



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

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# History

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

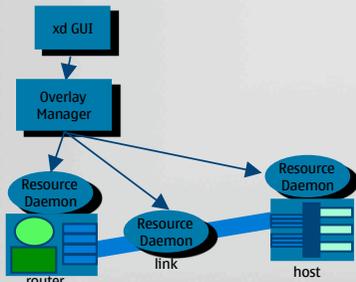
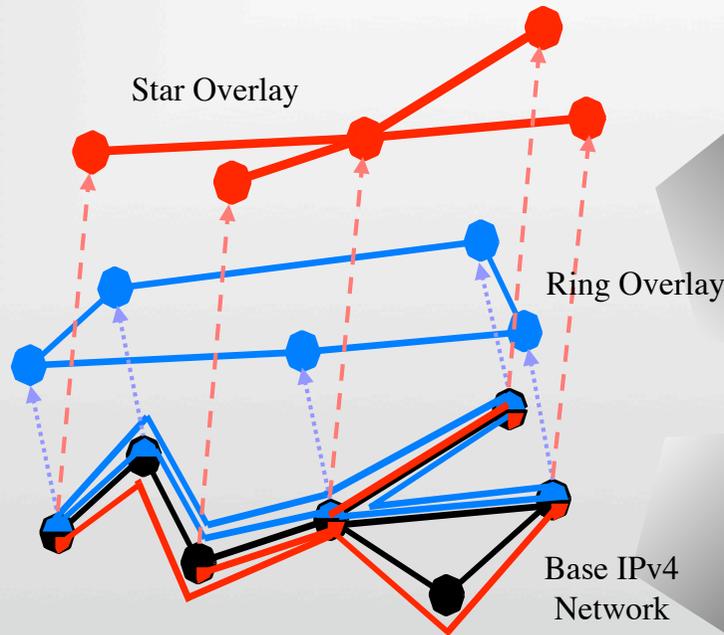
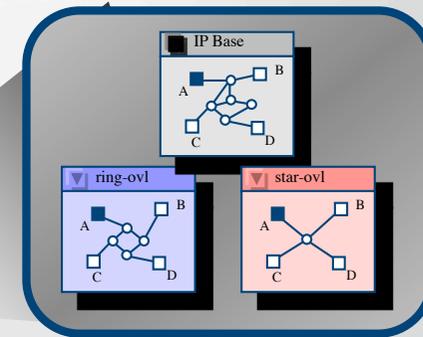


# X-Bone Overlay System

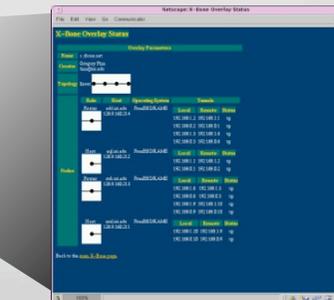
## Web GUI



## Multiple views



## X-Bone system

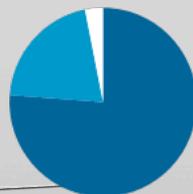


## Automated monitoring



# X-Bone Timeline

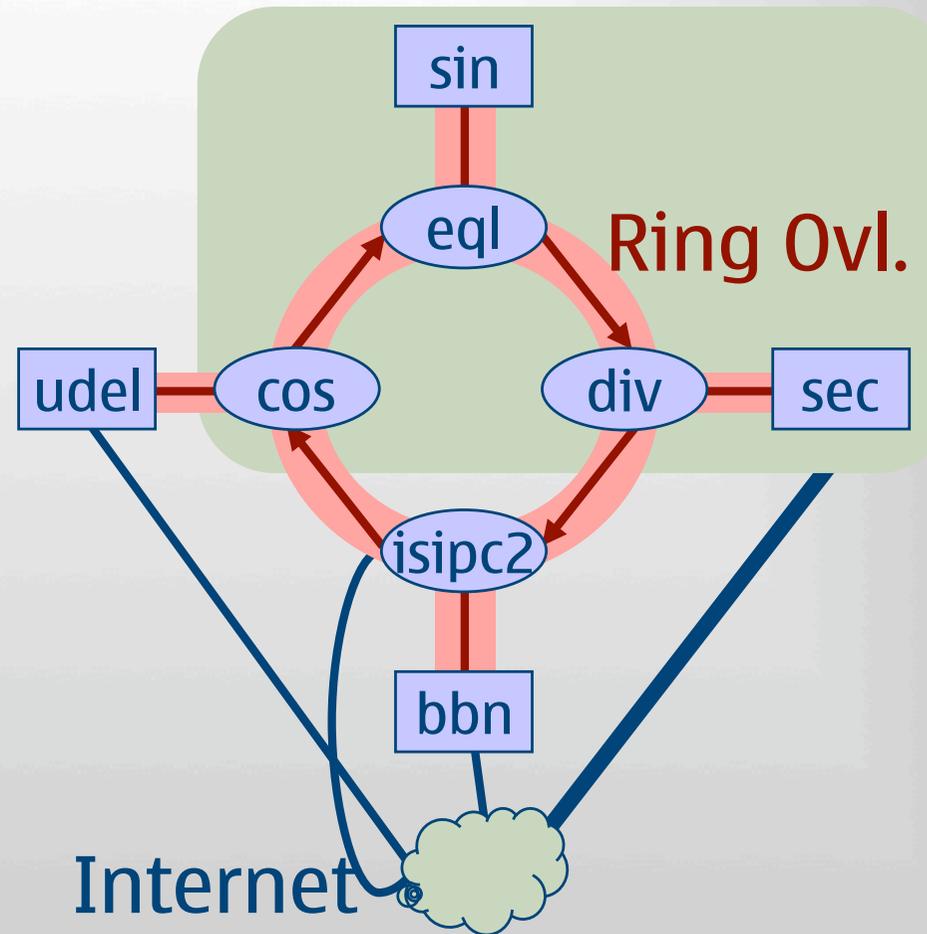
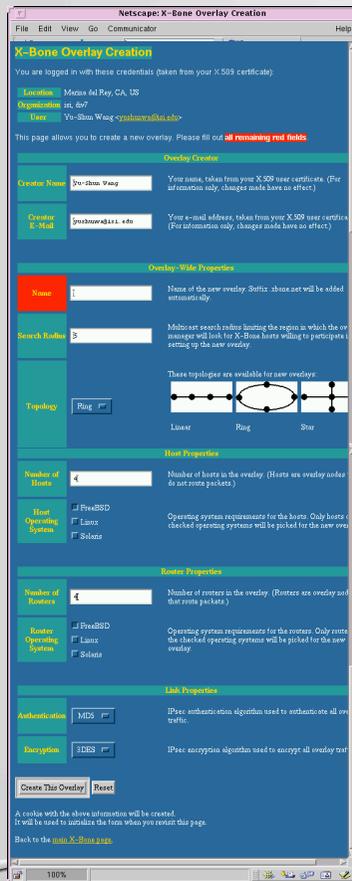
- 1997 – first whitepaper
- 1998-2001 – X-Bone (DARPA)
  - IP overlays with revisitation, recursion (LISP)
  - 2000 – running code (FreeBSD, Linux)
  - 2000 – application deployment
  - 2001 – TetherNet “NAT-buster” to support demos
- 2001-2004 – DynaBone (DARPA)
  - 800-way spread-spectrum parallel overlays
  - 15-level deep overlays
- 2001-2003 – NetFS (NSF)
  - File system configuration of network properties
- 2002-2005 – X-Tend (NSF)
  - X-Bone for testbed uses
- 2003-2005 – DataRouter (int.)
  - Support for overlay P2P forwarding
- 2005-2006 – Agile Tunnels (NSA)
  - Partial overlays for DDOS safety
- 2006-2009 – RNA (NSF)
  - Extending X-Bone Choices model to general protocol stack architecture





# Creating a Ring

## Request





# Virtual Internet – Why

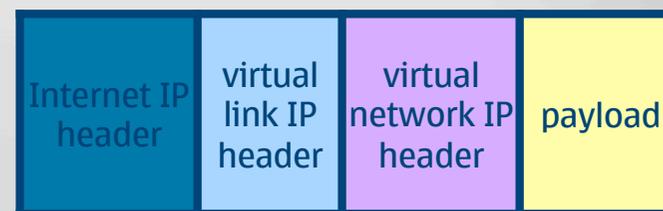
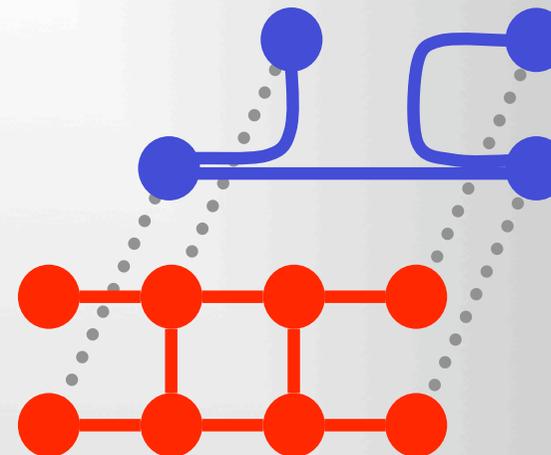
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- “network equivalent of virtual memory”
- protection
  - separate topology, optionally secured
  - test + deploy new protocol/service
- sharing
  - increase utility of infrastructure
- abstraction
  - adapt topology to application



# Virtual Internet – What

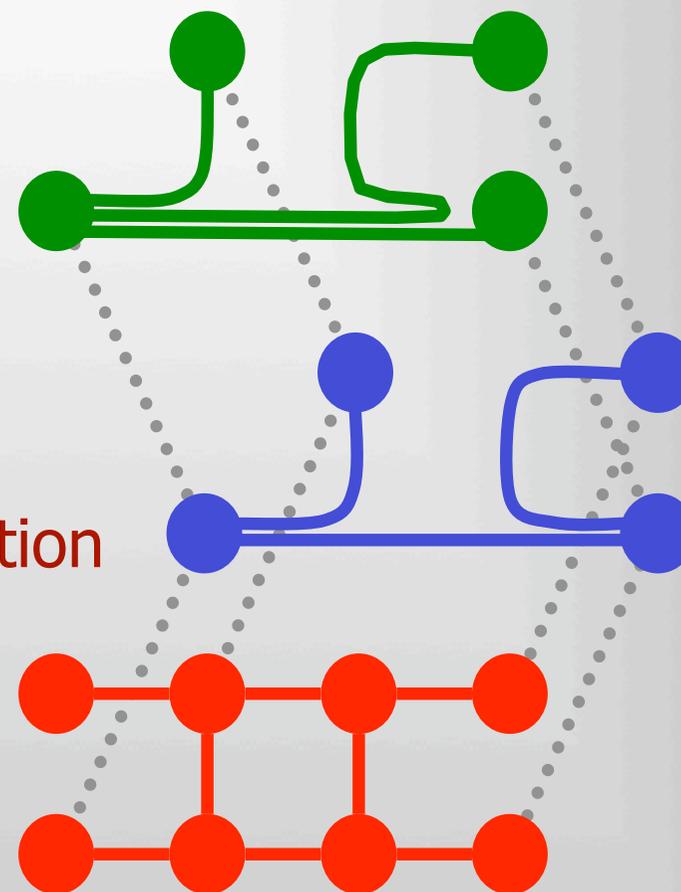
- network = hosts + routers + links
- virtual network =
  - virtual host → packet src/sink
  - + virtual router → packet gateway
  - + virtual link → tunnel X over Y
- virtual Internet – “network of networks”
  - use Internet as physical media
  - create virtual link & network layers
  - strong L2 vs. weak L3 host model
- a virtual Internet should look exactly like the real thing
  - “if an app can know it runs in a VI, we did it wrong”





# 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”





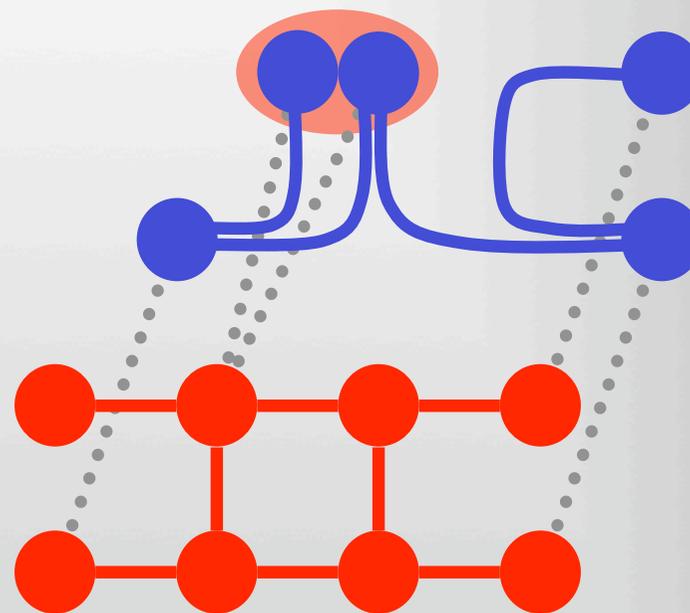
# Feature – Concurrency

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- 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

# 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





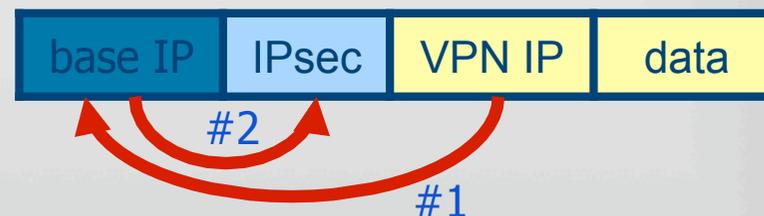
# Feature – Security

- 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

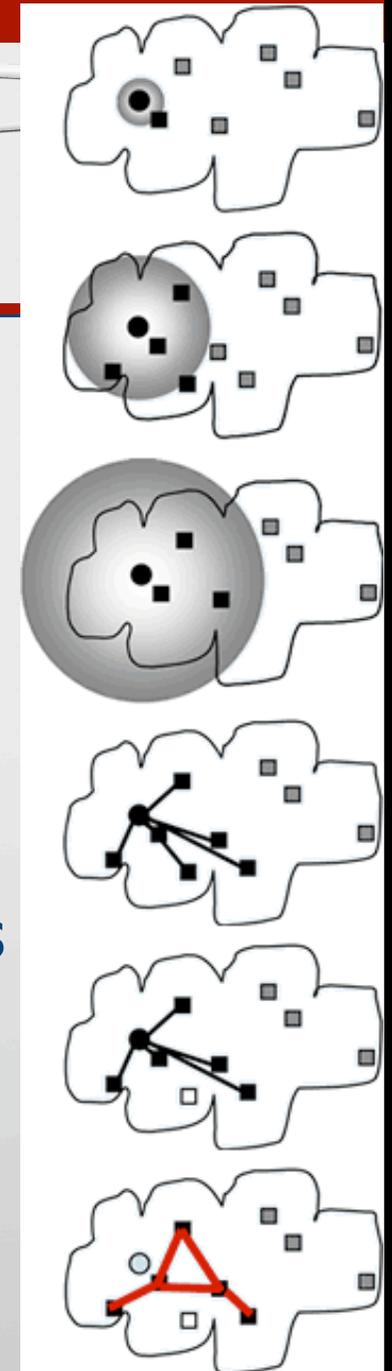


- IPIP tunnels + IPsec transport mode
  - modular tunnel mode equivalent
  - huge IETF debate around 2000 (draft-touch-ipsec-vpn-05.txt)



# The X-Bone System

- deployment + management system for VIs
  - programs → standardized API
  - humans → web interface
- virtual network description language
  - high-level: 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 Status

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- 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



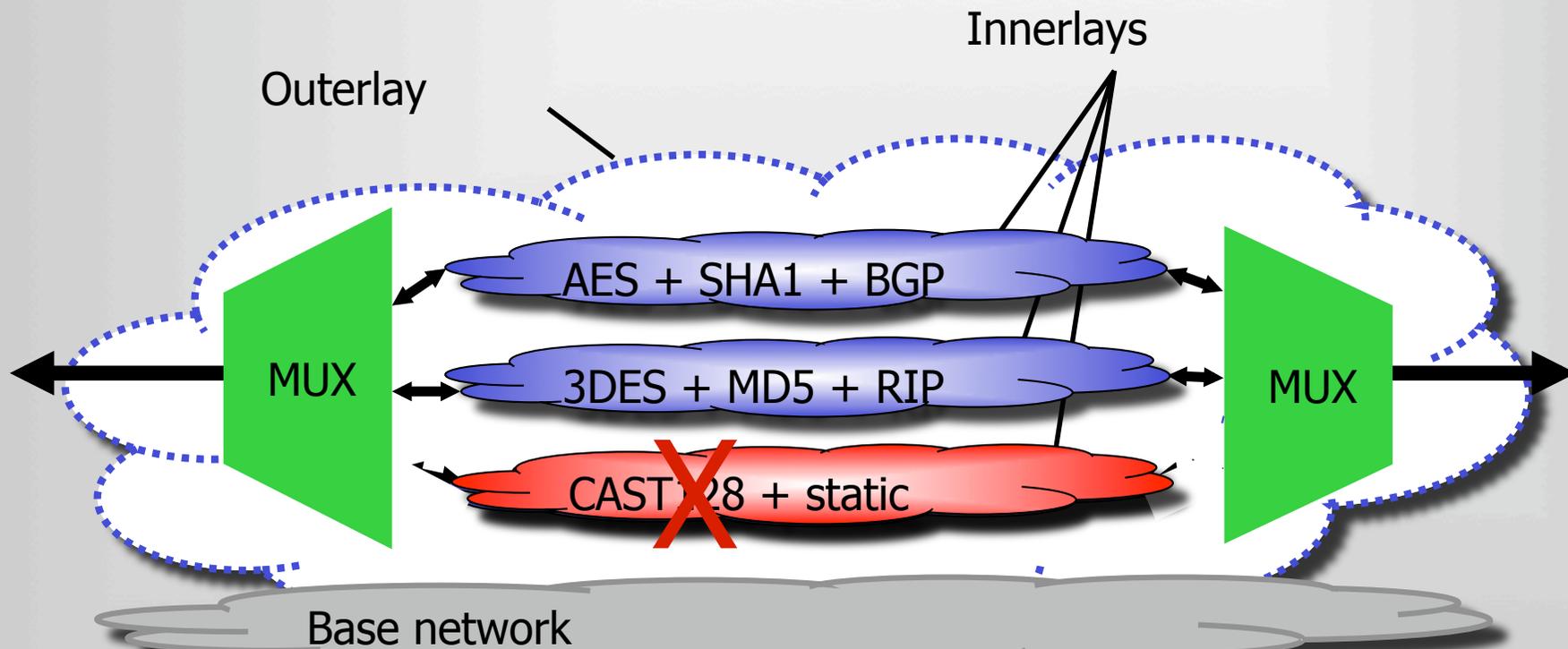
Information Sciences Institute

# Follow-On Work at USC/ISI



# DynaBone (~2001-2003)

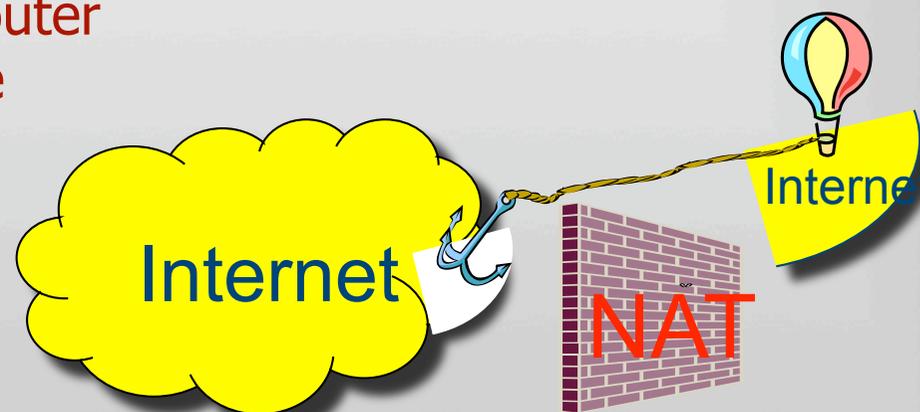
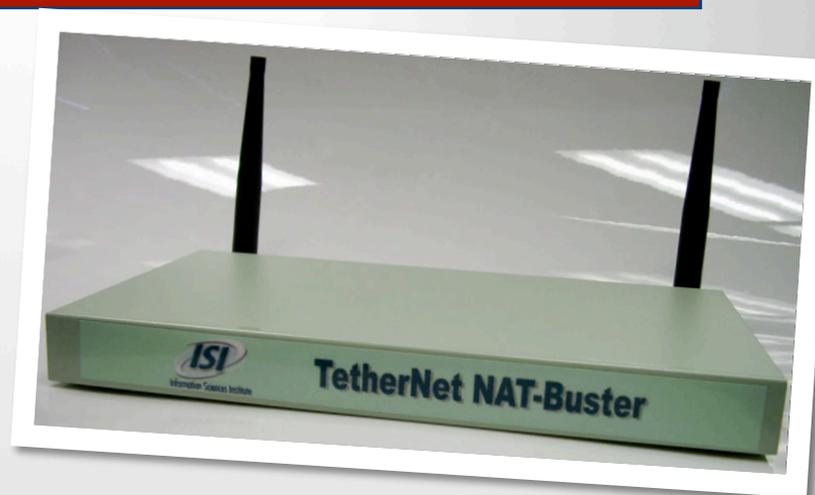
- parallel inner virtual networks = algorithmic & protocol diversity
- spread-spectrum multiplexer, wrapped inside outer virtual network





# TetherNet (~2001-2004)

- 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 totether router at remote site



# Other Related Projects

- X-Tend (~2003-2007?)
  - maintain + extend X-Bone as tool for research + education
- GeoNet (~2000-2002)
  - geographically-addressed overlays
- NetFS (~2002-2004?)
  - access control for the network stack via a pseudo file system

