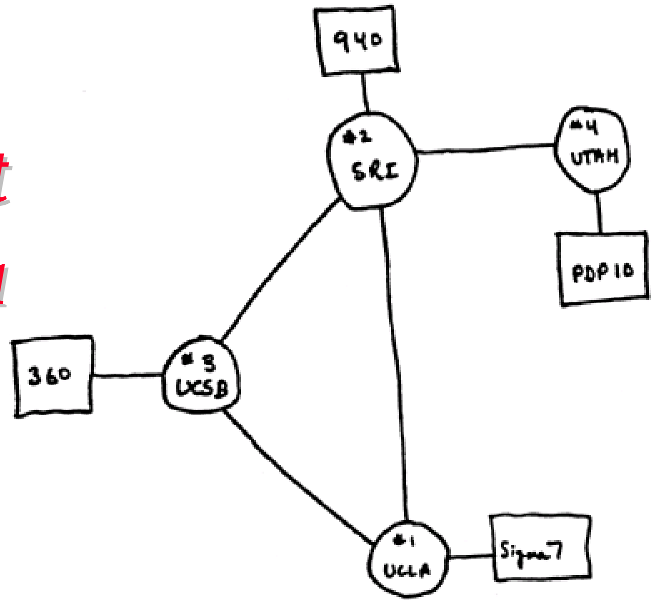
Internet 3.0:

Ten Problems with Current Internet Architecture and a Proposal for the Next Generation



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These slides are available on-line at:

http://www.cse.wustl.edu/~jain/talks/in3_ms.htm

1. What is Internet 3.0?
2. Why should you keep on the top of Internet 3.0?
3. What are we missing in the current Internet?
4. Our Proposed Architecture for Internet 3.0: GINA

What is Internet 3.0?

- Internet 3.0 is the architecture of the next generation of Internet
- Named by me along the lines of "Web 2.0"
- National Science Foundation is planning a $300M+ research and infrastructure program on next generation Internet
  - Testbed: "Global Environment for Networking Innovations" (GENI)
  - Architecture: "Future Internet Design" (FIND).
- Internet 3.0 is more intuitive then GENI/FIND
- Most of the networking researchers will be working on GENI/FIND for the coming years
- Q: How would you design Internet today? Clean slate design.
- Ref: http://www.nsf.gov/cise/geni/

Web 2.0

Buy the bubble: Fortune's Web 2.0 investment guide

2005 Venture Capital Web 2.0 investment statistics: US entrepreneurs raise ten times more than Europe

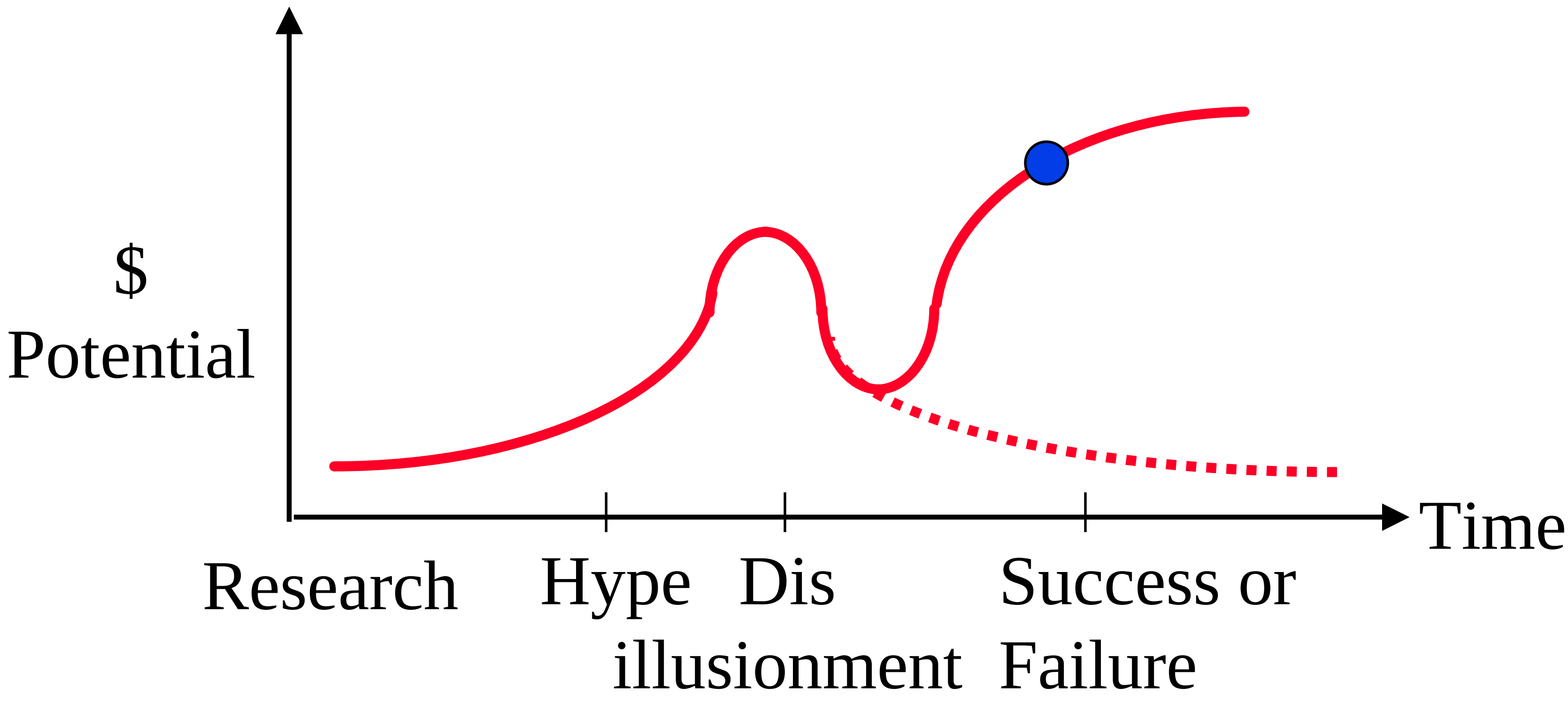
Web 1.0	**Web 2.0**
Publisher generated content	User generated content
Personal web sites	Blogs
Content Mgmt Systems	Wikis
Directories	Tagging

- Ref: http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html

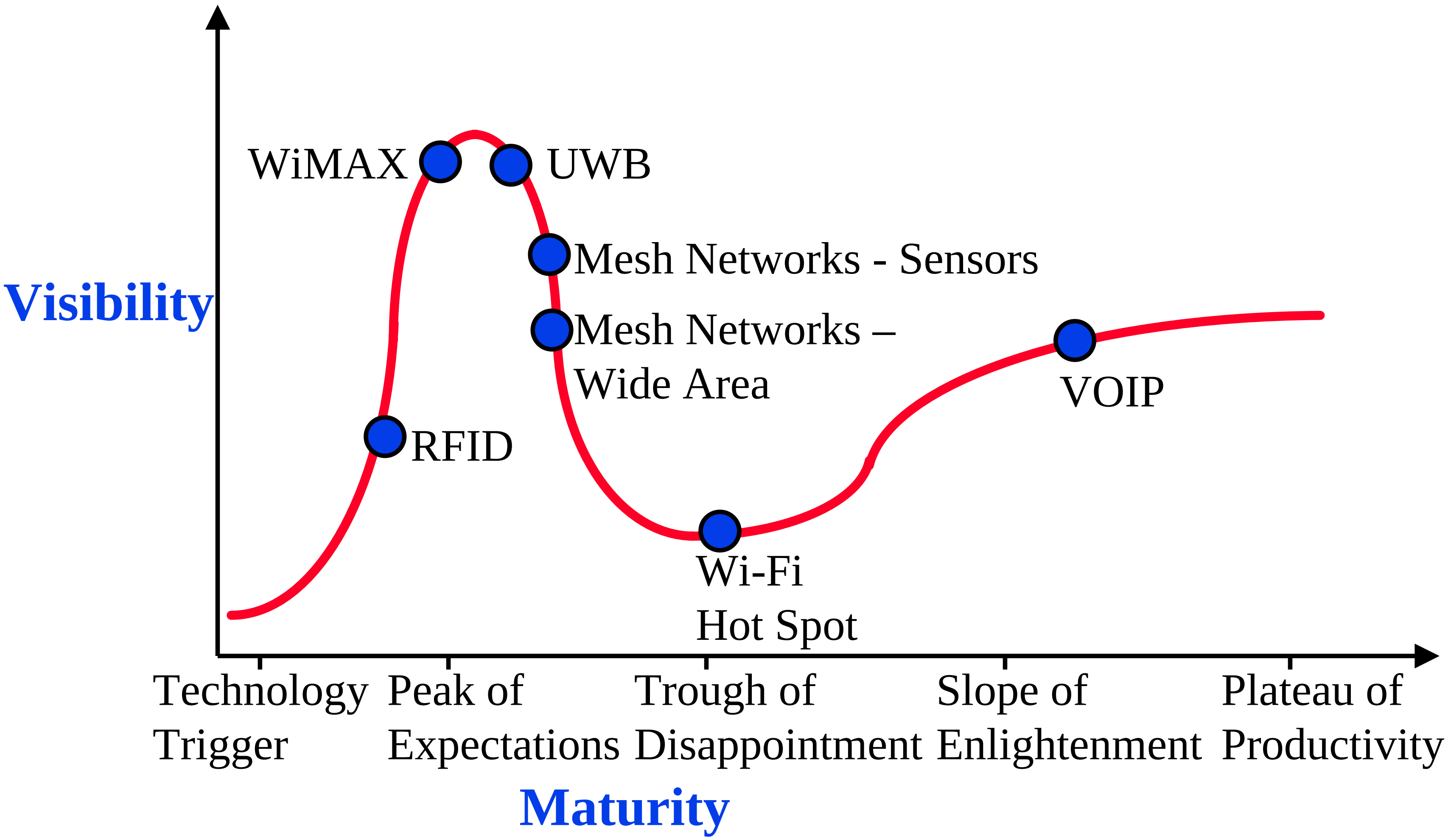
Why to worry about Internet 3.0?

Billion dollar question!

Life Cycles of Technologies

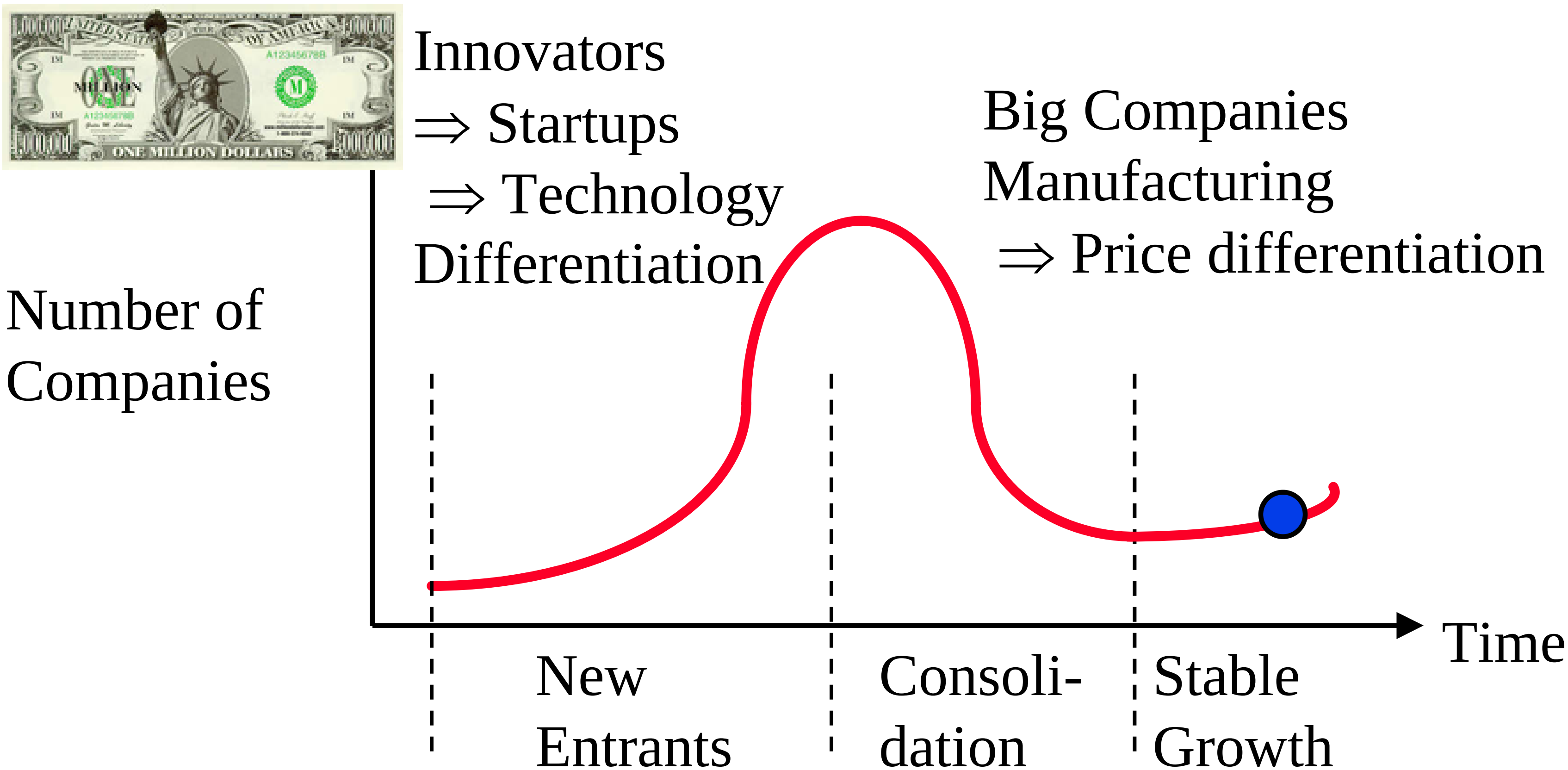


Networking Hype Cycle 2004



Based on Gartner Research (July 2004)

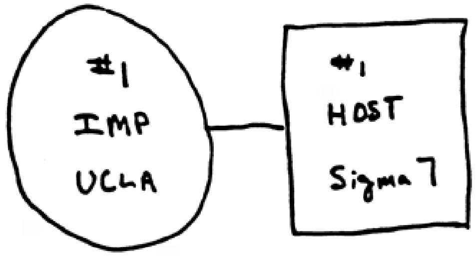
Industry Growth: Formula for Success



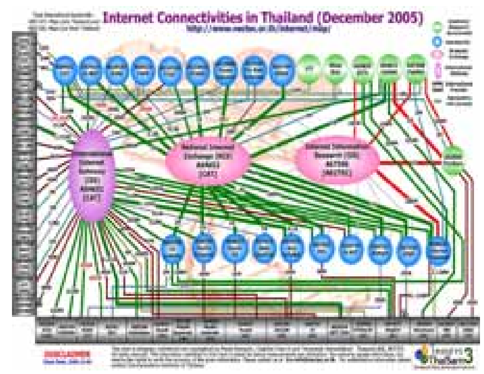
- **10-20-70 Formula**: 10% of R&D on distant future, 20% on near future, 70% on today's products

Internet Generations

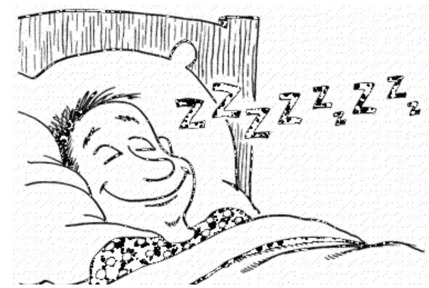
- **Internet 1.0** (1969 – 1989) – Research project
  - RFC1 is dated April 1969.
  - ARPA project started a few years earlier
  - IP, TCP, UDP
  - Mostly researchers
  - Industry was busy with proprietary protocols: SNA, DECnet, AppleTalk, XNS



- **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,…



Ten Problems with Current Internet



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

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

3. Location independent addressing
   ⇒ Most services require nearest server.
   ⇒ Also, Mobility requires location

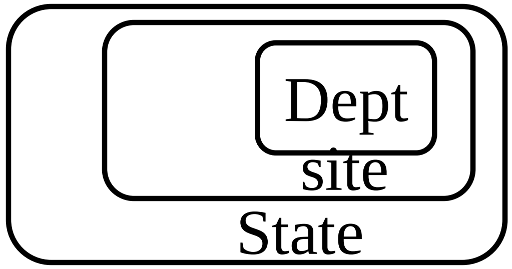
4. Single-Computer to single-computer communication ⇒ Numerous patches needed for communication with globally distributed systems.

Problems (cont)

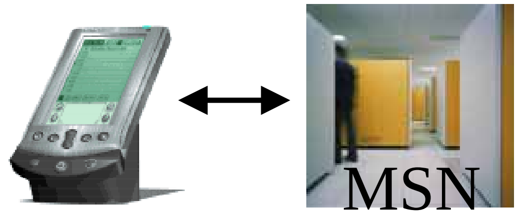
5. No representation for real end system: the human.

6. Designed for research
   ⇒ Trusted systems
   Used for Commerce
   ⇒ Untrusted systems
7. Control, management, and Data path are intermixed ⇒ security issues

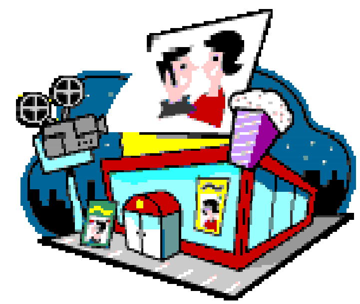
Problems (cont)



8. Difficult to represent organizational, administrative hierarchies and relationships
9. Symmetric Protocols
   ⇒ No difference between a PDA and a Microsoft.com server.



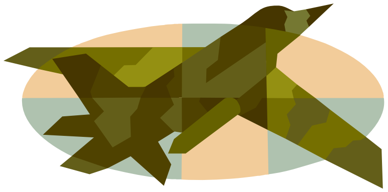
10. Stateless ⇒ Can't remember a flow ⇒ QoS difficult.
    QoS is generally for a flow and not for one packet



Our Proposed Solution: GINA

- **Generalized Inter-Networking Architecture**
- Take the best of what is already known
  - Wireless Networks, Optical networks, …
  - Transport systems: Airplane, automobile, …
  - Communication systems: Wired Phone networks, Cellular networks,…
- Develop a consistent general purpose, evolvable architecture that can be customized by implementers, service providers, and users



GINA: Overview

Generalized Internet Networking Architecture

1. Separates address and ID $\Rightarrow$ Allows mobility
2. Distinguishes *logical* and *physical* connectivity
3. Hybrid (Packet and stream based) communication
   $\Rightarrow$ Allows strict real time constraints
4. Delegation to servers
   $\Rightarrow$ Allows energy conservation and simple devices
5. Control and data path separation $\Rightarrow$ Allows non-packet based (e.g., power grid, wavelength routers, SONET routers) along with packet based data. The control is pure packet based.
6. Service based IDs = Distributed servers
   Allows mxn cast.

Names, IDs, Addresses

Name: John Smith

ID: 012-34-5678

Address:
1234 Main Street
Big City, MO 12345
USA

- Address 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
  - Addresses: Wired phone numbers, IP addresses

Objects in GINA

- Object = Addressable Entity
- Current: End-Systems and Intermediate Systems
- GINA:
  - Computers, Routers/Firewalls….
  - Networks
  - Humans
  - Companies, Departments, Cities, States, Countries, Power grids
  - Process in a computer
  - Recursive ⇒ Set of Objects is also one object, e.g., Networks of Networks

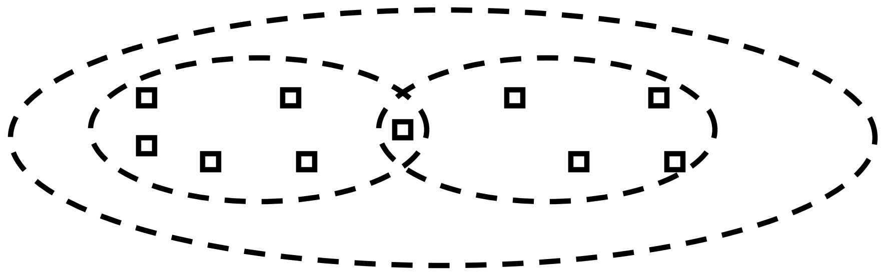
You can connect to a human, organization, or a department

Names, Ids, Addresses, and Keys

- Each Object has:
  - Name**s**: ASCII strings for human use
  - ID**s**: Numeric string for computer use
  - Addresse**s**: where the Object is located
    - Home Address, Current Address
  - Keys: Public, Private, Secret
  - Other attributes, Computer Power, Storage capacity
- Each object has one or more IDs, zero or more names, one or more addresses and zero or more other attributes

You connect to an ID not an address ⇒ Allows Mobility

Realms

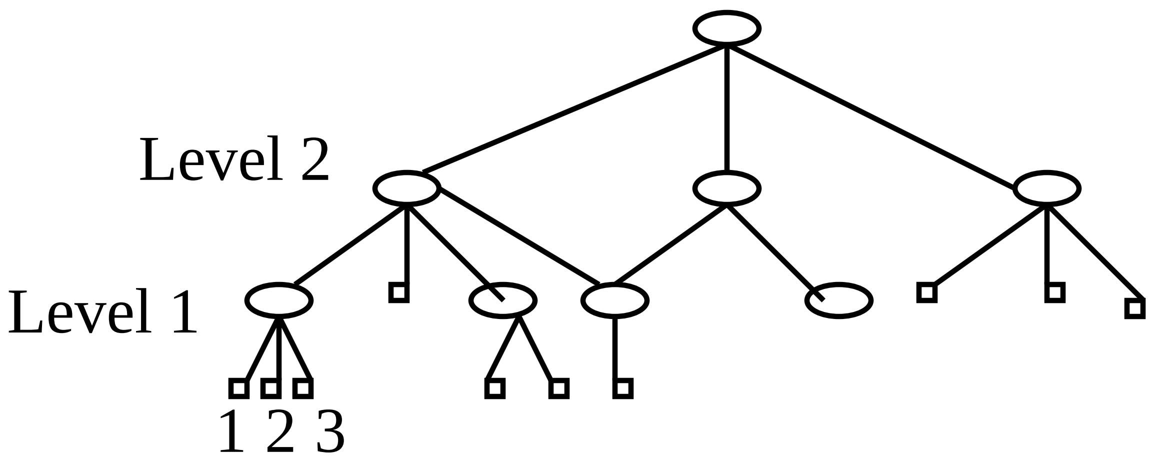


- Object names and Ids are defined within a realm
- A realm is a **logical** grouping of objects that have a certain level of **trust**
- Objects inside the realms communicate with each other at a higher level of trust than with objects outside the realms
- Objects can be and generally are members of multiple realms
- Realm managers set policies for packets crossing the realm boundaries
- Realms can be treated as single object and have names, Ids, addresses.
- Realms are recursive ⇒ A group of realms = one realm
- Boundaries: Organizational, Technological, Governmental, ISP

Realm = Organization

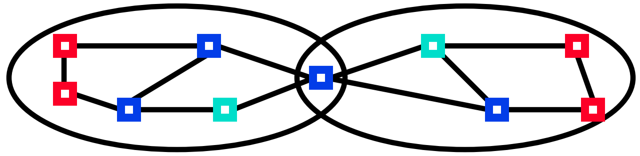
Hierarchy of IDs

- Universe is organized as a hierarchy of realms
- Each realm has a set of parents and a set of children
- Parent Ids can be prefixed to realm ids
- A child may have multiple parents ⇒ Hierarchy is not a tree
- Any path to the root of a level gives the ID for the object at that level, e.g., level2_id.level1_id…object_id = level2 id of object



Realm Hierarchy = Organizational Structure

Object Addresses



- Address of an object indicates its ***physical attachment point***
- Networks are organized as a set of ***zones***
- Object address in the current zone is sufficient to reach it inside that zone
- Zones are **physical** grouping of objects based on connectivity. Does not imply trust.
- Each object registers its names, addresses, IDs, and attributes with the registry of the relevant realms and zones
- Zones are objects and have Ids, realms, addresses too
- An object's address at higher level zones is obtained by prefixing it with of addresses of ancestor zones

Zonal Hierarchy = Network Structure

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

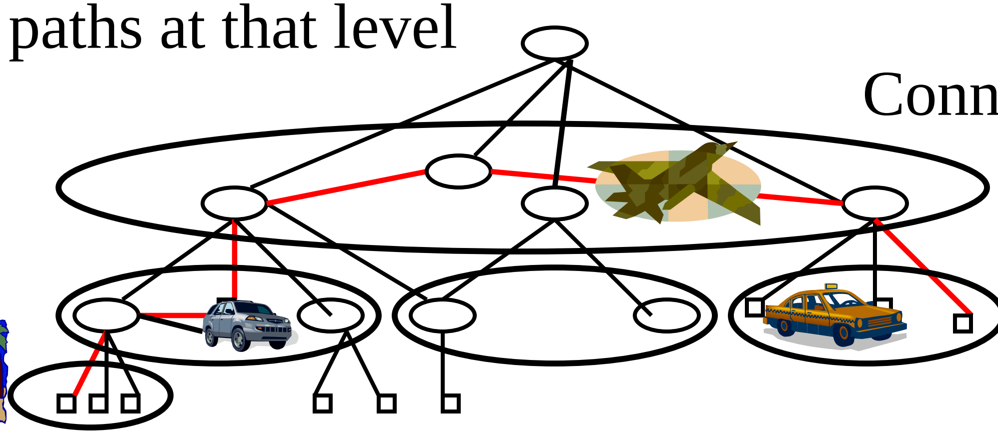
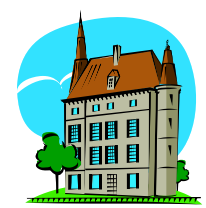
Physical connectivity ≠ Trust

Routing

- Based on physical connectivity with logical constraints
- Routing organized as paths through several levels of hierarchy
- At each level packets follow an optimal path from the entry point to that level to exit point in that zone
- Routing table exchanges at each level are used to find the optimal paths at that level

Connectivity Graph



Highly scalable hierarchical routing

Server Objects

- Each realm has a set of server objects, e.g., forwarding, authentication, encryption, storage, transformation, …
- 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

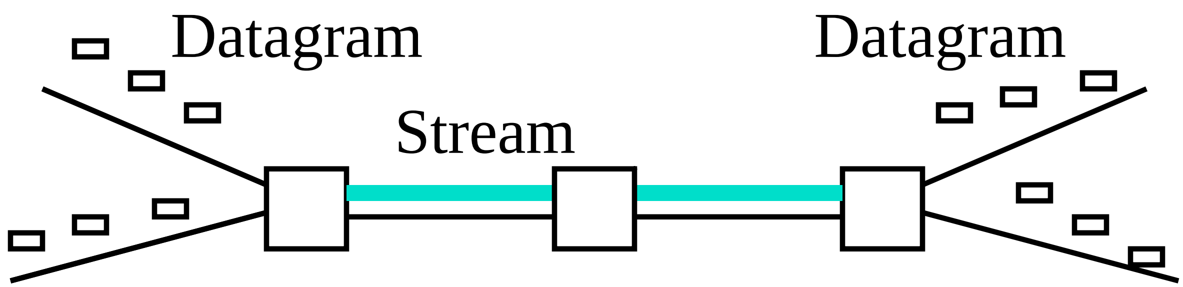
Packet Headers

- You have to know the name of the destination to be able to communicate with it.
- The destination name has to be up to the level where you have a common ancestor.
- The names can be translated to the ID of the destination by using registries at appropriate levels
- The packets contain either Ids or addresses of the destination
- Current level Ids are translated to address

Packets contain IDs $\Rightarrow$ Network handles mobility

Packet and Circuit Switching

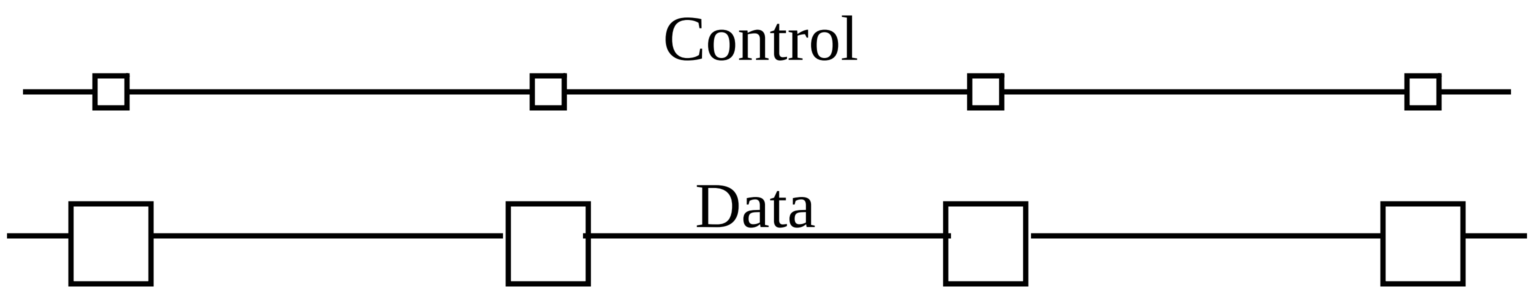
- Packets are good for sharing. Circuits are good for isolation.
- Critical applications need isolation ⇒ Use separate networks.
- When Internet 1.0 was designed, the circuit was the competition.
- Latest wireless networks, e.g., WiMAX offers both circuits and packets
- GINA offers both packet and circuit switching with intermediate granularities of multigrams and streams.



Packets, **multigrams**, flows, streams ⇒ Multiple levels of isolation

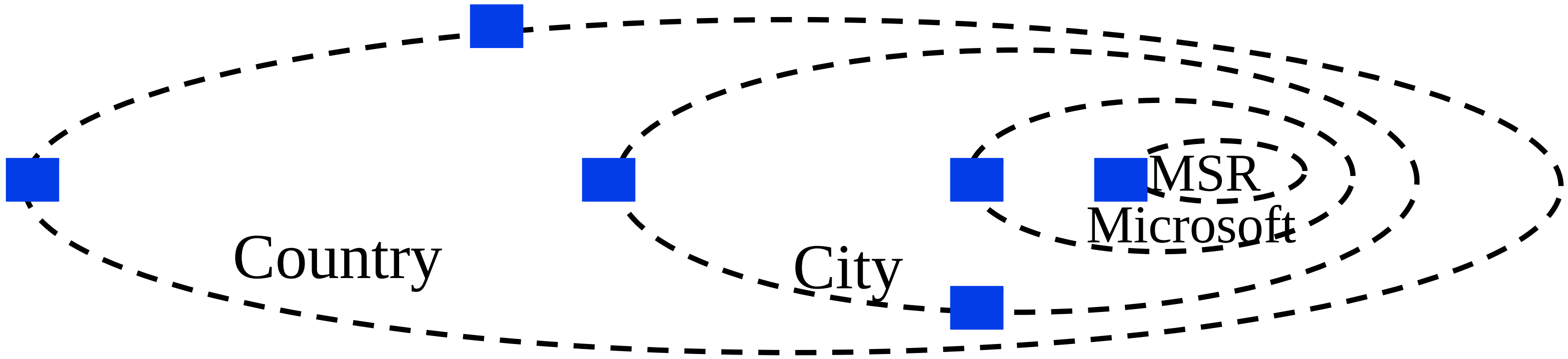
Control and Data Plane Separation

- Streams use control channel and data channel that may have separate paths
- Data plane can be packets, wavelengths, power grids,…



Separate planes ⇒ Generalized switching and Security

Security



- Multi-level architecture. Gatekeepers on the entrance
- Authentication checked on entry to **realm**. Not at every router.
- Authentication at multiple levels: country, city, home.
- Group Authentication: n-packets can be authenticated by one authentication
- Personal introductions (certificates)
- VPN and firewalls are part of the **logical** architecture

Organizational control of security

Gatekeepers

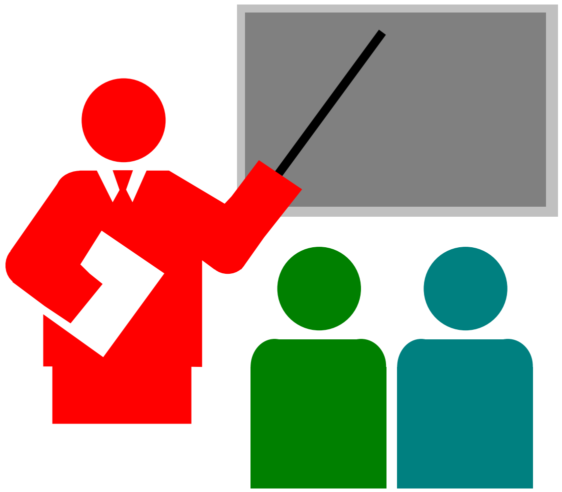
- Gatekeepers also enforce policies and do policing (Monitor bandwidth, type of traffic, contents)
- Add authentication headers
(country, city, home, level)
- All services do not have to reside in each gatekeeper.
- Gatekeepers may also delegate services to other servers

Organizational control of all policies

Internet 1.0 vs. Internet 3.0

	Feature	Internet 1.0	Internet 3.0
1.	Energy Efficiency	Always-on	Green $\Rightarrow$ Mostly Off
2.	Mobility	Mostly stationary computers	Mostly mobile *objects*
3.	Computer-Human Relationship	Multi-user systems $\Rightarrow$ Machine to machine comm.	Multi-systems user $\Rightarrow$ Personal comm. systems
4.	End Systems	Single computers	Globally distributed systems
5.	Protocol Symmetry	Communication between equals $\Rightarrow$ Symmetric	Unequal: PDA vs. big server $\Rightarrow$ Asymmetric
6.	Design Goal	Research $\Rightarrow$ Trusted Systems	Commerce $\Rightarrow$ No Trust Map to organizational structure
7.	Ownership	No concept of ownership	Hierarchy of ownerships, administrations, communities
8.	Sharing	Sharing $\Rightarrow$ Interference, QoS Issues	Sharing *and* Isolation $\Rightarrow$ Critical infrastructure
9.	Switching units	Packets	Packets, Circuits, Wavelengths, Electrical Power Lines, …
10.	Applications	Email and Telnet	Information Retrieval, Distributed Computing, Distributed Storage, Data diffusion

Summary



1. Internet 3.0 is the next generation of Internet.
2. It must be green (energy efficient), secure, allow mobility.
3. Must be designed for commerce.
4. Active industry involvement in the design essential. Leading networking companies must actively participate.
5. Our proposal Generalized InterNet Architecture (GINA) addresses many issues.

Thank You!


Hvala
Grazie
धन्यवाद
Bedankt
Teşekkürler
Díky
Köszönettel
ขอบคุณ
شكراً
Ευχαριστώ
Merci
Gracias
Obrigado!
Vielen Dank
תודה