An Experimental Study of Homegateway Characteristics

Seppo Hätönen	University of Helsinki
Aki Nyrhinen	University of Helsinki
Lars Eggert	Nokia Research Center
Stephen Strowes	University of Glasgow
Pasi Sarolahti	Aalto University
Markku Kojo	University of Helsinki

Motivation

- NAT devices (”home gateways”) are everywhere
- Used as access points and home firewalls/ routers
- Behaviors vary widely
- Impact on future Internet is not well known except that there are problems

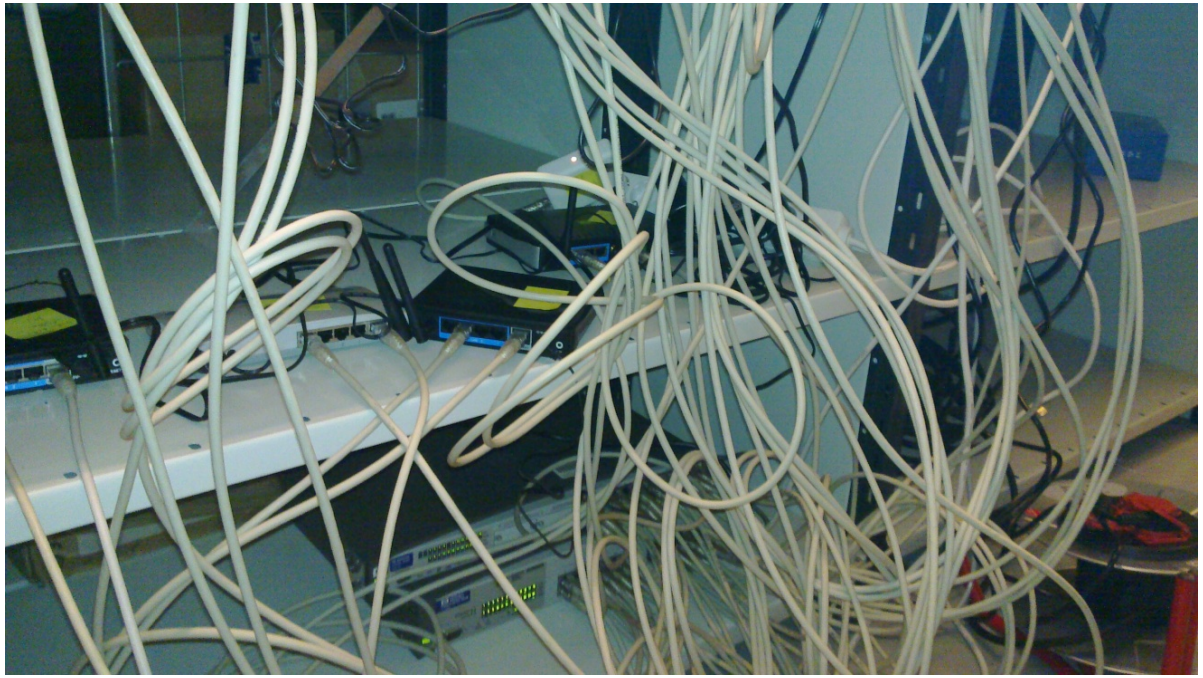
The Devices

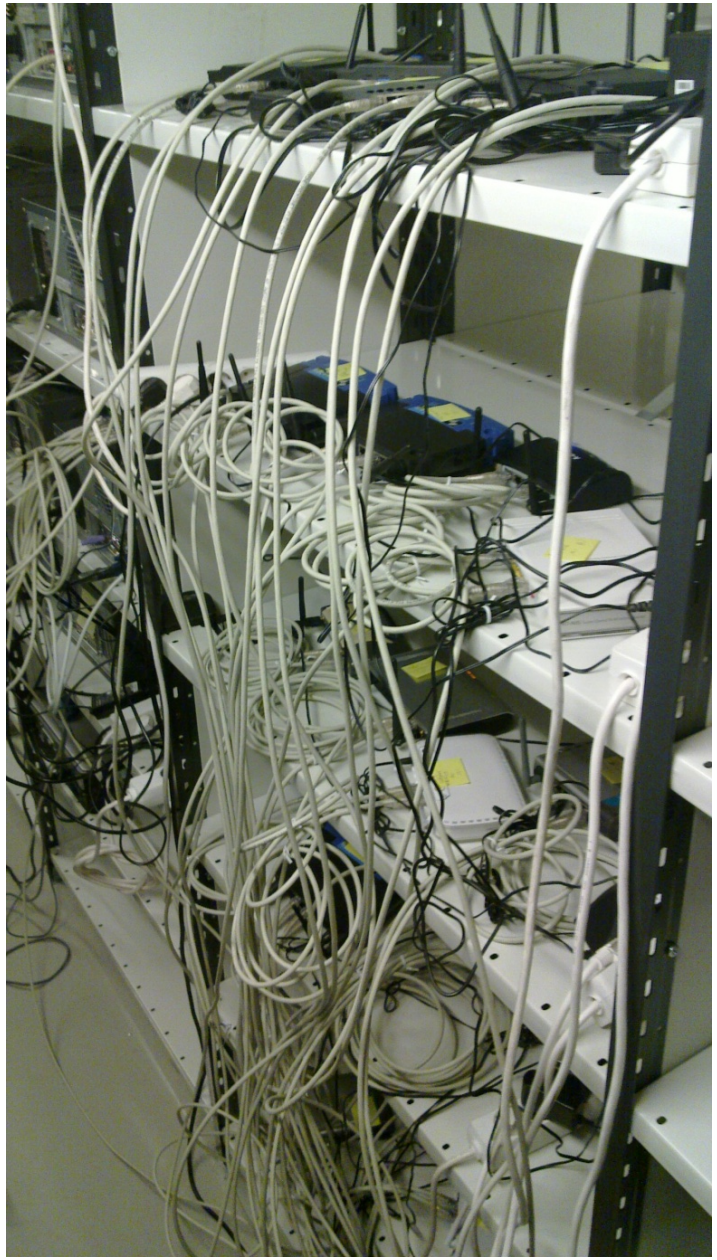
The Devices

- HU and Nokia bought 20 devices for the testbed
- 14 donated devices were added to the testbed by the time of writing
- Currently around 70 devices are waiting to be added, including DSL and cable devices

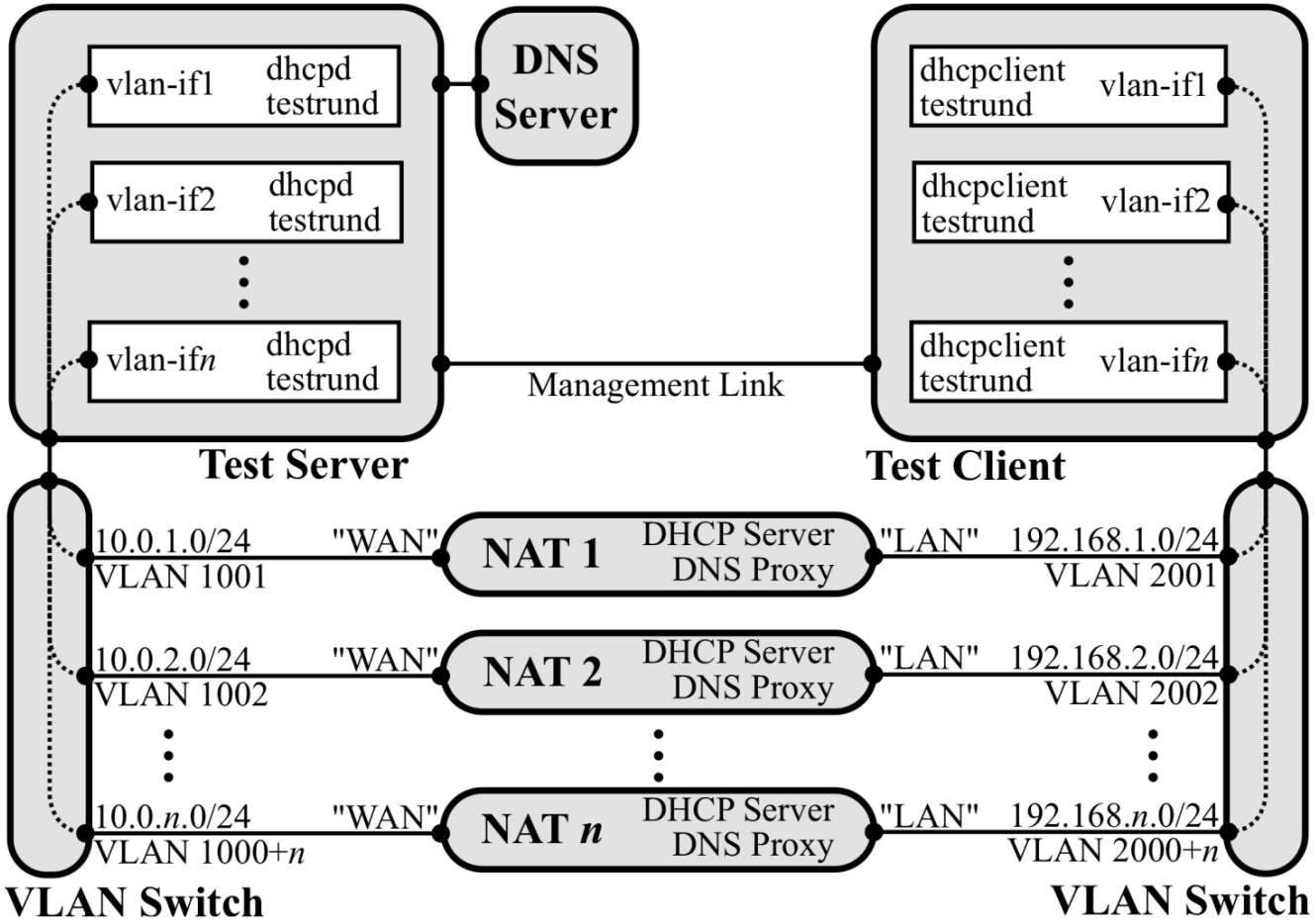
Vendor	Model	Firmware	Tag
A-Link	WNAP	e2.0.9A	*al*
Apple	Airport Express	7.4.2	*ap*
Asus	RT-N15	2.0.1.1	*as1*
Belkin	Wireless N Router	F5D8236-4_WW_3.00.02	*be1*
	Enhanced N150	F6D4230-4_WW_1.00.03	*be2*
Buffalo	WZR-AGL300NH	R1.06/B1.05	*bu1*
D-Link	DIR-300	1.03	*dl1*
	DIR-300	1.04	*dl2*
	DI-524up	v1.06	*dl3*
	DI-524	v2.0.4	*dl4*
	DIR-100	v1.12	*dl5*
	DIR-600	v2.01	*dl6*
	DIR-615	v4.00	*dl7*
	DIR-635	v2.33EU	*dl8*
	DI-604	v3.09	*dl9*
	DI-713P	2.60 build 6a	*dl10*
Edimax	6104WG	2.63	*ed*
Jensen	Air:Link 59300	1.15	*je*
Linksys	BEFSR41c2	1.45.11	*ls1*
	WR54G	v7.00.1	*ls2*
	WRT54GL v1.1	v4.30.7	*ls3*
	WRT54GL-EU	v4.30.7	*ls5*
	WRT54G	OpenWRT RC5	*owrt*
	WRT54GL v1.1	tomato 1.27	*to*
Netgear	RP614 v4	V1.0.2_06.29	*ng1*
	WGR614 v7	(1.0.13_1.0.13)	*ng2*
	WGR614 v9	V1.2.6_18.0.17	*ng3*
	WNR2000-100PES	v.1.0.0.34_29.0.45	*ng4*
	WGR614 v4	V5.0_07	*ng5*
Netwjork	54M	Ver 1.2.6	*nw1*
SMC Barricade	SMC7004VBR	R1.07	*smc*
Telewell	TW-3G	V7.04b3	*te*
Webee	Wireless N Router	e2.0.9D	*we*
ZyXel	P-335U	V3.60(AMB.2)C0	*zy1*

The Testbed



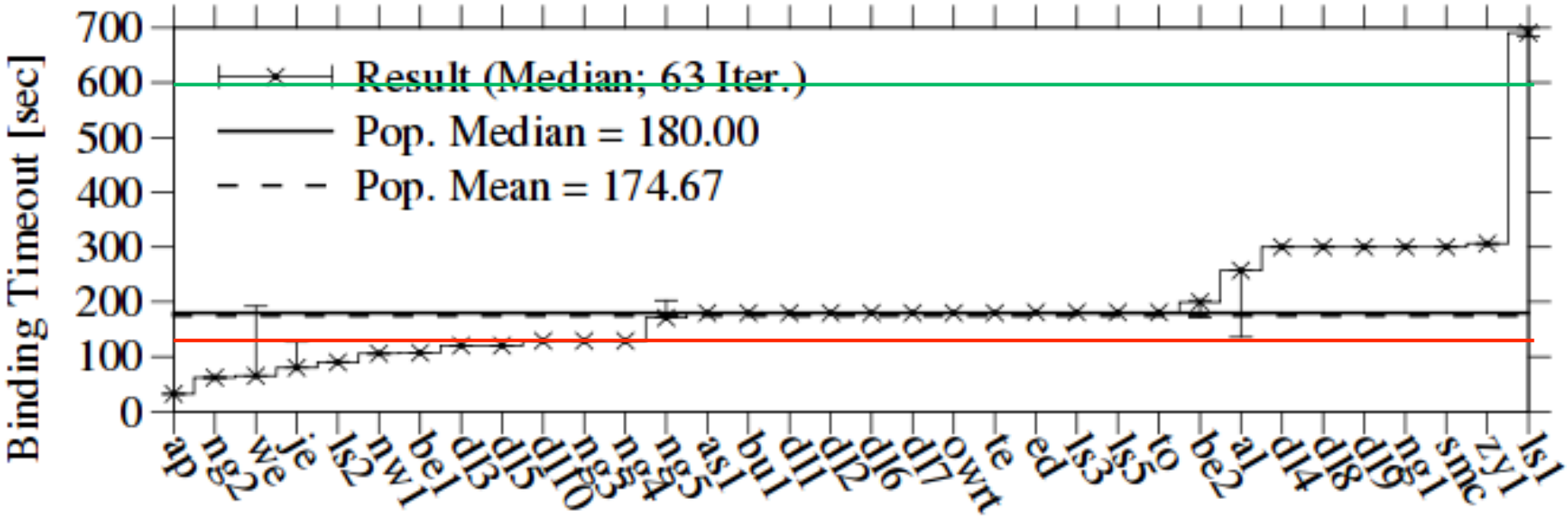


The Testbed


vlan-if1
dhcpd
testrund
vlan-if2
dhcpd
testrund
vlan-ifn
dhcpd
testrund
DNS
Server
Management Link
dhcpclient
testrund
vlan-if1
dhcpclient
testrund
vlan-if2
dhcpclient
testrund
vlan-ifn
Test Server
Test Client
10.0.1.0/24
VLAN 1001
"WAN"
NAT 1
DHCP Server
DNS Proxy
"LAN"
192.168.1.0/24
VLAN 2001
10.0.2.0/24
VLAN 1002
"WAN"
NAT 2
DHCP Server
DNS Proxy
"LAN"
192.168.2.0/24
VLAN 2002
10.0.n.0/24
VLAN 1000+n
"WAN"
NAT n
DHCP Server
DNS Proxy
"LAN"
192.168.n.0/24
VLAN 2000+n
VLAN Switch
VLAN Switch

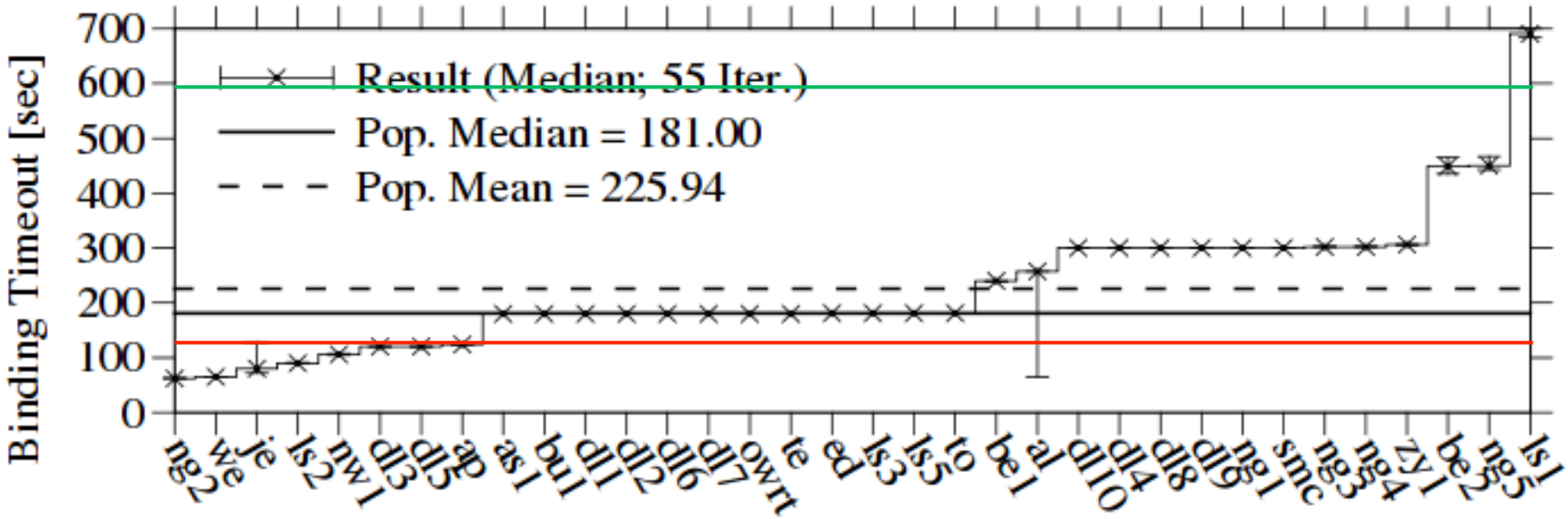
UDP Binding Timeout

- Inbound UDP traffic only; client only creates the binding with a single packet
- Result: Median is 180s, not much variation. ~1/5 less than IETF requirement, almost all less than IETF recommendation



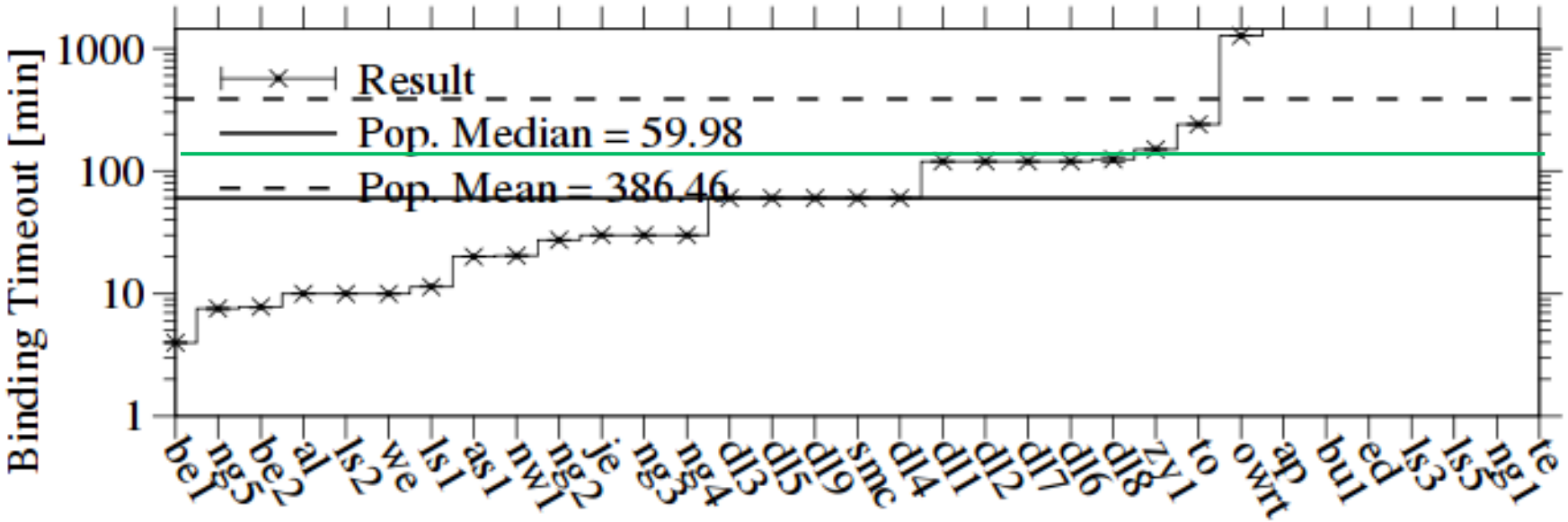
UDP Binding Timeout

- Bidirectional traffic; client sends a response packet to the server
- Result: Median is 181s, somewhat longer timeouts



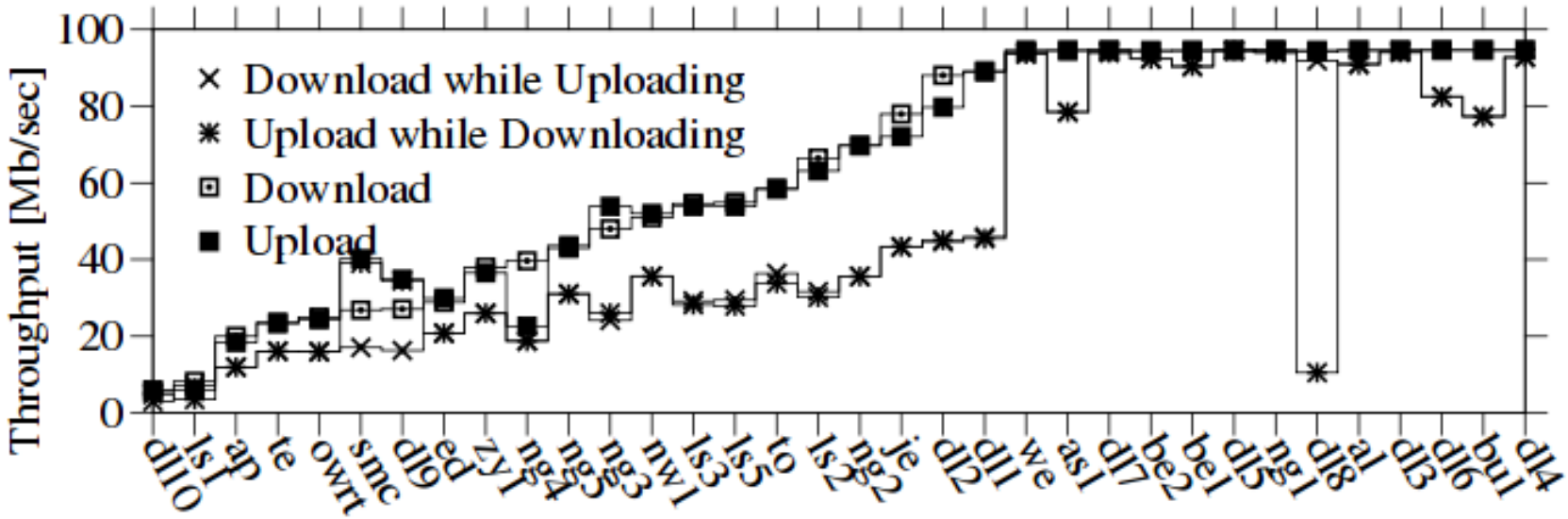
TCP Binding Timeout

- No keepalives
- Scale from few minutes to over 24h
- Some really short, more than half of the devices use shorter than IETF recommendation



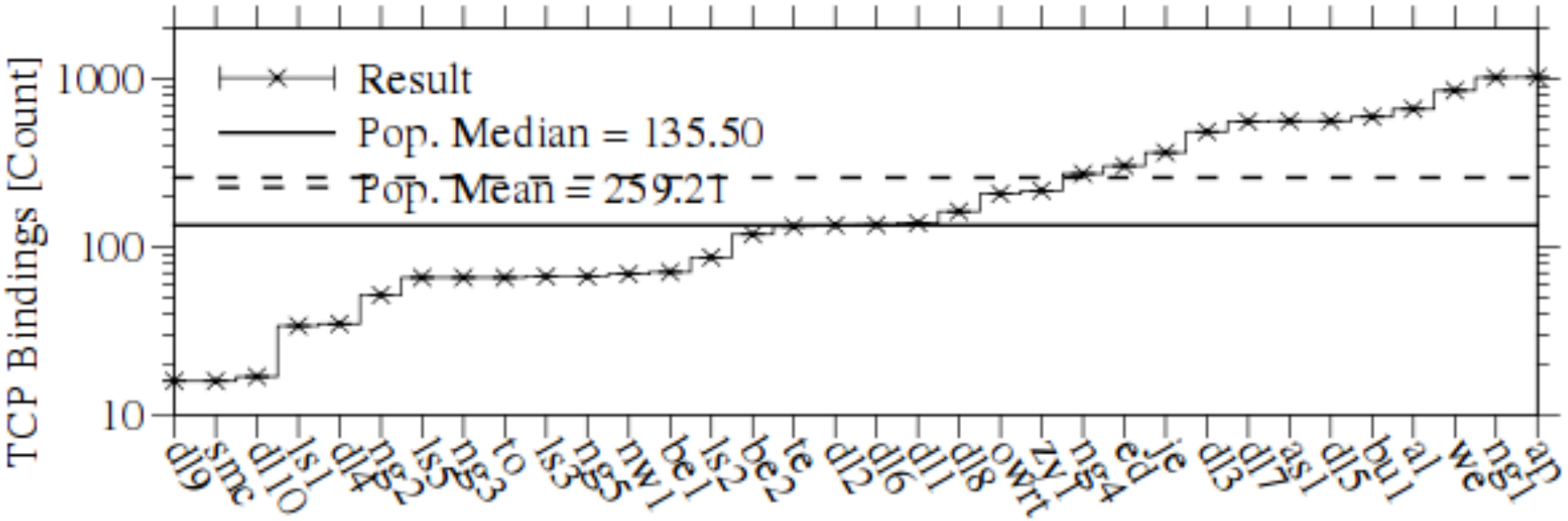
TCP Throughput

- Throughput over of a 100MB bulk transfer (2x unidirectional, 1x bidirectional)
- Result: Only 1/3 of devices reach max
  - bidir. median = ~ 35Mb/sec **vs.** unidir. median = ~68 Mb/sec
  - Some really bad



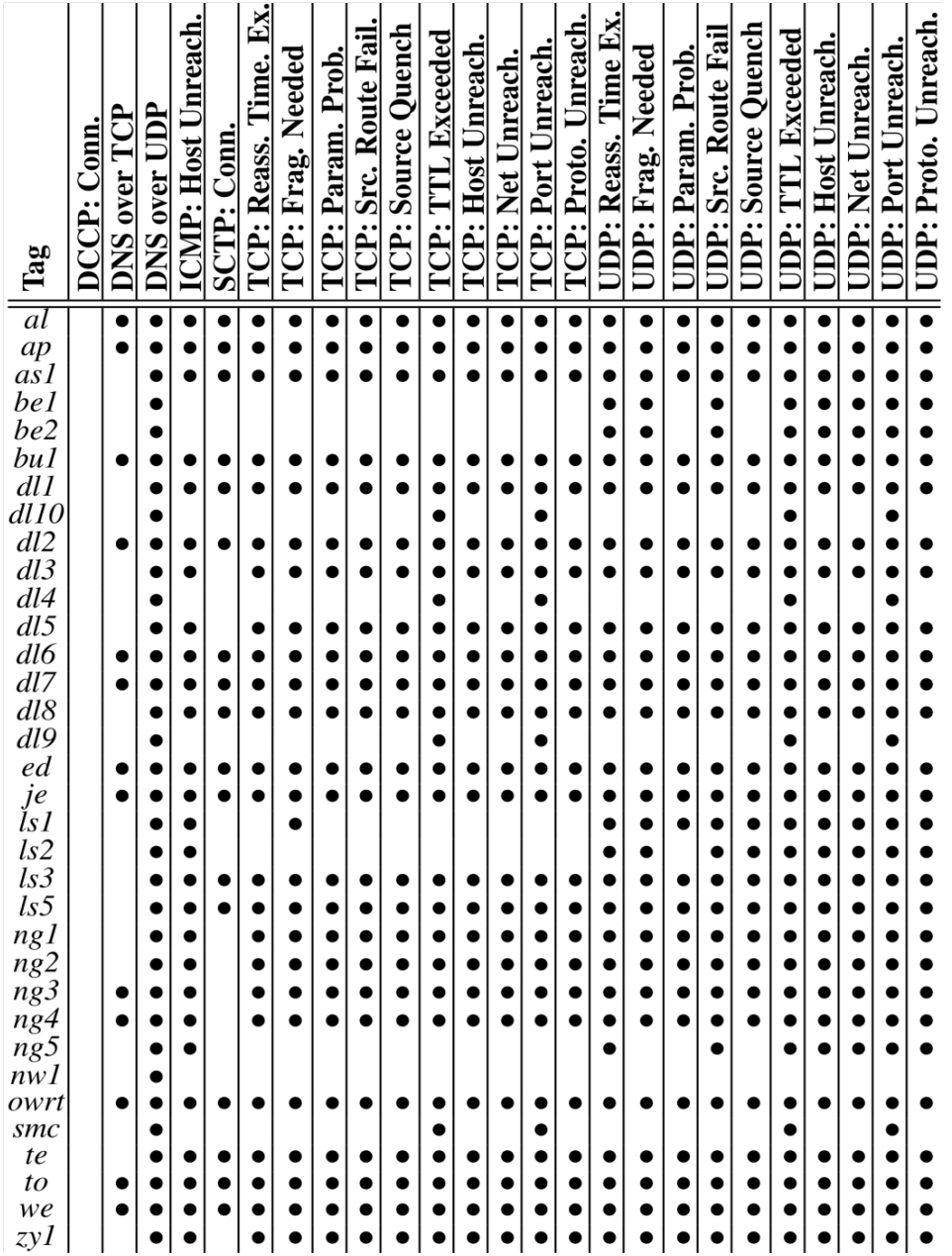
Maximum Number of TCP Bindings

- Maximum number of TCP bindings to a single server port
- Result: from 16 to 1024



Other Results

- No DCCP support
- SCTP: 18/34
  - Highly questionable at this point
- DNS over UDP works
- DNS over TCP: 13/34



Tag	DCCP: Conn.	DNS over TCP	DNS over UDP	ICMP: Host Unreach.	SCTP: Conn.	TCP: Reass. Time. Ex.	TCP: Frag. Needed	TCP: Param. Prob.	TCP: Src. Route Fail.	TCP: Source Quench	TCP: TTL Exceeded	TCP: Host Unreach.	TCP: Net Unreach.	TCP: Port Unreach.	TCP: Proto. Unreach.	UDP: Reass. Time Ex.	UDP: Frag. Needed	UDP: Param. Prob.	UDP: Src. Route Fail	UDP: Source Quench	UDP: TTL Exceeded	UDP: Host Unreach.	UDP: Net Unreach.	UDP: Port Unreach.	UDP: Proto. Unreach.
al		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ap		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
as1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
be1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
be2			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
bu1		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl10			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl2		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl3			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl4			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl5			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl6		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl7			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl8			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
dl9			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ed		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
je		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls2			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls3			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ls5			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng2			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng3		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng4		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
ng5			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
nw1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
owrt		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
smc			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
te			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
to		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
we		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
zy1			●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●

Other Results

- ICMP handling: Not good
- One device did not translate ICMP messages at all
- All others translated at least ”Port Unreachable” and ”TTL Exceeded”

Tag	DCCP: Conn.	DNS over TCP	DNS over UDP	ICMP: Host Unreach.	SCTP: Conn.	TCP: Reass. Time. Ex.	TCP: Frag. Needed	TCP: Param. Prob.	TCP: Src. Route Fail.	TCP: Source Quench	TCP: TTL Exceeded	TCP: Host Unreach.	TCP: Net Unreach.	TCP: Port Unreach.	TCP: Proto. Unreach.	UDP: Reass. Time Ex.	UDP: Frag. Needed	UDP: Param. Prob.	UDP: Src. Route Fail	UDP: Source Quench	UDP: TTL Exceeded	UDP: Host Unreach.	UDP: Net Unreach.	UDP: Port Unreach.	UDP: Proto. Unreach.
al		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ap		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
as1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
be1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
be2			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
bu1		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl10			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl2		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl3			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl4			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl5			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl6		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl7		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl8			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
dl9			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ed		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
je		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ls1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ls2			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ls3			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ls5			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ng1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ng2			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ng3		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ng4		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
ng5			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
nw1			•																						
owrt		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
smc			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
te			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
to	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
we			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
zy1			•	•		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Summary

- NAT behaviors do vary widely
- No common characteristics detected

Next Steps

- More comprehensive tests are planned
  - How fast can NATs create bindings
  - NAT traversal
  - Etc.
- Follow-up study planned as a part of FI SHOK 2011

Thank You

- Thank you for the donated devices
- Ideas about new tests are appreciated!
- Contact us at

nat-study@fit.nokia.com

Measurement data is available at
http://www.cs.helsinki.fi/group/wiseciti/nat-study/results/results.tar.gz