X-Bone + 10
A Decade of International Collaboration

Joe Touch

Postel Center Director, USC/ISI

Research Assoc. Prof., USC CS & EE/Systems
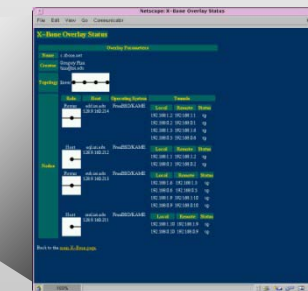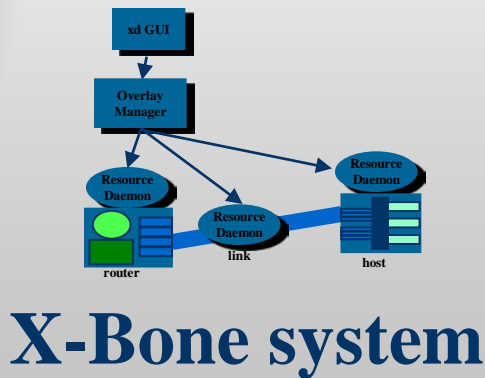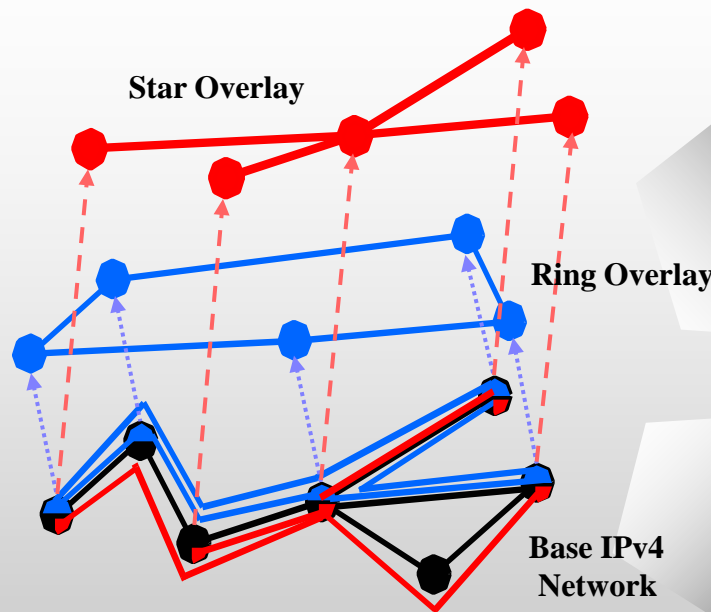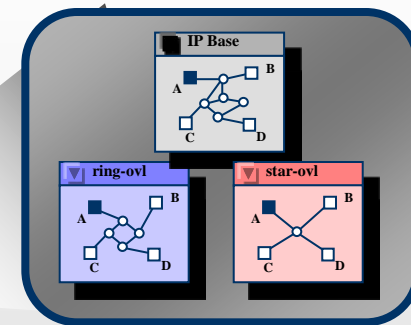
USC **Viterbi**
School of Engineering

X-Bone Overlay System

Web GUI

Multiple views

Star Overlay

Ring Overlay

IP Base

ring-ovl

star-ovl

X-Bone system

xd GUI

Overlay Manager

Resource Daemon

Resource Daemon

Resource Daemon

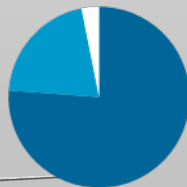router

link

host

**Base IPv4 Network**

Automated monitoring

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

Ring Ovl.

sin

eql

udel — cos — div — sec

isipc2

bbn
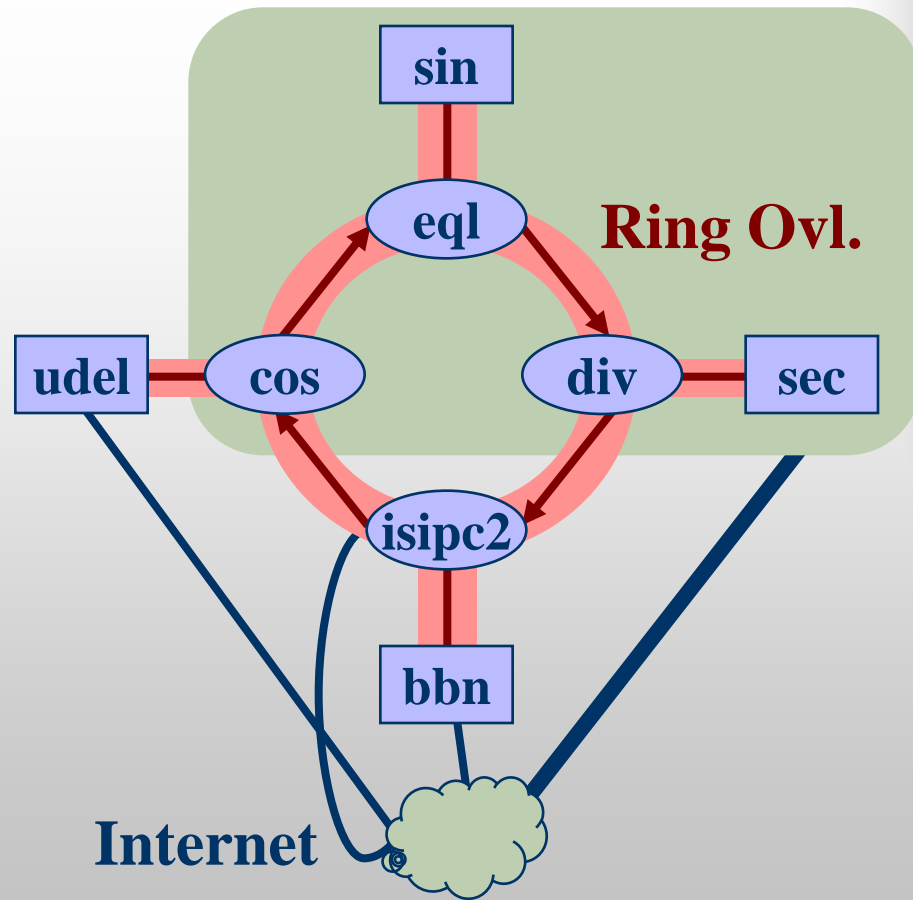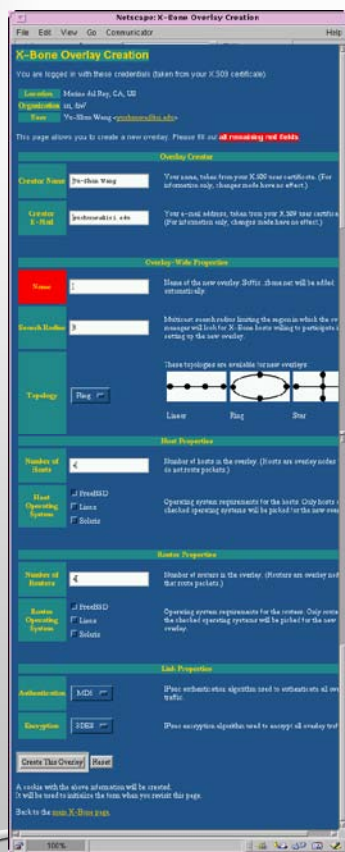
Internet

VI – definition

- Virtual Internet is network composed of:
  - Virt. hosts, virt. routers, virt. links (**tunnels**), i.e., an end-to-end system
  - provides at least the same services as IA
  - in a virtual context
- First-principles extension
  - More than a patch
  - More than interim
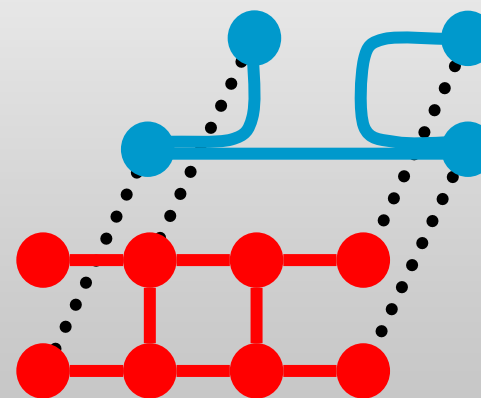
VIA Principles

- *TENET 1. Internet-like*
  - VIs = VRs + VHs + tunnels
  - Tunnels are links; separate net addresses
  - Emulating the Internet
- *TENET 2. All-Virtual*
  - decoupled from their base network
- *TENET 3. Recursion-as-router*
 - some of VRs are VI networks

Extra constraints

- Internet-based
  - Routing (link up) vs. provisioning (link add)
  - *…one header to bind them all…*
    (use IP, provide IP □recursion)
- Complete E2E system
  - All VNs are E2E
- VN "Turing Test"
  - A net can't tell it's virtual
- Use existing protocols, OSs, apps.

Recursion-as-Router

- **Sub-overlays look like routers**
  - L3 version of *rbridges (IETF TRILL WG)*
 - *Similar to LISP/NERD/etc.*
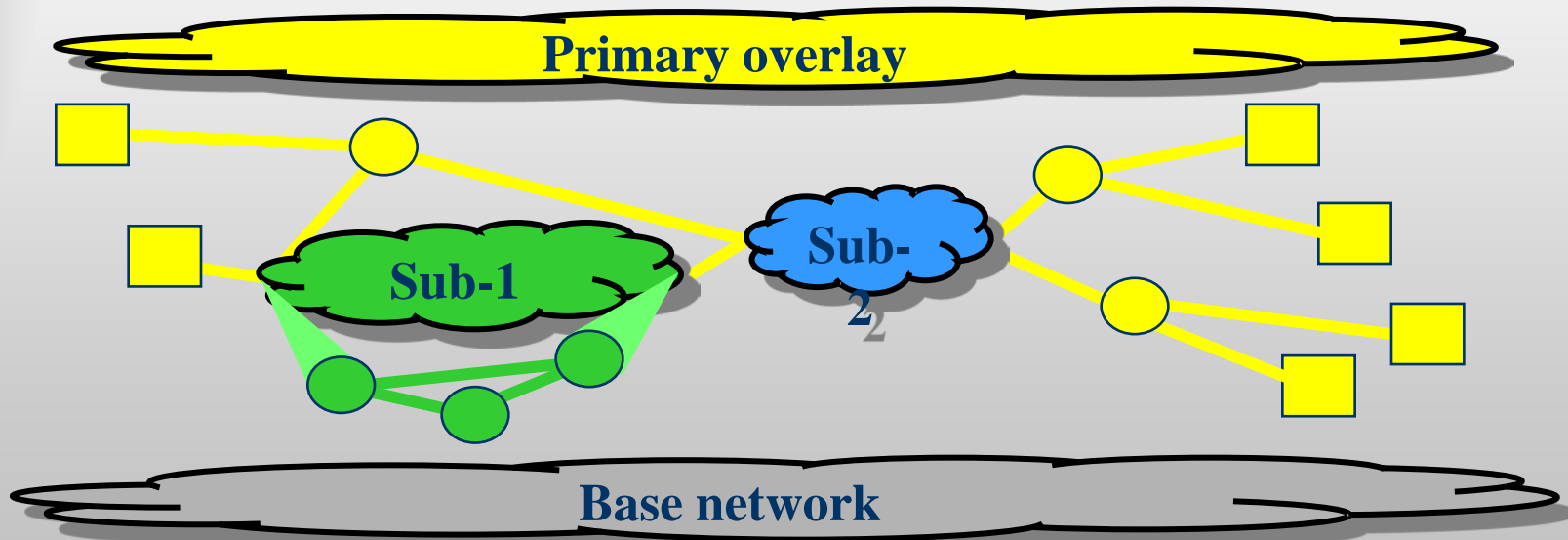
Software Features

- Running code since 2000
  - FreeBSD port, Linux RPM, Cisco via buddy host
- Secure
  - TLS control plane, IPsec data plane
  - "Red teamed" software
- IPv4, IPv6 (both with IPsec)
  - Integrated with DNS updates, dynamic routing
- Per socket association to overlays
  - Allows process to bind to multiple overlays
- Application deployment
  - slice configuration, control distributed services
- Supports recursion, revisitation

Potential Uses

- **Test new protocols**
  - Test denial-of-service solutions
- **Deploy new services incrementally**
  - Dynamic routing, proxylets, security
- **Increase lab & testbed utility**
  - Overlapping nets, add delay & loss
- **Scale to very many nodes**
  - Simplify view of topology
- **Support fault tolerance**
  - Added level of recovery
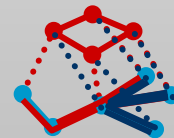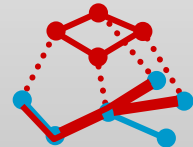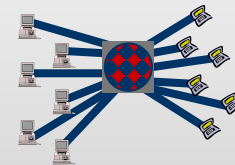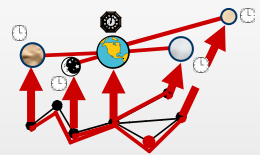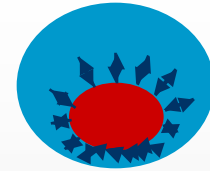
What We Don't Do...

- **Optimize the overlay topology**
  - we use a plug-in module (AI folk can provide)
  - it requires network status (not quite mature)
  - fault tolerance only via ground truth (future work)
  - X-Bone is capability more than performance (now)
- **Non-IP overlays**
  - Single, common interoperation layer
  - IP recurses / stacks nicely
  - "The lowest level at which experimentation is permitted is also the highest level at which experimentation occurs." – J.Touch, 1996

VI Features

- Recursion
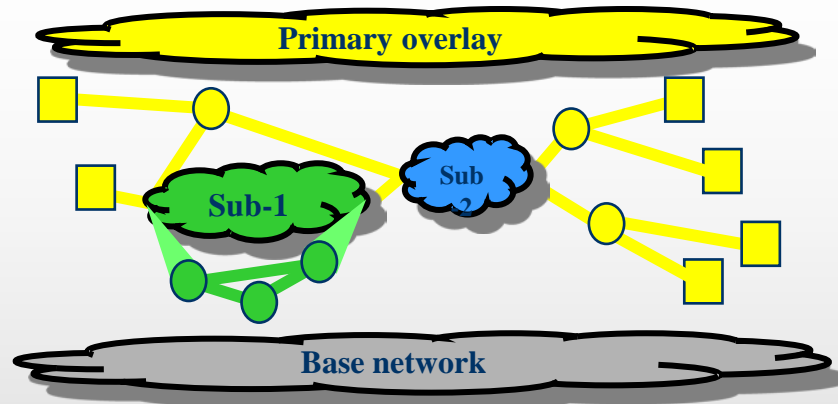 - Control (like BGP AS's)
  - Network (like LISP/NERD)
    - BARP (label distrib)

- Revisitation

- Integration of resolution, choices
  - Shims and glue layers as fundamental

- Service for deploying & managing VIs
  - Language for describing VIs

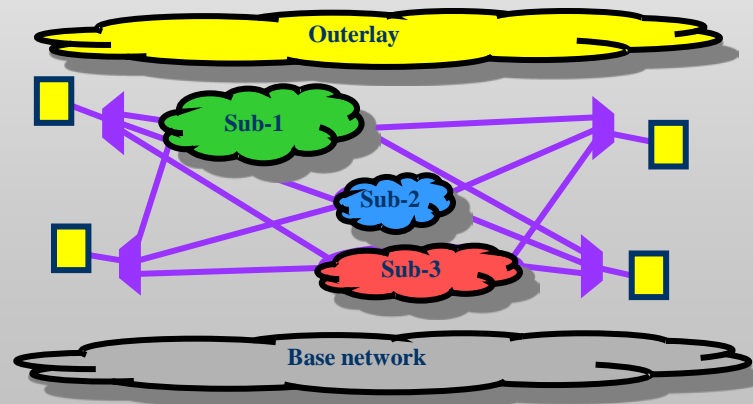**Control / deployment**   **Network**
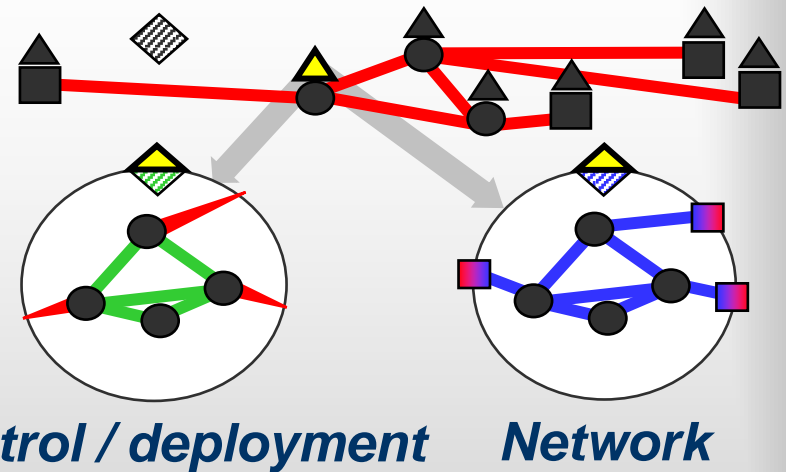
More VI Features…

- Compose:
  - DTN, Plutarch

- Alternate:
  - Control Plane, FEC, Boosters,
  - Dynabone

TetherNet

- Rents a block of addresses
  - Auto-configures secure tunnel
- Undoes effect of NAT/NAPT
  - Also effect of net non-neutrality
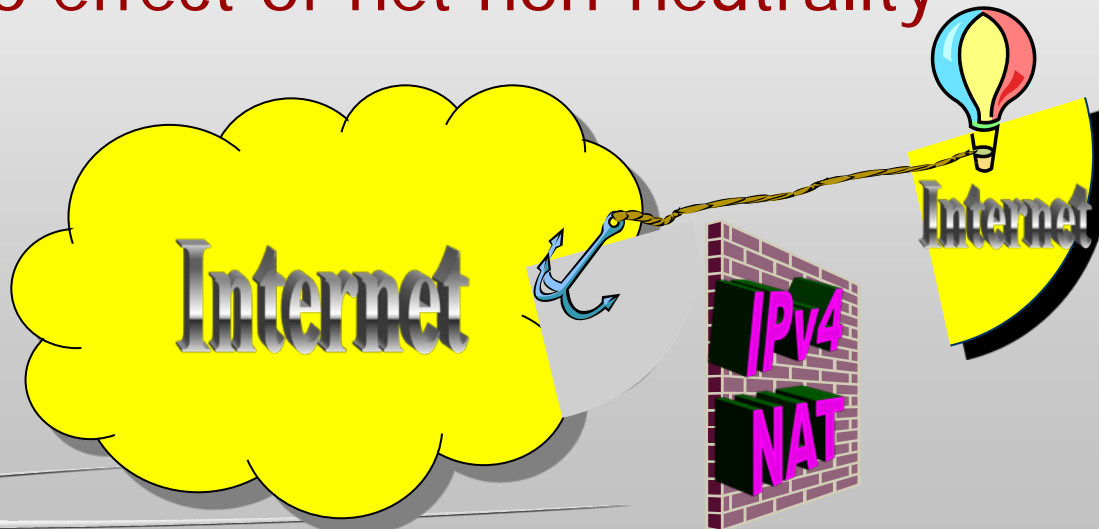
DynaBone Spread Spectrum

Outerlay

TCP S/F – 3DES

Others – MD5

UDP – SHA1

Base network

800 Innerlays
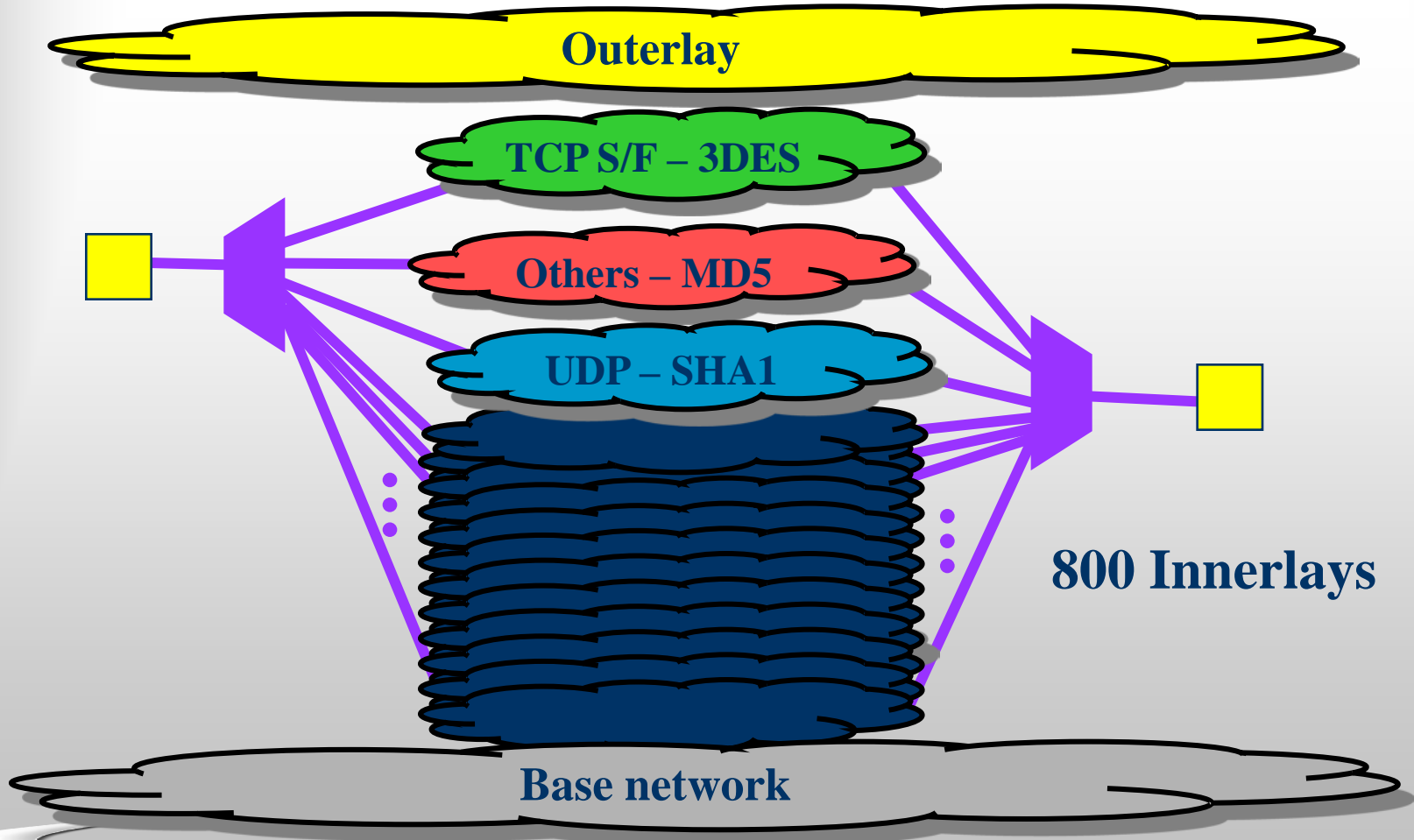
Agile Tunnel Protocol (ATP)

- Client
  - **-> tunnel head** @client
  - **-> roaming tunnel tail**
  - -> server (hidden)

- Works like an inverse tunnel:
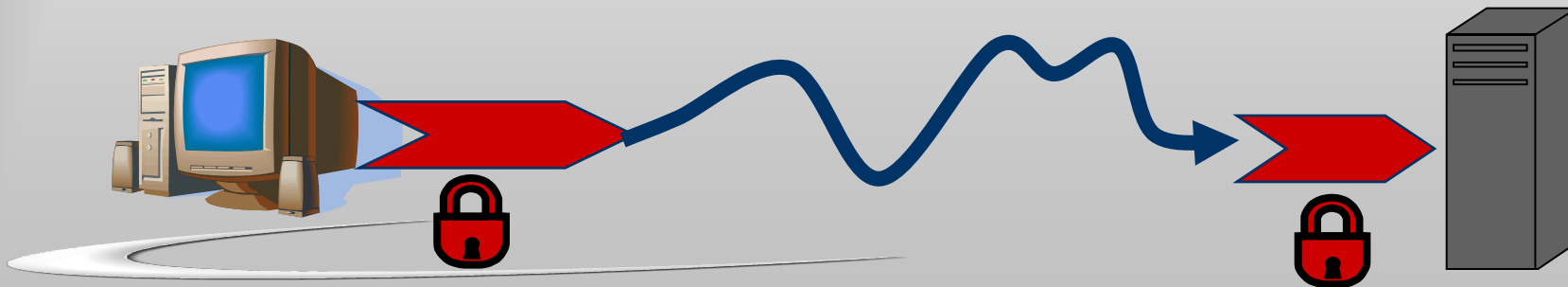
DataRouter for P2P

- P2P re-implements network arch.
- Need app.-layer forwarding at net layer
- Add string-based forwarding

s/(bird)(.*)(isi.edu)/(D2)($2)(usc.edu)/

Recursive Net Arch

- Layering as more than software engr.
  - Layers defined by scope, context
- Create a one layer 'stem cell' protocol
  - Integrate resolution, "choices" from X-Bone
  - Template of basic functions, ala J. Day
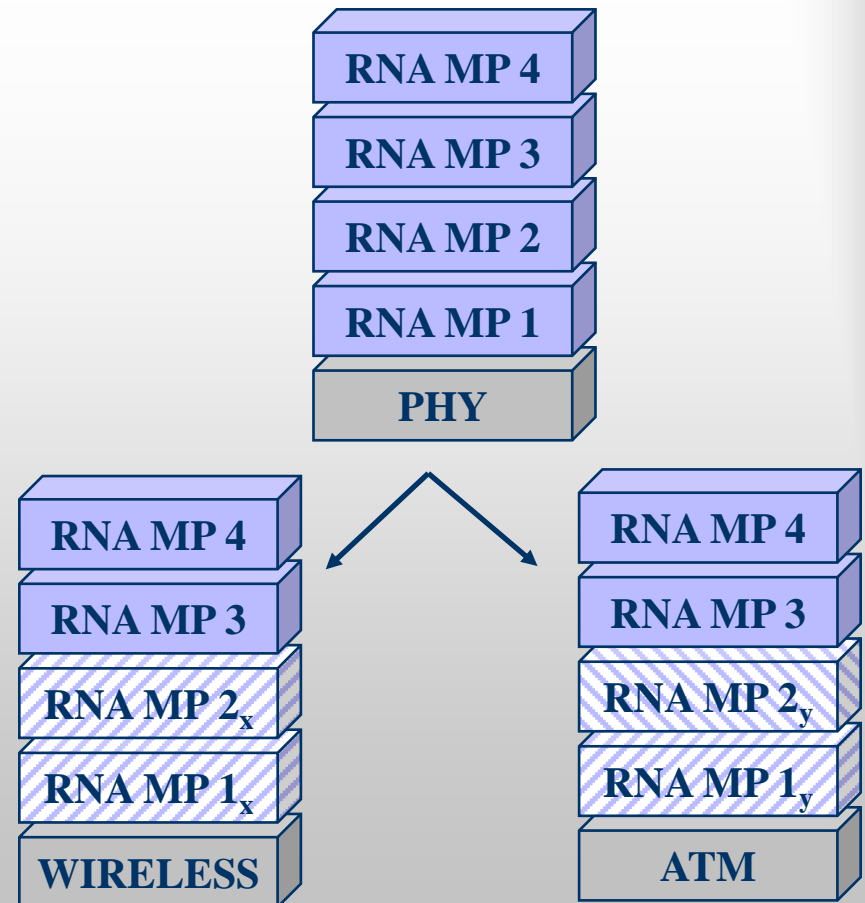
VI Observations

- Virtualization *changes* the architecture
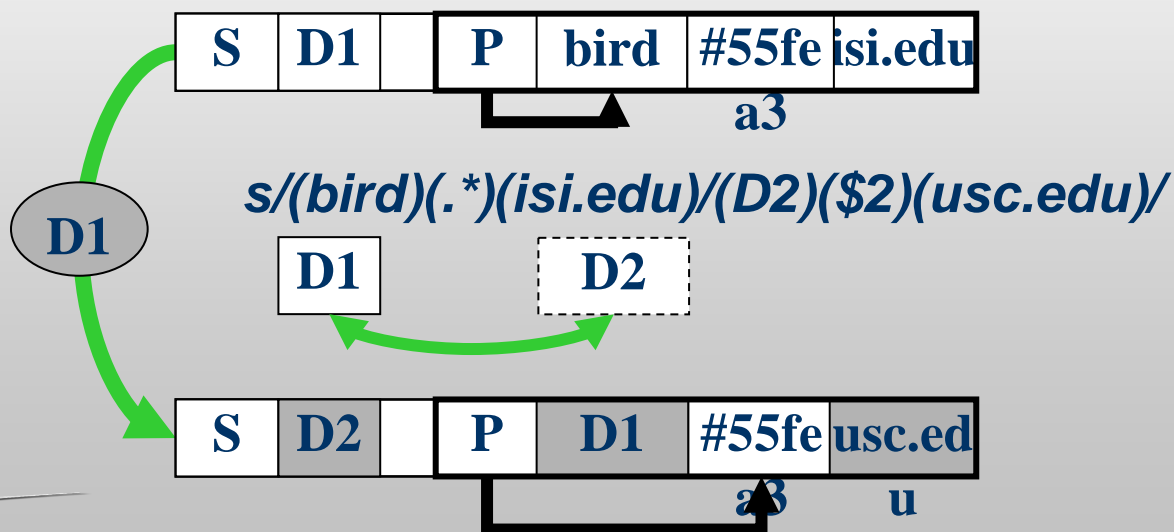 - Hosts are really processes,
    everything else is really a router or system
  - Devices aren't localized
    - Subnet as a router
    - NAT as a host front-end
  - Link and net layers are tightly coupled
- Core concepts from previous glue/shims
  - A single model yields layering, forwarding, routing, and dynamic composition

Current Efforts

- IRTF NetVirt BOF / NVRG mailing list
  - Met in Phila. March 2008
    - A- 'next gen' testbeds / GENI, 4WARD, AKARI, ...
    - B- 'next generation' research / FIND, FIRE, ...
    - C- virt extensions / PPVPN, L*VPN, X-Bone, LISP/NERD, PWE

- Future Internet meetings
  - ICCCN 2008 "FIAPP" (future Internet arch and protocols)
  - CoNext 2008 "ReArch" (re-architecting the Internet)
  - ICCCN 2009 "NAP" (net arch & protocols)

US-EU Collaboration

- UPC / O. Ardaiz Villanueva (Spain)
  - Visiting researcher, overlay service deployment
- UCL MICE / Peter Kirstein (UK)
  - X-Bone collab. within DARPA Active Nets
  - Deploy a MICE teleconferencing overlay
- EU 4-WARD / Martina Zitterbart (Germany)
  - RNA collaboration with Univ. Karlsruhe,
    NC State NetSilo / Rouskas
  - Unifying approaches to protocol layering

US-Japan Collaboration

- WIDE / Jun-ichiro (Itojun) Hagano
  - X-Bone, FreeBSD virtualization support
- WIDE / Hideaki Imaizumi
  - Dynabone, Visiting researcher, IPv6 transition mech.
- WIDE / Shigeya Suzuki
  - X-Tend, Visiting researcher, RF tags
- NEC / Norihito Fujita
  - X-Tend, Visting researcher, P2P network overlays

Project Issues

- Coordinating projects
  - Separate preconditions
  - Separate goals (esp. funded independently)
  - Separate funding trajectories
    - *very* hard to coordinate a-priori
- Support for travel
  - Meetings are more international anyway
  - Direct support for guest presentations

People Issues

- In-person visits
  - Visiting researchers
  - Guest presentations
- Regular meetings
  - "T-Troup" participation, group talks & paper reviews
  - External review collaboration
- Social support
  - Lunches, coffees, Friday bagels
  - Off-time - "WoW"s, holidays, sharing local favorites

Things that help...

- Support / piggyback on other meetings
  - Sigcomm 2007, Kyoto (Jun Murai/Keio Univ., chair)
  - CoNext Rearch 2008, Madrid
- Skype + Powerpoint
  - Cheaper than telephone
  - Easier than teleconferencing
- Be conscious of language issues
  - Alternate descriptions
  - Simpler description/words... *without simplifying the ideas*