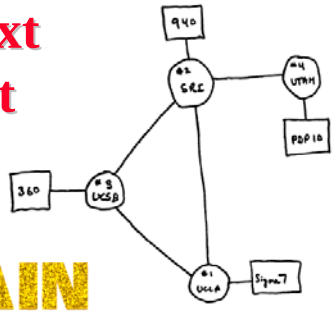
# Internet 3.0: The Next Generation Internet

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These slides and Audio/Video recordings of this talk are at:
http://www.cse.wustl.edu/~jain/talks/in3_cse.htm





## Overview

1. What is Internet 3.0?
2. What are we missing in the current Internet?
3. Our Proposed Architecture for Internet 3.0
4. Relationship to other research projects in CSE

# Next Generation Internet Projects

- In 2005 US National Science Foundation started a large research and infrastructure program on next generation Internet
- Q: How would you design Internet today? Clean slate design.
- "Future Internet Design" (FIND): 48+ projects
  - Stanford, MIT, Berkeley, CMU, …
  - "An Architecture for Diversified Internet" at WUSTL
- "Global Environment for Networking Innovations" (GENI): 29+ projects
- European Union: 7th Framework program
- Japan: AKARI (A small light in the dark pointing to the future)
- China, Korea, Australia, …20+ countries
- **Ref**: See our survey report, WUSTL-2009-69, Oct 2, 2009



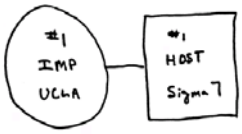


# Internet 3.0: Next Generation Internet

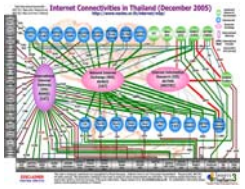
- Internet 3.0 is the name of the Washington University project on the next generation Internet
- Named by me along the lines of "Web 2.0"
- Internet 3.0 is more intuitive then GENI/FIND
- Goal 1: Develop a *clean slate architecture* to overcome limitations of the current internet
- Goal 2: Develop an *incremental approach* to implement the architecture

# Internet Generations

- **Internet 1.0** (1969 – 1989) – Research project
  - RFC1 is dated April 1969.
  - ARPA project started a few years earlier
  - IP, TCP, UDP
  - Mostly researchers
  - Industry was busy with proprietary protocols: SNA, DECnet, AppleTalk, XNS




- **Internet 2.0** (1989 – Present) – Commerce ⇒ new requirements
  - Security RFC1108 in 1989
  - NSFnet became commercial
  - Inter-domain routing: OSPF, BGP,
  - IP Multicasting
  - Address Shortage IPv6
  - Congestion Control, Quality of Service,…

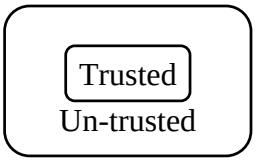






# Key Problems with Current Internet

1. Designed for research
   ⇒ Trusted systems
   Used for Commerce
   ⇒ Untrusted systems
2. Difficult to represent organizational, administrative hierarchies and relationships. Perimeter based.
   ⇒ Difficult to enforce organizational policies



# Problems (cont)

3. Identity and location in one (IP Address)
   Makes mobility complex.

4. Assumes live and awake end-systems
   Does not allow communication while sleeping.
   Many energy conscious systems today sleep.

5. No representation for real end system: the human.

Ref: Our Milcom 2006 paper





# Names, IDs, Locators

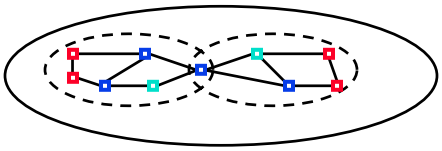
**Name**: John Smith

**ID**: 012-34-5678

**Locator**:
1234 Main Street
Big City, MO 12345
USA

- Locator changes as you move, ID and Names remain the same.
- **Examples**:
  - Names: Company names, DNS names (microsoft.com)
  - IDs: Cell phone numbers, 800-numbers, Ethernet addresses, Skype ID, VOIP Phone number
  - Locators: Wired phone numbers, IP addresses

# Realms



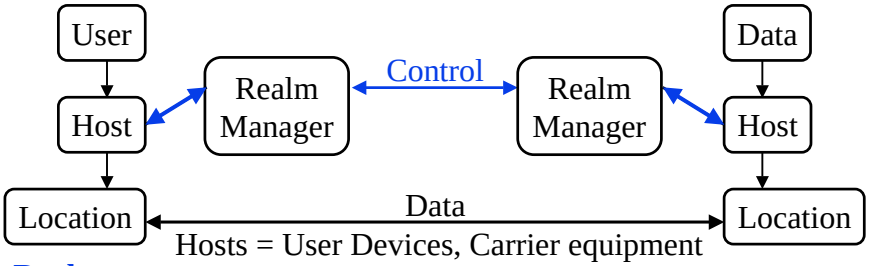
- Object names and Ids are defined within a realm
- A realm is a **logical** grouping of objects under an administrative domain
- The Administrative domain may be based on Trust Relationships
- A realm represents an organization
  - Realm managers set policies for communications
  - Realm members can share services.
  - Objects are generally members of multiple realms
- Realm Boundaries: Organizational, Governmental, ISP, P2P,…

**Realm = Administrative Groupvc**





# Id-Locator Split Architecture (MILSA)




Hosts = User Devices, Carrier equipment

**Realm managers**:

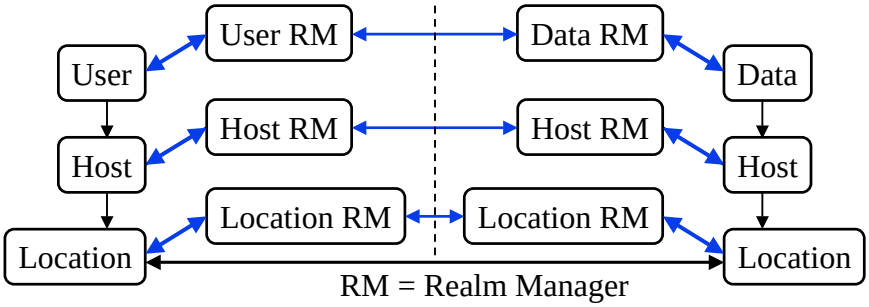
- Resolve current location for a given host-ID
- Enforce policies related to authentication, authorization, privacy
- Allow mobility, multi-homing, location privacy
- Different from several other ID-locator splitting proposals. Our Emphasis on organizational control.
- Ref: Our Globecom 2008 paper [2]

# User- Host- and Data Centric Models

- All discussion so far assumed host-centric communication
  - Host mobility and multihoming
  - Policies, services, and trust are related to hosts
- User Centric View:
  - Bob wants to watch a movie
  - Starts it on his media server
  - Continues on his iPhone during commute to work
  - Movie exists on many servers
  - Bob may get it from different servers at different times or multiple servers at the same time
- Can we just give IDs/locators to users and treat them as hosts? No! ⇒ Policy Oriented Naming Architecture (PONA)

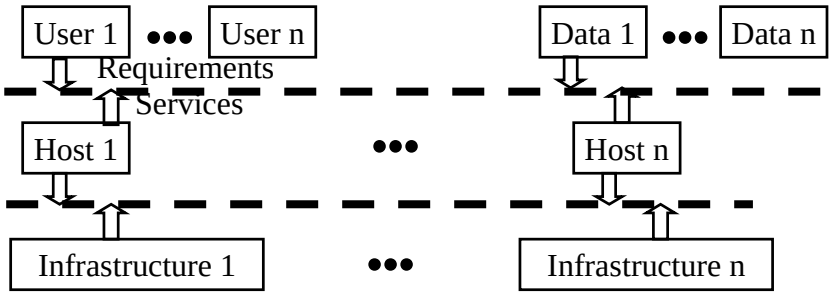


# Policy Oriented Naming Architecture




- Both Users and data need hosts for communication
- Data is easily replicable. All copies are equally good.
- Users, Hosts, Infrastructure, Data belong to different realms (organizations).
- Each object has to follow its organizational policies.

# Multi-Tier Object-Oriented View



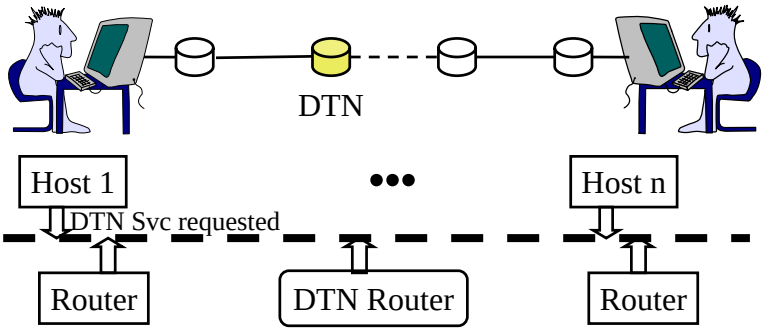

- Objects provide services. Higher tiers specify the requirements
- Tier service broker (shown by dotted line) composes a service – can negotiate with multiple realms in that tier
- Higher tier may not/need not find details of lower tiers

**Allows creating requirement specific networking context**



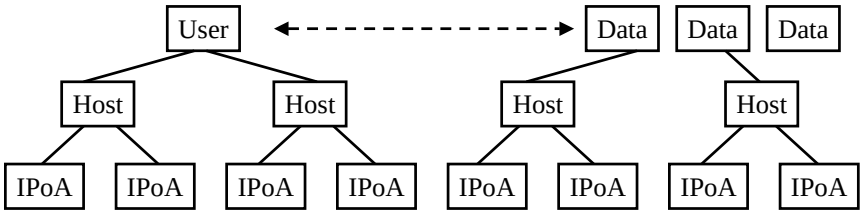


# Disruption Tolerant Network (DTN)




- Normally all routers on the end-to-end path should be up
- DTN-aware routers store data until it can be forwarded
- In Internet 3.0, DTN service can be advertised by DTN routers and negotiated by the service broker

# Multi-Tier Issues

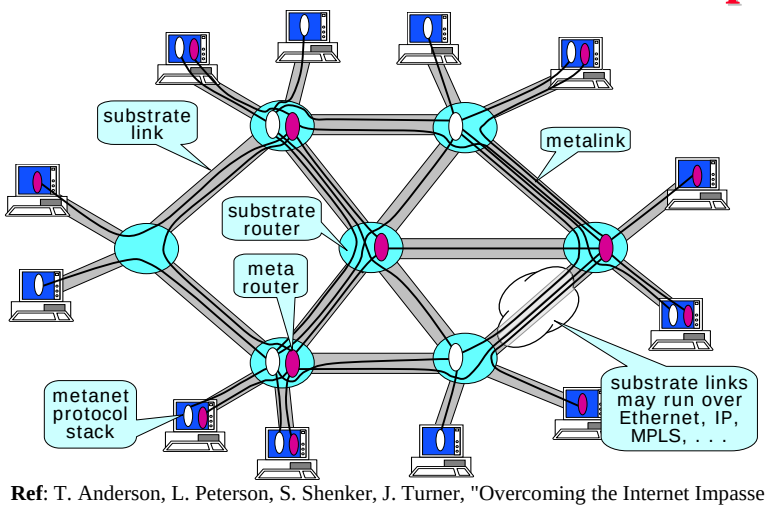



- **Multi-Tier Multi-homing**: Users are accessible via multiple hosts. Each host has multiple Infrastructure Point of Attachments (IPoAs)
- **Multi-Tier Mobility**: Users are constantly changing hosts. Hosts are changing their IPoAs.
- **Multi-Tier Virtualization**





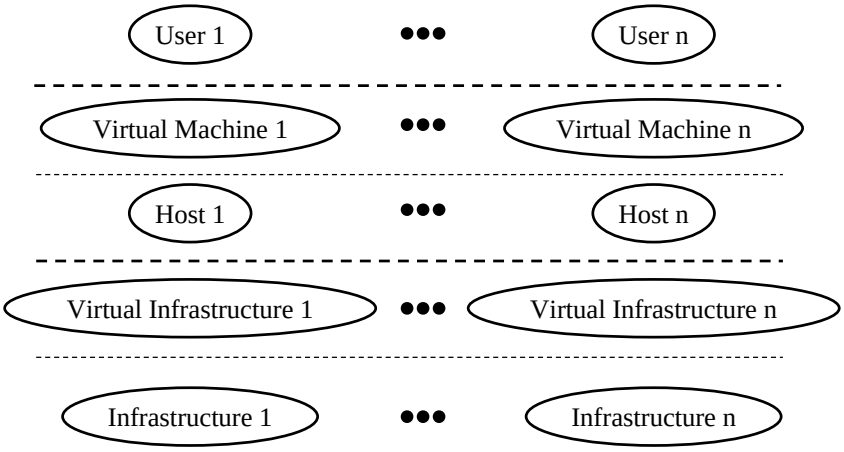
# Virtualizable Network Concept




**Ref**: T. Anderson, L. Peterson, S. Shenker, J. Turner, "Overcoming the Internet Impasse through Virtualization," Computer, April 2005, pp. 34 – 41.

Slide taken from Jon Turner's presentation at Cisco Routing Research Symposium

# Multi-Tier Virtualization

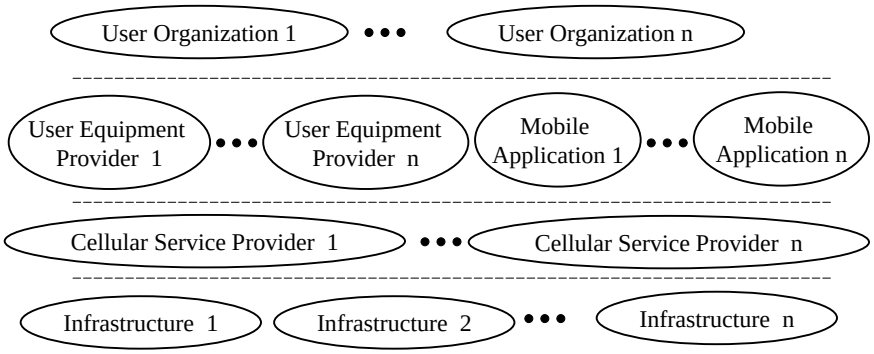



- A tier can be broken in many virtual tiers





# Cellular Networks of the Future




- **Other Examples**:
  - P2P: File sharing groups over hosts over infrastructure
  - Distributed Services: Services over multi-homed hosts
  - National Security: Infrastructure vs. national boundaries

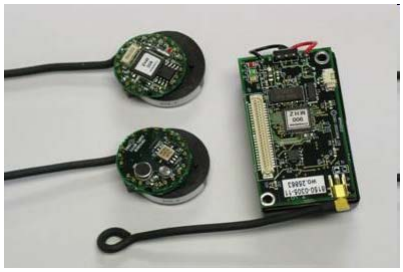
# Collaboration Possibilities

- Internet 3.0 and Sensor Networks
- Internet 3.0 and SPP
- Large Scale Scientific Computing: Gnome
- Internet 3.0 and Medical Applications



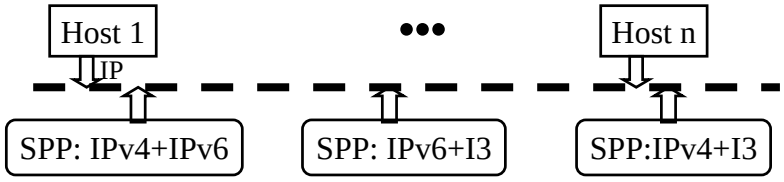
# Internet 3.0 and Sensor Networks

- Sensors are battery operated
  ⇒ Sensor networks need to be energy aware
- Delay and Fault tolerant Mobile Sensor Networks (DFT-MSN)
- We can apply Internet 3.0 model to Sensor networks in DTN and other requirement specific networking contexts



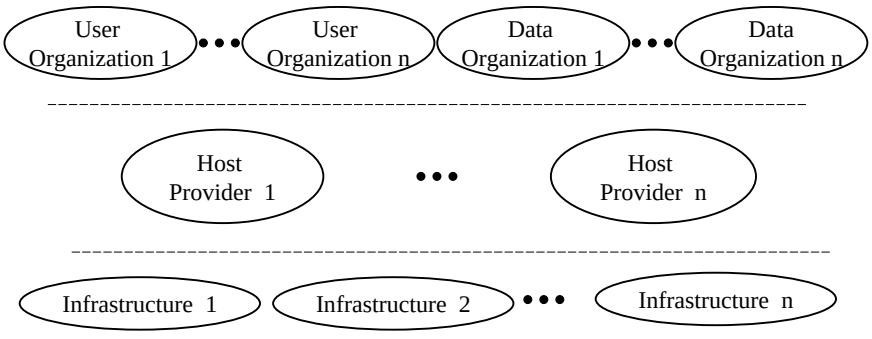
# Internet 3.0 and SPP

- Supercharged PlanetLab Platform
- Allows multiple routing paradigms on a router
- SPPs can host different overlays with different requirements
- Internet 3.0 requirement specific capability negotiation methodology can be used to find underlay between any two SPP nodes





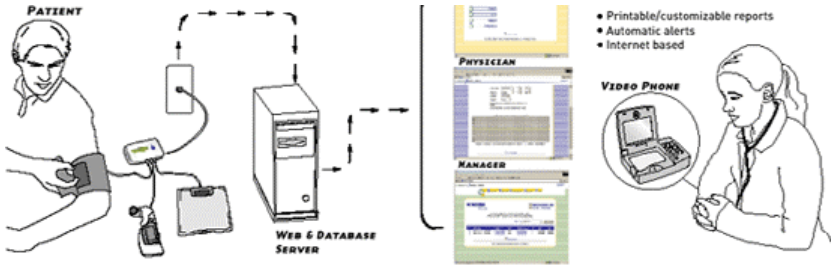

# Large Scale Scientific Computing




- Authenticate/authorize data using data/user policies
- Lease hosts that meet user/data policies
- Connect hosts using host policies
- Transfer data in infrastructure while meeting host requirements

# Internet 3.0 and Medical Applications

- Patient monitoring at homes
  - User-user (or data) communication is more appropriate than host-host communication.
  - Users can be multi-homed: cellular, Wi-Fi, DSL, …






# Internet 1.0 vs. Internet 3.0: Features

| | Feature | Internet 1.0 | Internet 3.0 |
|---|---|---|---|
| 1. | Energy Efficiency | Always-on | Green ⇒ Mostly Off |
| 2. | Mobility | Mostly stationary computers | Mostly mobile *objects* |
| 3. | Computer-Human Relationship | Multi-user systems ⇒ Machine to machine comm | Multi-systems user ⇒ Personal comm systems |
| 4. | End Systems | Single computers | User/Data/Distributed systems |
| 5. | Design Goal | Research ⇒ Trusted Systems | Commerce ⇒ No Trust Map to organizational structure |
| 6. | Ownership | No concept of ownership | Hierarchy of ownerships |

# Internet 1.0 vs. Internet 3.0: Design

| | Design Issue | Internet 1.0 Solution | Internet 3.0 Solution |
|---|---|---|---|
| 1 | Connections | Host-Host | User-Data (Hosts are intermediate systems) |
| 2 | Information | Complete knowledge of all tiers | Only service API's are disclosed |
| 3 | Resource allocation | Algorithmic Optimization | Policy based |
| 4 | Multi-homing | Host multihoming | Multi-tier multihoming (User/Data/Host) |
| 5 | Mobility | Host mobility | Multi-tier mobility (User/data/host) |





# Summary

1. Internet 3.0 is the next generation of Internet.
2. It must be secure, allow mobility, and be energy efficient.
3. Must be designed for commerce
   ⇒ Must represent multi-organizational structure and policies
4. Different ownership/policies of users, hosts, infrastructure
   ⇒ Multi-tier, object oriented, service broker architecture
5. Object-oriented architecture allows services to be composed that meet upper tier's requirements while not requiring disclosure of lower tier's mechanisms and details

# References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4. Jianli Pan, Raj Jain, Subharthi Paul, Mic Bowman, Xiaohu Xu, Shanzhi Chen, "**Enhanced MILSA Architecture for Naming, Addressing, Routing and Security Issues in the Next Generation Internet**," Proceedings of IEEE International Conference in Communications (ICC) 2009, Dresden, Germany, June 14-18, 2009, (sponsored by Huawei) http://www.cse.wustl.edu/~jain/papers/emilsa.htm
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