The X-Bone & its Virtual Internet Architecture 10 Years Later

Lars Eggert

Dagstuhl Seminar on Network Virtualization for the Future Internet

Schloss Dagstuhl, Germany

September 18-19, 2008

Nokia Research Center

NOKIA

Talk Outline

history

Virtual Internets

- why
- what
- architecture highlights

related projects at ISI (time permitting...)

- X-Bone, DynaBone, TetherNet

Nokia Research Center

NOKIA

History

X-Bone was a series of research projects at USC/ISI

- X-Bone, DynaBone, TetherNet, X-Tend, NetFS, GeoNet, ...
- 1997-2005+
- initial funding from DARPA, follow-on funding from the NSF
- http://www.isi.edu/xbone/

key results

- an architecture (the “Virtual Internet” architecture)
- a deployment/management system (the “X-Bone”)
- follow-on work using virtual nets:

DynaBone	spread-spectrum virtual networks
TetherNet	rent real Internet behind firewall + NAT
GeoNet	geographically-routed virtual networks

Prior & Related Work

new services & protocols

- Cronus, M/6/Q/A-Bone

multi/other layers

- Cronus, Supranet, MorphNet, VANs

partial solutions

- VPN, VNS, RON, Detour, PPVPN, SOS

virtualization, revisitation, recursion

- X-Bone, Spawning, Netlab/Emulab

OS virtualization

- VMware, jails, vserver, XEN, PlanetLab

Virtual Internet – Why

"network equivalent of virtual memory"

protection

- separate topology, optionally secured
- test + deploy new protocol/service

sharing

- increase utility of infrastructure

abstraction

- adapt topology to application

Nokia Research Center

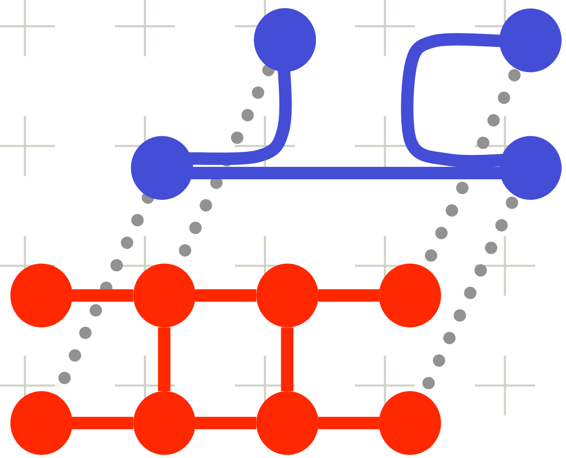
NOKIA

Virtual Internet – What

network = hosts + routers + links

virtual network =

	virtual host	→ packet src/sink
+	virtual router	→ packet gateway
+	virtual link	→ tunnel *X* over *Y*



virtual Internet – "network of networks"

- use Internet as physical media
- create virtual link & network layers
- strong L2 vs. weak L3 host model

Internet IP header	virtual link IP header	virtual network IP header	payload

a virtual Internet should look exactly like the real thing

- "if an app can know it runs in a VI, we did it wrong

VI Architecture Feature – Recursion

virtual Internets on top of virtual Internets

our litmus test:

- system should be able to do recursive VI-in-VI without hacks

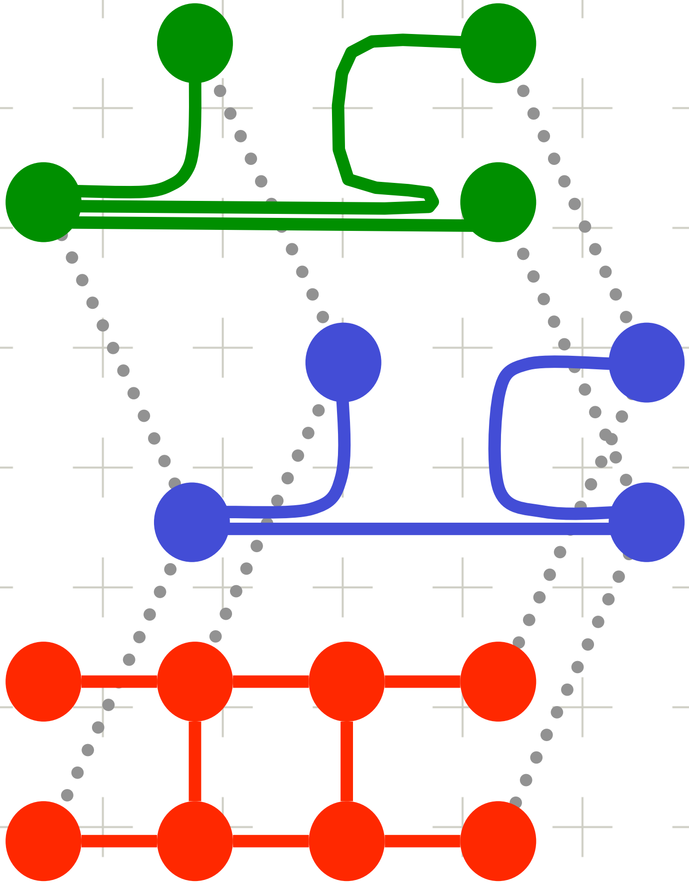
recursion has real uses cases

e.g., allows transparent reconfiguration

- change outer VI w/o affecting inner
- fault tolerance, basis for DynaBone

also allows VI "embedding"

"router is a network inside"



VI Architecture Feature – Concurrency

one node participates in multiple virtual Internets at the same time

basis for isolation & abstraction

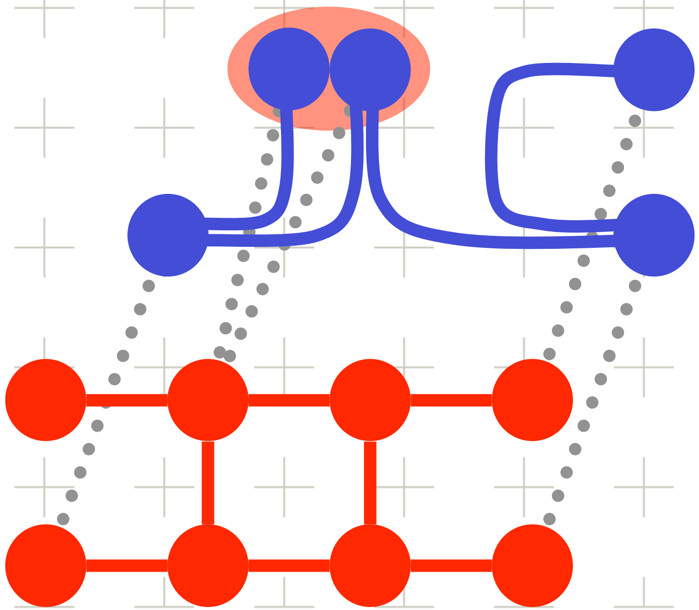
bind different apps/VMs to different VIs on the same physical node

VI Architecture Feature – Revisitation

one node participates in the same virtual Internet but multiple times

allows creation of VIs larger than physical resources

fully decouples virtual from physical topologies



Nokia Research Center

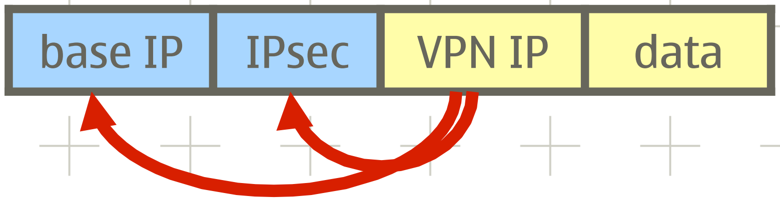
NOKIA

VI Architecture Feature – Hop-by-Hop Security

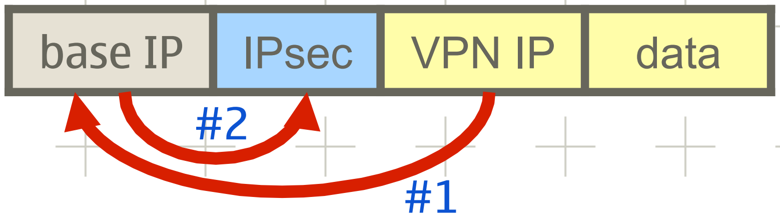
security in the Virtual Internet architecture is a virtual link property

- decoupled from topology
- transparently coexists with end-to-end security inside the VI
- transparently coexists with security underneath a VI

IPsec tunnel mode



IPIP tunnel + IPsec transport mode



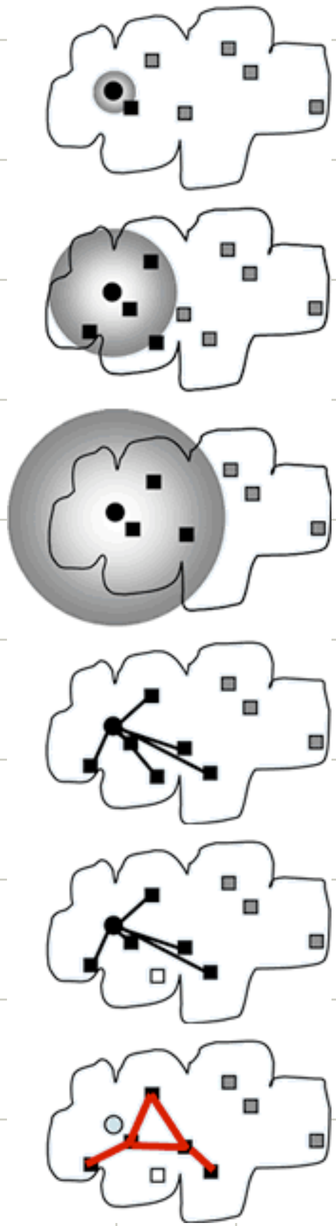
IPIP tunnels + IPsec transport mode

- modular tunnel mode equivalent
- huge IETF debate around 2000 (draft-touch-ipsec-vpn-05.txt)

Nokia Research Center

NOKIA

The X-Bone System



deployment + management system for virtual Internets

- programs → standardized API
- humans → web interface

high-level virtual network description language

- express virtual topology + services
- XML

collaborating, distributed management daemons

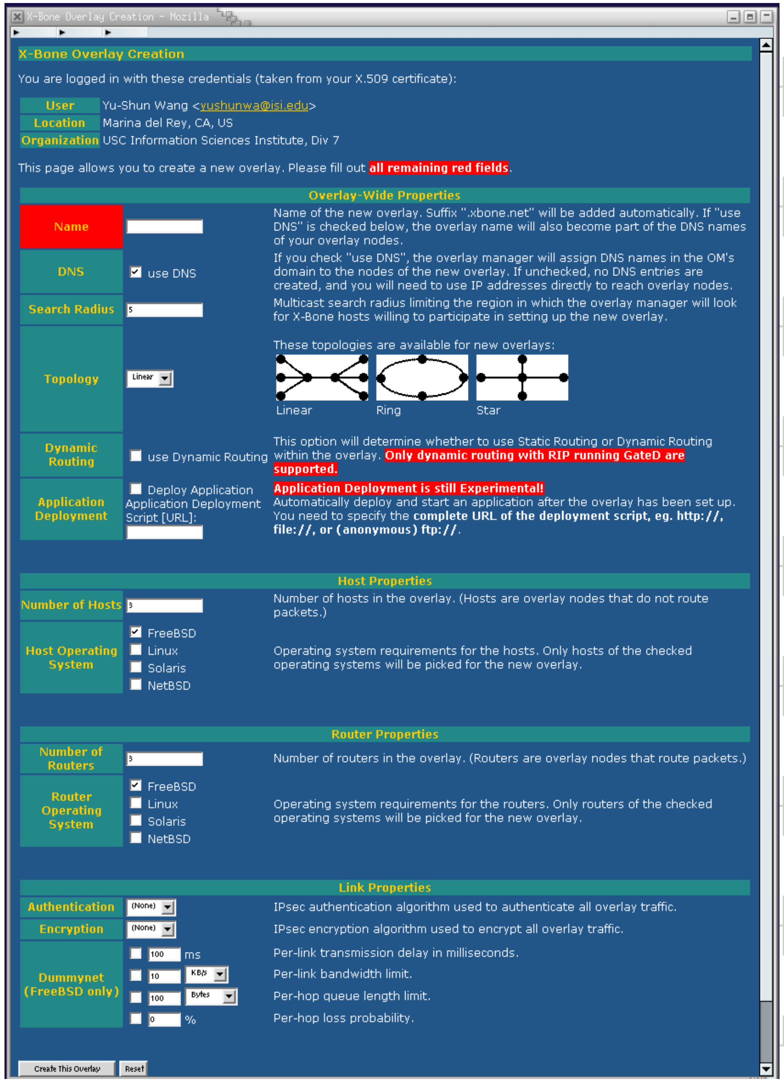
- multicast expanding-ring discovery
- distributed resource reservation
- instantiate + manage virtual network

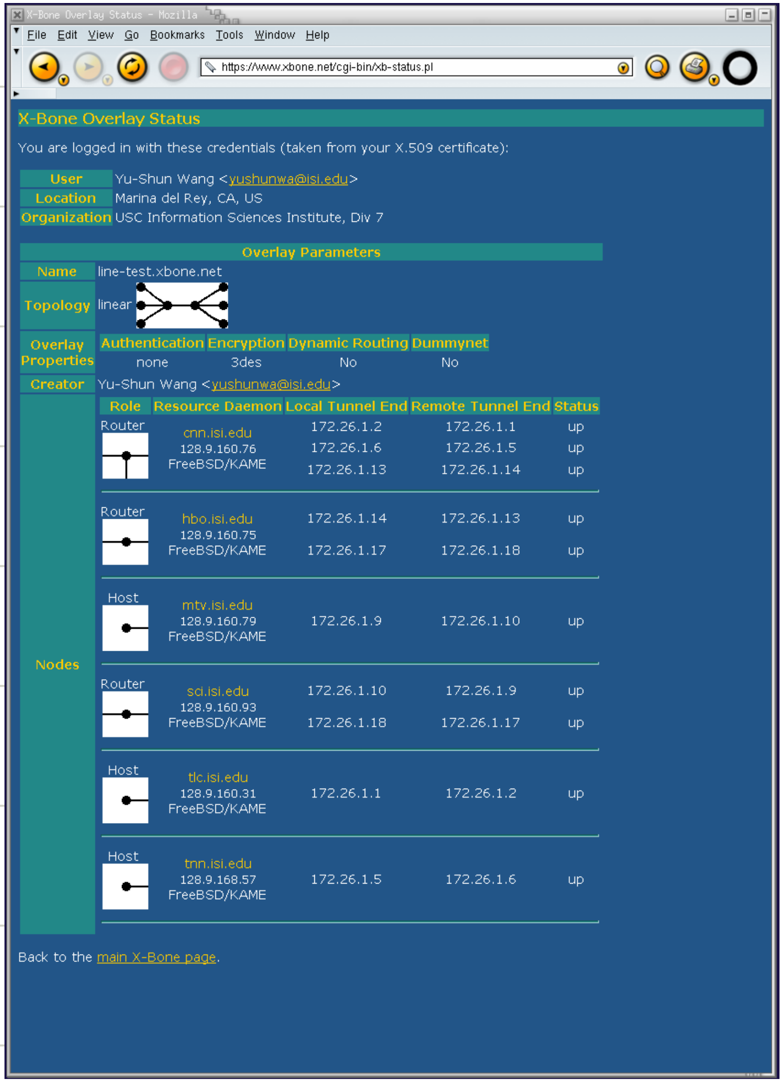
non-goals: topology optimization, non-IP VIs, ...

Nokia Research Center

NOKIA

X-Bone Screenshots





Nokia Research Center

NOKIA

X-Bone Status

current release: 3.2
- mature: 10 years of open source availability

platforms: FreeBSD, Linux
- unofficial: NetBSD, Cisco

widely used (by 2003):
- UCL, UPenn, Aerospace, DOD Canada, Sinica Taiwan + more

Related Work at USC/ISI

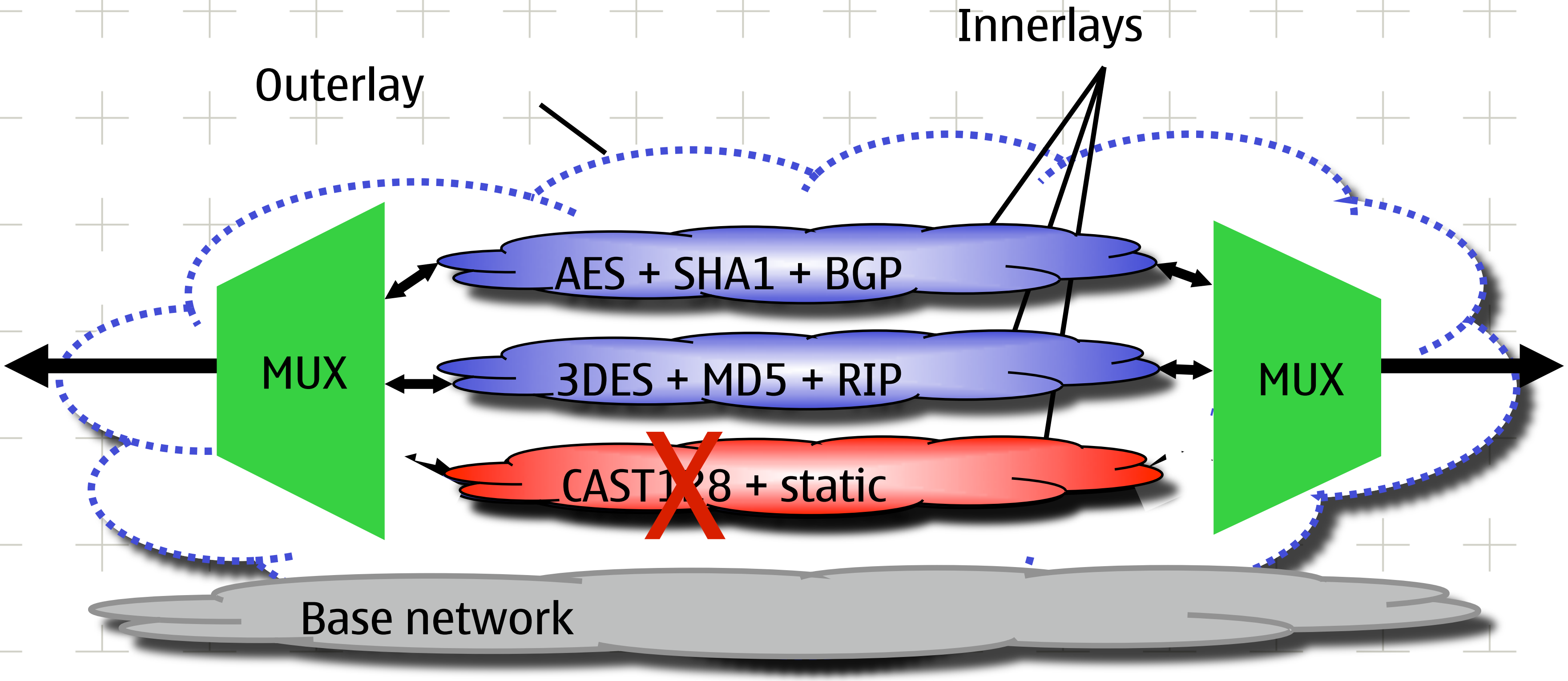
Nokia Research Center

NOKIA

DynaBone

parallel inner virtual networks = algorithmic & protocol diversity

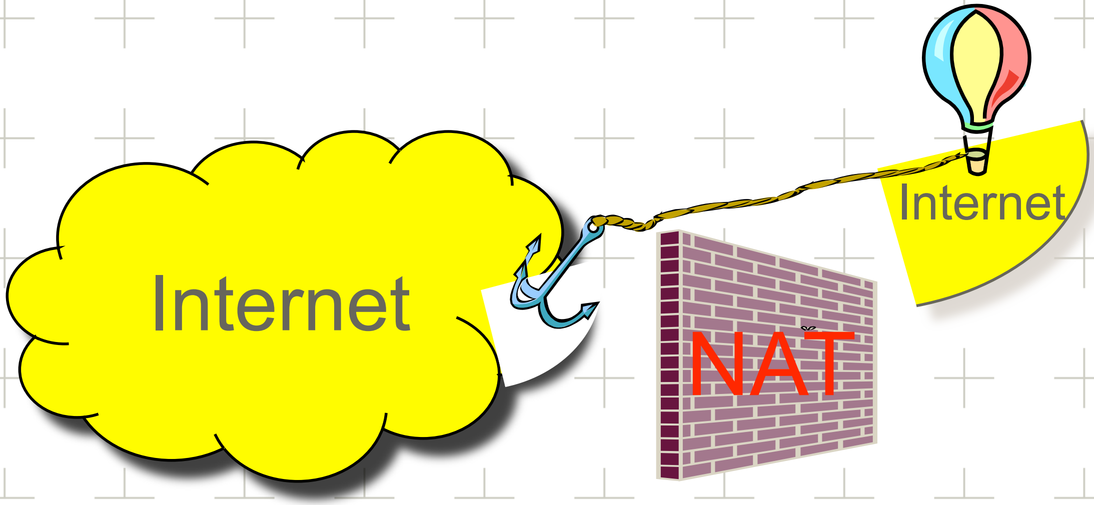
spread-spectrum multiplexer, wrapped inside outer virtual network



TetherNet

issue: firewalls, NATs, clueless ISPs
- broken end-to-end connectivity

solution: relocate real Internet subnet
- real = routable IP + DNS + no fw + ...
- tunnel subnet from anchor router to tether router at remote site



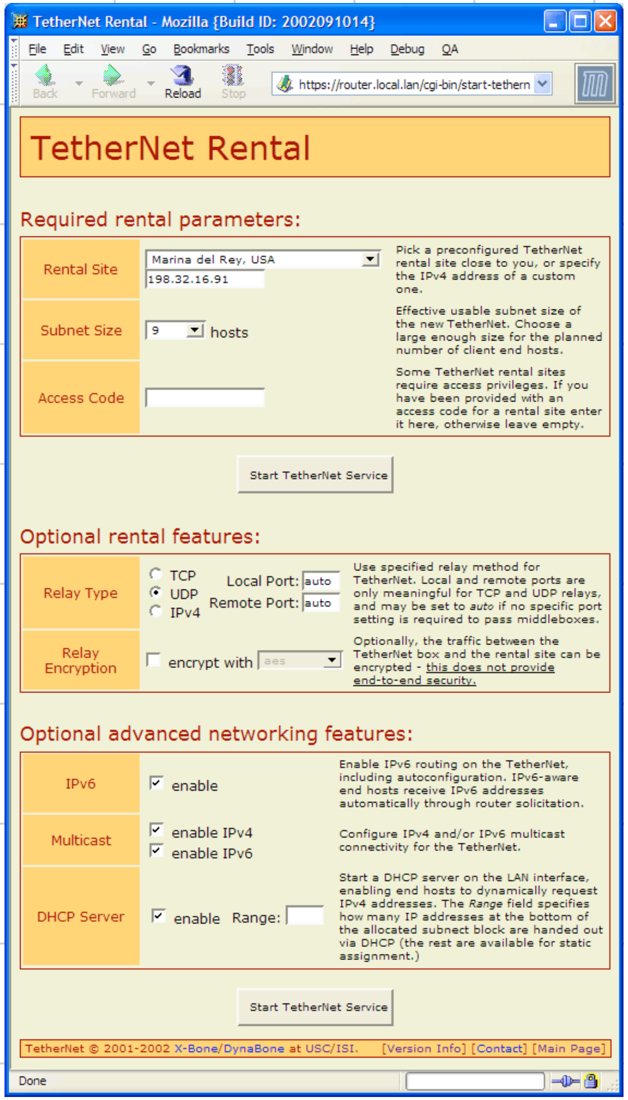
TetherNet Features

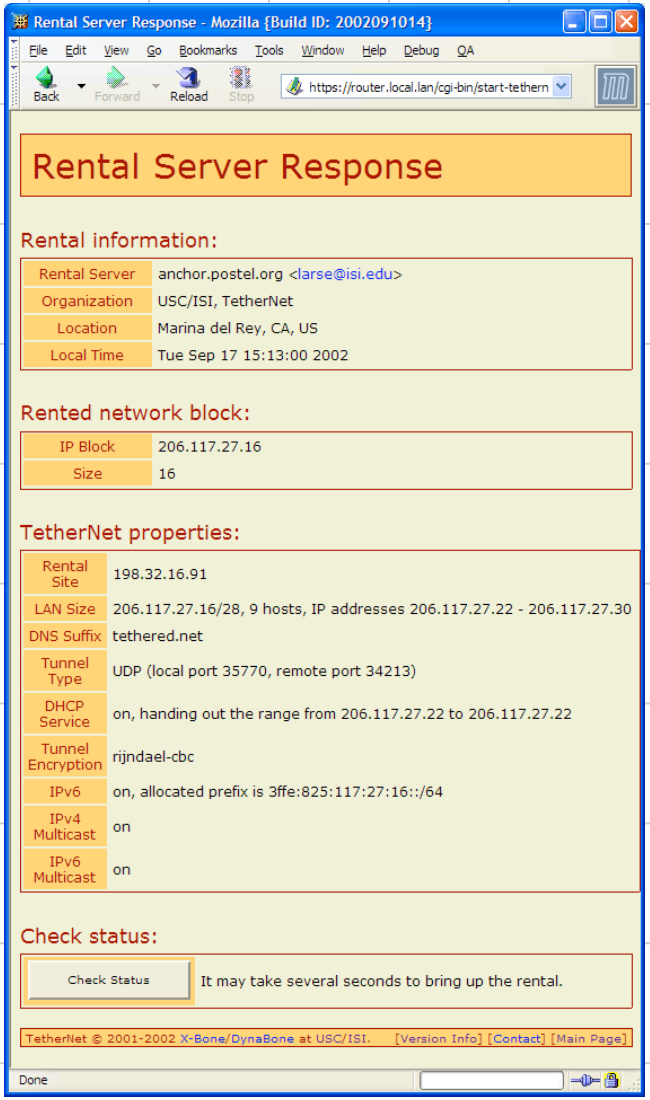
true Internet behind NATs and firewalls

- IPv4 + IPv6
- multicast
- fwd/rev DNS
- traffic shaping
- 802.11b AP
- secure: IPsec for traffic, X.509 for user auth
- web interface configuration

U.S. patent filed, talks with licensees

TetherNet Screenshots





Nokia Research Center

NOKIA

Other Projects

X-Tend

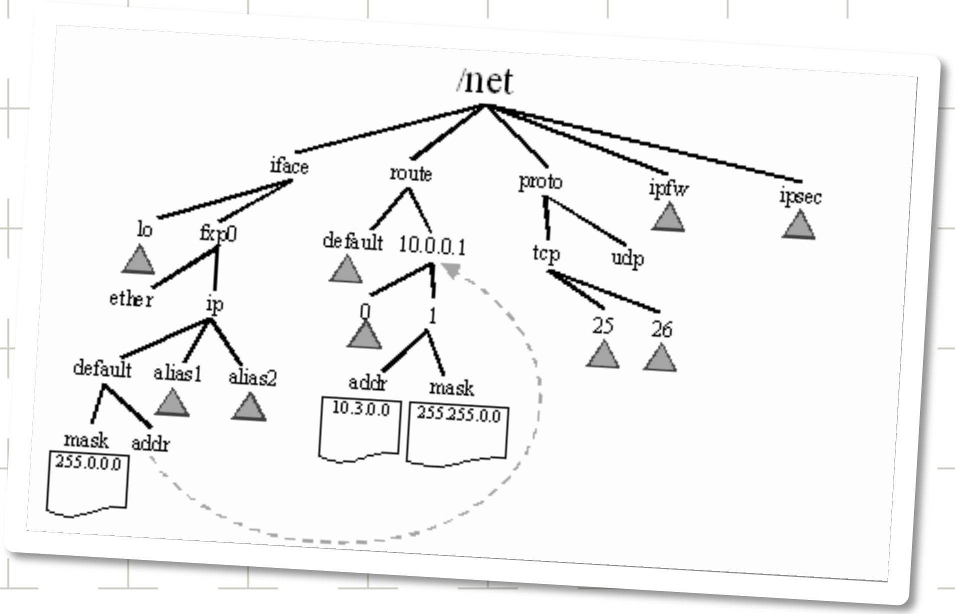
maintain + extend X-Bone as tool for research + education

GeoNet

geographically-addressed overlays

NetFS

access control for the
network stack via
a pseudo file system



Nokia Research Center

NOKIA

THANK YOU!