Internet 3.0: The Next Generation Internet

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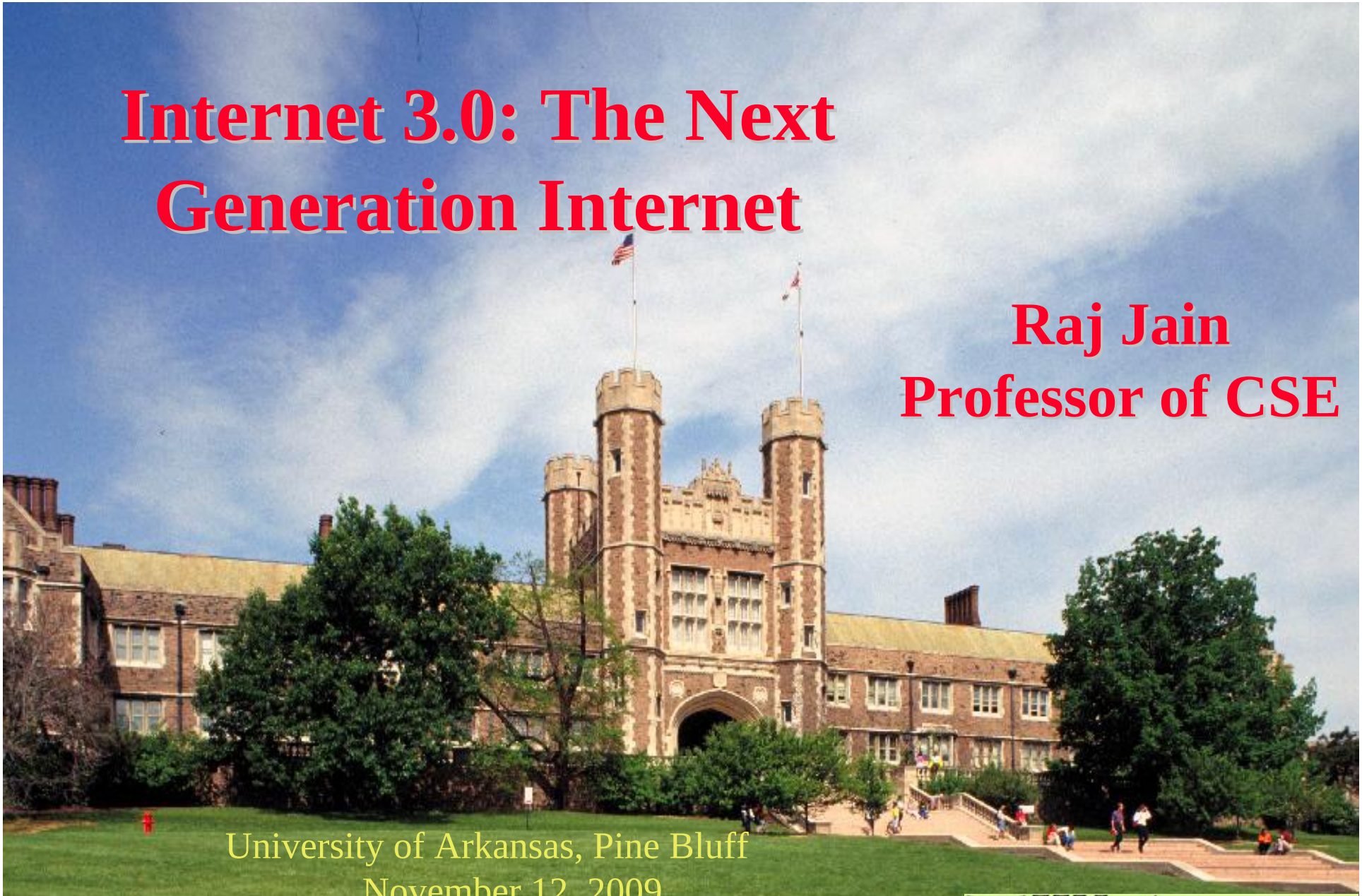

University of Arkansas, Pine Bluff
November 12, 2009

These slides and Audio/Video recordings of this talk are at:
http://www.cse.wustl.edu/~jain/talks/in3_uap.htm

Washington University in St. Louis

Graduate Study @ Washington University

- 24 faculty members, 71 Ph.D. students, in:
  - Robotics, Graphics, HCI, AI/Bioinformatics, networking, high-performance architectures, chip multi-processors, mobile systems/sensor networks, software systems, optimization.
- PhD students are (almost always) fully funded.
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- Information Day on Saturday, November 14 (10am-3pm)

Overview

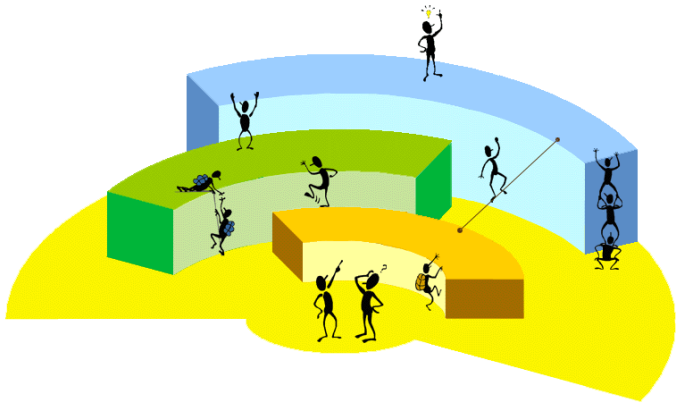
1. What is Internet 3.0?
2. What are we missing in the current Internet?
3. Our Proposed Architecture for Internet 3.0

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

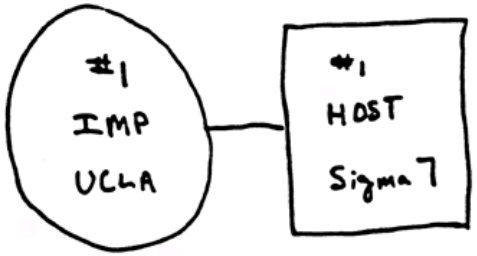
Internet 3.0: Next Generation Internet

- Internet 3.0 is the name of the Washington University project on the next generation Internet
- Goal 1: Represent the commercial reality of distributed Internet ownership and organization
- Goal 2: Develop a *clean slate architecture* to overcome limitations of the current internet
- Goal 3: Develop an *incremental approach* to implement the architecture

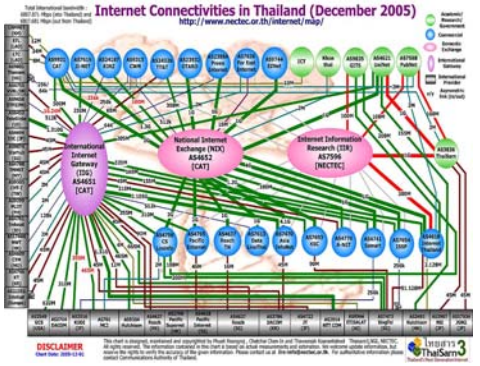


Internet Generations

- **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

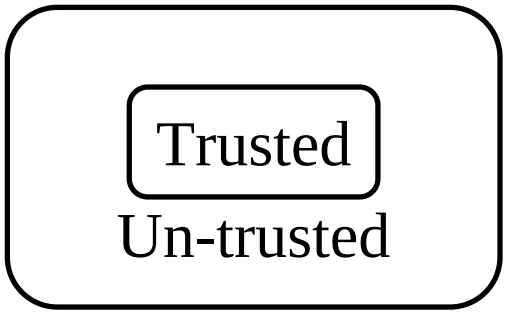


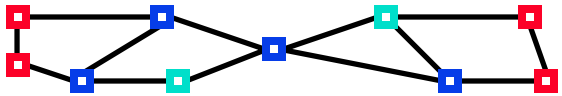
- **Internet 2.0** (1989 – Present) – Commerce ⇒ new requirements
  - Security RFC1108 in 1989
  - NSFnet became commercial
  - Inter-domain routing: BGP (Policy-based)
  - Address Shortage IPv6
  - Congestion Control, Quality of Service,…



Key Problems with Current Internet

1. **Security**:
   Fundamental architecture design issue
   Control+Data are intermixed
   Security is just one of the policies.
2. No concept of **ownership**
   (except at infrastructure level)
   Difficult to represent organizational, administrative hierarchies and relationships. Perimeter based.
   $\Rightarrow$ Difficult to enforce organizational policies



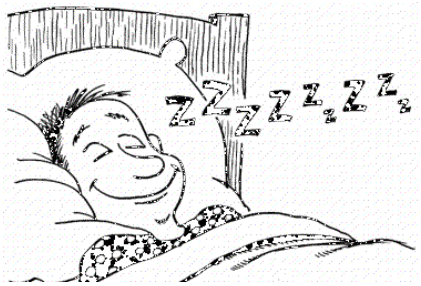


Realms

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

Physical vs. Logical Connectivity

- Physically and logically connected:
  All computers in my lab
  = Private Network,
  Firewalled Network

- Physically disconnected but logically connected:
  My home and office computers

- Physically connected but logically disconnected: Passengers on a plane, Neighbors, Conference attendees sharing a wireless network, A visitor

Physical connectivity ≠ Trust

Names, IDs, Locators

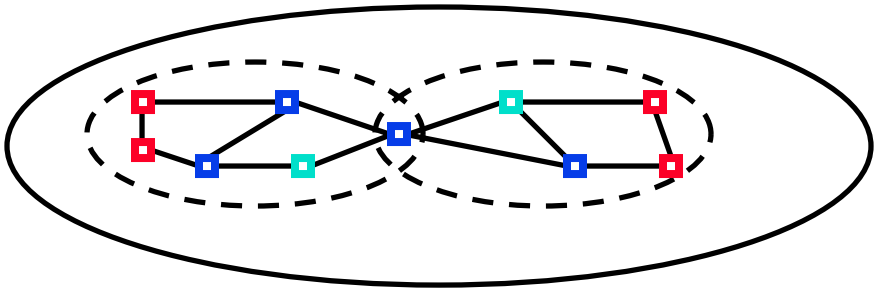
Name: John Smith

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

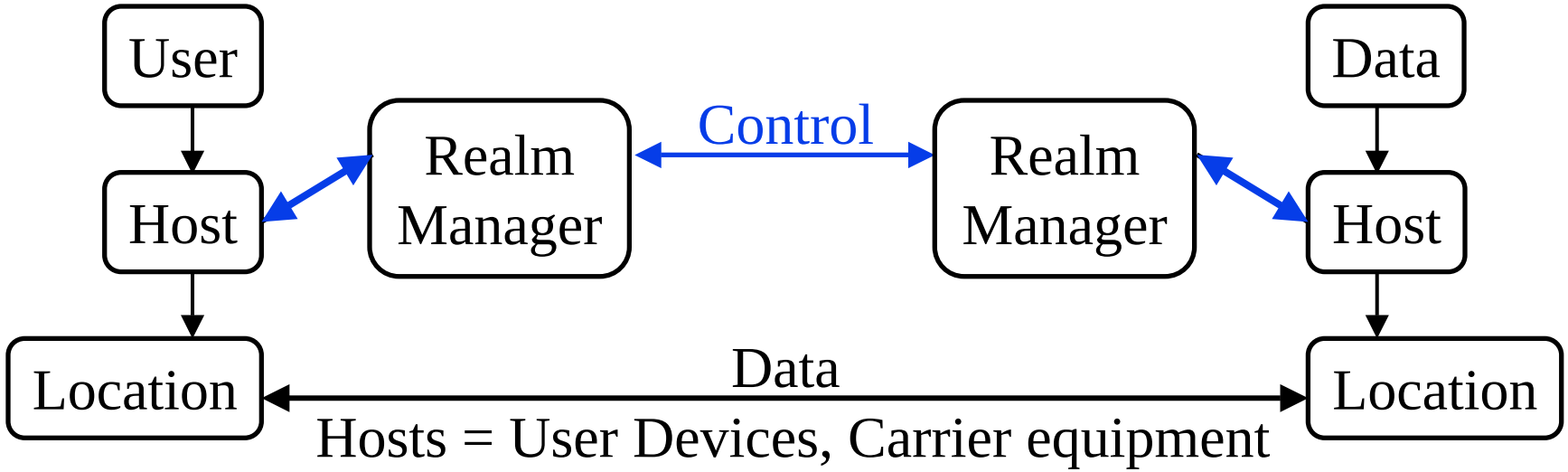
Realms



- 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)



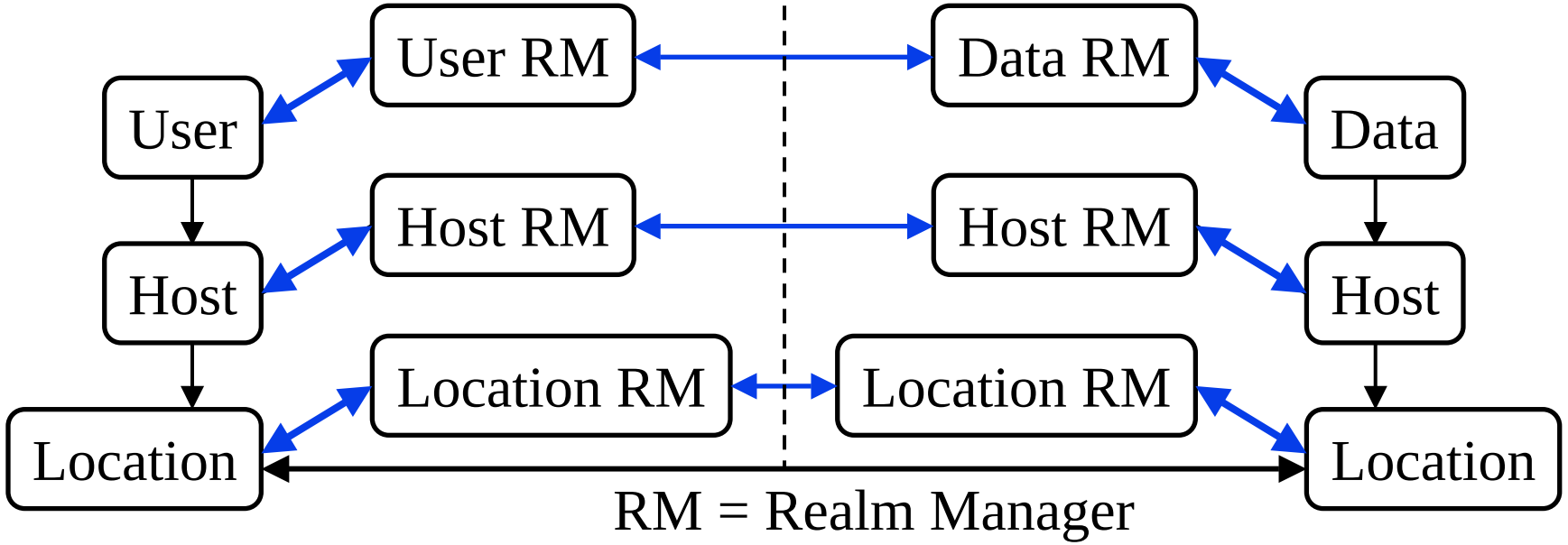
Realm managers:

- 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-Based Networking Architecture



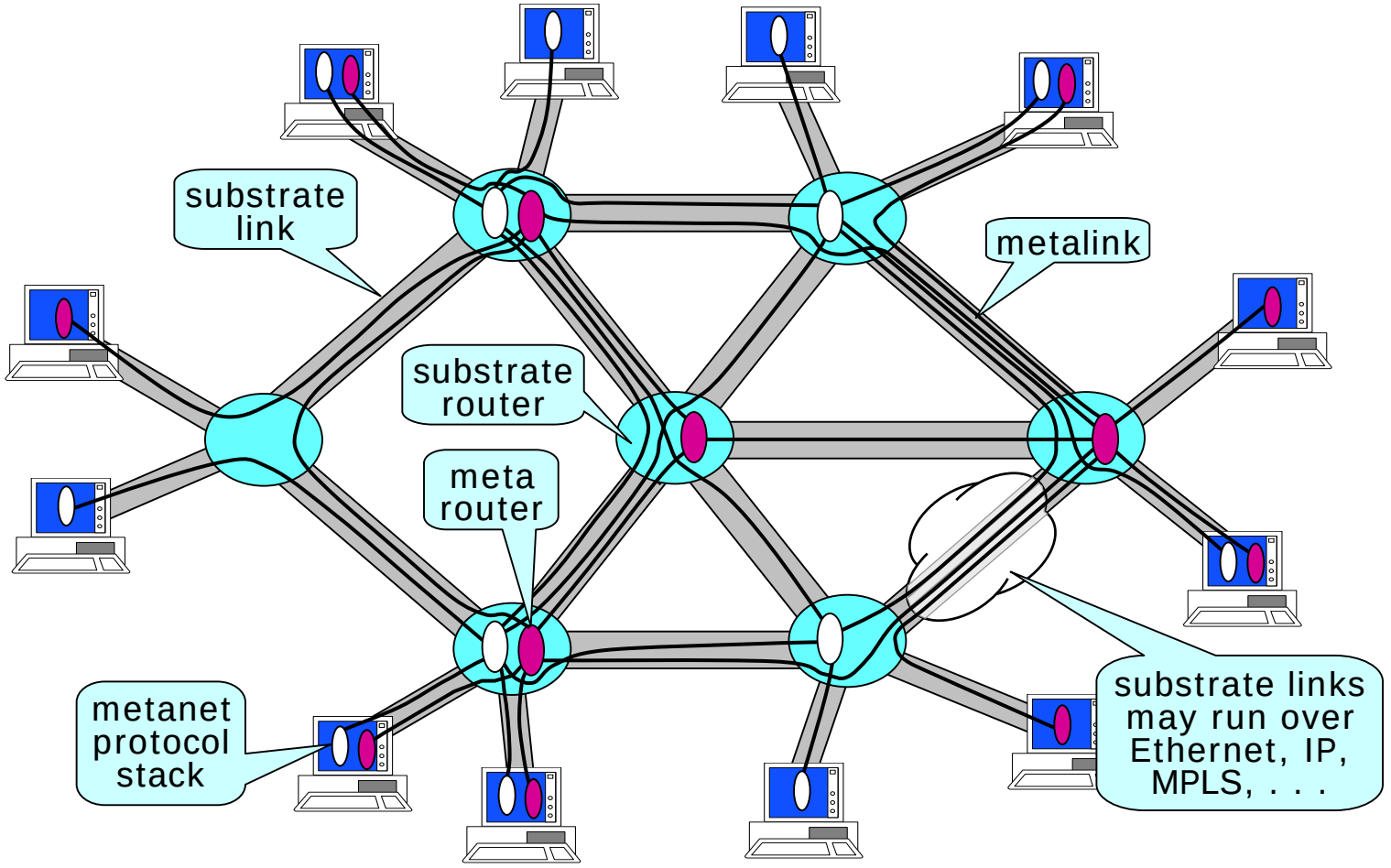
- Both Users and data need hosts for communication
- Data is easily replicable/divisible. All copies are equally good.
- Users, Hosts, Infrastructure, Data belong to different realms (organizations).
- Each object has to follow its organizational policies.

Server Objects

- Each realm has a set of server objects, e.g., forwarding, authentication, encryption,
- Some objects have built-in servers, e.g., an "enterprise router" may have forwarding, encryption, authentication services.
- Other objects rely on the servers in their realm
- Forwarding servers are located at the boundary of two realms
- Encryption servers encrypt the packets
- Authentication servers (AS) add their signatures to packets and verify signatures of received packets..
- Storage servers store packets while the object may be sleeping and may optionally aggregate/compress/transform/disseminate data. Could wake up objects.
- Persistent connections: Across system restarts, HW replacement, Object mobility

Servers allow simple energy efficient end devices

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

http://www.cse.wustl.edu/~jain/talks/in3_uap.htm

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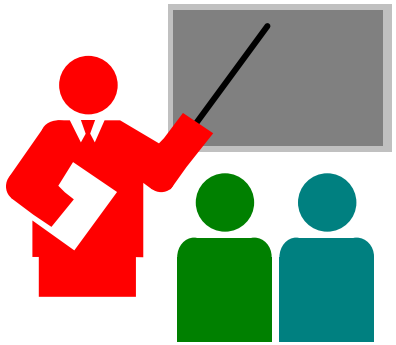
Internet 1.0 vs. Internet 3.0: Features

	Feature	Internet 1.0	Internet 3.0
1.	Energy Efficiency	Always-on	Energy aware
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 Govt Funded	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	Resource allocation	Algorithmic Optimization	Policy based
2	Intelligence	Manual/applications	In the network
3	Connections	Host-Host	User-Data (Hosts are intermediate systems)
4.	Ownership	Single=> Single Tier	Commercial Reality => Multi-Tier
5	Information	Complete knowledge of all tiers	Only service API's are disclosed
6	Mobility	Host mobility	Multi-tier mobility (User/data/host)
7	Multi-homing	Host multihoming	Multi-tier multihoming (User/Data/Host)
8	Virtualization	Network virtualization	Multi-Tier virtualization

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
   $\Rightarrow$ Must represent multi-organizational structure and policies
4. Different ownership/policies of users, hosts, infrastructure
   $\Rightarrow$ 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

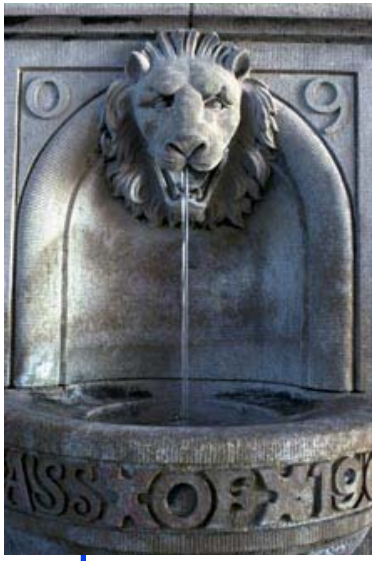
1. Jain, R., "**Internet 3.0: Ten Problems with Current Internet Architecture and Solutions for the Next Generation**," in Proceedings of Military Communications Conference (MILCOM 2006), Washington, DC, October 23-25, 2006, http://www.cse.wustl.edu/~jain/papers/gina.htm
2. Subharthi Paul, Raj Jain, Jianli Pan, and Mic Bowman, "**A Vision of the Next Generation Internet: A Policy Oriented View**," British Computer Society Conference on Visions of Computer Science, Sep 2008, http://www.cse.wustl.edu/~jain/papers/pona.htm
3. Jianli Pan, Subharthi Paul, Raj Jain, and Mic Bowman, "**MILSA: A Mobility and Multihoming Supporting Identifier-Locator Split Architecture for Naming in the Next Generation Internet**," Globecom 2008, Nov 2008, http://www.cse.wustl.edu/~jain/papers/milsa.htm

References (Cont)

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
5. Jianli Pan, Subharthi Paul, Raj Jain, Xiaohu Xu, "**Hybrid Transition Mechanism for MILSA Architecture for the Next Generation Internet**," Proceedings of IEEE Globecom 2008 2nd International Workshop on the Networks of the Future, Hawaii, December 4, 2009, http://www.cse.wustl.edu/~jain/papers/milsat.htm

References (Cont)

6. Subharthi Paul, Jianli Pan, and Raj Jain, "**Architectures for the Future Networks and the Next Generation Internet: A Survey**," WUSTL Technical Report, WUCSE-2009-69, October 2, 2009, 59 pp., http://www.cse.wustl.edu/~jain/papers/i3survey.htm



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