads

(Default: 16**) Sets the minimum thread pool size for remote procedure calls.

rpc_recv_buff_size_in_bytes

(Default: N/A**) Sets the receiving socket buffer size for remote procedure calls.

rpc_send_buff_size_in_bytes

(Default: N/A**) Sets the sending socket buffer size in bytes for remote procedure calls.

streaming_socket_timeout_in_ms

(Default: 0 - never timeout streams**) Enable or disable socket timeout for streaming operations. When a timeout occurs during streaming, streaming is retried from the start of the current file. Avoid setting this value too low, as it can result in a significant amount of data re-streaming.

rpc_server_type

(Default: sync) Cassandra provides three options for the RPC server. On Windows, sync is about 30% slower than hsha. On Linux, sync and hsha performance is about the same, but hsha uses less memory.

- sync: (default) One connection per thread in the RPC pool. For a very large number of clients, memory is the limiting factor. On a 64 bit JVM, 128KB is the minimum stack size per thread. Connection pooling is strongly recommended.
- hsha: Half synchronous, half asynchronous. The RPC thread pool is used to manage requests, but the threads are multiplexed across the different clients. All Thrift clients are handled asynchronously using a small number of threads that does not vary with the number of clients (and thus scales well to many clients). The RPC requests are synchronous (one thread per active request).
- Your own RPC server: You must provide a fully-qualified class name of an o.a.c.t.TServerFactory that can create a server instance.

thrift_framed_transport_size_in_mb

(Default: 15) Frame size (maximum field length) for Thrift. The frame is the row or part of the row the application is inserting.

thrift_max_message_length_in_mb

(Default: 16) The maximum length of a Thrift message in megabytes, including all fields and internal Thrift overhead (1 byte of overhead for each frame). Message length is usually used in conjunction with batches. A frame length greater than or equal to 24 accommodates a batch with four inserts, each of which is 24 bytes. The required message length is greater than or equal to 24+24+24+24+4 (number of frames).

Fault detection properties

Settings to handle poorly performing or failing nodes.

dynamic_snitch_badness_threshold

(Default: 0.0) Sets the performance threshold for dynamically routing requests away from a poorly performing node. A value of 0.2 means Cassandra continues to prefer the static snitch values until the node response time is 20% worse than the best performing node. Until the threshold is reached, incoming client requests are statically routed to the closest replica (as determined by the snitch). Having requests consistently routed to a given replica can help keep a working set of data hot when read repair is less than 1.

dynamic_snitch_reset_interval_in_ms

(Default: 600000) Time interval in milliseconds to reset all node scores, which allows a bad node to recover.

dynamic_snitch_update_interval_in_ms

(Default: 100) The time interval in milliseconds for calculating read latency.

hinted_handoff_enabled

(Default: true) Enable or disable hinted handoff. A hint indicates that the write needs to be replayed to an unavailable node. Where Cassandra writes the hint depends on the version:

- Prior to 1.0: Writes to a live replica node.
- 1.0 and later: Writes to the coordinator node.

hinted_handoff_throttle_in_kb

(Default: 1024) Maximum throttle per delivery thread in kilobytes per second. This rate reduces proportionally to the number of nodes in the cluster. For example, if there are two nodes in the cluster, each delivery thread will use the maximum rate; if there are three, each node will throttle to half of the maximum, since the two nodes are expected to deliver hints simultaneously.

max_hint_window_in_ms

(Default: 10800000 - 3 hours) Defines how long in milliseconds to generate and save hints for an unresponsive node. After this interval, new hints are no longer generated until the node is back up and responsive. If the node goes down again, a new interval begins. This setting can prevent a sudden demand for resources when a node is brought back online and the rest of the cluster attempts to replay a large volume of hinted writes.

max_hints_delivery_threads

(Default: 2) Number of threads with which to deliver hints. For multiple data center deployments, consider increasing this number because cross data-center handoff is generally slower.

phi_convict_threshold

(Default: 8**) Adjusts the sensitivity of the failure detector on an exponential scale. Lower values increase the likelihood that an unresponsive node will be marked as down, while higher values decrease the likelihood that transient failures will cause a node failure. In unstable network environments (such as EC2 at times), raising the value to 10 or 12 helps prevent false failures. Values higher than 12 and lower than 5 are not recommended.

Automatic backup properties

Automatic backup settings.

auto_snapshot

(Default: true) Enable or disable whether a snapshot is taken of the data before keyspace truncation or dropping of tables. To prevent data loss, using the default setting is strongly advised. If you set to false, you will lose data on truncation or drop.

incremental_backups

(Default: false) Backs up data updated since the last snapshot was taken. When enabled, Cassandra creates a hard link to each SSTable flushed or streamed locally in a backups/ subdirectory of the keyspace data. Removing these links is the operator's responsibility.

snapshot_before_compaction

(Default: false) Enable or disable taking a snapshot before each compaction. This option is useful to back up data when there is a data format change. Be careful using this option because Cassandra does not clean up older snapshots automatically.

Security properties

Server and client security settings.

authenticator

(Default: `org.apache.cassandra.auth.AllowAllAuthenticator`) The authentication backend. It implements IAuthenticator, which is used to identify users. The available authenticators are:

- `org.apache.cassandra.auth.AllowAllAuthenticator`: Disables authentication; no checks are performed.
- `org.apache.cassandra.auth.PasswordAuthenticator`: Authenticates users with usernames and hashed passwords stored in the system_auth.credentials table. If you use this authenticator, increase the system_auth keyspace replication factor.

authorizer

(Default: `org.apache.cassandra.auth.AllowAllAuthorizer`) The authorization backend. It implements IAuthenticator, which limits access and provides permissions. The available authorizers are:

- `org.apache.cassandra.auth.AllowAllAuthorizer`: Disables authorization; allows any action to any user.

- `org.apache.cassandra.auth.CassandraAuthorizer`: Stores permissions in system_auth.permissions table. If you use this authenticator, increase the system_auth keyspace replication factor.

permissions_validity_in_ms

(Default: 2000) How long permissions in cache remain valid. Depending on the authorizer, fetching permissions can be resource intensive. This setting is automatically disabled when AllowAllAuthorizer is set.

server_encryption_options

Enable or disable inter-node encryption. You must also generate keys and provide the appropriate key and trust store locations and passwords. No custom encryption options are currently enabled. The available options are:

- internode_encryption: (Default: none) Enable or disable encryption of inter-node communication using the TLS_RSA_WITH_AES_128_CBC_SHA cipher suite for authentication, key exchange, and encryption of data transfers. The available inter-node options are:
  - all: Encrypt all inter-node communications.
  - none: No encryption.
  - dc: Encrypt the traffic between the data centers (server only).
  - rack: Encrypt the traffic between the racks(server only).
- keystore: (Default: `conf/.keystore`) The location of a Java keystore (JKS) suitable for use with Java Secure Socket Extension (JSSE), which is the Java version of the Secure Sockets Layer (SSL), and Transport Layer Security (TLS) protocols. The keystore contains the private key used to encrypt outgoing messages.
- keystore_password: (Default: *cassandra*) Password for the keystore.
- truststore: (Default: `conf/.truststore`) Location of the truststore containing the trusted certificate for authenticating remote servers.
- truststore_password: (Default: *cassandra*) Password for the truststore.

The passwords used in these options must match the passwords used when generating the keystore and truststore. For instructions on generating these files, see Creating a Keystore to Use with JSSE.

The advanced settings are:

- protocol: (Default: TLS)
- algorithm: (Default: SunX509)
- store_type: (Default: JKS)
- cipher_suites: (Default: TLS_RSA_WITH_AES_128_CBC_SHA,TLS_RSA_WITH_AES_256_CBC_SHA)
- require_client_auth: (Default: false) Enables or disables certificate authentication.

client_encryption_options

Enable or disable client-to-node encryption. You must also generate keys and provide the appropriate key and trust store locations and passwords. No custom encryption options are currently enabled. The available options are:

- enabled: (Default: false) To enable, set to true.
- keystore: (Default: `conf/.keystore`) The location of a Java keystore (JKS) suitable for use with Java Secure Socket Extension (JSSE), which is the Java version of the Secure Sockets Layer (SSL), and Transport Layer Security (TLS) protocols. The keystore contains the private key used to encrypt outgoing messages.
- keystore_password: (Default: *cassandra*) Password for the keystore. This must match the password used when generating the keystore and truststore.
- require_client_auth: (Default: false) Enables or disables certificate authentication. (Available starting with Cassandra 1.2.3.)
- truststore: (Default: `conf/.truststore`) Set if require_client_auth is true.
- truststore_password: *<truststore_password>* Set if require_client_auth is true.

The advanced settings are:

- protocol: (Default: TLS)
- algorithm: (Default: SunX509)
- store_type: (Default: JKS)
- cipher_suites: (Default: TLS_RSA_WITH_AES_128_CBC_SHA,TLS_RSA_WITH_AES_256_CBC_SHA)

internode_send_buff_size_in_bytes

(Default: N/A**) Sets the sending socket buffer size in bytes for inter-node calls.

internode_recv_buff_size_in_bytes

(Default: N/A**) Sets the receiving socket buffer size in bytes for inter-node calls.

internode_compression

(Default: all) Controls whether traffic between nodes is compressed. The valid values are:

- all: All traffic is compressed.
- dc: Traffic between data centers is compressed.
- none: No compression.

inter_dc_tcp_nodelay

(Default: false) Enable or disable tcp_nodelay for inter-data center communication. When disabled larger, but fewer, network packets are sent. This reduces overhead from the TCP protocol itself. However, if cross data-center responses are blocked, it will increase latency.

ssl_storage_port

(Default: 7001) The SSL port for encrypted communication. Unused unless enabled in encryption_options.

Configuring the heap dump directory

Analyzing the heap dump file can help troubleshoot memory problems.

Cassandra starts Java with the option `-XX:-HeapDumpOnOutOfMemoryError`. Using this option triggers a heap dump in the event of an out-of-memory condition. The heap dump file consists of references to objects that cause the heap to overflow. By default, Cassandra puts the file a subdirectory of the working, root directory when running as a service. If Cassandra does not have write permission to the root directory, the heap dump fails. If the root directory is too small to accommodate the heap dump, the server crashes.

For a heap dump to succeed and to prevent crashes, configure a heap dump directory that meets these requirements:

- Accessible to Cassandra for writing
- Large enough to accommodate a heap dump

This file is located in:

- Packaged installs: `/etc/dse/cassandra`
- Tarball installs: `<install_location>/resources/cassandra/conf`

Base the size of the directory on the value of the Java `-mx` option.

1. Open the `cassandra-env.sh` file for editing.

   ```
   # set jvm HeapDumpPath with CASSANDRA_HEAPDUMP_DIR
   ```

2. Scroll down to the comment about the heap dump path:

   ```
   # set jvm HeapDumpPath with CASSANDRA_HEAPDUMP_DIR
   ```

3. On the line after the comment, set the `CASSANDRA_HEAPDUMP_DIR` to the path you want to use:

   ```
   # set jvm HeapDumpPath with CASSANDRA_HEAPDUMP_DIR
   CASSANDRA_HEAPDUMP_DIR =<path>
   ```

4. Save the `cassandra-env.sh` file and restart.

Generating tokens

If not using virtual nodes (vnodes), you still need to calculate tokens for your cluster.

The following topics in the Cassandra 1.1 documentation provide conceptual information about tokens:

- Data Distribution in the Ring
- Replication Strategy

About calculating tokens for single or multiple data centers in Cassandra 1.2 and later

- Single data center deployments: calculate tokens by dividing the hash range by the number of nodes in the cluster.
- Multiple data center deployments: calculate the tokens for each data center so that the hash range is evenly divided for the nodes in each data center.

For more explanation, see be sure to read the conceptual information mentioned above.

The method used for calculating tokens depends on the type of partitioner:

Calculating tokens for the Murmur3Partitioner

Use this method for generating tokens when you are **not** using virtual nodes (vnodes) and using the Murmur3Partitioner (default). This partitioner uses a maximum possible range of hash values from -2^{63} to $+2^{63}-1$. To calculate tokens for this partitioner:

```
python -c 'print [str(((2**64 / number_of_tokens) * i) - 2**63) for i in
 range(number_of_tokens)]'
```

For example, to generate tokens for 6 nodes:

```
python -c 'print [str(((2**64 / 6) * i) - 2**63) for i in range(6)]'
```

The command displays the token for each node:

```
[ '-9223372036854775808', '-6148914691236517206', '-3074457345618258604',
  '-2' , '3074457345618258600', '6148914691236517202' ]
```

Calculating tokens for the RandomPartitioner

To calculate tokens when using the RandomPartitioner in Cassandra 1.2 clusters, use the Cassandra 1.1 Token Generating Tool.

Configuring virtual nodes

Enabling virtual nodes on a new cluster

Generally when all nodes have equal hardware capability, they should have the same number of virtual nodes (vnodes). If the hardware capabilities vary among the nodes in your cluster, assign a proportional number of vnodes to the larger machines. For example, you could designate your older machines to use 128 vnodes and your new machines (that are twice as powerful) with 256 vnodes.

Set the number of tokens on each node in your cluster with the num_tokens parameter in the `cassandra.yaml` file.

The recommended value is 256. Do not set the initial_token parameter.

Enabling virtual nodes on an existing production cluster

For production clusters, enabling virtual nodes (vnodes) has less impact on performance if you bring up a another data center configured with vnodes already enabled and let Cassandra automatic mechanisms distribute the existing data into the new nodes. Using the shuffle utility can be an expensive process on a running production system because the data to be shuffled around. Bootstrapping a new data center is a much safer way to enable vnodes.

1. Add a new data center to the cluster.
2. Once the new data center with vnodes enabled is up, switch your clients to use the new data center.
3. Run a full repair with nodetool repair.

   This step ensures that after you move the client to the new data center that any previous writes are added to the new data center and that nothing else, such as hints, is dropped when you remove the old data center.
4. Update your schema to no longer reference the old data center.
5. Remove the old data center from the cluster.

   See Decommissioning a data center on page 102.

Logging configuration

Logging configuration

To get more diagnostic information about the runtime behavior of a specific Cassandra node than what is provided by Cassandra's JMX MBeans and the nodetool utility, you can increase the logging levels on specific portions of the system using log4j.

Cassandra provides logging functionality using Simple Logging Facade for Java (SLF4J) with a log4j backend. Additionally, the output.log captures the stdout of the Cassandra process, which is configurable using the standard Linux logrotate facility. You can also change logging levels via JMX using the JConsole tool.

The logging levels from most to least verbose are:

- TRACE
- DEBUG
- INFO
- WARN
- ERROR
- FATAL

Note: Be aware that increasing logging levels can generate a lot of logging output on even a moderately trafficked cluster.

Changing Logging Levels

Changing logging levels using the log4j-server.properties file.

The default logging level is determined by the following line in the `log4j-server.properties` file:

```
log4j.rootLogger=INFO,stdout,R
```

To exert more fine-grained control over your logging, you can specify the logging level for specific categories. The categories usually (but not always) correspond to the package and class name of the code doing the logging. For example, the following setting logs DEBUG messages from all classes in the `org.apache.cassandra.db` package:

```
log4j.logger.org.apache.cassandra.db=DEBUG
```

In this example, DEBUG messages are logged specifically from the `StorageProxy` class in the `org.apache.cassandra.service` package:

```
log4j.logger.org.apache.cassandra.service.StorageProxy=DEBUG
```

To determine which category a particular message in the log belongs to, you change the following line:

```
log4j.appender.R.layout.ConversionPattern=%5p [%t] %d{ISO8601} %F (line %L) %m
%n
```

1. Add `%c` at the beginning of the conversion pattern:

   ```
   log4j.appender.R.layout.ConversionPattern=%c %5p [%t] %d{ISO8601} %F (line
    %L) %m%n
   ```

   Each log message is now prefixed with the category.
2. After Cassandra runs for a while, use the following command to determine which categories are logging the most messages:

   ```
   cat system.log.* | egrep 'TRACE|DEBUG|INFO|WARN|ERROR|FATAL' | awk '{ print
    $1 }' | sort | uniq -c | sort -n
   ```
3. If you find that a particular class logs too many messages, use the following format to set a less verbose logging level for that class by adding a line for that class:

   ```
   loggerog4j.logger.package.class=WARN
   ```

   For example a busy Solr node can log numerous INFO messages from the SolrCore, LogUpdateProcessorFactory, and SolrIndexSearcher classes. To suppress these messages, add the following lines:

   ```
   log4j.logger.org.apache.solr.core.SolrCore = WARN
   log4j.logger.org.apache.solr.update.processor.LogUpdateProcessorFactory=WARN
   log4j.logger.org.apache.solr.search.SolrIndexSearcher=WARN
   ```
4. After determining which category a particular message belongs to you may want to revert the messages back to the default format. Do this by removing `%c` from the `ConversionPattern`.

Changing the rotation and size of the Cassandra output.log

Controlling the rotation and size of the `output.log`.

Cassandra's `output.log` logging configuration is controlled by the `log4j-server.properties` file in the following directories:

- Packaged installs: `/etc/dse/cassandra`
- Tarball installs: `<install_location>/resources/cassandra/conf`

The `output.log` stores the stdout of the Cassandra process; it is not controllable from log4j. However, you can rotate it using the standard Linux logrotate facility.

The `copytruncate` directive is critical because it allows the log to be rotated without any support from Cassandra for closing and reopening the file. For more information, refer to the logrotate man page.

To configure logrotate to work with Cassandra, create a file called `/etc/logrotate.d/cassandra` with the following contents:

```
/var/log/cassandra/output.log {
  size 10M
  rotate 9
  missingok
  copytruncate
  compress
}
```

Changing the rotation and size of the Cassandra system.log

Controlling the rotation and size of the `system.log`.

Cassandra's system.log logging configuration is controlled by the `log4j-server.properties` file in the following directories:

- Packaged installs: `/etc/dse/cassandra`
- Tarball installs: `<install_location>/resources/cassandra/conf`

The maximum log file size and number of backup copies are controlled by the following lines:

```
log4j.appender.R.maxFileSize=20MB
log4j.appender.R.maxBackupIndex=50
```

The default configuration rolls the log file once the size exceeds 20MB and maintains up to 50 backups. When the `maxFileSize` is reached, the current log file is renamed to `system.log.1` and a new `system.log` is started. Any previous backups are renumbered from `system.log.n` to `system.log.n+1`, which means the higher the number, the older the file. When the maximum number of backups is reached, the oldest file is deleted.

- By default, logging output is placed the `/var/log/cassandra/system.log`. You can change the location of the output by editing the `log4j.appender.R.File` path. Be sure that the directory exists and is writable by the process running Cassandra.
- If an issue occurred but has already been rotated out of the current `system.log`, check to see if it is captured in an older backup. If you want to keep more history, increase the `maxFileSize`, `maxBackupIndex`, or both. Make sure you have enough space to store the additional logs.

Commit log archive configuration

Cassandra provides commitlog archiving and point-in-time recovery.

You configure this feature in the `commitlog_archiving.properties` configuration file, which is located in the following directories:

- Cassandra Packaged installs: `/etc/cassandra/conf`
- Cassandra Binary installs: `<install_location>/conf`
- DataStax Enterprise Packaged installs: `/etc/dse/cassandra`
- DataStax Enterprise Binary installs: `<install_location>/resources/cassandra/conf`

The commands `archive_command` and `restore_command` expect only a single command with arguments. STDOUT and STDIN or multiple commands cannot be executed. To workaround, you can script multiple commands and add a pointer to this file. To disable a command, leave it blank.

- Archive a commitlog segment:

Command	**archive_command=**	
Parameters	`<path>`	Fully qualified path of the segment to archive.
	`<name>`	Name of the commit log.
Example	`archive_command=/bin/ln <path> /backup/<name>`	

- Restore an archived commitlog:

Command	**restore_command=**	
Parameters	`<from>`	Fully qualified path of the an archived commitlog segment from the `<restore_directories>`.
	`<to>`	Name of live commit log directory.
Example	`restore_command=cp -f <from> <to>`	

- Set the restore directory location:

Command	restore_directories=
Format	`restore_directories=<restore_directory location>`

- Restore mutations created up to and including the specified timestamp:

Command	restore_point_in_time=
Format	`<timestamp>`
Example	`restore_point_in_time=2012-08-16 20:43:12`

Restore stops when the first client-supplied timestamp is greater than the restore point timestamp. Because the order in which Cassandra receives mutations does not strictly follow the timestamp order, this can leave some mutations unrecovered.

Operations

Monitoring Cassandra

Monitoring a Cassandra cluster

Understanding the performance characteristics of your Cassandra cluster is critical to diagnosing issues and planning capacity.

Cassandra exposes a number of statistics and management operations via Java Management Extensions (JMX). Java Management Extensions (JMX) is a Java technology that supplies tools for managing and monitoring Java applications and services. Any statistic or operation that a Java application has exposed as an MBean can then be monitored or manipulated using JMX.

During normal operation, Cassandra outputs information and statistics that you can monitor using JMX-compliant tools, such as:

- The Cassandra nodetool utility
- DataStax OpsCenter management console
- JConsole

Using the same tools, you can perform certain administrative commands and operations such as flushing caches or doing a node repair.

Monitoring using nodetool utility

The nodetool utility is a command-line interface for monitoring Cassandra and performing routine database operations. Included in the Cassandra distribution, nodetool and is typically run directly from an operational Cassandra node.

The nodetool utility supports the most important JMX metrics and operations, and includes other useful commands for Cassandra administration. This utility is commonly used to output a quick summary of the ring and its current state of general health with the status command. For example:

```
paul@ubuntu:~/cassandra-1.2.0$ bin/nodetool status
Datacenter: datacenter1
=======================
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address          Load       Tokens  Owns   Host ID                               Rack
UN  10.194.171.160   53.98 KB   256     0.8%   a9fa31c7-f3c0-44d1-b8e7-a2628867840c  rack1
UN  10.196.14.48     93.62 KB   256     9.9%   f5bb146c-db51-475c-a44f-9facf2f1ad6e  rack1
DN  10.196.14.239    ?          256     8.2%   b8e6748f-ec11-410d-c94f-9b67d88a28e7  rack1
```

The nodetool utility provides commands for viewing detailed metrics for tables, server metrics, and compaction statistics. Commands include decommissioning a node, running repair, and moving partitioning tokens.

The nodetool cfstats command

The nodetool cfstats command displays statistics for each table and keyspace. This example shows an excerpt of the output of the command after flushing a table of wikipedia data to disk.

```
----------------
Keyspace: wiki
```

```
 Read Count: 3589
 Read Latency: 1.9554240735580943 ms.
 Write Count: 3579
 Write Latency: 0.32189075160659397 ms.
 Pending Tasks: 0
  Column Family: solr
  SSTable count: 1
  Space used (live): 9592399
  Space used (total): 9592399
  SSTable Compression Ratio: 0.5250859637980083
  Number of Keys (estimate): 3584
  Memtable Columns Count: 0
  Memtable Data Size: 0
  Memtable Switch Count: 1
  Read Count: 3589
  Read Latency: 1.955 ms.
  Write Count: 3579
  Write Latency: 0.322 ms.
  Pending Tasks: 0
  Bloom Filter False Positives: 0
  Bloom Filter False Ratio: 0.00000
  Bloom Filter Space Used: 4488
  Compacted row minimum size: 180
  Compacted row maximum size: 219342
  Compacted row mean size: 5559
----------------
```

This table describes the nodetool cfstats output.

Table 6: nodetool cfstats output

Name of statistic	Example value	Brief description	Related information
Keyspace	wiki	Name of the keyspace	Keyspace and table storage configuration
Read latency	1.9554240735580943 ms.	Read latency of tables in the keyspace	OpsCenter alert metrics
Write count	3579	Write count of tables in the keyspace	Same as above
Write latency	0.32189075160659397 ms.	Write latency of tables in the keyspace	Same as above
Pending tasks	0	Tasks in the queue for reads, writes, and cluster operations of tables in the keyspace	OpsCenter pending task metrics
Column family	solr	Name of the Cassandra table	
SSTable count	1	Number of SSTables	How to use the SSTable counts metric and OpsCenter alert metrics

Name of statistic	Example value	Brief description	Related information
		containing data from the table	
Space used (live)	9592399	Bytes, the space that is measured depends on operating system	Advanced system alert metrics
Space used (total)	9592399	Same as above	Same as above
SSTable compression ratio	0.5250859637080093	Percentage of reduction in data-representation size resulting from compression	Types of compression (sstable_compression option)
Number of keys (estimate)	3584	Sum of storage engine rows (containers for columns) in each SStable, approximate (within 128)	Counting keys in Cassandra article
Memtable columns count	0	Number of cells (storage engine rows x columns) of data in the memtable	Cassandra memtable structure in memory
Memtable data size	0	Size in bytes of the memtable data	Same as above
Memtable switch	1	Number of times a full memtable was swapped for an empty one that increases each time the memtable	How memtables are measured article

Name of statistic	Example value	Brief description	Related information
		for a table is flushed to disk	
Read count	3589	Number of pending read requests	OpsCenter alert documentation
Read latency	1.955 ms.	Round trip time to complete a read request in milliseconds	Factors that affect read latency
Write count	3579	Number of pending write requests	OpsCenter alert documentation
Write latency	0.322 ms.	Round trip time to complete a read request in milliseconds	Factors that affect write latency
Pending tasks	0	Number of read, write, and cluster operations that are pending	OpsCenter pending task metrics documentation
Bloom filter false positives	0	Number of false positives, which occur when the bloom filter said the row existed, but it actually did not exist in absolute numbers	Tuning bloom filters
Bloom filter false ratio	0.00000	Fraction of all bloom filter checks resulting in a false positive	Same as above
Bloom filter space used	4488	Bytes of bloom filter data	Same as above

Name of statistic	Example value	Brief description	Related information
Compacted row minimum size	180	Lower size limit in MB for table rows being compacted in memory	Used to calculate what the approximate row cache size should be. Multiply the reported row cache size, which is the number of rows in the cache, by the compacted row mean size for every table and sum them.
Compacted row maximum size	219342	Upper size limit in bytes for compacted table rows, configurable in the cassandra.yaml (in_memory_compaction_limit_in_mb)	Same as above
Compacted row mean size	5559	The average size in bytes of compacted table rows	Same as above

The nodetool cfhistograms command

The nodetool cfhistograms command provides statistics about a table, including read/write latency, row size, column count, and number of SSTables.

The syntax of the command is:

```
nodetool cfhistograms <keyspace> <table>
```

For example, to get statistics about the solr table in the wiki keyspace on Linux, use this command:

```
cd <install_location>/bin
    nodetool cfhistograms wiki solr
```

An example of output is:

```
wiki/solr histograms
Offset      SSTables     Write Latency      Read Latency          Row Size
  Column Count
1               3579                 0                 0                 0
               0
2                  0                 0                 0                 0
               0
. . .
35                 0                 0                 0                 0
               0
42                 0                 0                27                 0
               0
50                 0                 0               187                 0
               0
60                 0                10               460                 0
               0
72                 0               200               689                 0
               0
86                 0               663               552                 0
               0
```

```
103                 0                 796               367               0
                0
124                 0                 297               736               0
                0
149                 0                 265               243               0
                0
179                 0                 460               263               0
                0
. . .
25109160            0                   0                 0               0
                0
```

The Offset column corresponds to the x-axis in a histogram. It represents buckets of values. More precisely, it is a series of ranges where each offset includes the range of values greater than the previous offset and less than or equal to the current offset. The offsets start at 1 and each subsequent offset is calculated by multiplying the previous offset by 1.2, rounding up, and removing duplicates. The offsets can range from 1 to approximately 25 million, with less precision as the offsets get larger.

Columns of metrics represent the number of values that fall into a particular offset's range. Latencies are shown in terms of microseconds (µs), Row Size is in bytes, and SSTables and Column Count are counts.

To illustrate:

- Offset 1 shows that 3579 requests only had to look at one SSTable. The SSTables column corresponds to how many SSTables were involved in a read request.
- Offset 86 shows that there were 663 requests with a write latency between 73 and 86 µs. The range falls into the 73 to 86 bucket.

OpsCenter, described later on this page, displays the same information in an better format for understanding the statistics.

The netstats command

The nodetool netstats command provides statistics about network operations and connections.

The syntax of the command is:

```
nodetool cfnetstats <host>
```

An example of output is:

```
Mode: NORMAL
Not sending any streams.
Not receiving any streams.
Read Repair Statistics:
Attempted: 1
Mismatch (Blocking): 0
Mismatch (Background): 0
Pool Name                    Active   Pending      Completed
Commands                        n/a         0              0
Responses                       n/a         0              0
```

- Attempted

  The number of successfully completed read repair operations
- Mismatch (blocking)

  The number of read repair operations since server restart that blocked a query.
- Mismatch (background)

  The number of read repair operations since server restart performed in the background.
- Pool name

  Information about client read and write requests by thread pool.

nodetool tpstats command

The nodetool tpstats command provides statistics about the number of active, pending, and completed tasks for each stage of Cassandra operations by thread pool. A high number of pending tasks for any pool can indicate performance problems.

The syntax of the command is:

```
nodetool tpstats
```

An example of output is:

```
Pool Name                    Active   Pending      Completed   Blocked  All
 time blocked
ReadStage                         0         0             15         0
         0
RequestResponseStage              0         0              0         0
         0
MutationStage                     0         0           3674         0
         0
ReadRepairStage                   0         0              0         0
         0
ReplicateOnWriteStage             0         0              0         0
         0
GossipStage                       0         0              0         0
         0
AntiEntropyStage                  0         0              0         0
         0
MigrationStage                    0         0              0         0
         0
MemoryMeter                       0         0              1         0
         0
MemtablePostFlusher               0         0            267         0
         0
FlushWriter                       0         0              9         0
         1
MiscStage                         0         0              0         0
         0
commitlog_archiver                0         0              0         0
         0
InternalResponseStage             0         0              0         0
         0
HintedHandoff                     0         0              0         0
         0

Message type           Dropped
RANGE_SLICE                  0
READ_REPAIR                  0
BINARY                       0
READ                         0
MUTATION                     0
_TRACE                       0
REQUEST_RESPONSE             0
```

This table describes key indicators:

Table 7: nodetool tpstats output

Name of statistic	Brief description	Related information
Mutation stage	Status of write requests. A high number of pending write requests indicates a problem handling them.	Tune hardware or Cassandra configuration.

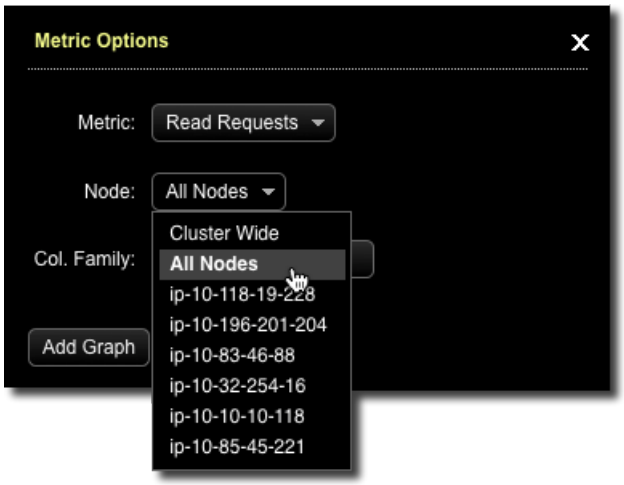
Name of statistic	Brief description	Related information
Flush writer	Status of the sort and write-to-disk operations.	Tune hardware or Cassandra configuration.

DataStax OpsCenter

DataStax OpsCenter is a graphical user interface for monitoring and administering all nodes in a Cassandra cluster from one centralized console. DataStax OpsCenter is bundled with DataStax support offerings. You can register for a free version for development or non-production use.

OpsCenter provides a graphical representation of performance trends in a summary view that is hard to obtain with other monitoring tools. The GUI provides views for different time periods as well as the capability to drill down on single data points. Both real-time and historical performance data for a Cassandra or DataStax Enterprise cluster are available in OpsCenter. OpsCenter metrics are captured and stored within Cassandra.

Within OpsCenter you can customize the performance metrics viewed to meet your monitoring needs. Administrators can also perform routine node administration tasks from OpsCenter. Metrics within OpsCenter are divided into three general categories: table metrics, cluster metrics, and OS metrics. For many of the available metrics, you can view aggregated cluster-wide information or view information on a per-node basis.



Monitoring using JConsole

JConsole is a JMX-compliant tool for monitoring Java applications such as Cassandra. It is included with Sun JDK 5.0 and higher. JConsole consumes the JMX metrics and operations exposed by Cassandra and displays them in a well-organized GUI. For each node monitored, JConsole provides these six separate tab views:

- Overview

  Displays overview information about the Java VM and monitored values.
- Memory

  Displays information about memory use.
- Threads

  Displays information about thread use.
- Classes

  Displays information about class loading.
- VM Summary

  Displays information about the Java Virtual Machine (VM).
- Mbeans

  Displays information about MBeans.

The Overview and Memory tabs contain information that is very useful for Cassandra developers. The Memory tab allows you to compare heap and non-heap memory usage, and provides a control to immediately perform Java garbage collection.

For specific Cassandra metrics and operations, the most important area of JConsole is the MBeans tab. This tab lists the following Cassandra MBeans:

- org.apache.cassandra.db

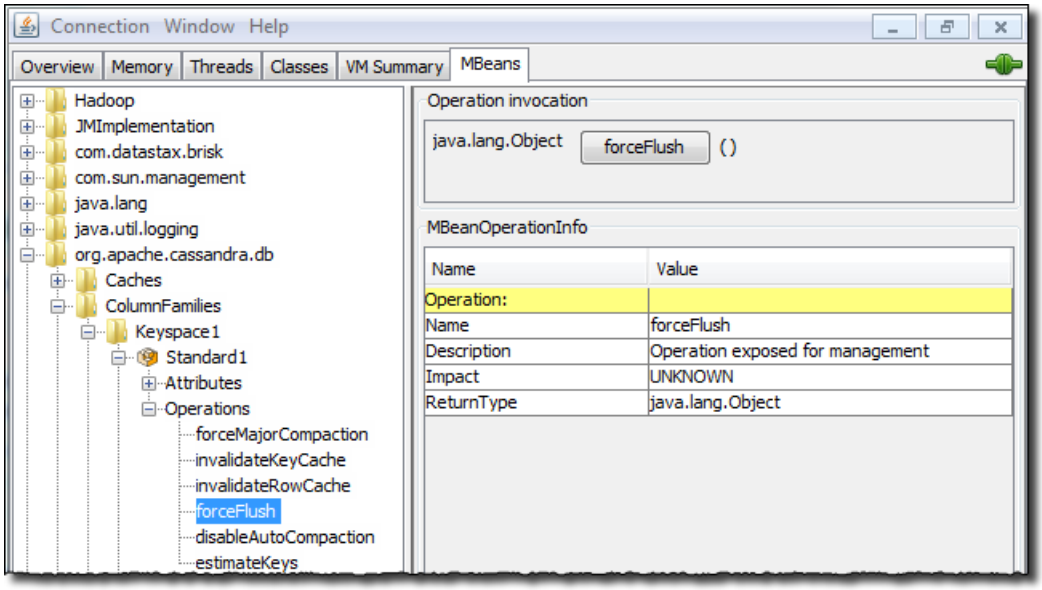
  Includes caching, table metrics, and compaction.
- org.apache.cassandra.internal

  Internal server operations such as gossip and hinted handoff.
- org.apache.cassandra.net

  Inter-node communication including FailureDetector, MessagingService and StreamingService.
- org.apache.cassandra.request

  Tasks related to read, write, and replication operations.

When you select an MBean in the tree, its MBeanInfo and MBean Descriptor are displayed on the right, and any attributes, operations or notifications appear in the tree below it. For example, selecting and expanding the org.apache.cassandra.db MBean to view available actions for a table results in a display like the following:



If you choose to monitor Cassandra using JConsole, keep in mind that JConsole consumes a significant amount of system resources. For this reason, DataStax recommends running JConsole on a remote machine rather than on the same host as a Cassandra node.

The JConsole CompactionManagerMBean exposes compaction metrics that can indicate when you need to add capacity to your cluster.

Compaction metrics

Monitoring compaction performance is an important aspect of knowing when to add capacity to your cluster. The following attributes are exposed through CompactionManagerMBean:

Table 8: Compaction Metrics

Attribute	Description
CompletedTasks	Number of completed compactions since the last start of this Cassandra instance
PendingTasks	Number of estimated tasks remaining to perform
ColumnFamilyInProgress	The table currently being compacted. This attribute is null if no compactions are in progress.
BytesTotalInProgress	Total number of data bytes (index and filter are not included) being compacted. This attribute is null if no compactions are in progress.
BytesCompacted	The progress of the current compaction. This attribute is null if no compactions are in progress.

Thread pool and read/write latency statistics

Cassandra maintains distinct thread pools for different stages of execution. Each of the thread pools provide statistics on the number of tasks that are active, pending, and completed. Trends on these pools for increases in the pending tasks column indicate when to add additional capacity. After a baseline is established, configure alarms for any increases above normal in the pending tasks column. Use nodetool tpstats on the command line to view the thread pool details shown in the following table.

Table 9: Compaction Metrics

Thread Pool	Description
AE_SERVICE_STAGE	Shows anti-entropy tasks.
CONSISTENCY-MANAGER	Handles the background consistency checks if they were triggered from the client's consistency level.
FLUSH-SORTER-POOL	Sorts flushes that have been submitted.
FLUSH-WRITER-POOL	Writes the sorted flushes.
GOSSIP_STAGE	Activity of the Gossip protocol on the ring.
LB-OPERATIONS	The number of load balancing operations.
LB-TARGET	Used by nodes leaving the ring.
MEMTABLE-POST-FLUSHER	Memtable flushes that are waiting to be written to the commit log.
MESSAGE-STREAMING-POOL	Streaming operations. Usually triggered by bootstrapping or decommissioning nodes.
MIGRATION_STAGE	Tasks resulting from the call of system_* methods in the API that have modified the schema.
MISC_STAGE	
MUTATION_STAGE	API calls that are modifying data.
READ_STAGE	API calls that have read data.
RESPONSE_STAGE	Response tasks from other nodes to message streaming from this node.
STREAM_STAGE	Stream tasks from this node.

Read/Write latency metrics

Cassandra tracks latency (averages and totals) of read, write, and slicing operations at the server level through StorageProxyMBean.

Table statistics

For individual tables, ColumnFamilyStoreMBean provides the same general latency attributes as StorageProxyMBean. Unlike StorageProxyMBean, ColumnFamilyStoreMBean has a number of other statistics that are important to monitor for performance trends. The most important of these are:

Table 10: Compaction Metrics

Attribute	Description
MemtableDataSize	The total size consumed by this table's data (not including metadata).
MemtableColumnsCount	Returns the total number of columns present in the memtable (across all keys).
MemtableSwitchCount	How many times the memtable has been flushed out.

Attribute	Description
RecentReadLatencyMicros	The average read latency since the last call to this bean.
RecentWriterLatencyMicros	The average write latency since the last call to this bean.
LiveSSTableCount	The number of live SSTables for this table.

The recent read latency and write latency counters are important in making sure operations are happening in a consistent manner. If these counters start to increase after a period of staying flat, you probably need to add capacity to the cluster.

You can set a threshold and monitor LiveSSTableCount to ensure that the number of SSTables for a given table does not become too great.

Tuning Bloom filters

Cassandra uses Bloom filters to determine whether an SSTable has data for a particular row.

Bloom filters are unused for range scans, but are used for index scans. Bloom filters are probabilistic sets that allow you to trade memory for accuracy. This means that higher Bloom filter attribute settings bloom_filter_fp_chance use less memory, but will result in more disk I/O if the SSTables are highly fragmented. Bloom filter settings range from 0 to 1.0 (disabled). The default value of bloom_filter_fp_chance depends on the compaction_strategy. The LeveledCompactionStrategy uses a higher default value (0.1) because it generally defragments more effectively than the SizeTieredCompactionStrategy, which has a default of 0.01. Memory savings are nonlinear; going from 0.01 to 0.1 saves about one third of the memory.

The settings you choose depend the type of workload. For example, to run an analytics application that heavily scans a particular table, you would want to inhibit the Bloom filter on the table by setting it high.

To view the observed Bloom filters false positive rate and the number of SSTables consulted per read use cfstats in the nodetool utility.

Starting in version 1.2, Bloom filters are stored off-heap so you don't need include it when determining the -Xmx settings (the maximum memory size that the heap can reach for the JVM).

To change the bloom_filter_attribute on a table, use CQL. For example:

```
ALTER TABLE addamsFamily WITH bloom_filter_fp_chance = 0.1;
```

After updating the value of bloom_filter_fp_chance on a table, Bloom filters need to be regenerated in one of these ways:

- Initiate compaction
- Upgrade SSTables

You do not have to restart Cassandra after regenerating SSTables.

Data caching

Configuring data caches

Cassandra includes integrated caching and distributes cache data around the cluster for you. When a node goes down, the client can read from another cached replica of the data. The integrated architecture also facilitates troubleshooting because there is no separate caching tier, and cached data matches what's in the database exactly. The integrated cache solves the cold start problem by virtue of saving

your cache to disk periodically and being able to read contents back in when it restarts—you never have to start with a cold cache.

About the partition key cache

The partition key cache is a cache of the partition index for a Cassandra table. Using the key cache instead of relying on the OS page cache saves CPU time and memory. However, enabling just the key cache results in disk (or OS page cache) activity to actually read the requested data rows.

About the row cache

The row cache is similar to a traditional cache like memcached: when a row is accessed, the entire row is pulled into memory (merging from multiple SSTables if necessary) and cached so that further reads against that row can be satisfied without hitting disk at all.

Typically, you enable either the partition key or row cache for a table. The main exception is for archive tables that are infrequently read. You should disable caching entirely for archive tables.

Enabling and configuring caching

Enable or disable caching and using CQL to configure the caching storage parameter. Set parameters in the cassandra.yaml file to configure caching properties:

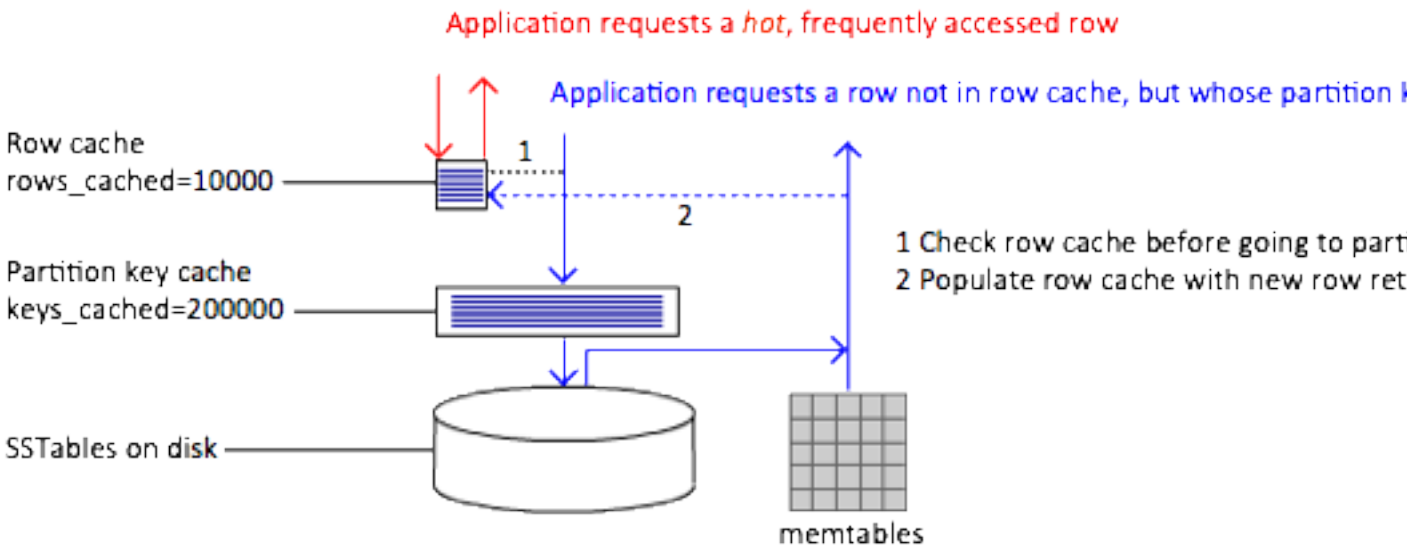
- Partition key cache size
- Row cache size
- How often Cassandra saves partition key caches to disk
- How often Cassandra saves row caches to disk
- The row cache implementation

  Set the caching attribute in the WITH clause of the table definition. For example, configure Cassandra to configure the partition key cache and row cache.

```
CREATE TABLE users (
  userid text PRIMARY KEY,
  first_name text,
  last_name text,
)
WITH caching = 'all';
```

How caching works

When both row cache and partition key cache are configured, the row cache returns results whenever possible. In the event of a row cache miss, the partition key cache might still provide a hit that makes the disk seek much more efficient. This diagram depicts two read operations on a table with both caches already populated.



One read operation hits the row cache, returning the requested row without a disk seek. The other read operation requests a row that is not present in the row cache but is present in the partition key cache. After accessing the row in the SSTable, the system returns the data and populates the row cache with this read operation.

Tips for efficient cache use

Some tips for efficient cache use are:

- Store lower-demand data or data with extremely long rows in a table with minimal or no caching.
- Deploy a large number of Cassandra nodes under a relatively light load per node.
- Logically separate heavily-read data into discrete tables.

Cassandra memtables have overhead for index structures on top of the actual data they store. If the size of the values stored in the heavily-read columns is small compared to the number of columns and rows themselves, this overhead can be substantial. Rows having this type of data do not lend themselves to efficient row caching.

Monitoring and adjusting caching

Make changes to cache options in small, incremental adjustments, then monitor the effects of each change using DataStax Opscenter or the nodetool utility. The output of the `nodetool info` command shows the following row cache and key cache metrics, which are configured in the `cassandra.yaml` file:

- Cache size in bytes
- Capacity in bytes
- Number of hits
- Number of requests
- Recent hit rate
- Duration in seconds after which Cassandra saves the key cache.

For example, on start-up, the information from `nodetool info` might look something like this:

```
Token            : (invoke with -T/--tokens to see all 256 tokens)
ID               : 387d15ba-7103-491b-9327-1a691dbb504a
Gossip active    : true
Thrift active    : true
Native Transport active: true
Load             : 11.35 KB
Generation No    : 1384180190
```

```
Uptime (seconds) : 437
Heap Memory (MB) : 136.33 / 1996.81
Data Center      : datacenter1
Rack             : rack1
Exceptions       : 0
Key Cache        : size 360 (bytes), capacity 103809024 (bytes), 15 hits, 19
 requests, 0.789 recent hit rate, 14400 save period in seconds
Row Cache        : size 0 (bytes), capacity 0 (bytes), 0 hits, 0 requests, NaN
 recent hit rate, 0 save period in seconds
```

In the event of high memory consumption, consider tuning data caches.

Configuring memtable throughput

Configuring memtable throughput can improve write performance. Cassandra flushes memtables to disk, creating SSTables when the commit log space threshold has been exceeded. Configure the commit log space threshold per node in the cassandra.yaml. How you tune memtable thresholds depends on your data and write load. Increase memtable throughput under either of these conditions:

- The write load includes a high volume of updates on a smaller set of data.
- A steady stream of continuous writes occurs. This action leads to more efficient compaction.

Allocating memory for memtables reduces the memory available for caching and other internal Cassandra structures, so tune carefully and in small increments.

Compaction and compression

Compaction

During compaction, Cassandra combines multiple data files to improve the performance of partition scans and to reclaim space from deleted data.

Compaction is a periodic background process. During compaction Cassandra merges SSTables by combining row fragments, evicting expired tombstones, and rebuilding indexes. Because the SSTables are sorted, the merge is efficient (no random disk I/O). After a newly merged SSTable is complete, the input SSTables are reference counted and removed as soon as possible. During compaction, there is a temporary spike in disk space usage and disk I/O.

Cassandra provides two compaction strategies:

- `SizeTieredCompactionStrategy`: The default compaction strategy. This strategy gathers SSTables of similar size and compacts them together into a larger SSTable. You can configure this strategy with CQL-configurable thresholds.
- `LeveledCompactionStrategy`: Introduced in Cassandra 1.0, this strategy creates SSTables of a fixed, relatively small size (5 MB by default) that are grouped into levels. Within each level, SSTables are guaranteed to be non-overlapping. Each level (L0, L1, L2 and so on) is 10 times as large as the previous. To enable this strategy, set the compaction_strategy for the table.

For more information about compaction strategies and which strategy to choose, see compaction strategies and the articles When to Use Leveled Compaction and Leveled Compaction in Apache Cassandra.

Compaction can impact reads that are not fulfilled by the cache because temporary increases in disk I/O and utilization occur. However, after a compaction completes, off-cache read performance improves since there are fewer SSTable files on disk that need to be checked.

In Cassandra 1.2 and later, you can configure when compaction (eviction) occurs for tombstones for TTL-configured and deleted columns with the tombstone parameters. Setting these parameters helps you avoid having to manually performing compaction to recover disk space.

The compaction_strategy_options parameter sets attributes related to the chosen compaction-strategy:

Note: The attribute names documented here are the names as they are stored in the system keyspace within Cassandra. A few attributes have slightly different names in CQL. See CQL keyspace and table properties.

Parameter	SizeTieredCompactionStrategy	LeveledCompactionStrategy
bucket_high	Yes	No
bucket_low	Yes	No
max_compaction_threshold	Yes	Yes
min_compaction_threshold	Yes	Yes
min_sstable_size	Yes	No
sstable_size_in_mb	No	Yes
tombstone_compaction_interval	Yes	Yes
tombstone_threshold	Yes	Yes

You can specify a number of compaction parameters in the cassandra.yaml file:

- snapshot_before_compaction
- in_memory_compaction_limit_in_mb
- multithreaded_compaction
- compaction_preheat_key_cache
- concurrent_comactors
- compaction_throughput_mb_per_sec

Starting with Cassandra 1.2.5, the compaction_throughput_mb_per_sec parameter works better with large partitions because compaction is throttled to the specified total throughput across the entire system. In older releases, Cassandra only checked the compaction throughput between partitions, so large partitions could cause spikes in I/O demand.

Cassandra provides a start-up option for testing compaction strategies without affecting the production workload.

For information about compaction metrics, see Compaction metrics on page 89.

About full compactions

A full compaction applies only to `SizeTieredCompactionStrategy`. It merges all SSTables into one large SSTable. However, a full compaction is not recommended because the large SSTable that is created will not be compacted until the amount of actual data increases four-fold (or min_compaction_threshold). Addtionally, during runtime, full compaction is I/O and CPU intensive and can temporarily double disk space usage when no old versions or tombstones are evicted.

To initiate a full compaction for all tables in a keyspace use the nodetool compact command.

Configuring compaction

In addition to consolidating SSTables, the compaction process merges keys, combines columns, evicts tombstones, and creates a new index in the merged SSTable.

There are two different compaction strategies that you can configure on a table:

- Size-tiered compaction
- Leveled compaction

To configure compaction, construct a property map in the CQL collection format:

```
name = { 'name' : value, 'name', value : 'name',
 value
      ... }
```

In this string, italics indicates optional.

1. Create or update a table to set the compaction strategy using the ALTER or CREATE TABLE statements.

   ```
   ALTER TABLE users WITH
     compaction = { 'class' :  'LeveledCompactionStrategy'  }
   ```

2. Control the frequency and scope of a minor compaction of a table that uses the default size-tiered compaction strategy by setting the CQL 3 min_threshold attribute.

   ```
   ALTER TABLE users
     WITH compaction =
     {'class' : 'SizeTieredCompactionStrategy', 'min_threshold' : 6 }
   ```

   For the list of options and more information, see CQL keyspace and table properties.

Compression

Compression maximizes the storage capacity of Cassandra nodes by reducing the volume of data on disk and disk I/O, particularly for read-dominated workloads. Cassandra quickly finds the location of rows in the SSTable index and decompresses the relevant row chunks.

Write performance is not negatively impacted by compression in Cassandra as it is in traditional databases. In traditional relational databases, writes require overwrites to existing data files on disk. The database has to locate the relevant pages on disk, decompress them, overwrite the relevant data, and finally recompress. In a relational database, compression is an expensive operation in terms of CPU cycles and disk I/O. Because Cassandra SSTable data files are immutable (they are not written to again after they have been flushed to disk), there is no recompression cycle necessary in order to process writes. SSTables are compressed only once when they are written to disk. Writes on compressed tables can show up to a 10 percent performance improvement.

When to compress data

Compression is best suited for tables that have many rows and each row has the same columns, or at least as many columns, as other rows. For example, a table containing user data such as username, email, and state, is a good candidate for compression. The greater the similarity of the data across rows, the greater the compression ratio and gain in read performance.

A table that has rows of different sets of columns is not well-suited for compression. Dynamic tables do not yield good compression ratios.

Don't confuse table compression with compact storage of columns, which is used for backward compatibility of old applications with CQL 3.

Depending on the data characteristics of the table, compressing its data can result in:

- 2x-4x reduction in data size
- 25-35% performance improvement on reads
- 5-10% performance improvement on writes

After configuring compression on an existing table, subsequently created SSTables are compressed. Existing SSTables on disk are not compressed immediately. Cassandra compresses existing SSTables when the normal Cassandra compaction process occurs. Force existing SSTables to be rewritten and compressed by using nodetool upgradesstables (Cassandra 1.0.4 or later) or nodetool scrub.

Configuring compression

Compression is enabled by default in Cassandra 1.1 and later.

1. Disable compression, using CQL to set the compression parameters to an empty string.

```
CREATE TABLE DogTypes (
              block_id uuid,
              species text,
              alias text,
              population varint,
              PRIMARY KEY (block_id)
            )
            WITH compression = { 'sstable_compression' : '' };
```

2. Enable compression on an existing table, using ALTER TABLE to set the compression algorithm sstable_compression to LZ4Compressor (Cassandra 1.2.2 and later), SnappyCompressor, or DeflateCompressor.

```
CREATE TABLE DogTypes (
              block_id uuid,
              species text,
              alias text,
              population varint,
              PRIMARY KEY (block_id)
            )
            WITH compression = { 'sstable_compression' : 'LZ4Compressor' };
```

3. Change compression on an existing table, using ALTER TABLE and setting the compression algorithm sstable_compression to DeflateCompressor.

```
ALTER TABLE CatTypes
  WITH compression = { 'sstable_compression' : 'DeflateCompressor',
 'chunk_length_kb' : 64 }
```

You tune data compression on a per-table basis using CQL to alter a table.

Testing compaction and compression

Write survey mode is a Cassandra startup option for testing new compaction and compression strategies. In write survey mode, you can test out new compaction and compression strategies on that node and benchmark the write performance differences, without affecting the production cluster.

Write survey mode adds a node to a database cluster. The node accepts all write traffic as if it were part of the normal Cassandra cluster, but the node does not officially join the ring.

Also use write survey mode to try out a new Cassandra version. The nodes you add in write survey mode to a cluster must be of the same major release version as other nodes in the cluster. The write survey mode relies on the streaming subsystem that transfers data between nodes in bulk and differs from one major release to another.

If you want to see how read performance is affected by modifications, stop the node, bring it up as a standalone machine, and then benchmark read operations on the node.

Enable write survey mode by starting a Cassandra node using the write_survey option.

```
bin/cassandra – Dcassandra.write_survey=true
```

This example shows how to start a tarball installation of Cassandra.

Tuning Java resources

Consider tuning Java resources in the event of a performance degradation or high memory consumption.

There are two files that control environment settings for Cassandra:

- conf/cassandra-env.sh

  Java Virtual Machine (JVM) configuration settings
- bin/cassandra-in.sh

Sets up Cassandra environment variables such as CLASSPATH and JAVA_HOME.

Heap sizing options

If you decide to change the Java heap sizing, both MAX_HEAP_SIZE and HEAP_NEWSIZE should should be set together in conf/cassandra-env.sh.

- MAX_HEAP_SIZE

  Sets the maximum heap size for the JVM. The same value is also used for the minimum heap size. This allows the heap to be locked in memory at process start to keep it from being swapped out by the OS.
- HEAP_NEWSIZE

  The size of the young generation. The larger this is, the longer GC pause times will be. The shorter it is, the more expensive GC will be (usually). A good guideline is 100 MB per CPU core.

Tuning the Java heap

Because Cassandra is a database, it spends significant time interacting with the operating system's I/O infrastructure through the JVM, so a well-tuned Java heap size is important. Cassandra's default configuration opens the JVM with a heap size that is based on the total amount of system memory:

System Memory	Heap Size
Less than 2GB	1/2 of system memory
2GB to 4GB	1GB
Greater than 4GB	1/4 system memory, but not more than 8GB

Many users new to Cassandra are tempted to turn up Java heap size too high, which consumes the majority of the underlying system's RAM. In most cases, increasing the Java heap size is actually detrimental for these reasons:

- In most cases, the capability of Java 6 to gracefully handle garbage collection above 8GB quickly diminishes.
- Modern operating systems maintain the OS page cache for frequently accessed data and are *very* good at keeping this data in memory, but can be prevented from doing its job by an elevated Java heap size.

If you have more than 2GB of system memory, which is typical, keep the size of the Java heap relatively small to allow more memory for the page cache.

Some Solr users have reported that increasing the stack size improves performance under Tomcat. To increase the stack size, uncomment and modify the default -Xss128k setting in the cassandra-env.sh file. Also, decreasing the memtable space to make room for Solr caches might improve performance. Modify the memtable space using the memtable_total_space_in_mb property in the cassandra.yaml file.

Because MapReduce runs outside the JVM, changes to the JVM do not affect Analytics/Hadoop operations directly.

How Cassandra uses memory

Using a java-based system like Cassandra, you can typically allocate about 8GB of memory on the heap before garbage collection pause time starts to become a problem. Modern machines have much more memory than that and Cassandra can make use of additional memory as page cache when files on disk are accessed. Allocating more than 8GB of memory on the heap poses a problem due to the amount of Cassandra metadata about data on disk. The Cassandra metadata resides in memory and is proportional to total data. Some of the components grow proportionally to the size of total memory. In Cassandra 1.2

and later, the Bloom filter and compression offset map that store this metadata reside off-heap, greatly increasing the capacity per node of data that Cassandra can handle efficiently.

About the off-heap row cache

Cassandra can store cached rows in native memory, outside the Java heap. This results in both a smaller per-row memory footprint and reduced JVM heap requirements, which helps keep the heap size in the sweet spot for JVM garbage collection performance. Using the off-heap row cache requires the JNA library to be installed; otherwise, Cassandra falls back on the on-heap cache provider.

Tuning Java garbage collection

Cassandra's GCInspector class logs information about garbage collection whenever a garbage collection takes longer than 200ms. Garbage collections that occur frequently and take a moderate length of time to complete (such as ConcurrentMarkSweep taking a few seconds), indicate that there is a lot of garbage collection pressure on the JVM. Remedies include adding nodes, lowering cache sizes, or adjusting the JVM options regarding garbage collection.

JMX options

Cassandra exposes a number of statistics and management operations via Java Management Extensions (JMX). Java Management Extensions (JMX) is a Java technology that supplies tools for managing and monitoring Java applications and services. Any statistic or operation that a Java application has exposed as an MBean can then be monitored or manipulated using JMX. JConsole, the nodetool utility, and DataStax OpsCenter are examples of JMX-compliant management tools.

By default, you can modify the following properties in the conf/cassandra-env.sh file to configure JMX to listen on port 7199 without authentication.

- com.sun.management.jmxremote.port

  The port on which Cassandra listens from JMX connections.
- com.sun.management.jmxremote.ssl

  Enable/disable SSL for JMX.
- com.sun.management.jmxremote.authenticate

  Enable/disable remote authentication for JMX.
- -Djava.rmi.server.hostname

  Sets the interface hostname or IP that JMX should use to connect. Uncomment and set if you are having trouble connecting.

Repairing nodes

Running node repair.

The nodetool repair command repairs inconsistencies across all of the replicas for a given range of data. Run repair in these situations:

- During normal operation as part of regular, scheduled cluster maintenance unless Cassandra applications perform no deletes.
- During node recovery; for example, when bringing a node back into the cluster after a failure.
- On nodes containing data that is not read frequently.
- To update data on a node that has been down.

Guidelines for running routine node repair include:

- The hard requirement for routine repair frequency is the value of gc_grace. Run a repair operation at least once on each node within this time period. Following this important guideline ensures that deletes are properly handled in the cluster.
- Use caution when running routine node repair on more than one node at a time and schedule regular repair operations for low-usage hours.
- In systems that seldom delete or overwrite data, you can raise the value of gc_grace with minimal impact to disk space. This allows wider intervals for scheduling repair operations with the nodetool utility.

Repair requires intensive disk I/O. This occurs because of the validation compaction used for building the Merkle tree. To mitigate heavy disk usage:

- Use the nodetool compaction throttling options (setcompactionthroughput and setcompactionthreshold).
- Use nodetool snapshot and *sequentially* repair from the snapshot. Recall that snapshots are just hardlinks to existing SSTables, immutable, and require almost no disk space. This means that for any given replica set, only one replica at a time performs the validation compaction. This allows the dynamic snitch to maintain performance for your application via the other replicas.

  Note: Using the nodetool repair -pr (–partitioner-range) option repairs only the primary range for that node, the other replicas for that range still have to perform the Merkle tree calculation, causing a validation compaction. Because all the replicas are compacting at the same time, all the nodes may be slow to respond for that portion of the data.

Repair can result in overstreaming. Overstreaming occurs, for example, when there is a single damaged partition, but many more streams are sent.

This happens because the Merkle trees don't have infinite resolution and Cassandra makes a tradeoff between the size and space. Currently, Cassandra uses a fixed depth of 15 for the tree (32K leaf nodes). For a node containing a million partitions with one damagaed partition, about 30 partitions are streamed, which is the number that fall into each of the *leaves* of the tree. Of course, the problem gets worse when more partitions exist per node, and results in a lot of disk space usage and needless compaction.

To mitigate overstreaming, you can use subrange repair (available starting in Cassandra 1.1.11). Subrange repair allows for repairing only a portion of the data belonging to the node. Because the Merkle tree precision is fixed, this effectively increases the overall precision.

To use subrange repair:

1. Use the Java `describe_splits` call to ask for a split containing 32K partitions.
2. Iterate throughout the entire range incrementally or in parallel. This completely eliminates the overstreaming behavior and wasted disk usage overhead.
3. Pass the tokens you received for the split to the nodetool repair -st (–start-token) and -et (–end-token) options.
4. Pass the -local (–in-local-dc) option to nodetool to repair only within the local datacenter. This reduces the cross data-center transfer load.

Adding or removing a node or data center

Adding nodes an existing cluster

Adding nodes when using virtual nodes.

Virtual nodes (vnodes) greatly simplify adding nodes to an existing cluster:

- Calculating tokens and assigning them to each node is no longer required.
- Rebalancing a cluster is no longer necessary because a node joining the cluster assumes responsibility for an even portion of the data.

For a detailed explanation about how this works, see Virtual nodes on page 15.

Note: If you do not use vnodes, follow the instructions in the 1.1 topic Adding Capacity to an Existing Cluster.

1. Install Cassandra on the new nodes, but do not start Cassandra.

   If you used a packaged install, Cassandra starts automatically and you must and stop the node and clear the data.
2. Set the following properties in the `cassandra.yaml` and `cassandra-topology.properties` configuration files:

   - cluster_name: the name of the cluster the new node is joining.
   - listen_address/broadcast_address: the IP address or host name that other Cassandra nodes use to connect to the new node.
   - endpoint_snitch: the snitch Cassandra uses for locating nodes and routing requests.
   - num_tokens: the number of vnodes to assign to the node. If the hardware capabilities vary among the nodes in your cluster, you can assign a proportional number of vnodes to the larger machines.
   - seed_provider: the - seeds list in this setting determines which nodes the new node should contact to learn about the cluster and establish the gossip process. Change other non-default settings you have made to your existing cluster in the `cassandra.yaml` file and `cassandra-topology.properties` files. Use the `diff` command to find and merge (by head) any differences between existing and new nodes.
3. Start Cassandra on each new node. Allow two minutes between node initializations. You can monitor the startup and data streaming process using nodetool netstats.
4. After all new nodes are running, run nodetool cleanup on each of the previously existing nodes to remove the keys no longer belonging to those nodes. Wait for cleanup to complete on one node before doing the next.

   Cleanup may be safely postponed for low-usage hours.

Adding a data center to a cluster

Adding a data center to an existing cluster.

1. Ensure that you are using NetworkTopologyStrategy for all of your keyspaces.
2. For each node, set the following properties in the cassandra.yaml file:.
   a) Add (or edit) auto_bootstrap: false.

      By default, this setting is true and not listed in the `cassandra.yaml` file. Setting this parameter to false prevents the new nodes from attempting to get all the data from the other nodes in the data center. When you run nodetool rebuild in the last step, each node is properly mapped.
   b) Set other properties, such as -seeds and listen_address, to match the cluster settings.

      For more guidance, see Initializing a multiple node cluster (multiple data centers) on page 42.
   c) If you want to enable vnodes, set num_tokens.

      The recommended value is 256. Do not set the initial_token parameter.
3. If using the PropertyFileSnitch, update the `cassandra-topology.properties` file on all servers to include the new nodes. You do not need to restart.
4. Ensure that your client does not auto-detect the new nodes so that they aren't contacted by the client until explicitly directed. For example in Hector, use `sethostConfig.setAutoDiscoverHosts(false);`
5. If using a QUORUM consistency level for reads or writes, check the LOCAL_QUORUM or EACH_QUORUM consistency level to see if the level meets your requirements for multiple data centers.
6. Start Cassandra on the new nodes.
7. After all nodes are running in the cluster:

a) Change the strategy_options for your keyspace to the desired replication factor for the new data center. For example: set strategy options to DC1:2, DC2:2. For more information, see ALTER KEYSPACE.
b) Run nodetool rebuild on all nodes in the new data center.

Replacing a dead node

Replace a node that has died for some reason, such as hardware failure.

Note: This precedure applies to clusters using vnodes. If not using vnodes, use the instructions in the Cassandra 1.1 documentation.

You must prepare and start the replacement node, integrate it into the cluster, and then remove the dead node.

1. Confirm that the node is dead:
   - Run nodetool ring if not using vnodes.
   - Run nodetool status if using vnodes.

   The nodetool command shows a down status for the dead node (DN)

```
paul@ubuntu:~/cassandra-1.2.0$ bin/nodetool status
Datacenter: datacenter1
=======================
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address          Load       Tokens  Owns   Host ID                               Rack
UN  10.194.171.160   53.98 KB   256     0.8%   a9fa31c7-f3c0-44d1-b8e7-a2628867840c  rack1
UN  10.196.14.48     93.62 KB   256     9.9%   f5bb146c-db51-475c-a44f-9facf2f1ad6e  rack1
DN  10.196.14.239    ?          256     8.2%   b8e6748f-ec11-410d-c94f-9b67d88a28e7  rack1
```

2. Note Host ID of the dead node; it is used in the last step.
3. Add and start the replacement node as described in Adding nodes an existing cluster on page 100.
4. Using the Host ID of the dead node, remove the dead node from the cluster using the nodetool removenode command. You may need to use the force option.

Decommissioning a data center

Properly removing a data center ensures that no information is lost.

1. Make sure no clients are still writing to any nodes in the data center.
2. Run a full repair with nodetool repair.

   This ensures that all data is propagated from the data center being decommissioned.
3. Change all keyspaces so they no longer reference the data center being removed.
4. Run nodetool decommission on every node in the data center being removed.

Removing a node

Reduce the size of a data center.

Use these instructions when you want to remove up nodes to reduce the size of your cluster, not for replacing a dead node.

Attention: If you are not using virtual nodes (vnodes), you must rebalance the cluster.

1. Run a repair on each keyspace:

   ```
   $ nodetool repair -h ip_address_of_node keyspace_name
   ```

   The nodetool repair command repairs inconsistencies across all of the replicas for a given range of data.
2. If the node is up, run nodetool decommission.

This assigns the ranges that the node was responsible for to other nodes and replicates the data appropriately.

Use nodetool netstats to monitor the progress.

3. If the node is down, following the steps in Replacing a dead node on page 102 except don't replace the node.
4. If using vnodes, remove the node using the nodetool removenode command.
5. If not using vnodes, removing a node from the cluster will create a hotspot. Adjust your tokens to evenly distribute the data across the remaining nodes before running the nodetool removenode command.

   For information on how to do this, see the following topics in the Cassandra 1.1 documentation:

   - About Data Partitioning in Cassandra
   - Generating Tokens

Backing up and restoring data

Cassandra backs up data by taking a snapshot of all on-disk data files (SSTable files) stored in the data directory.

You can take a snapshot of all keyspaces, a single keyspace, or a single table while the system is online.

Using a parallel ssh tool (such as pssh), you can snapshot an entire cluster. This provides an *eventually consistent* backup. Although no one node is guaranteed to be consistent with its replica nodes at the time a snapshot is taken, a restored snapshot resumes consistency using Cassandra's built-in consistency mechanisms.

After a system-wide snapshot is performed, you can enable incremental backups on each node to backup data that has changed since the last snapshot: each time an SSTable is flushed, a hard link is copied into a `/backups` subdirectory of the data directory (provided JNA is enabled).

Note: If JNA is enabled, snapshots are performed by hard links. If not enabled, I/O activity increases as the files are copied from one location to another, which significantly reduces efficiency.

Taking a snapshot

Snapshots are taken per node using the nodetool snapshot command. To take a global snapshot, run the nodetool snapshot command using a parallel ssh utility, such as pssh.

A snapshot first flushes all in-memory writes to disk, then makes a hard link of the SSTable files for each keyspace. By default the snapshot files are stored in the `/var/lib/cassandra/data/<keyspace_name>/<table_name>/snapshots` directory.

You must have enough free disk space on the node to accommodate making snapshots of your data files. A single snapshot requires little disk space. However, snapshots can cause your disk usage to grow more quickly over time because a snapshot prevents old obsolete data files from being deleted. After the snapshot is complete, you can move the backup files to another location if needed, or you can leave them in place.

Run the nodetool snapshot command, specifying the hostname, JMX port, and keyspace. For example:

```
$ nodetool -h localhost -p 7199 snapshot demdb
```

The snapshot is created in `<data_directory_location>/<keyspace_name>/<table_name>/snapshots/<snapshot_name>`. Each snapshot folder contains numerous `.db` files that contain the data at the time of the snapshot.

Deleting snapshot files

When taking a snapshot, previous snapshot files are not automatically deleted. You should remove old snapshots that are no longer needed.

The nodetool clearsnapshot command removes all existing snapshot files from the snapshot directory of each keyspace. You should make it part of your back-up process to clear old snapshots before taking a new one.

To delete all snapshots for a node, run the nodetool `clearsnapshot` command. For example:

```
$ nodetool -h localhost -p 7199 clearsnapshot
```

To delete snapshots on all nodes at once, run the nodetool clearsnapshot command using a parallel ssh utility.

Enabling incremental backups

When incremental backups are enabled (disabled by default), Cassandra hard-links each flushed SSTable to a backups directory under the keyspace data directory. This allows storing backups offsite without transferring entire snapshots. Also, incremental backups combine with snapshots to provide a dependable, up-to-date backup mechanism.

As with snapshots, Cassandra does not automatically clear incremental backup files. DataStax recommends setting up a process to clear incremental backup hard-links each time a new snapshot is created.

Edit the `cassandra.yaml` configuration file on each node in the cluster and change the value of incremental_backups to true.

Restoring from a Snapshot

Restoring a keyspace from a snapshot requires all snapshot files for the table, and if using incremental backups, any incremental backup files created after the snapshot was taken.

Generally, before restoring a snapshot, you should truncate the table. If the backup occurs before the delete and you restore the backup after the delete without first truncating, you do not get back the original data (row). Until compaction, the tombstone is in a different SSTable than the original row, so restoring the SSTable containing the original row does not remove the tombstone and the data still appears to be deleted.

You can restore a snapshot in several ways:

- Use the sstableloader tool.
- Copy the snapshot SSTable directory (see Taking a snapshot) to the data directory (`/var/lib/cassandra/data/<keyspace>/<table>/`), and then call the JMX method `loadNewSSTables()` in the column family MBean for each column family through JConsole. Instead of using the `loadNewSSTables()` call, you can also use nodetool refresh.
- Use the Node Restart Method described below.

Node restart method

If restoring a single node, you must first shutdown the node. If restoring an entire cluster, you must shut down all nodes, restore the snapshot data, and then start all nodes again.

Note: Restoring from snapshots and incremental backups temporarily causes intensive CPU and I/O activity on the node being restored.

1. Shut down the node.
2. Clear all files in `/var/lib/cassandra/commitlog`.
3. Delete all `*.db` files in the directory:

   ```
   <data_directory_location>/<keyspace_name>/<table_name>
   ```

   DO NOT delete the `/snapshots` and `/backups` subdirectories.
4. Locate the most recent snapshot folder in this directory:

   ```
   <data_directory_location>/<keyspace_name>/<table_name>/snapshots/
   <snapshot_name>
   ```
5. Copy its contents into this directory:

   ```
   <data_directory_location>/<keyspace_name>/<table_name> directory.
   ```
6. If using incremental backups, copy all contents of this directory:

```
<data_directory_location>/<keyspace_name>/<table_name>/backups
```

7. Paste it into this directory:

   ```
   <data_directory_location>/<keyspace_name>/<table_name>
   ```

8. Restart the node.

   Restarting causes a temporary burst of I/O activity and consumes a large amount of CPU resources.

9. Run nodetool repair.

Cassandra tools

The nodetool utility

A command line interface for Cassandra for managing a cluster.

Command format

- Packaged installs: `nodetool -h HOSTNAME [-p JMX_PORT ] COMMAND`
- Tarball installs: `<install_location>/bin/nodetool -h HOSTNAME [-p JMX_PORT ] COMMAND`
- Remote Method Invocation: `nodetool -h HOSTNAME [-p JMX_PORT -u JMX_USERNAME -pw JMX_PASSWORD ] COMMAND`

  If a username and password for RMI authentication are set explicitly in the `cassandra-env.sh` file for the host, then you must specify credentials:

Options

Flag	Option	Description
-a	--include-all-sstables	Rewrite/upgrade all SSTables including the most recent when rebuilding SSTables.
-et	--end-token arg	Token at which repair range ends.
-h	--host arg	Hostname of node or IP address.
-local	--in-local-dc	Only repair against nodes in the same data center.
-p	--port arg	Remote JMX agent port number.
-pr	--partitioner-range	Repair only the first range returned by the partitioner for the node.
-pw	--password arg	Remote JMX agent password.
-st	--start-token arg	Token at which repair range starts.
-T	--tokens	Display all tokens.
-u	--username arg	Remote JMX agent username.
Snapshot options only		
-cf	--column-family arg	Only take a snapshot of the specified table.
-snapshot	--with-snapshot	Repair one node at a time using snapshots.
-t	--tag arg	Optional name to give a snapshot.

Commands

Square brackets indicate optional parameters.

cfhistograms *keyspace table*

Displays statistics on the read/write latency for a table. These statistics, which include row size, column count, and bucket offsets, can be useful for monitoring activity in a table.

cfstats

Displays statistics for every keyspace and table.

cleanup *[keyspace][table]*

Triggers the immediate cleanup of keys no longer belonging to this node. This has roughly the same effect on a node that a major compaction does in terms of a temporary increase in disk space usage and an increase in disk I/O. Optionally takes a list of table names.

clearsnapshot *[keyspaces...] -t [snapshotName]*

Deletes snapshots for the specified keyspaces. You can remove all snapshots or remove the snapshots with the given name.

compact *[keyspace][table]*

For tables that use the SizeTieredCompactionStrategy, initiates an immediate major compaction of all tables in keyspace. For each table in keyspace, this compacts all existing SSTables into a single SSTable. This can cause considerable disk I/O and can temporarily cause up to twice as much disk space to be used. Optionally takes a list of table names.

compactionstats

Displays compaction statistics.

decommission

Tells a live node to decommission itself (streaming its data to the next node on the ring). Use netstats to monitor the progress. Also see http://wiki.apache.org/cassandra/Operations#Removing_nodes_entirely.

describering *keyspace*

Shows the partition ranges (formerly token ranges) for a given keyspace.

disablebackup

Disable incremental backup.

disablebinary

Disable native transport (binary protocol).

disablegossip

Disable Gossip. Effectively marks the node dead.

disablehandoff

Disable storing of future hints on the current node.

disablethrift

Disable the Thrift server.

drain

Flushes all memtables for a node and causes the node to stop accepting write operations. Read operations will continue to work. You typically use this command before upgrading a node to a new version of Cassandra.

enablebackup

Enable incremental backup.

enablebinary

Re-enable native transport (binary protocol).

enablegossip

Re-enables Gossip.

enablehandoff

Re-enable storing future hints on the current node.

enablethrift

Re-enable the Thrift server.

flush *[keyspace] [table]*

Flushes all memtables for a keyspace to disk, allowing the commit log to be cleared. Optionally takes a list of table names.

getcompactionthreshold *keyspace table*

Gets the current compaction threshold settings for a table. See http://wiki.apache.org/cassandra/MemtableSSTable.

getendpoints *keyspace table key*

Displays the end points that owns the key. The key is only accepted in HEX format.

getsstables *keyspace table key*

Displays the sstable filenames that own the key.

gossipinfo

Shows the gossip information for the cluster.

info [-T or --tokens]

Outputs node information including the token, load info (on disk storage), generation number (times started), uptime in seconds, and heap memory usage.

invalidatekeycache *[keyspace] [tables]*

Invalidates, or deletes, the key cache. Optionally takes a keyspace or list of table names. Leave a blank space between each table name.

invalidaterowcache *[keyspace] [tables]*

Invalidates, or deletes, the row cache. Optionally takes a keyspace or list of table names. Leave a blank space between each table name.

join

Causes the node to join the ring. This assumes that the node was initially *not* started in the ring, that is, started with `-Djoin_ring=false`. Note that the joining node should be properly configured with the desired options for seed list, initial token, and auto-bootstrapping.

move *new_token*

Moves a node to a new token. This essentially combines decommission and bootstrap. See http://wiki.apache.org/cassandra/Operations#Moving_nodes.

netstats *host*

Displays network information such as the status of data streaming operations (bootstrap, repair, move, and decommission) as well as the number of active, pending, and completed commands and responses.

pausehandoff

Pause the hints delivery process.

predictconsistency *replication_factor time [versions] [latency_percentile]*

Predict the latency and consistency "t" milliseconds after writes.

proxyhistograms

Print statistic histograms for network operations.

rangekeysample

Displays the sampled keys held across all keyspaces.

rebuild *[source_dc_name]*

Rebuilds data by streaming from other nodes (similar to bootstrap). Use this command to bring up a new data center in an existing cluster. See Adding a data center to a cluster.

rebuild_index *keyspace table_name.index_name,index_name1*

Fully rebuilds the native index for a given table. Example of index_names: Standard3.IdxName, Standard3.IdxName1.

refresh *keyspace [table]*

Loads newly placed SSTables on to the system without restart.

removenode force | status *Host ID*

Remove node by host ID, or force completion of pending removal. Show status of current node removal. To get host ID, run status.

repair ***keyspace [table] [-pr]***

Begins an anti-entropy node repair operation. If the -pr option is specified, only the first range returned by the partitioner for a node is repaired. This allows you to repair each node in the cluster in succession without duplicating work. Without -pr, all replica ranges that the node is responsible for are repaired. Optionally takes a list of table names.

resetlocalschema

Reset the node's local schema and resync.

resumehandoff

Resume the hints delivery process.

ring

Displays node status and information about the ring as determined by the node being queried. This can give you an idea of the load balance and if any nodes are down. If your cluster is not properly configured, different nodes may show a different ring; this is a good way to check that every node views the ring the same way.

If you are using virtual nodes (vnodes), use nodetool status; it is much less verbose.

scrub ***[keyspace][table]***

Rebuilds SSTables on a node for the named tables and snapshots data files before rebuilding as a safety measure. If possible use upgradesstables. While scrub rebuilds SSTables, it also discards data that it deems broken and creates a snapshot, which you have to remove manually. If scrub can't validate the column value against the column definition's data type, it logs the row key and skips to the next row.

setcachecapacity ***key-cache-capacity row-cache-capacity***

Set the global key and row cache capacities in megabytes.

setcompactionthroughput ***value_in_mb***

Set the maximum throughput for compaction in the system in megabytes per second. To disable throttling, set to 0.

setcompactionthreshold ***keyspace table min_threshold max_threshold***

Set minimum and maximum compaction thresholds for a table. This parameter controls how many SSTables of a similar size must be present before a minor compaction is scheduled. The max_threshold sets an upper bound on the number of SSTables that may be compacted in a single minor compaction. Also see http://wiki.apache.org/cassandra/MemtableSSTable.

setstreamthroughput ***value_in_mb***

Set the maximum streaming throughput in the system in megabytes per second. To disable throttling, set to 0.

settraceprobability ***value***

Probabilistic tracing is useful to determine the cause of intermittent query performance problems by identifying which queries are responsible. This option traces some or all statements sent to a cluster. Tracing a request usually requires at least 10 rows to be inserted.

A probability of 1.0 will trace everything whereas lesser amounts (for example, 0.10) only sample a certain percentage of statements. Care should be taken on large and active systems, as system-wide tracing will have a performance impact. Unless you are under very light load, tracing all requests (probability 1.0) will probably overwhelm your system. Start with a small fraction, for example, 0.001 and increase only if necessary. The trace information is stored in a systems_traces keyspace that holds two tables – sessions and events, which can be easily queried to answer questions, such as what the most time-consuming query has been since a trace was started. Query the parameters map and thread column in the system_traces.sessions and events tables for probabilistic tracing information.

snapshot ***[keyspaces...] -cf [tableName] -t [snapshotName]***

Takes an online snapshot of Cassandra's data. You can specify the table for particular keyspaces using the *snapshotName* option. Before taking the snapshot, the node is flushed. The results are stored in Cassandra's data directory under the snapshots directory of each keyspace. See Install locations and http://wiki.apache.org/cassandra/Operations#Backing_up_data.

status

Display cluster information, such as state, load, host ID, and token.

statusbinary

Status of native transport (binary protocol).

statusthrift

Status of the thrift server.

stop *[operation type]*

Stops an operation from continuing to run. Options are COMPACTION, VALIDATION, CLEANUP, SCRUB, INDEX_BUILD. For example, this allows you to stop a compaction that has a negative impact on the performance of a node. After the compaction stops, Cassandra continues with the rest in the queue. Eventually, Cassandra restarts the compaction.

tpstats

Displays the number of active, pending, and completed tasks for each of the thread pools that Cassandra uses for stages of operations. A high number of pending tasks for any pool can indicate performance problems. See: http://wiki.apache.org/cassandra/Operations#Monitoring.

upgradesstables *[-a] [keyspace] [tables]*

Rebuilds SSTables on a node for the named tables that are not on the current version. Use when upgrading your server or changing compression options (available from Cassandra 1.0.4 and later).

Use -a to include all SSTables, even those already on the current version.

version

Displays the Cassandra release version for the node being queried.

Cassandra bulk loader

The sstableloader tool provides the ability to bulk load external data into a cluster, load existing SSTables into another cluster with a different number nodes or replication strategy, and restore snapshots.

The sstableloader tool streams a set of SSTable data files to a live cluster. It does not simply copy the set of SSTables to every node, but transfers the relevant part of the data to each node, conforming to the replication strategy of the cluster. The table into which the data is loaded does not need to be empty.

Because sstableloader uses Cassandra gossip, make sure that the `cassandra.yaml` configuration file is in the classpath and set to communicate with the cluster. At least one node of the cluster must be configured as seed. If necessary, properly configure the following properties: listen_address, storage_port, rpc_address, and rpc_port.

If you use sstableloader to load external data, you must first generate SSTables. If you use DataStax Enterprise, you can use Sqoop to migrate your data or if you use Cassandra, follow the procedure described in Using the Cassandra Bulk Loader blog.

Before loading the data, you must define the schema of the column families with CQL, CLI, or Thrift.

To get the best throughput from SSTable loading, you can use multiple instances of sstableloader to stream across multiple machines. No hard limit exists on the number of SSTables that sstablerloader can run at the same time, so you can add additional loaders until you see no further improvement.

If you use sstableloader on the same machine as the Cassandra node, you can't use the same network interface as the Cassandra node. However, you can use the JMX **StorageService** > **bulkload() call** from that node. This method takes the absolute path to the directory where the SSTables are located, and

loads them just as sstableloader does. However, because the node is both source and destination for the streaming, it increases the load on that node. This means that you should load data from machines that are not Cassandra nodes when loading into a live cluster.

The sstableloader bulk loads the SSTables found in the directory *<dir_path>* to the configured cluster. The parent directory of *<dir_path>* is used as the keyspace name. For example to load an SSTable named `Standard1-he-1-Data.db` into keyspace Keyspace1, the files `Keyspace1-Standard1-he-1-Data.db` and `Keyspace1-Standard1-he-1-Index.db` must be in a directory called `Keyspace1/Standard1/`.

Packaged installs:

```
bash sstableloader [options ] <dir_path>
```

Tarball installs:

```
cd <install_location>/bin
bash sstableloader [options ] <dir_path>
```

For example:

```
$ ls -1 Keyspace1/Standard1/
Keyspace1-Standard1-he-1-Data.db
Keyspace1-Standard1-he-1-Index
$ <path_to_install>/bin/sstableloader -d localhost Keyspace1/<dir_name>/
```

where `<dir_name>` is the directory containing the SSTables.

Table 11: sstableloader

Short option	Long option	Description
-d <initial hosts>	--nodes <initial hosts>	Connect to comma separated list of hosts for initial ring information.
	-debug	Display stack traces.
-h	--help	Do not stream to this comma separated list of nodes.
-i <NODES>	--ignore <NODES>	Display help.
	--no-progress	Do not display progress.
-p <rpc port>	--port <rpc port>	RPC port (default 9160).
-t <throttle>	--throttle <throttle>	Throttle speed in Mbits (default unlimited).
-v	--verbose	Verbose output.

The cassandra utility

Starts the Cassandra Java server process.

Usage:

```
cassandra [OPTIONS]
```

Set the following environment variables:

- *JAVA_HOME*: path location of your Java Virtual Machine (JVM) installation.
- *CLASSPATH*: path containing all of the required Java class files (`.jar`).
- *CASSANDRA_CONF*: directory containing the Cassandra configuration files.

For convenience, on Linux, Cassandra uses an include file, `cassandra.in.sh`, to source these environment variables. It will check the following locations for this file:

- Environment setting for *CASSANDRA_INCLUDE* if set
- *install_location*`/bin`
- `/usr/share/cassandra/cassandra.in.sh`
- `/usr/local/share/cassandra/cassandra.in.sh`
- `/opt/cassandra/cassandra.in.sh`
- *USER_HOME*`/.cassandra.in.sh`

Cassandra also uses the Java options set in `$CASSANDRA_CONF/cassandra-env.sh`. If you want to pass additional options to the Java virtual machine, such as maximum and minimum heap size, edit the options in that file rather than setting *JVM_OPTS* in the environment.

Table 12: Options

Option	Description
-f	Start the cassandra process in foreground (default is to start as a background process).
-p *filename*	Log the process ID in the named file. Useful for stopping Cassandra by killing its PID.
-v	Print the version and exit.
-D *parameter*	Passes in one of the following startup parameters: **access.properties=*filename*** The file location of the `access.properties` file. **cassandra-pidfile=*filename*** Log the Cassandra server process ID in the named file. Useful for stopping Cassandra by killing its PID. **cassandra.config=*directory*** The directory location of the `cassandra.yaml` file. **cassandra.initial_token=*token*** Sets the initial partitioner token for a node the first time the node is started. **cassandra.join_ring=*true|false*** Set to false to start Cassandra on a node but not have the node join the cluster. **cassandra.load_ring_state=*true|false*** Set to false to clear all gossip state for the node on restart. Use if you have changed node information in cassandra.yaml (such as listen_address). **cassandra.renew_counter_id=*true|false*** Set to true to reset local counter info on a node. Used to recover from data loss to a counter table. First remove all SSTables for counter tables on the node, then restart the node with -Dcassandra.renew_counter_id=true, then run nodetool repair once the node is up again. **cassandra.replace_token=*token*** To replace a node that has died, restart a new node in its place and use this parameter to pass in the token that the new node is assuming. The new node must not have any data in its data directory and the token passed must already be a token that is part of the ring. **cassandra.write_survey=*true*** For testing new compaction and compression strategies. It allows you to experiment with different strategies and benchmark write performance differences without affecting the production workload. See Testing compaction and compression on page 97.

```
cassandra.framed
cassandra.host
cassandra.port=<port>
cassandra.rpc_port =<port>
cassandra.start_rpc =< true|false>
cassandra.storage_port =<port>
corrupt-sstable-root
legacy-sstable-root
mx4jaddress
mx4jport
passwd.mode
passwd.properties =<file>
```

Start Cassandra on a node and log its PID to a file:

```
cassandra -p ./cassandra.pid
```

Clear gossip state when starting a node. This is useful if the node has changed its configuration, such as its listen IP address:

```
cassandra -Dcassandra.load_ring_state=false
```

Start Cassandra on a node in stand-alone mode (do not join the cluster configured in the `cassandra.yaml` file):

```
cassandra -Dcassandra.join_ring=false
```

The cassandra-stress tool

A Java-based stress testing utility for benchmarking and load testing a Cassandra cluster.

The binary installation of the tool also includes a daemon, which in larger-scale testing can prevent potential skews in the test results by keeping the JVM warm.

Modes of operation:

- **Inserting**: Loads test data.
- **Reading**: Reads test data.
- **Indexed range slicing**: Works with RandomPartitioner on indexed tables.

The cassandra-stress tool creates a keyspace called Keyspace1 and within that, tables named Standard1, Super1, Counter1, and SuperCounter1, depending on what type of table is being tested. These are automatically created the first time you run the stress test and will be reused on subsequent runs unless you drop the keyspace using CQL or CLI. It is not possible to change the names; they are hard-coded.

Commands:

- Packaged installs: `cassandra-stress [options]`
- Tarball installs: `<install_location>/tools/bin/cassandra-stress [options]`

You can use these modes with or without the cassandra-stress daemon running (binary installs only).

Options for cassandra-stress

Short option	Long option	Description
-V	--average-size-values	Generate column values of average rather than specific size.

Short option	Long option	Description
-C <CARDINALITY>	--cardinality <CARDINALITY>	Number of unique values stored in columns. Default is 50.
-c <COLUMNS>	--columns <COLUMNS>	Number of columns per key. Default is 5.
-S <COLUMN-SIZE>	--column-size <COLUMN-SIZE>	Size of column values in bytes. Default is 34.
-Z <COMPACTION-STRATEGY>	--compaction-strategy <COMPACTION-STRATEGY>	Specifies which compaction strategy to use.
-U <COMPARATOR>	--comparator <COMPARATOR>	Specifies which column comparator to use. Supported types are: TimeUUIDType, AsciiType, and UTF8Type.
-I <COMPRESSION>	--compression <COMPRESSION>	Specifies the compression to use for SSTables. Default is no compression.
-e <CONSISTENCY-LEVEL>	--consistency-level <CONSISTENCY-LEVEL>	Consistency level to use (ONE, QUORUM, LOCAL_QUORUM, EACH_QUORUM, ALL, ANY). Default is ONE.
-x <CREATE-INDEX>	--create-index <CREATE-INDEX>	Type of index to create on columns (KEYS).
-L l	--enable-cql	Perform queries using CQL (Cassandra Query Language).
-y <TYPE>	--family-type <TYPE>	Sets the table type.
-f <FILE>	--file <FILE>	Write output to a given file.
-h	--help	Show help.
-k	--keep-going	Ignore errors when inserting or reading. When set, --keep-trying has no effect. Default is false.
-K <KEEP-TRYING>	--keep-trying <KEEP-TRYING>	Retry on-going operation N times (in case of failure). Use a positive integer. The default is 10.
-g <KEYS-PER-CALL>	-g, --keys-per-call <KEYS-PER-CALL>	Number of keys to per call. Default is 1000.
-d <NODES>	--nodes <NODES>	Nodes to perform the test against. Must be comma separated with no spaces. Default is localhost.
-D <NODESFILE>	--nodesfile <NODESFILE>	File containing host nodes (one per line).
-W	--no-replicate-on-write	Set replicate_on_write to false for counters. Only for counters with a consistency level of ONE (CL=ONE). See Counter columns in Data modeling.
-F <NUM-DIFFERENT-KEYS>	--num-different-keys <NUM-DIFFERENT-KEYS>	Number of different keys. If less than NUM-KEYS, the same key is re-used multiple times. Default is NUM-KEYS.
-n <NUMKEYS>	--num-keys <NUMKEYS>	Number of keys to write or read. Default is 1,000,000.
-o <OPERATION>	--operation <OPERATION>	Operation to perform: INSERT, READ, INDEXED_RANGE_SLICE, MULTI_GET,

Short option	Long option	Description
		COUNTER_ADD, COUNTER_GET. Default is INSERT.
-p <PORT>	--port <PORT>	Thrift port. Default is 9160.
-i <PROGRESS-INTERVAL>	--progress-interval <PROGRESS-INTERVAL>	The interval, in seconds, at which progress is output. Default is 10 seconds.
-Q <QUERY-NAMES>	--query-names <QUERY-NAMES>	Comma-separated list of column names to retrieve from each row.
-r	--random	Use random key generator. When used --stdev has no effect. Default is false.
-l <REPLICATION-FACTOR>	--replication-factor <REPLICATION-FACTOR>	Replication Factor to use when creating tables. Default is 1.
-R <REPLICATION-STRATEGY>	--replication-strategy <REPLICATION-STRATEGY>	Replication strategy to use (only on insert and when a keyspace does not exist.) The default is SimpleStrategy.
-T <SEND-TO>	--send-to <SEND-TO>	Sends the command as a request to the cassandra-stressd daemon at the specified IP address. The daemon must already be running at that address.
-N <SKIP-KEYS>	--skip-keys <SKIP-KEYS>	Fraction of keys to skip initially. Default is 0.
-s <STDEV>	--stdev <STDEV>	Standard deviation. Default is 0.1.
-O <STRATEGY-PROPERTIES>	--strategy-properties <STRATEGY-PROPERTIES>	Replication strategy properties in the following format: <dc_name>:<num>,<dc_name>:<num>, ... For use with NetworkTopologyStrategy.
-t <THREADS>	--threads <THREADS>	Number of threads to use. Default is 50.
-m	--unframed	Use unframed transport. Default is false.
-P	--use-prepared-statements	(CQL only) Perform queries using prepared statements.

Using the Daemon Mode

Usage for the daemon mode in binary installs.

Run the daemon from:

```
<install_location>/tools/bin/cassandra-stressd  start|stop|status  [-h
 <host>]
```

During stress testing, you can keep the daemon running and send it commands through it using the `--send-to` option.

- Insert 1,000,000 rows to given host:

  ```
  /tools/bin/cassandra-stress -d 192.168.1.101
  ```

  When the number of rows is not specified, one million rows are inserted.
- Read 1,000,000 rows from given host:

  ```
  tools/bin/cassandra-stress -d 192.168.1.101 -o read
  ```
- Insert 10,000,000 rows across two nodes:

```
/tools/bin/cassandra-stress -d 192.168.1.101,192.168.1.102 -n
 10000000
```

- Insert 10,000,000 rows across two nodes using the daemon mode:

```
/tools/bin/cassandra-stress -d 192.168.1.101,192.168.1.102 -n
 10000000 --send-to 54.0.0.1
```

Interpreting the output of cassandra-stress

About the period output from the running tests.

Each line reports data for the interval between the last elapsed time and current elapsed time, which is set by the --progress-interval option (default 10 seconds).

```
7251,725,725,56.1,95.1,191.8,10
19523,1227,1227,41.6,86.1,189.1,21
41348,2182,2182,22.5,75.7,176.0,31
...
```

Data	Description
`total`	Total number of operations since the start of the test.
`interval_op_rate`	Number of operations performed per second during the interval (default 10 seconds).
`interval_key_rate`	Number of keys/rows read or written per second during the interval (normally be the same as `interval_op_rate` unless doing range slices).
`latency`	Average latency for each operation during that interval.
`95th`	95% of the time the latency was less than the number displayed in the column (Cassandra 1.2 or later).
`99th`	99% of the time the latency was less than the number displayed in the column (Cassandra 1.2 or later).
`elapsed`	Number of seconds elapsed since the beginning of the test.

The cassandra-shuffle utility

Shift a single-token-per-node architecture to virtual nodes (vnodes) without downtime.

The cassandra-shuffle utility splits up all the contiguous partition ranges (formerly token ranges) for each node and then randomly distributes them into virtual nodes throughout the cluster. Shuffling is a two-phase operation. The utility first schedules the range transfers and then begins transferring the scheduled ranges. You can shuffle on a per-data center basis and mix virtual node-enabled and non-virtual node data centers.

For a complete description of how it works, see the blog Upgrading an existing cluster to vnodes.

In a terminal window:

1. In the cassandra.yaml file, set the num_tokens parameter.

   A good starting point for this parameter is 256.
2. Restart the node.

   The node sleeps for RING_DELAY to make sure its view of the ring is accurate, and then splits its current range into the number of specified tokens. However, while the range is split into many tokens, the range remains *contiguous*; it is still equivalent to what it was before, but with more tokens.
3. To distribute the tokens, initialize the shuffle operation:

```
shuffle create
```

4. Starts the transfers:

```
shuffle enable
```

5. To see what transfers remain at any point:

```
shuffle ls
```

Commands and options

Table 13: Commands

`shuffle [options] <sub-command>`	
`create`	Initialize the shuffle operation.
`ls`	Lists pending relocations.
`clear`	Clears pending relocations.
`en[able]`	Enables shuffling.
`dis[able]`	Disables shuffling.

Table 14: Options

Flag	Option	Description
-dc	--only-dc	Apply only to named DC (create only).
-u	--username	JMX username.
-tp	--thrift-port	Thrift port number (Default: 9160).
-p	--port	JMX port number (Default: 7199).
-tf	--thrift-framed	Enable framed transport for Thrift (Default: false).
-en	--and-enable	Immediately enable shuffling (create only).
pw	--password	JMX password.
-H	--help	Print help information.
-h	--host	JMX hostname or IP address (Default: localhost).
-th	--thrift-host	Thrift hostname or IP address (Default: JMX host).

The sstablescrub utility

Scrub the all the SSTables for the specified table.

Use this tool to fix (throw away) corrupted tables. Before using this tool, try rebuild the tables using nodetool scrub. Because corrupted rows are thrown away, run a repair after running this tool.

Usage:

- Packaged installs: `sstablescrub [options] <keyspace> <table>`
- Tarball installs: `<install_location>/bin/sstablescrub [options] <keyspace> <table>`

Table 15: Options

Flag	Option	Description
	--debug	Display stack traces.
-h	--help	Display help.
-m	--manifest-check	Only check and repair the leveled manifest, without actually scrubbing the SSTables.
-v	--verbose	Verbose output.

The sstable2json / json2sstable utilities

The sstable2json utility

Converts the on-disk SSTable representation of a table into a JSON formatted document.

Converting SSTables this way is useful for testing and debugging.

Note: Starting with version 0.7, json2sstable and sstable2json must be run so that the schema can be loaded from system tables. This means that the `cassandra.yaml` file must be in the classpath and refer to valid storage directories. For more information, see the Import/Export section of http://wiki.apache.org/cassandra/Operations.

Usage:

```
bin/sstable2json SSTABLE
   [-k KEY  [-k KEY  [... ]]] [-x KEY  [-x KEY  [... ]]] [-e ]
```

SSTABLE should be a full path to a `{table-name}-Data.db` file in Cassandra's data directory. For example, `/var/lib/cassandra/data/Keyspace1/Standard1-e-1-Data.db`.

- -k allows you to include a specific set of keys. The KEY must be in HEX format. Limited to 500 keys.
- -x allows you to exclude a specific set of keys. Limited to 500 keys.
- -e causes keys to only be enumerated.

The output is:

```
{
   ROW_KEY:
   {
     [
       [COLUMN_NAME, COLUMN_VALUE, COLUMN_TIMESTAMP, IS_MARKED_FOR_DELETE],
       [COLUMN_NAME, ... ],
       ...
     ]
   },
   ROW_KEY:
   {
     ...
   },
   ...
}
```

Row keys, column names and values are written in as the HEX representation of their byte arrays. Line breaks are only in between row keys in the actual output.

Tracking data expiration

The output of the sstable2json command reveals the life cycle of Cassandra data. In this procedure, you use the sstable2json to view data in a row that is not scheduled to expire, data that has been evicted and marked with a tombstone, and a row that has had data removed from it.

1. Create the playlists table in the music keyspace as shown in Data modeling.
2. Insert the row of data about ZZ Top in playlists:

```
INSERT INTO music.playlists (id, song_order, song_id, title, artist, album)
  VALUES (62c36092-82a1-3a00-93d1-46196ee77204,
  1,
  a3e64f8f-bd44-4f28-b8d9-6938726e34d4,
  'La Grange',
  'ZZ Top',
  'Tres Hombres');
```

3. Flush the data to disk.

```
sudo ./nodetool flush music playlists
```

   You need to have access permission to the data directories to flush data to disk.

4. Look at the json representation of the SSTable data, for example:

```
sudo ./sstable2json
  /var/lib/cassandra/data/music/playlists/music-playlists-ib-1-Data.db
```

   Output is:

```
[
{"key": "62c3609282a13a0093d146196ee77204","columns": [[
"1:","",1370179611971000], [
"1:album","Tres Hombres",1370179611971000], [
"1:artist","ZZ Top",1370179611971000], [
"1:song_id","a3e64f8f-bd44-4f28-b8d9-6938726e34d4",1370179611971000], [
"1:title","La Grange",1370179611971000]]}
]
```

5. Specify the time-to-live (TTL) for the ZZ Top row, for example 300 seconds.

```
INSERT INTO music.playlists
  (id, song_order, song_id, title, artist, album)
  VALUES (62c36092-82a1-3a00-93d1-46196ee77204,
  1,
  a3e64f8f-bd44-4f28-b8d9-6938726e34d4,
  'La Grange',
  'ZZ Top',
  'Tres Hombres')
  USING TTL 300;
```

   After inserting the TTL property on the row to expire the data, Cassandra marks the row with tombstones. You need to list all columns when re-inserting data if you want Cassandra to remove the entire row.

6. Flush the data to disk again.

   Do this while the data is evicted, but before the time-to-live elapses and data is removed.

7. Run the sstable2json command again.

```
sudo ./sstable2json
  /var/lib/cassandra/data/music/playlists/music-playlists-ib-2-Data.db
```

   The tombstone markers--"e" followed by the TTL value, 300--are visible in the json representation of the data.

```
[
{"key": "62c3609282a13a0093d146196ee77204","columns": [[
"1:","",1370179816450000,"e",300,1370180116], [
"1:album","Tres Hombres",1370179816450000,"e",300,1370180116], [
```

```
"1:artist","ZZ Top",1370179816450000,"e",300,1370180116], [
"1:song_id","a3e64f8f-bd44-4f28-
b8d9-6938726e34d4",1370179816450000,"e",300,1370180116], [
"1:title","La Grange",1370179816450000,"e",300,1370180116]]}
]
```

8. After the TTL elapses, flush the data to disk again.
9. Run the sstable2json command again.

```
sudo ./sstable2json
  /var/lib/cassandra/data/music/playlists/music-playlists-ib-2-Data.db
```

The json representation of the column data shows that the tombstones and data values for the ZZ Top row have been deleted from the SSTable. The values are now marked with "d":

```
[
{"key":"62c3609282a13a0093d146196ee77204","columns": [[
"1:","51ab4a14",1370179816450000,"d"], [
"1:album","51ab4a14",1370179816450000,"d"], [
"1:artist","51ab4a14",1370179816450000,"d"], [
"1:song_id","51ab4a14",1370179816450000,"d"], [
"1:title","51ab4a14",1370179816450000,"d"]]}
]
```

Tracking counter columns

You can use the sstable2json command to get information about a counter column.

1. Run the counter example presented earlier `that loads data into a counter column and flushes data to disk.
   The counter is initialized to 1.
2. Run the sstable2json command.

```
sudo ./sstable2json
         /var/lib/cassandra/data/counterks/page_view_counts/counterks-
page_view_counts-ib-1-Data.db
```

```
[
{"key": "7777772e64617461737461782e636f6d","columns": [[
"home:","",1370187164256000], [
"home:counter_value","0001000058852cd0cb9311e2940971f75c7d064100000000000000000100000000
]
```

3. Increase the counter column by 2 and flush the data to disk again.
4. Run the sstable2json command again.

```
sudo ./sstable2json
         /var/lib/cassandra/data/counterks/page_view_counts/counterks-
page_view_counts-ib-2-Data.db
```

```
[
{"key": "7777772e64617461737461782e636f6d","columns": [[
"home:","",1370187315683000], [
"home:counter_value","0001000058852cd0cb9311e2940971f75c7d064100000000000000000100000000
]
```

-9223372036854775808 is the timestamp of the last delete.

The json2sstable utility

Converts a JSON representation of a table (aka column family) to a Cassandra usable SSTable format.

Note: Starting with version 0.7, json2sstable and sstable2json must be run so that the schema can be loaded from system tables. This means that the `cassandra.yaml` file must be in the classpath and refer to valid storage directories. For more information, see the Import/Export section of http://wiki.apache.org/cassandra/Operations.

Usage:

```
bin/json2sstable -K KEYSPACE -c COLUMN_FAMILY JSON SSTABLE
```

JSON should be a path to the JSON file.

SSTABLE should be a full path to a `{table-name}-Data.db` file in Cassandra's data directory. For example, `/var/lib/cassandra/data/Keyspace1/Standard1-e-1-Data.db`.

sstablekeys

The sstablekeys utility is shorthand for sstable2json with the -e option.

Instead of dumping all of a table's data, it dumps only the keys

Usage:

```
bin/sstablekeys SSTABLE
```

SSTABLE should be a full path to a `{table-name}-Data.db` file in Cassandra's data directory. For example, `/var/lib/cassandra/data/Keyspace1/Standard1-e-1-Data.db`.

The sstableupgrade tool

Upgrade the SSTables in the specified table (or snapshot) to match the current version of Cassandra.

This tool rewrites the SSTables in the specified table to match the currently installed version of Cassandra.

If restoring with sstableloader, you must upgrade your snapshots before restoring for any snapshot taken in a major version older than the major version that Cassandra is currently running.

Usage:

- Packaged installs: `sstableupgrade [options] <keyspace> <cf> [snapshot]`
- Tarball installs: `<install_location>/bin/sstableupgrade [options] <keyspace> <cf> [snapshot]`

The snapshot option only upgrades the specified snapshot.

Table 16: Options

Flag	Option	Description
	--debug	Display stack traces.
-h	--help	Display help.

Using CLI

Using CLI

The legacy Cassandra CLI client utility can be used to do limited Thrift data definition (DDL) and data manipulation (DML) within a Cassandra cluster. CQL 3 is the recommended API for Cassandra. You can access CQL 3 tables using CLI. The CLI utility is located in /usr/bin/cassandra-cli in packaged installations or <install_location>/bin/cassandra-cli in binary installations.

A command must be terminated by a semicolon (;). Using the return key without a semicolon at the end of the line echoes an ellipsis (. . .), which indicates that the CLI expects more input.

Starting CLI on a single node

To start the CLI and connect to a particular Cassandra instance, launch the script together with -host and -port options. Cassandra connects to the cluster named in the cassandra.yaml file. Test Cluster is the default cluster name.

Start CLI and connect to a single-node cluster on localhost.

```
$ cassandra-cli -host localhost -port 9160
```

Start CLI in a multinode cluster

Specify the IP address and port number to connect to a node in a multinode cluster

Connect to a node in a multinode cluster.

```
$ cassandra-cli -host 110.123.4.5 -port 9160
```

Creating a keyspace

You can use the CLI to create a keyspace. Use single quotation marks around the string value of placement_strategy:

Create a keyspace called demo having a replication factor of 1 and using the SimpleStrategy replica placement strategy.

```
[default@unknown] CREATE KEYSPACE demo
  with placement_strategy = 'org.apache.cassandra.locator.SimpleStrategy'
  and strategy_options = {replication_factor:1};
```

You can verify the creation of a keyspace with the SHOW KEYSPACES command.

The new keyspace is listed along with the system keyspace and any other existing keyspaces.

Accessing CQL 3 tables

In Cassandra 1.2 and later, you can use the CLI GET command to query tables created with or without the COMPACT STORAGE directive in CQL 3. The CLI SET command can also be used with CQL 3 tables.

About data types

In a relational database, you must specify a data type for each column when you define a table. The data type constrains the values that can be inserted into that column. For example, if you have a column defined as an integer datatype, you would not be allowed to insert character data into that column. Column names in a relational database are typically fixed labels (strings) that are assigned when you define the table schema.

In Cassandra CLI and Thrift, the data type for a column (or row key) value is called a *validator*. The data type for a column name is called a *comparator*. Cassandra validates that data type of the keys of rows.

Columns are sorted, and stored in sorted order on disk, so you have to specify a comparator for columns. You can define the validator and comparator when you create your table schema (which is recommended), but Cassandra does not require it. Internally, Cassandra stores column names and values as hex byte arrays (BytesType). This is the default client encoding used if data types are not defined in the table schema (or if not specified by the client request).

Cassandra comes with the following built-in data types, which can be used as both validators (row key and column value data types) or comparators (column name data types). One exception is CounterColumnType, which is only allowed as a column value (not allowed for row keys or column names).

Table 17:

Internal /CLI Type	CQL Name	Description
BytesType	blob	Arbitrary hexadecimal bytes (no validation)
AsciiType	ascii	US-ASCII character string
UTF8Type	text, varchar	UTF-8 encoded string
IntegerType	varint	Arbitrary-precision integer
Int32Type	int	4-byte integer
InetAddressType	inet	IP address string in IPv4 or IPv6 format
LongType	bigint	8-byte long
UUIDType	uuid	UUID
TimeUUIDType	timeuuid	Type 1 UUID only (CQL3)
DateType	timestamp	Date plus time, encoded as 8 bytes since epoch
BooleanType	boolean	true or false
FloatType	float	4-byte floating point
DoubleType	double	8-byte floating point
DecimalType	decimal	Variable-precision decimal
CounterColumnType	counter	Distributed counter value (8-byte long)

About validators

Using the CLI you can define a default row key validator for a table using the key_validation_class property. Using CQL, you use built-in key validators to validate row key values. For static tables, define each column and its associated type when you define the table using the column_metadata property.

Key and column validators may be added or changed in a table definition at any time. If you specify an invalid validator on your table, client requests that respect that metadata are confused, and data inserts or updates that do not conform to the specified validator are rejected.

You cannot know the column names of dynamic tables ahead of time, so specify a default_validation_class instead of defining the per-column data types.

Key and column validators can be added or changed in a table definition at any time. If you specify an invalid validator on the table, client requests that respect that metadata get confused, and data inserts or updates that do not conform to the specified validator are rejected.

About comparators

Within a row, columns are always stored in sorted order by their *column name*. A *comparator* specifies the data type for the column name, as well as the sort order in which columns are stored within a row. Unlike a validator, the comparator may *not* be changed after the table is defined, so this is an important consideration when defining a table in Cassandra.

Typically, static table names will be strings, and the sort order of columns is not important in that case. For dynamic tables, however, sort order is important. For example, in a table that stores time series data (the column names are timestamps), having the data in sorted order is required for slicing result sets out of a row of columns.

Creating a table

In this procedure, you define a static table, a table having designated column names, and a dynamic table. In a static table, most rows have approximately the same columns. The settings of comparator, key_validation_class, and validation_class set the default encoding used for column names, row key values and column values. In the case of column names, the comparator also determines the sort order.

1. Connect to the keyspace where you want to define the table.

```
[default@unknown] USE demo;
```

2. Define a table having full_name, email, state, gender, and birth_year columns.

```
[default@demo] CREATE COLUMN FAMILY users
                 WITH comparator = UTF8Type
                 AND key_validation_class=UTF8Type
                 AND column_metadata = [
                 {column_name: full_name, validation_class: UTF8Type}
                 {column_name: email, validation_class: UTF8Type}
                 {column_name: state, validation_class: UTF8Type}
                 {column_name: gender, validation_class: UTF8Type}
                 {column_name: birth_year, validation_class: LongType}
                ];
```

3. Create a dynamic table called blog_entry. Notice that here we do not specify column definitions as the column names are expected to be supplied later by the client application.

```
[default@demo] CREATE COLUMN FAMILY blog_entry
                 WITH comparator = TimeUUIDType
                 AND key_validation_class=UTF8Type
                 AND default_validation_class = UTF8Type;
```

Creating a counter table

A counter table contains counter columns. A counter column is a specific kind of column whose user-visible value is a 64-bit signed integer that can be incremented (or decremented) by a client application. The counter column tracks the most recent value (or count) of all updates made to it. A counter column cannot be mixed in with regular columns of a table, you must create a table specifically to hold counters.

1. Create a table that holds counter columns by setting the default_validation_class of the table to CounterColumnType.

```
[default@demo] CREATE COLUMN FAMILY page_view_counts
                 WITH default_validation_class=CounterColumnType
                 AND key_validation_class=UTF8Type AND comparator=UTF8Type;
```

2. Insert a row and counter column into the table (with the initial counter value set to 0).

```
[default@demo] INCR page_view_counts['www.datastax.com'][home] BY 0;
```

3. Increment the counter.

```
[default@demo] INCR page_view_counts['www.datastax.com'][home] BY 1;
```

Inserting rows and columns

You can use the SET command to insert columns for a particular row key into the users table. You can only set one column at a time in a SET command.

The Cassandra CLI sets the consistency level for the client. The level defaults to ONE for all write and read operations.

1. Set each of the columns for user bobbyjo, which is the row key.

```
[default@demo] SET users['bobbyjo']['full_name']='Robert Jones';
```

```
[default@demo] SET users['bobbyjo']['email']='bobjones@gmail.com';
[default@demo] SET users['bobbyjo']['state']='TX';
[default@demo] SET users['bobbyjo']['gender']='M';
[default@demo] SET users['bobbyjo']['birth_year']='1975';
```

2. Set each of the columns for the row having the key yomama.

```
[default@demo] SET users['yomama']['full_name']='Cathy Smith';
[default@demo] SET users['yomama']['state']='CA';
[default@demo] SET users['yomama']['gender']='F';
[default@demo] SET users['yomama']['birth_year']='1969';
```

3. Creating an entry in the blog_entry table for row key yomama:

```
[default@demo] SET blog_entry['yomama'][timeuuid()] = 'I love my new
 shoes!';
```

Reading rows and columns

Use the CLI GET command within to retrieve a particular row from a table. Use the LIST command to return a batch of rows and their associated columns (default limit of rows returned is 100).

Cassandra stores all data internally as hex byte arrays by default. If you do not specify a default row key validation class, column comparator and column validation class when you define the table, Cassandra CLI will expect input data for row keys, column names, and column values to be in hex format (and data will be returned in hex format).

To pass and return data in human-readable format, you can pass a value through an encoding function. Available encodings are:

- ascii
- bytes
- integer (a generic variable-length integer type)
- lexicalUUID
- long
- utf8

You can also use the ASSUME command to specify the encoding in which table data should be returned for the entire client session.

1. Get the first 100 rows (and all associated columns) from the users table.

```
[default@demo] LIST users;
```

2. Return a particular row key and column in UTF8 format.

```
[default@demo] GET users[utf8('bobbyjo')][utf8('full_name')];
```

3. Return row keys, column names, and column values in ASCII-encoded format.

```
[default@demo] ASSUME users KEYS AS ascii;
[default@demo] ASSUME users COMPARATOR AS ascii;
[default@demo] ASSUME users VALIDATOR AS ascii;
```

Setting an expiring column

When you set a column in Cassandra, you can optionally set an expiration time, or time-to-live (TTL) attribute for the data. The data is not actually deleted from disk until normal Cassandra compaction processes are completed.

Define a coupon_code column and set an expiration date on that column.

```
[default@demo] SET users['bobbyjo']
[utf8('coupon_code')] = utf8('SAVE20') WITH ttl=864000;
```

After ten days, or 864,000 seconds have elapsed since the setting of this column, its value will be marked as deleted and no longer be returned by read operations.

Indexing a column

The CLI can be used to create indexes on column values. You can add the index when you create a table or add it later using the UPDATE COLUMN FAMILY command.

1. Add an index to the birth_year column of the users column family.

```
[default@demo] UPDATE COLUMN FAMILY users WITH comparator = UTF8Type
  AND column_metadata =
    [{column_name: birth_year,
      validation_class: LongType,
      index_type: KEYS
     }
    ];
```

2. Query Cassandra for users born in a given year.

```
[default@demo] GET users WHERE birth_year = 1969;
```

Deleting rows and columns

The CLI provides the DEL command to delete a row or column (or subcolumn).

1. Delete the coupon_code column for the yomama row key in the users table.

```
[default@demo] DEL users ['yomama']['coupon_code'];

[default@demo] GET users ['yomama'];
```

2. Delete an entire row.
   [default@demo] DEL users ['yomama'];

Dropping tables and keyspaces

With Cassandra CLI commands you can drop tables and keyspaces in much the same way that tables and databases are dropped in a relational database.

Drop the example users table and then drop the demo keyspace.

```
[default@demo] DROP COLUMN FAMILY users;

[default@demo] DROP KEYSPACE demo;
```

References

Starting and stopping Cassandra

Starting Cassandra as a service

Start the Cassandra Java server process for packaged installations.

Startup scripts are provided in `/etc/init.d`. The service runs as the *cassandra* user.

You must have root or sudo permissions to start Cassandra as a service.

On initial start-up, each node must be started one at a time, starting with your seed nodes:

```
$ sudo service cassandra start
```

On Enterprise Linux systems, the Cassandra service runs as a java process. On Debian systems, the Cassandra service runs as a jsvc process.

Starting Cassandra as a stand-alone process

Start the Cassandra Java server process for binary installations.

On initial start-up, each node must be started one at a time, starting with your seed nodes.

- To start Cassandra in the background:

```
$ cd <install_location>
$ bin/cassandra
```

- To start Cassandra in the foreground:

```
$ cd <install_location>
$ bin/cassandra -f
```

Stopping Cassandra as a service

Stop the Cassandra Java server process on packaged installations.

You must have root or sudo permissions to stop the Cassandra service:

```
$ sudo service cassandra stop
```

Stopping Cassandra as a stand-alone process

Stop the Cassandra Java server process on binary installations.

Find the Cassandra Java process ID (PID), and then kill the process using its PID number:

```
$ ps auwx | grep cassandra
$ sudo  kill <pid>
```

Clearing the data as a service

Remove all data from a packaged installation.

After stopping the service, run the following command:

```
$ sudo rm -rf /var/lib/cassandra/*
```

This command clears the data from the **default** directories.

Clearing the data as a stand-alone process

Remove all data from a binary installations.

After stopping the process, run the following command from the install directory:

```
$ cd <install_location>
$ sudo rm -rf /var/lib/cassandra/*
```

This command clears the data from the **default** directories.

Install locations

Locations of the configuration files

Cassandra 1.2 unpacks files into the directories listed here.

Locations of the configuration files

The configuration files, such as `cassandra.yaml` and `cassandra-topology.properties` are located in the following directories:

- Packaged installs: `/etc/cassandra/conf`
- Tarball installs: `<install_location>/conf`

For DataStax Enterprise installs, see Configuration File Locations.

Packaged install directories

The packaged releases install into these directories.

Directories	Description
`/var/lib/cassandra`	Data directories
`/var/log/cassandra`	Log directory
`/var/run/cassandra`	Runtime files
`/usr/share/cassandra`	Environment settings
`/usr/share/cassandra/lib`	JAR files
`/usr/bin`	Binary files
`/usr/sbin`	
`/etc/cassandra`	Configuration files
`/etc/init.d`	Service startup script
`/etc/security/limits.d`	Cassandra user limits
`/etc/default`	

Binary install directories

The binary tarball releases install into these directories.

Directories	Description
`bin`	Utilities and start scripts
`conf`	Configuration files and environment settings
`interface`	Thrift and Avro client APIs
`javadoc`	Cassandra Java API documentation
`lib`	JAR and license files

CLI keyspace and table storage configuration

Cassandra stores storage configuration attributes in the system keyspace. You set storage configuration attributes on a per-keyspace or per-table basis programmatically or using a client application, such as CLI or Thrift.

Keyspace attributes

A keyspace must have a user-defined name, a replica placement strategy, and options that specify the number of copies per data center or node.

Attribute	Default value
name	NA
placement_strategy	SimpleStrategy
strategy_options	N/A (container attribute)
durable_writes	N/A (container attribute)

name

Required. The name for the keyspace.

placement_strategy

Required. Determines how Cassandra distributes replicas for a keyspace among nodes in the ring. Values are:

- `SimpleStrategy` or `org.apache.cassandra.locator.SimpleStrategy`
- `NetworkTopologyStrategy` or `org.apache.cassandra.locator.NetworkTopologyStrategy`

NetworkTopologyStrategy requires a snitch to be able to determine rack and data center locations of a node. For more information about replication placement strategy, see Data replication on page 16.

strategy_options

Specifies configuration options for the chosen replication strategy class. The replication factor option is the total number of replicas across the cluster. A replication factor of 1 means that there is only one copy of each row on one node. A replication factor of 2 means there are two copies of each row, where each copy is on a different node. All replicas are equally important; there is no primary or master replica. As a general rule, the replication factor should not exceed the number of nodes in the cluster. However, you can increase the replication factor and then add the desired number of nodes.

When the replication factor exceeds the number of nodes, writes are rejected, but reads are served as long as the desired consistency level can be met.

For more information about configuring the replication placement strategy for a cluster and data centers, see Choosing keyspace replication options on page 16.

durable_writes

(Default: true) When set to false, data written to the keyspace bypasses the commit log. Be careful using this option because you risk losing data.

Table attributes

The following attributes can be declared per table.

Option	Default value
bloom_filter_fp_chance	0.01 or 0.1 (Value depends on the compaction strategy.)
bucket_high	1.5
bucket_low	0.5
caching	keys_only
column_metadata	N/A (container attribute)
column_type	Standard
comment	N/A
compaction_strategy	SizeTieredCompactionStrategy
compaction_strategy_options	N/A (container attribute)
comparator	BytesType
compare_subcolumns_with	BytesType*
compression_options	sstable_compression='SnappyCompressor'
default_validation_class	N/A
dclocal_read_repair_chance	0.0
gc_grace	864000 (10 days)
key_validation_class	N/A
max_compaction_threshold	32
min_compaction_threshold	4
memtable_flush_after_mins	N/A*
memtable_operations_in_millions	N/A*
memtable_throughput_in_mb	N/A*
min_sstable_size	50MB
name	N/A
populate_io_cache_on_flush	False
read_repair_chance	0.1or 1 (See description below.)
replicate_on_write	true
sstable_size_in_mb	160MB
tombstone_compaction_interval	1 day
tombstone_threshold	0.2

* Deprecated as of Cassandra 1.0, but can still be declared for backward compatibility.

compaction_strategy_options

(Default: N/A - container attribute) Sets attributes related to the chosen compaction-strategy. Attributes are:

- bucket_high

- bucket_low
- max_compaction_threshold
- min_compaction_threshold
- min_sstable_size
- sstable_size_in_mb
- tombstone_compaction_interval
- tombstone_threshold

bloom_filter_fp_chance

(Default: 0.01 for `SizeTieredCompactionStrategy`, 0.1 for `LeveledCompactionStrategy`) Desired false-positive probability for SSTable Bloom filters. When data is requested, the Bloom filter checks if the requested row exists before doing any disk I/O. Valid values are 0 to 1.0. A setting of 0 means that the unmodified (effectively the largest possible) Bloom filter is enabled. Setting the Bloom Filter at 1.0 disables it. The higher the setting, the less memory Cassandra uses. The maximum recommended setting is 0.1, as anything above this value yields diminishing returns. For detailed information, see Tuning Bloom filters.

bucket_high

(Default: 1.5) Size-tiered compaction considers SSTables to be within the same bucket if the SSTable size diverges by 50% or less from the default bucket_low and default bucket_high values: [average-size × bucket_low, average-size × bucket_high].

bucket_low

(Default: 0.5) See bucket_high for a description.

caching

(Default: keys_only) Optimizes the use of cache memory without manual tuning. Set caching to one of the following values:

- all
- keys_only
- rows_only
- none

Cassandra weights the cached data by size and access frequency. Use this parameter to specify a key or row cache instead of a table cache, as in earlier versions.

chunk_length_kb

(Default: 64KB) On disk SSTables are compressed by block (to allow random reads). This subproperty of compression defines the size (in KB) of the block. Values larger than the default value might improve the compression rate, but increases the minimum size of data to be read from disk when a read occurs. The default value (64) is a good middle-ground for compressing tables. Adjust compression size to account for read/write access patterns (how much data is typically requested at once) and the average size of rows in the table.

column_metadata

(Default: N/A - container attribute) Column metadata defines these attributes of a column:

- name: Binds a validation_class and (optionally) an index to a column.
- validation_class: Type used to check the column value.
- index_name: Name of the index.
- index_type: Type of index. Currently the only supported value is KEYS.

Setting a value for the name option is required. The validation_class is set to the default_validation_class of the table if you do not set the validation_class option explicitly. The value of index_type must be set to create an index for a column. The value of index_name is not valid unless index_type is also set.

Setting and updating column metadata with the Cassandra CLI requires a slightly different command syntax than other attributes; note the brackets and curly braces in this example:

```
[default@demo ] UPDATE COLUMN FAMILY users WITH  comparator =UTF8Type
```

```
AND   column_metadata =[{column_name: full_name, validation_class: UTF8Type,
 index_type: KEYS }];
```

column_type

(Default: Standard) The standard type of table contains regular columns.

comment

(Default: N/A) A human readable comment describing the table.

compaction_strategy

(Default: `SizeTieredCompactionStrategy`) Sets the compaction strategy for the table. The available strategies are:

- `SizeTieredCompactionStrategy`: The default compaction strategy and the only compaction strategy available in releases earlier than Cassandra 1.0. This strategy triggers a minor compaction whenever there are a number of similar sized SSTables on disk (as configured by min_compaction_threshold). Using this strategy causes bursts in I/O activity while a compaction is in process, followed by longer and longer lulls in compaction activity as SSTable files grow larger in size. These I/O bursts can negatively effect read-heavy workloads, but typically do not impact write performance. Watching disk capacity is also important when using this strategy, as compactions can temporarily double the size of SSTables for a table while a compaction is in progress.
- `LeveledCompactionStrategy`: The leveled compaction strategy creates SSTables of a fixed, relatively small size (5 MB by default) that are grouped into levels. Within each level, SSTables are guaranteed to be non-overlapping. Each level (L0, L1, L2 and so on) is 10 times as large as the previous. Disk I/O is more uniform and predictable as SSTables are continuously being compacted into progressively larger levels. At each level, row keys are merged into non-overlapping SSTables. This can improve performance for reads, because Cassandra can determine which SSTables in each level to check for the existence of row key data. This compaction strategy is modeled after Google's leveldb implementation. For more information, see the articles When to Use Leveled Compaction and Leveled Compaction in Apache Cassandra.

comparator

(Default: BytesType) Defines the data types used to validate and sort column names. There are several built-in column comparators available. The comparator cannot be changed after you create a table.

compare_subcolumns_with

(Default: BytesType) Required when the column_type attribute is set to Super. Same as comparator but for the sub-columns of a super column. Deprecated as of Cassandra 1.0, but can still be declared for backward compatibility.

compression_options

(Default: N/A - container attribute) Sets the compression algorithm and subproperties for the table. Choices are:

- sstable_compression
- chunk_length_kb
- crc_check_chance

crc_check_chance

(Default 1.0) When compression is enabled, each compressed block includes a checksum of that block for the purpose of detecting disk bitrot and avoiding the propagation of corruption to other replica. This option defines the probability with which those checksums are checked during read. By default they are always checked. Set to 0 to disable checksum checking and to 0.5, for instance, to check them on every other read.

default_validation_class

(Default: N/A) Defines the data type used to validate column values. There are several built-in column validators available.

dclocal_read_repair_chance

(Default: 0.0) Specifies the probability of read repairs being invoked over all replicas in the current data center. Contrast read_repair_chance.

gc_grace

(Default: 864000 [10 days]) Specifies the time to wait before garbage collecting tombstones (deletion markers). The default value allows a great deal of time for consistency to be achieved prior to deletion. In many deployments this interval can be reduced, and in a single-node cluster it can be safely set to zero.

key_validation_class

(Default: N/A) Defines the data type used to validate row key values. There are several built-in key validators available, however `CounterColumnType` (distributed counters) cannot be used as a row key validator.

max_compaction_threshold

(Default: 32) In `SizeTieredCompactionStrategy` sets the maximum number of SSTables processed by a minor compaction.

min_compaction_threshold

(Default: 4) In `SizeTieredCompactionStrategy` sets the minimum number of SSTables to trigger a minor compaction.

memtable_flush_after_mins

Deprecated as of Cassandra 1.0, but can still be declared for backward compatibility. Use commitlog_total_space_in_mb.

memtable_operations_in_millions

Deprecated as of Cassandra 1.0, but can still be declared for backward compatibility. Use commitlog_total_space_in_mb.

memtable_throughput_in_mb

Deprecated as of Cassandra 1.0, but can still be declared for backward compatibility. Use commitlog_total_space_in_mb.

min_sstable_size

(Default: 50MB) The `SizeTieredCompactionStrategy` groups SSTables for compaction into buckets. The bucketing process groups SSTables that differ in size by less than 50%. This results in a bucketing process that is too fine grained for small SSTables. If your SSTables are small, use min_sstable_size to define a size threshold (in bytes) below which all SSTables belong to one unique bucket.

populate_io_cache_on_flush

(Default: false) Populates the page cache on memtable flush and compaction. Enable only when all data on the node fits within memory. Use for fast reading of SSTables from IO cache (memory).

name

(Default: N/A) Required. The user-defined name of the table.

read_repair_chance

(Default: 0.1 or 1) Specifies the probability with which read repairs should be invoked on non-quorum reads. The value must be between 0 and 1. For tables created in versions of Cassandra before 1.0, it defaults to 1. For tables created in versions of Cassandra 1.0 and higher, it defaults to 0.1. However, for Cassandra 1.0, the default is 1.0 if you use CLI or any Thrift client, such as Hector or pycassa, and is 0.1 if you use CQL.

replicate_on_write

(Default: true) Applies only to counter tables. When set to true, replicates writes to all affected replicas regardless of the consistency level specified by the client for a write request. For counter tables, this should always be set to true.

sstable_size_in_mb

(Default: 160MB) The target size for SSTables that use the leveled compaction strategy. Although SSTable sizes should be less or equal to sstable_size_in_mb, it is possible to have a larger SSTable during compaction. This occurs when data for a given partition key is exceptionally large. The data is not split into two SSTables.

sstable_compression

(Default: `SnappyCompressor`) The compression algorithm to use. Valid values are `LZ4Compressor` available in Cassandra 1.2.2 and later), `SnappyCompressor`, and `DeflateCompressor`. Use an empty string ('') to disable compression. Choosing the right compressor depends on your requirements for space savings over read performance. LZ4 is fastest to decompress, followed by Snappy, then by Deflate. Compression effectiveness is inversely correlated with decompression speed. The extra compression from Deflate or Snappy is not enough to make up for the decreased performance for general-purpose workloads, but for archival data they may be worth considering. Developers can also implement custom compression classes using the `org.apache.cassandra.io.compress.ICompressor` interface. Specify the full class name as a "string constant".

tombstone_compaction_interval

(Default: 1 day) The minimum time to wait after an SSTable creation time before considering the SSTable for tombstone compaction. Tombstone compaction is the compaction triggered if the SSTable has more garbage-collectable tombstones than tombstone_threshold.

tombstone_threshold

(Default: 0.2) A ratio of garbage-collectable tombstones to all contained columns, which if exceeded by the SSTable triggers compaction (with no other SSTables) for the purpose of purging the tombstones.

Troubleshooting

This section contains the following topics:

Reads are getting slower while writes are still fast

The cluster's IO capacity is not enough to handle the write load it is receiving.

Check the SSTable counts in cfstats. If the count is continually growing, the cluster's IO capacity is not enough to handle the write load it is receiving. Reads have slowed down because the data is fragmented across many SSTables and compaction is continually running trying to reduce them. Adding more IO capacity, either via more machines in the cluster, or faster drives such as SSDs, will be necessary to solve this.

If the SSTable count is relatively low (32 or less) then the amount of file cache available per machine compared to the amount of data per machine needs to be considered, as well as the application's read pattern. The amount of file cache can be formulated as (`TotalMemory` – `JVMHeapSize`) and if the amount of data is greater and the read pattern is approximately random, an equal ratio of reads to the cache:data ratio will need to seek the disk. With spinning media, this is a slow operation. You may be able to mitigate many of the seeks by using a key cache of 100%, and a small amount of row cache (10000-20000) if you have some hot rows and they are not extremely large.

Nodes seem to freeze after some period of time

Some portion of the JVM is being swapped out by the operating system (OS).

Check your system.log for messages from the `GCInspector`. If the `GCInspector` is indicating that either the `ParNew` or `ConcurrentMarkSweep` collectors took longer than 15 seconds, there is a high probability that some portion of the JVM is being swapped out by the OS.

One way this might happen is if the `mmap` `DiskAccessMode` is used without JNA support. The address space will be exhausted by `mmap`, and the OS will decide to swap out some portion of the JVM that isn't in use, but eventually the JVM will try to GC this space. Adding the JNA libraries will solve this (they cannot be shipped with Cassandra due to carrying a GPL license, but are freely available) or the `DiskAccessMode` can be switched to `mmap_index_only`, which as the name implies will only `mmap` the indices, using much less address space.

DataStax recommends that Cassandra nodes disable swap entirely (`sudo swapoff --all`), since it is better to have the OS `OutOfMemory` (OOM) killer kill the Java process entirely than it is to have the JVM buried in swap and responding poorly. To make this change permanent, remove all swap file entries from `/etc/fstab`.

If the GCInspector isn't reporting very long GC times, but is reporting moderate times frequently (`ConcurrentMarkSweep` taking a few seconds very often) then it is likely that the JVM is experiencing extreme GC pressure and will eventually OOM. See the section below on OOM errors.

Nodes are dying with OOM errors

Nodes are dying with OutOfMemory exceptions.

Check for these typical causes:

Row cache is too large, or is caching large rows

Row cache is generally a high-end optimization. Try disabling it and see if the OOM problems continue.

The memtable sizes are too large for the amount of heap allocated to the JVM

You can expect N + 2 memtables resident in memory, where N is the number of tables. Adding another 1GB on top of that for Cassandra itself is a good estimate of total heap usage.

If none of these seem to apply to your situation, try loading the heap dump in MAT and see which class is consuming the bulk of the heap for clues.

Nodetool or JMX connections failing on remote nodes

Nodetool commands can be run locally but not on other nodes in the cluster.

If you can run nodetool commands locally but not on other nodes in the ring, you may have a common JMX connection problem that is resolved by adding an entry like the following in `<install_location>/conf/cassandra-env.sh` on each node:

```
JVM_OPTS = "$JVM_OPTS -Djava.rmi.server.hostname=<public name>"
```

If you still cannot run nodetool commands remotely after making this configuration change, do a full evaluation of your firewall and network security. The nodetool utility communicates through JMX on port 7199.

View of ring differs between some nodes

Indicates that the ring is in a bad state.

This situation can happen when not using virtual nodes (vnodes) and there are token conflicts (for instance, when bootstrapping two nodes simultaneously with automatic token selection.) Unfortunately, the only way to resolve this is to do a full cluster restart. A rolling restart is insufficient since gossip from nodes with the bad state will repopulate it on newly booted nodes.

Java reports an error saying there are too many open files

Java may not have open enough file descriptors.

Cassandra generally needs more than the default (1024) amount o f file descriptors. To increase the number of file descriptors, change the security limits on your Cassandra nodes as described in the Recommended Settings section of Insufficient user resource limits errors..

Another, much less likely possibility, is a file descriptor leak in Cassandra. Run `lsof -n | grep java` to check that the number of file descriptors opened by Java is reasonable and reports the error if the number is greater than a few thousand.

Insufficient user resource limits errors

Insufficient resource limits may result in a number of errors in Cassandra and OpsCenter.

Cassandra errors

Insufficient as (address space) or memlock setting

```
ERROR        [SSTableBatchOpen:1        ]        2012-07-25        15:46:02,913
 AbstractCassandraDaemon.java  (line 139 )
Fatal exception in thread Thread [SSTableBatchOpen:1,5,main ]
java.io.IOError: java.io.IOException: Map failed  at ...
```

Insufficient memlock settings

```
WARN [main ] 2011-06-15 09:58:56,861 CLibrary.java  (line 118 ) Unable to lock
 JVM memory  (ENOMEM ).
```

```
This can result in part of the JVM being swapped out, especially with mmapped
 I/O enabled.
Increase RLIMIT_MEMLOCK or run Cassandra as root.
```

Insufficient nofiles setting

```
WARN 05:13:43,644 Transport error occurred during acceptance of message.
org.apache.thrift.transport.TTransportException: java.net.SocketException:
Too many open files ...
```

Insufficient nofiles setting

```
ERROR [MutationStage:11 ] 2012-04-30 09:46:08,102 AbstractCassandraDaemon.java
  (line 139 )
Fatal exception in thread Thread [MutationStage:11,5,main ]
java.lang.OutOfMemoryError: unable to create new native thread
```

Recommended settings

You can view the current limits using the `ulimit -a` command. Although limits can also be temporarily set using this command, DataStax recommends making the changes permanent:

Packaged installs: Ensure that the following settings are included in the `/etc/security/limits.d/cassandra.conf` file:

```
cassandra - memlock unlimited
cassandra - nofile 100000
cassandra - nproc 32768
cassandra - as unlimited
```

Tarball installs: Ensure that the following settings are included in the `/etc/security/limits.conf` file:

```
* - memlock unlimited
* - nofile 100000
* - nproc 32768
* - as unlimited
```

If you run Cassandra as root, some Linux distributions such as Ubuntu, require setting the limits for root explicitly instead of using `*`:

```
root - memlock unlimited
root - nofile 100000
root - nproc 32768
root - as unlimited
```

For CentOS, RHEL, OEL systems, also set the nproc limits in `/etc/security/limits.d/90-nproc.conf`:

```
* - nproc 32768
```

For all installations, add the following line to `/etc/sysctl.conf`:

```
vm.max_map_count = 131072
```

To make the changes take effect, reboot the server or run the following command:

```
$ sudo sysctl -p
```

To confirm the limits are applied to the Cassandra process, run the following command where *<pid>* is the process ID of the currently running Cassandra process:

```
$ cat /proc/<pid>/limits
```

OpsCenter errors

See the OpsCenter Troubleshooting documentation.

Cannot initialize class org.xerial.snappy.Snappy

An error may occur when Snappy compression/decompression is enabled although its library is available from the classpath.

```
java.util.concurrent.ExecutionException: java.lang.NoClassDefFoundError:
    Could not initialize class org.xerial.snappy.Snappy
...
Caused by: java.lang.NoClassDefFoundError: Could not initialize class
 org.xerial.snappy.Snappy
   at
 org.apache.cassandra.io.compress.SnappyCompressor.initialCompressedBufferLength
       (SnappyCompressor.java:39 )
```

The native library `snappy-1.0.4.1-libsnappyjava.so` for Snappy compression is included in the `snappy-java-1.0.4.1.jar` file. When the JVM initializes the JAR, the library is added to the default temp directory. If the default temp directory is mounted with a noexec option, it results in the above exception.

One solution is to specify a different temp directory that has already been mounted without the noexec option, as follows:

- If you use the DSE/Cassandra command `$_BIN/dse cassandra` or `$_BIN/cassandra`, simply append the command line:
  - DSE: `bin/dse cassandra -t -Dorg.xerial.snappy.tempdir=/path/to/newtmp`
  - Cassandra: `bin/cassandra -Dorg.xerial.snappy.tempdir=/path/to/newtmp`
- If starting from a package using service dse start or service cassandra start, add a system environment variable *JVM_OPTS* with the value:

  ```
  JVM_OPTS=-Dorg.xerial.snappy.tempdir=/path/to/newtmp
  ```

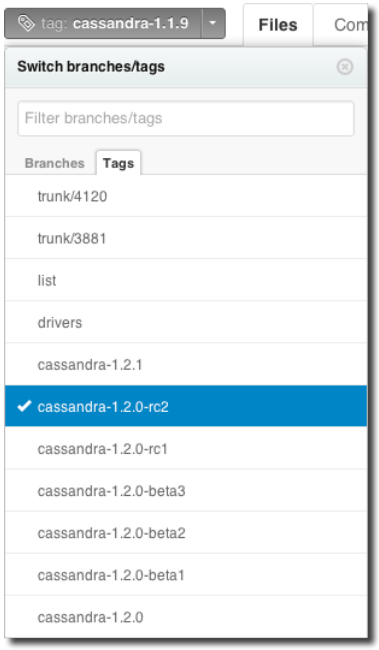
  The default `cassandra-env.sh` looks for the variable and appends to it when starting the JVM.

DataStax Community release notes

Fixes and New Features in Cassandra.

Current DataStax Community version: 1.2.10

For a list of fixes and new features, see the CHANGES.txt. You can view all version changes by branch or tag in the **branch** drop-down list:



Glossary

anti-entropy

The synchronization of replica data on nodes to ensure that the data is fresh.

Bloom filter

An off-heap structure associated with each SSTable that checks if any data for the requested row exists in the SSTable before doing any disk I/O.

cluster

Two or more Cassandra instances that exchange messages using the gossip protocol.

clustering

The storage engine process that creates an index and keeps data in order based on the index.

clustering column

Columns other than the partition key in a compound primary key definition.

column

The smallest increment of data, which contains a name, a value and a timestamp.

column family

A container for rows, similar to the table in a relational system. Called table in CQL 3.

commit log

A file to which Cassandra appends changed data for recovery in the event of a hardware failure.

compaction

A process that consists primarily of consolidating SSTables, but also discards tombstones and regenerates the index in the SSTable. A major compaction merges all SSTables into one. A minor compaction merges from 4 to 32 SSTables for a table.

composite partition key

Stores columns of a row on more than one node using partition keys declared in nested parentheses of the PRIMARY KEY definition of a table.

compound primary key

A primary key consisting of the partition key, which determines on which node data is stored, and one or more additional columns that determine clustering.

consistency

The synchronization of data on replicas in a cluster. Consistency is categorized as weak or strong.

consistency level

A setting that defines a successful write or read by the number of cluster replicas that acknowledge the write or respond to the read request, respectively.

coordinator node

The node that determines which nodes in the ring should get the request based on the cluster configured snitch.

cross-data center forwarding

A technique for optimizing replication across data centers that sends data from one data center to a node in another data center, and that node forwards the data to other nodes in its data center.

data center

A group of related nodes configured together within a cluster for replication and workload-segregation purposes. Not necessarily a physical data center.

gossip

A peer-to-peer communication protocol for exchanging location and state information between nodes.

HDFS

Hadoop Distributed File System that stores data on nodes to improve performance. A necessary component in addition to MapReduce in a Hadoop distribution.

idempotent

An operation that can occur multiple times without changing the result, such as Cassandra performing the same update multiple times without affecting the outcome.

index

A native Cassandra capability for finding a column in the database that does not involve using the primary key.

partition summary

A subset of the partition index. By default, 1 partition key out of every 128 is sampled.

keyspace

A namespace container that defines how data is replicated on nodes.

MapReduce

Hadoop's parallel processing engine that can process large data sets relatively quickly. A necessary component in addition to MapReduce in a Hadoop distribution.

memtable

A Cassandra table-specific, in-memory data structure that resembles a write-back cache.

mutation

1) An upsert. 2) A Thrift base class that has abstract methods for reading and writing data input and output.

node repair

A process that makes all data on a replica consistent.

partitioner

Distributes the data across the cluster. The types of partitioners are Murmur3Partitioner (default), RandomPartitioner, and OrderPreservingPartitioner.

partition key

The first column declared in the PRIMARY KEY definition, or in the case of a compound key, multiple columns can declare those columns that form the primary key.

partition range

The limits of the partition that differ depending on the configured partitioner. Murmur3Partitioner (default) range is -2^{63} to $+2^{63}$ and RandomPartitioner range is 0 to $2^{127}-1$.

partition index

A list of primary keys and the start position of data.

primary key

The partition key. One or more columns that uniquely identify a row in a table.

read repair

A process that updates Cassandra replicas with the most recent version of frequently-read data.

replication group

See data center.

replica placement strategy

A specification that determines the replicas for each row of data.

rolling restart

A procedure that is performed during upgrading nodes in a cluster for zero downtime. Nodes are upgraded and restarted one at a time, while other nodes continue to operate online.

row

1) Columns that have the same primary key. 2) A collection of cells per combination of columns in the storage engine.

slice

A Thrift API term for a set of columns from a single row, described either by name or as a contiguous run of columns from a starting point.

snitch

The mapping from the IP addresses of nodes to physical and virtual locations, such as racks and data centers. There are several types of snitches. The type of snitch affects the request routing mechanism.

SSTable

A sorted string table (SSTable) is an immutable data file to which Cassandra writes memtables periodically. SSTables are stored on disk sequentially and maintained for each Cassandra table.

strong consistency

When reading data, Cassandra performs read repair before returning results.

superuser

By default, each installation of Cassandra includes a superuser account named cassandra whose password is also cassandra. A superuser grants initial permissions to access Cassandra data, and subsequently a user may or may not be given the permission to grant/revoke permissions.

table

A collection of ordered (by name) columns fetched by row. A row consists of columns and have a primary key. The first part of the key is a column name. Subsequent parts of a compound key are other column names that define the order of columns in the table.

token

An element on the ring that depends on the partitioner. A token determines the node's position on the ring and the portion of data it is responsible for. The range for the Murmur3Partitioner (default) is -2^{63} to $+2^{63}$. The range for the RandomPartitioner is 0 to $2^{127}-1$.

tombstone

A marker in a row that indicates a column was deleted. During compaction, marked column are deleted.

TTL

Time-to-live. An optional expiration date for values inserted into a column. Also see Expiring columns in Removing data.

weak consistency

When reading data, Cassandra performs read repair after returning results.

wide row

A data partition, which CQL 3 transposes into familiar row-based resultsets.

upsert

A change in the database that updates a specified column in a row if the column exists or inserts the column if it does not exist.