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

Joe Touch, Greg Finn, Lars Eggert, Amy Hughes and Yu-Shun Wang

Workshop on Overlay and Network Virtualization

Kassel, Germany

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Talk Outline

history

Virtual Internets

- why
- what
- architecture highlights

related projects at ISI (time permitting…)

- X-Bone, DynaBone, TetherNet

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

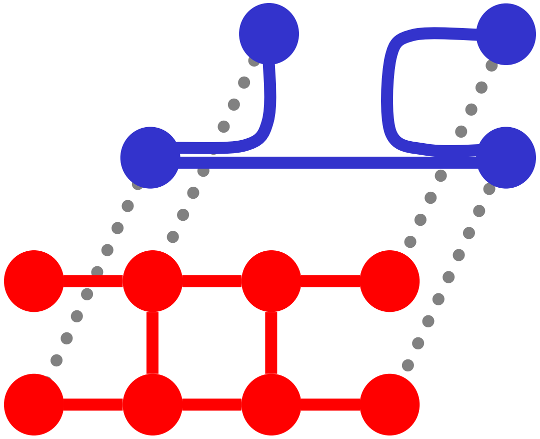
- adapt topology to application

Virtual Internet – What

network = hosts + routers + links

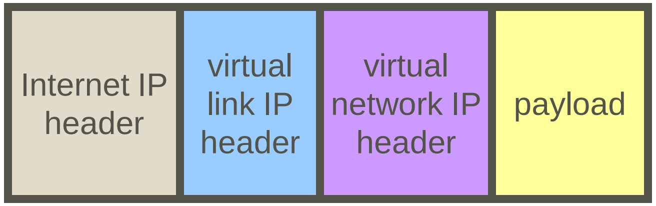
virtual network =

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

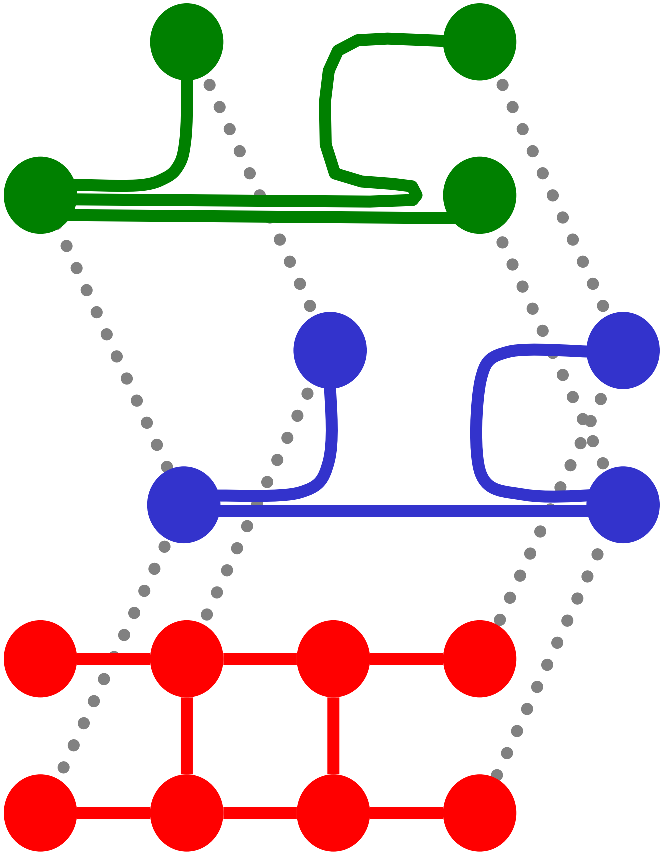
recursion has real uses cases

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

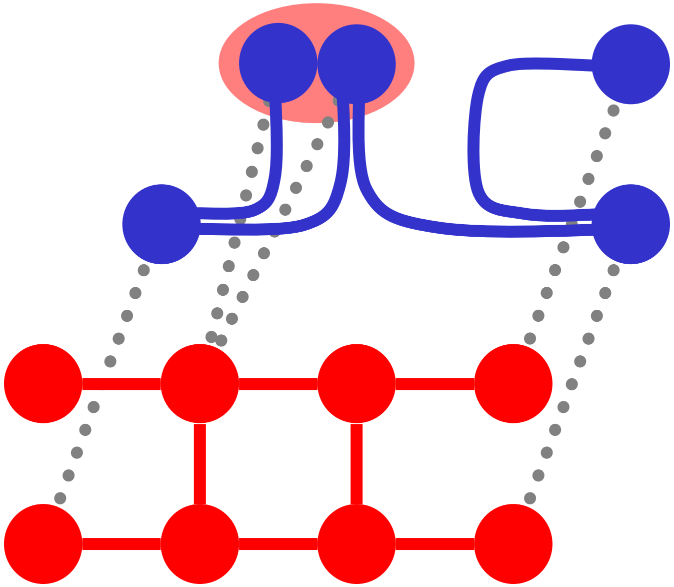
bind different apps/VMs to different VIs on the same physical node

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

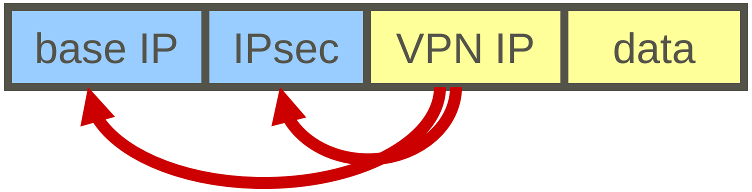


VI Architecture Feature – Hop-by-Hop Security

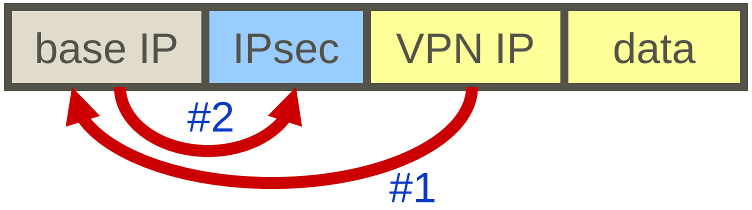
security in the Virtual Internet architecture is a virtual link property

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

IPsec tunnel mode


base IP | IPsec | VPN IP | data

IPIP tunnel + IPsec transport mode


base IP | IPsec | VPN IP | data

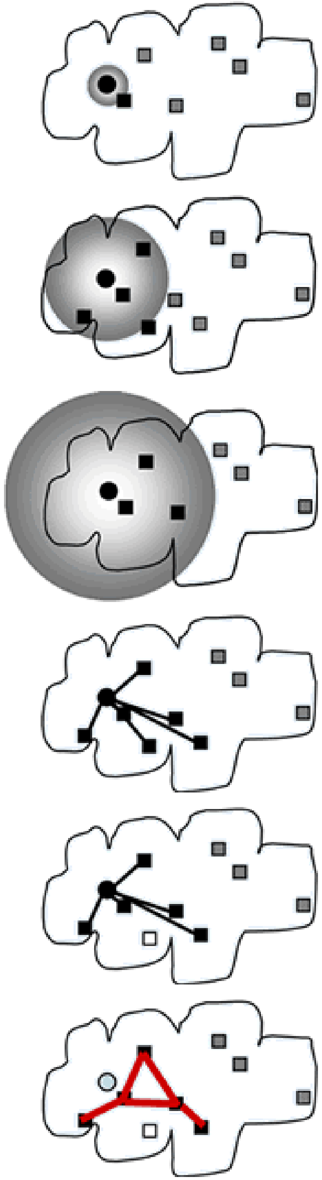
#2

#1

IPIP tunnels + IPsec transport mode

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

The X-Bone System



deployment + management system for virtual Internets

- programs → standardized API
- humans → web interface

high-level virtual network description language

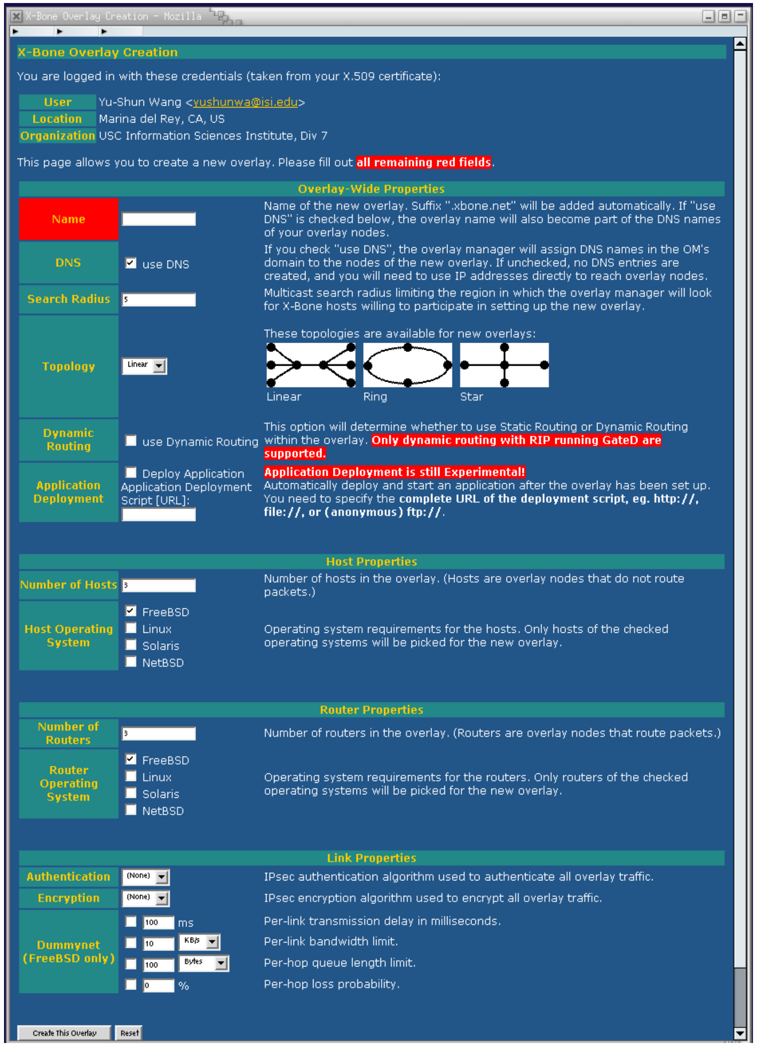
- express virtual topology + services
- XML

collaborating, distributed management daemons

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

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

X-Bone Screenshots



X-Bone Overlay Creation

You are logged in with these credentials (taken from your X.509 certificate):

User	Yu-Shun Wang <yushunwa@isi.edu>
Location	Marina del Rey, CA, US
Organization	USC Information Sciences Institute, Div 7

This page allows you to create a new overlay. Please fill out **all remaining red fields**.

Overlay-Wide Properties

Name		Name of the new overlay. Suffix ".xbone.net" will be added automatically. If "use DNS" is checked below, the overlay name will also become part of the DNS names of your overlay nodes.
DNS	☑ use DNS	If you check "use DNS", the overlay manager will assign DNS names in the OM's domain to the nodes of the new overlay. If unchecked, no DNS entries are created, and you will need to use IP addresses directly to reach overlay nodes.
Search Radius	5	Multicast search radius limiting the region in which the overlay manager will look for X-Bone hosts willing to participate in setting up the new overlay.
Topology	Linear	These topologies are available for new overlays: Linear Ring Star
Dynamic Routing	☐ use Dynamic Routing	This option will determine whether to use Static Routing or Dynamic Routing within the overlay. **Only dynamic routing with RIP running GateD are supported.**
Application Deployment	☐ Deploy Application Application Deployment Script [URL]:	**Application Deployment is still Experimental!** Automatically deploy and start an application after the overlay has been set up. You need to specify the **complete URL of the deployment script, eg. http://, file://, or (anonymous) ftp://**.

Host Properties

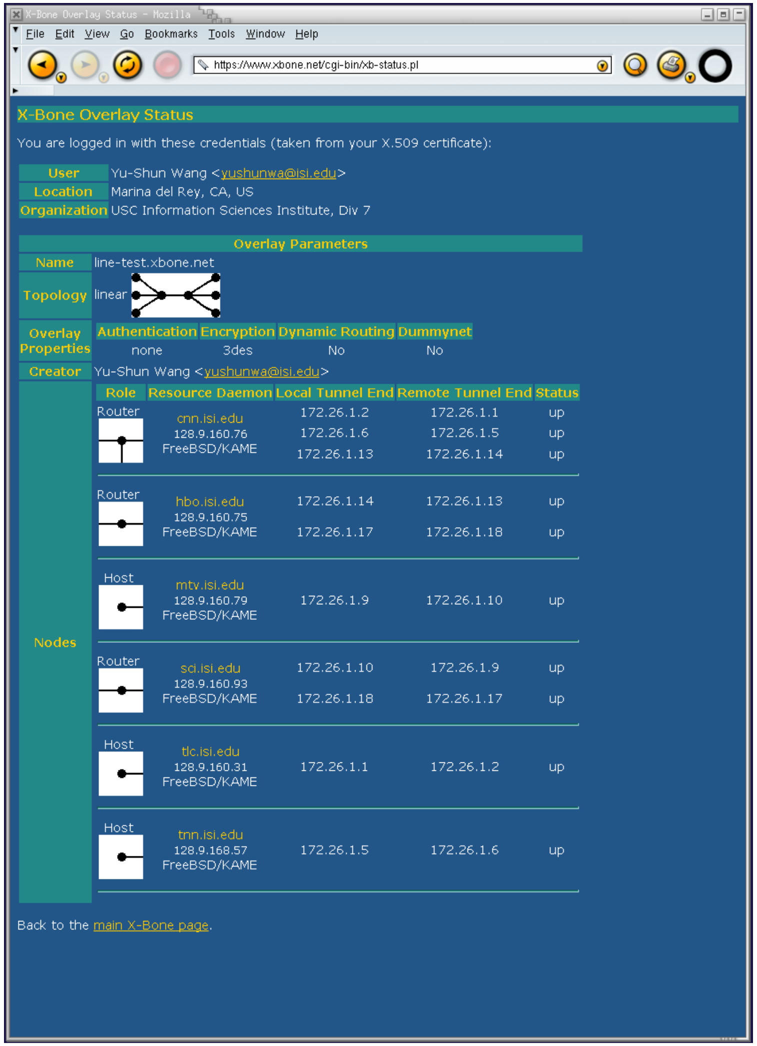
Number of Hosts	3	Number of hosts in the overlay. (Hosts are overlay nodes that do not route packets.)
Host Operating System	☑ FreeBSD ☐ Linux ☐ Solaris ☐ NetBSD	Operating system requirements for the hosts. Only hosts of the checked operating systems will be picked for the new overlay.

Router Properties

Number of Routers	3	Number of routers in the overlay. (Routers are overlay nodes that route packets.)
Router Operating System	☑ FreeBSD ☐ Linux ☐ Solaris ☐ NetBSD	Operating system requirements for the routers. Only routers of the checked operating systems will be picked for the new overlay.

Link Properties

Authentication	(None)	IPsec authentication algorithm used to authenticate all overlay traffic.
Encryption	(None)	IPsec encryption algorithm used to encrypt all overlay traffic.
Dummynet (FreeBSD only)	☐ 100 ms	Per-link transmission delay in milliseconds.
	☐ 10 KB/s	Per-link bandwidth limit.
	☐ 100 Bytes	Per-hop queue length limit.
	☐ 0 %	Per-hop loss probability.


X-Bone Overlay Status - Mozilla
File
Edit
View
Go
Bookmarks
Tools
Window
Help
https://www.xbone.net/cgi-bin/xb-status.pl

X-Bone Overlay Status

You are logged in with these credentials (taken from your X.509 certificate):

User	Yu-Shun Wang <yushunwa@isi.edu>
Location	Marina del Rey, CA, US
Organization	USC Information Sciences Institute, Div 7

Overlay Parameters

Name	line-test.xbone.net
Topology	linear
Creator	Yu-Shun Wang <yushunwa@isi.edu>

Overlay Properties:

Authentication	Encryption	Dynamic Routing	Dummynet
none	3des	No	No

Nodes:

Role	Resource Daemon	Local Tunnel End	Remote Tunnel End	Status
Router	cnn.isi.edu 128.9.160.76 FreeBSD/KAME	172.26.1.2	172.26.1.1	up
		172.26.1.6	172.26.1.5	up
		172.26.1.13	172.26.1.14	up
Router	hbo.isi.edu 128.9.160.75 FreeBSD/KAME	172.26.1.14	172.26.1.13	up
		172.26.1.17	172.26.1.18	up
Host	mtv.isi.edu 128.9.160.79 FreeBSD/KAME	172.26.1.9	172.26.1.10	up
Router	sci.isi.edu 128.9.160.93 FreeBSD/KAME	172.26.1.10	172.26.1.9	up
		172.26.1.18	172.26.1.17	up
Host	tlc.isi.edu 128.9.160.31 FreeBSD/KAME	172.26.1.1	172.26.1.2	up
Host	tnn.isi.edu 128.9.168.57 FreeBSD/KAME	172.26.1.5	172.26.1.6	up

Back to the main X-Bone page.

X-Bone Status

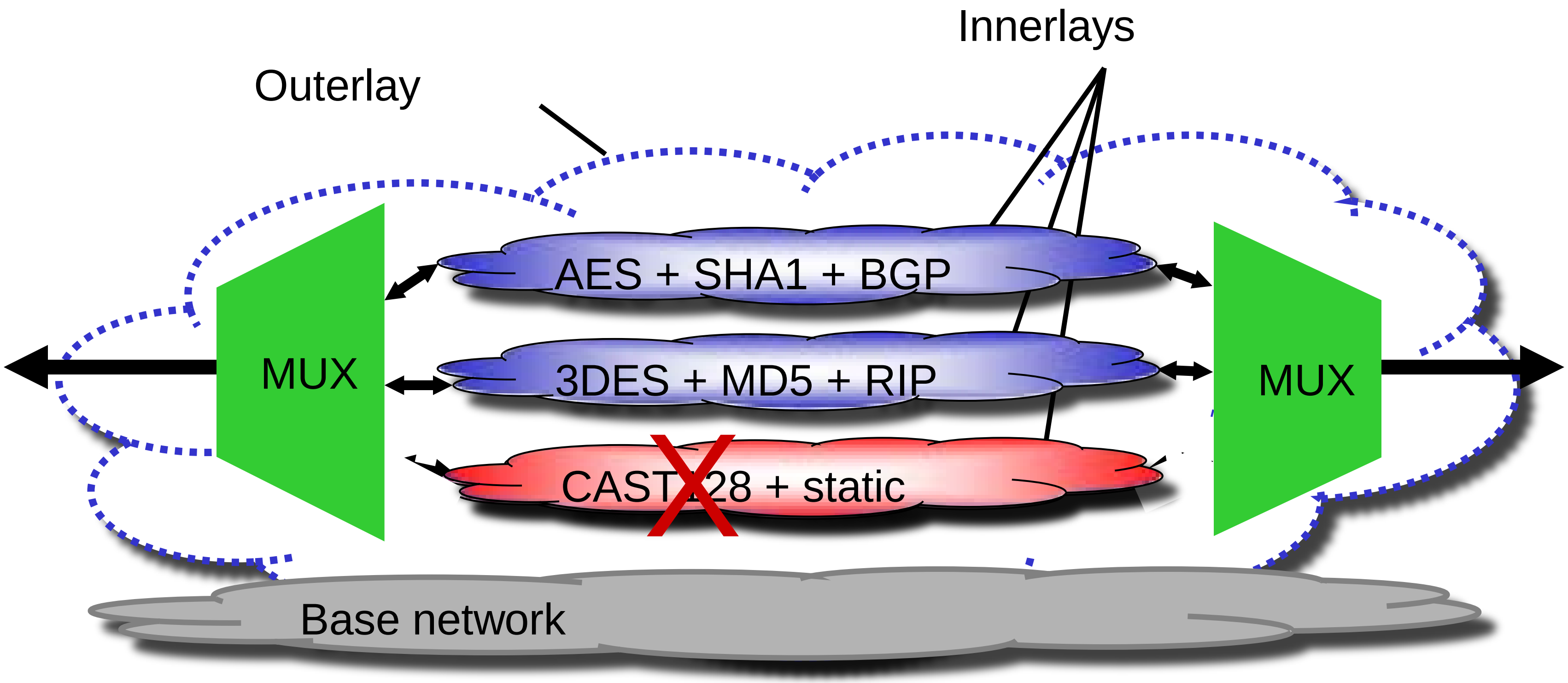
- current release: 3.2
  - mature: 10 years of open source availability
- platforms: FreeBSD, Linux
  - unofficial: NetBSD, Cisco
- widely used (by 2003):
  - UCL, UPenn, Aerospace, DOD Canada, Sinica Taiwan + more

Related Work at USC/ISI

DynaBone

parallel inner virtual networks = algorithmic & protocol diversity

spread-spectrum multiplexer, wrapped inside outer virtual network



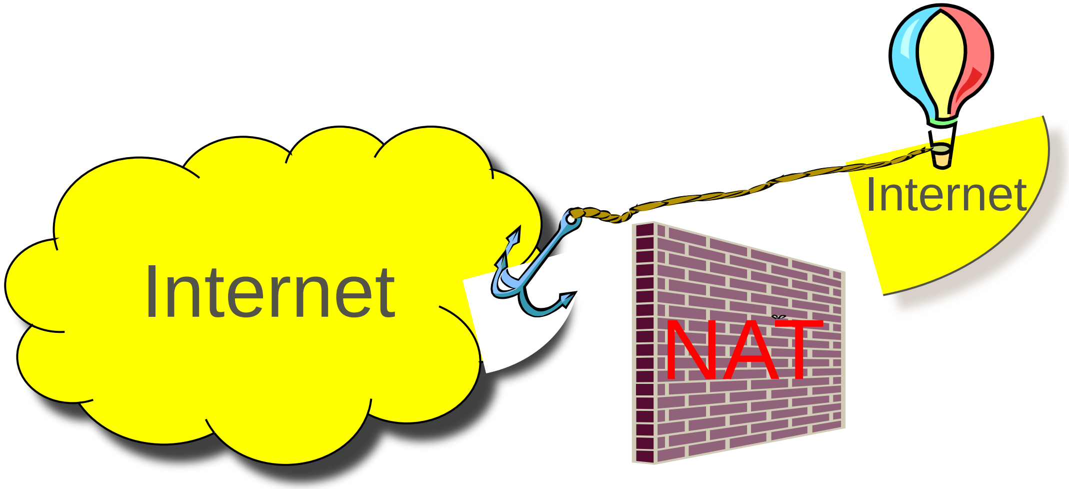
TetherNet

issue: firewalls, NATs, clueless ISPs

- broken end-to-end connectivity

solution: relocate real Internet subnet

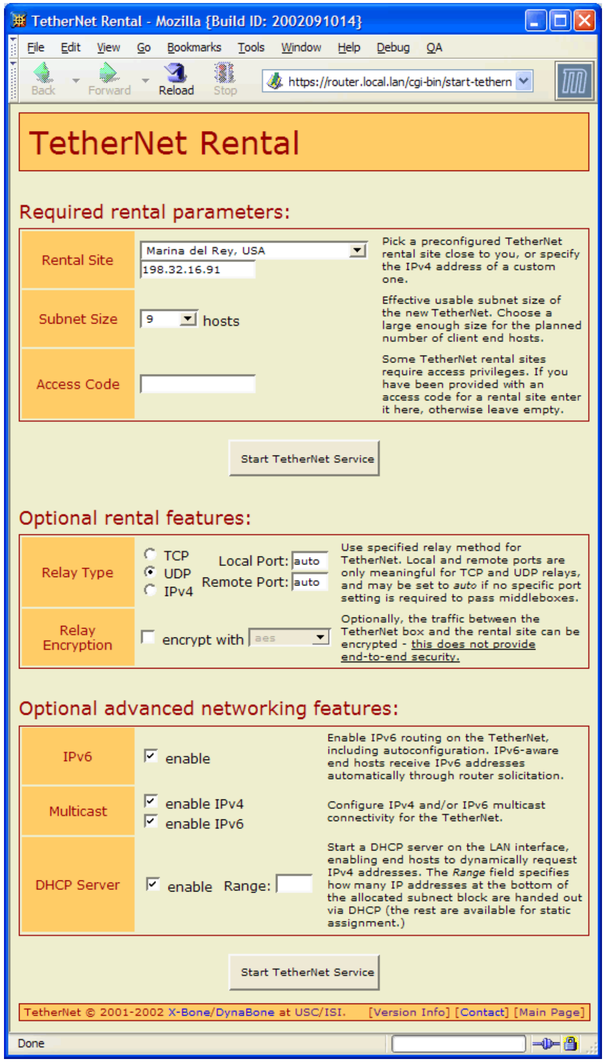
- real = routable IP + DNS + no fw + …
- tunnel subnet from anchor router to tether router at remote site



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


TetherNet Rental - Mozilla {Build ID: 2002091014}
File Edit View Go Bookmarks Tools Window Help Debug QA
Back Forward Reload Stop
https://router.local.lan/cgi-bin/start-tethern

TetherNet Rental

Required rental parameters:

Rental Site	Marina del Rey, USA 198.32.16.91	Pick a preconfigured TetherNet rental site close to you, or specify the IPv4 address of a custom one.
Subnet Size	9 hosts	Effective usable subnet size of the new TetherNet. Choose a large enough size for the planned number of client end hosts.
Access Code		Some TetherNet rental sites require access privileges. If you have been provided with an access code for a rental site enter it here, otherwise leave empty.

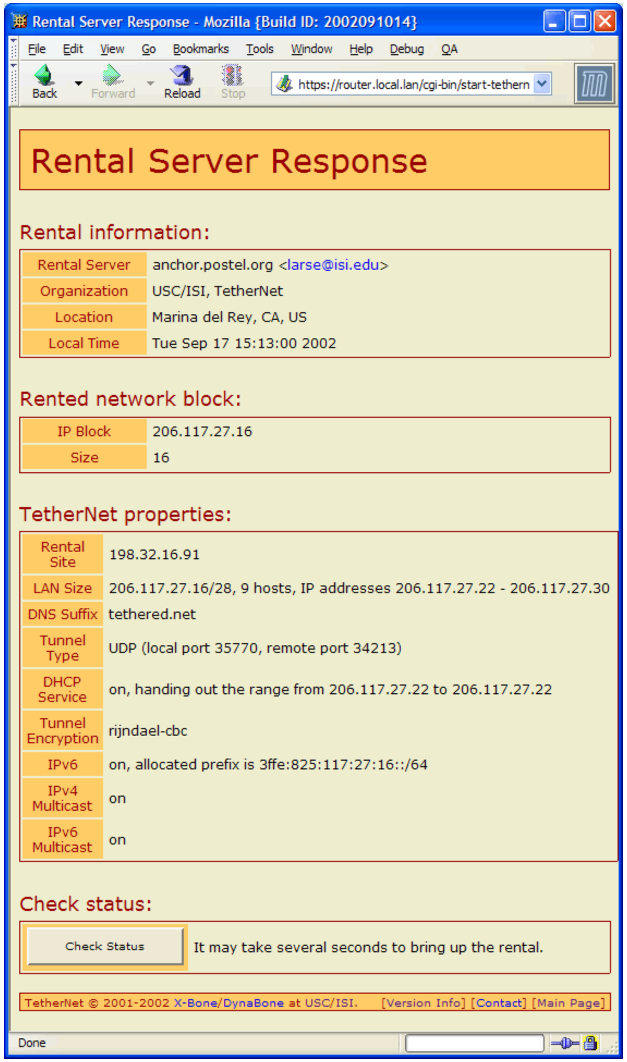
Optional rental features:

Relay Type	○ TCP ● UDP ○ IPv4 Local Port: auto Remote Port: auto	Use specified relay method for TetherNet. Local and remote ports are only meaningful for TCP and UDP relays, and may be set to *auto* if no specific port setting is required to pass middleboxes.
Relay Encryption	□ encrypt with aes	Optionally, the traffic between the TetherNet box and the rental site can be encrypted - this does not provide end-to-end security.

Optional advanced networking features:

IPv6	☑ enable	Enable IPv6 routing on the TetherNet, including autoconfiguration. IPv6-aware end hosts receive IPv6 addresses automatically through router solicitation.
Multicast	☑ enable IPv4 ☑ enable IPv6	Configure IPv4 and/or IPv6 multicast connectivity for the TetherNet.
DHCP Server	☑ enable Range:	Start a DHCP server on the LAN interface, enabling end hosts to dynamically request IPv4 addresses. The *Range* field specifies how many IP addresses at the bottom of the allocated subnect block are handed out via DHCP (the rest are available for static assignment.)

TetherNet © 2001-2002 X-Bone/DynaBone at USC/ISI. [Version Info] [Contact] [Main Page]


Rental Server Response - Mozilla {Build ID: 2002091014}
File Edit View Go Bookmarks Tools Window Help Debug QA
Back Forward Reload Stop
https://router.local.lan/cgi-bin/start-tethern

Rental Server Response

Rental information:

Rental Server	anchor.postel.org <larse@isi.edu>
Organization	USC/ISI, TetherNet
Location	Marina del Rey, CA, US
Local Time	Tue Sep 17 15:13:00 2002

Rented network block:

IP Block	206.117.27.16
Size	16

TetherNet properties:

Rental Site	198.32.16.91
LAN Size	206.117.27.16/28, 9 hosts, IP addresses 206.117.27.22 - 206.117.27.30
DNS Suffix	tethered.net
Tunnel Type	UDP (local port 35770, remote port 34213)
DHCP Service	on, handing out the range from 206.117.27.22 to 206.117.27.22
Tunnel Encryption	rijndael-cbc
IPv6	on, allocated prefix is 3ffe:825:117:27:16::/64
IPv4 Multicast	on
IPv6 Multicast	on

Check status:

It may take several seconds to bring up the rental.

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Other Projects

X-Tend

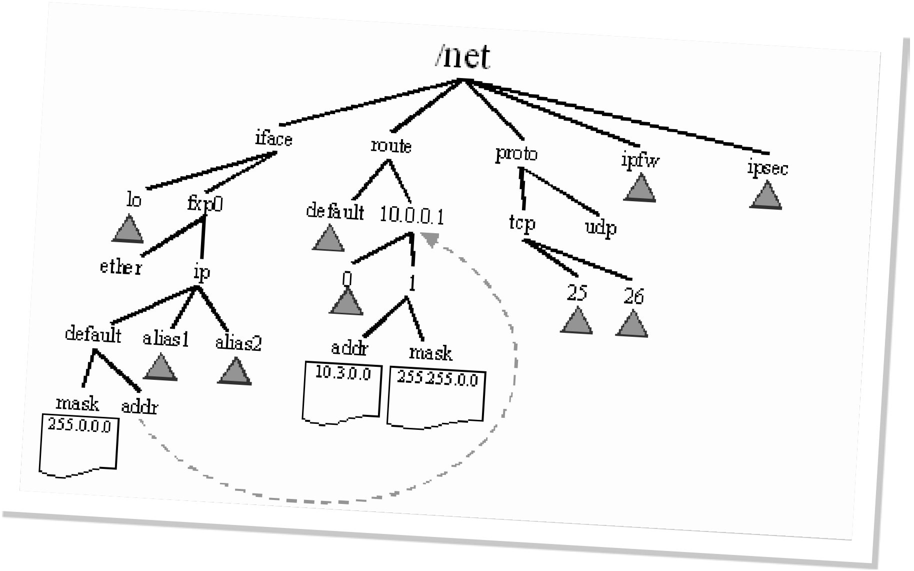
maintain + extend X-Bone as tool for research + education

GeoNet

geographically-addressed overlays

NetFS

access control for the network stack via a pseudo file system



THANK YOU!