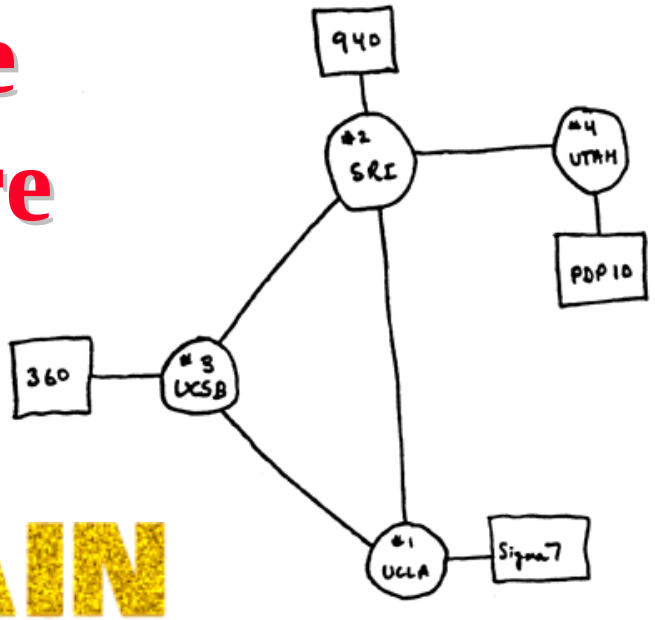
Internet 3.0: Future Internet Architecture



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These slides and Audio recordings of this talk are at:
http://www.cse.wustl.edu/~jain/talks/in3_nsf.htm

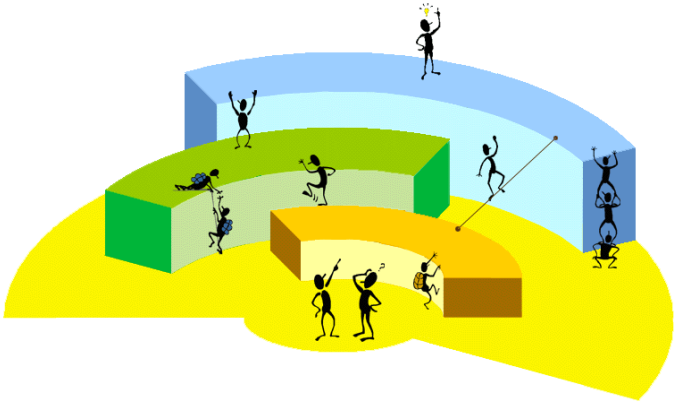
Overview

1. Internet 3.0: Key goals
2. Policy Based Networking Architecture
3. User- Host- and Data Centric Models
4. Multi-Tier Object-Oriented View
5. Future Network Design Principles

Ack: This research was funded by grants from Intel Corporation

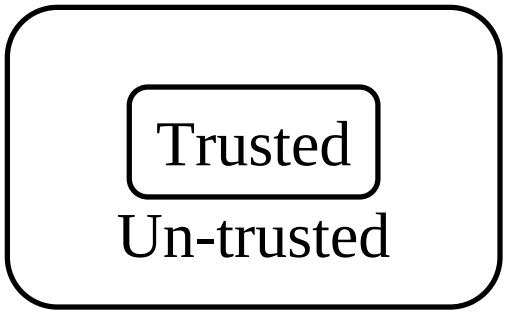
Internet 3.0:Future Internet Architecture

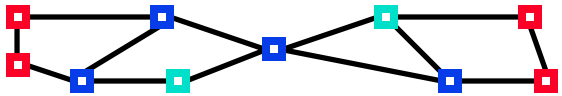
- Goal 1: Develop a *clean slate architecture* to overcome limitations of the current internet
- Goal 2: Represent the commercial reality of distributed Internet ownership and organization
- Goal 3: Develop an *incremental approach* to implement the architecture



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

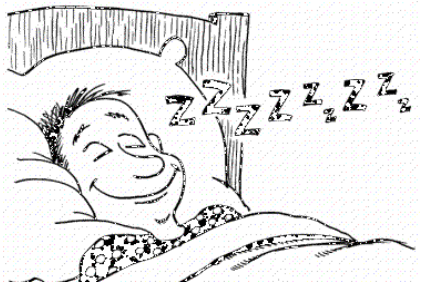




Realms

Problems (cont)

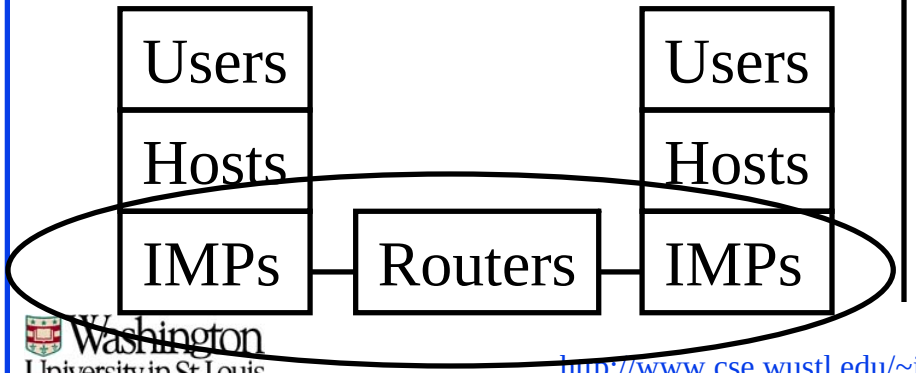
3. Assumes live and awake end-systems
   Does not allow communication while sleeping.
   Many energy conscious systems today sleep.
4. No representation for real end system: the human.



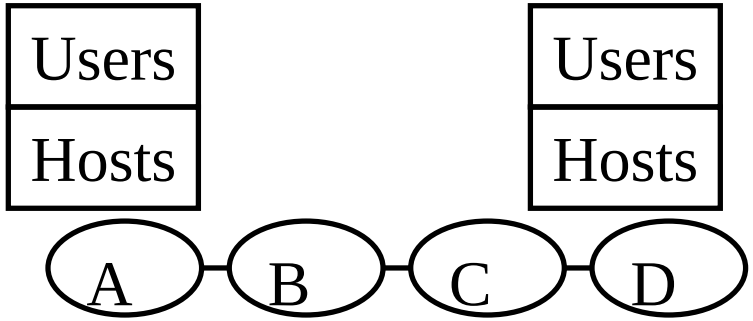
Ref: Our Milcom 2006 paper

Internet Generations

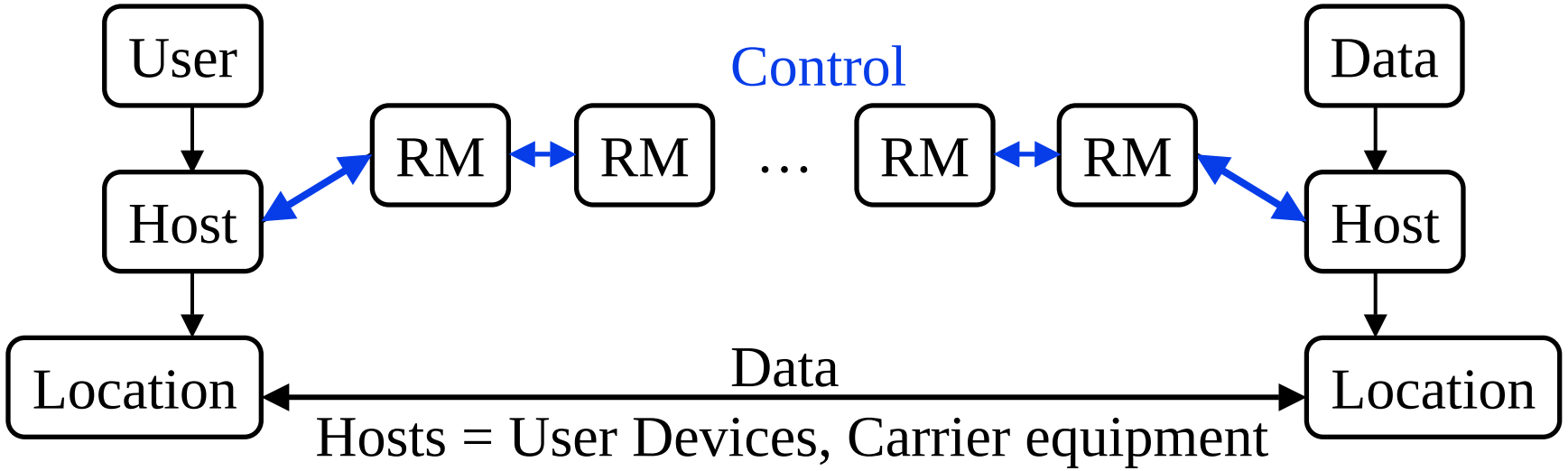
- **Internet 1.0** (1969 – 1989)
  - Research project
  - Single ownership
    ⇒ Logical Trust
  - Assumes complete knowledge of the topology and resources
  - Algorithmic optimality
    ⇒ RIP



- **Internet 2.0** (1989 – 2009)
  - Commercial Use
  - Multiple ownership
    ⇒ Distrust
  - No knowledge of Other organizations' internal topology and resources
  - ***Policy based*** routing
    ⇒ BGP



1. Policy Based Networking Architecture



Realm managers (RM): Many organizational functions

- Resolve current location for a given host-ID
- Enforce policies related to authentication, authorization, privacy
- Allow **mobility**, multi-homing, location privacy

2. Intelligence in the network ⇒ Suitable for the masses

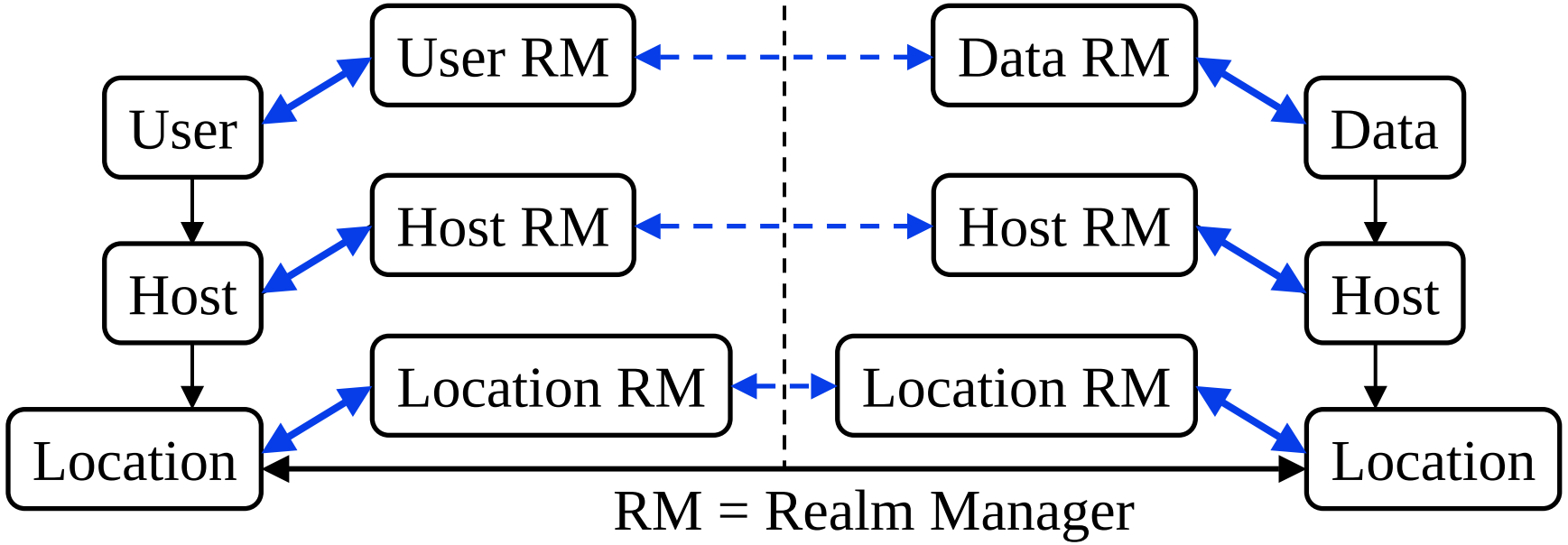
- Ref: Our Globecom 2008 paper [2]

3. 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
- Host organization may be different from user organization and both may be different from network organization

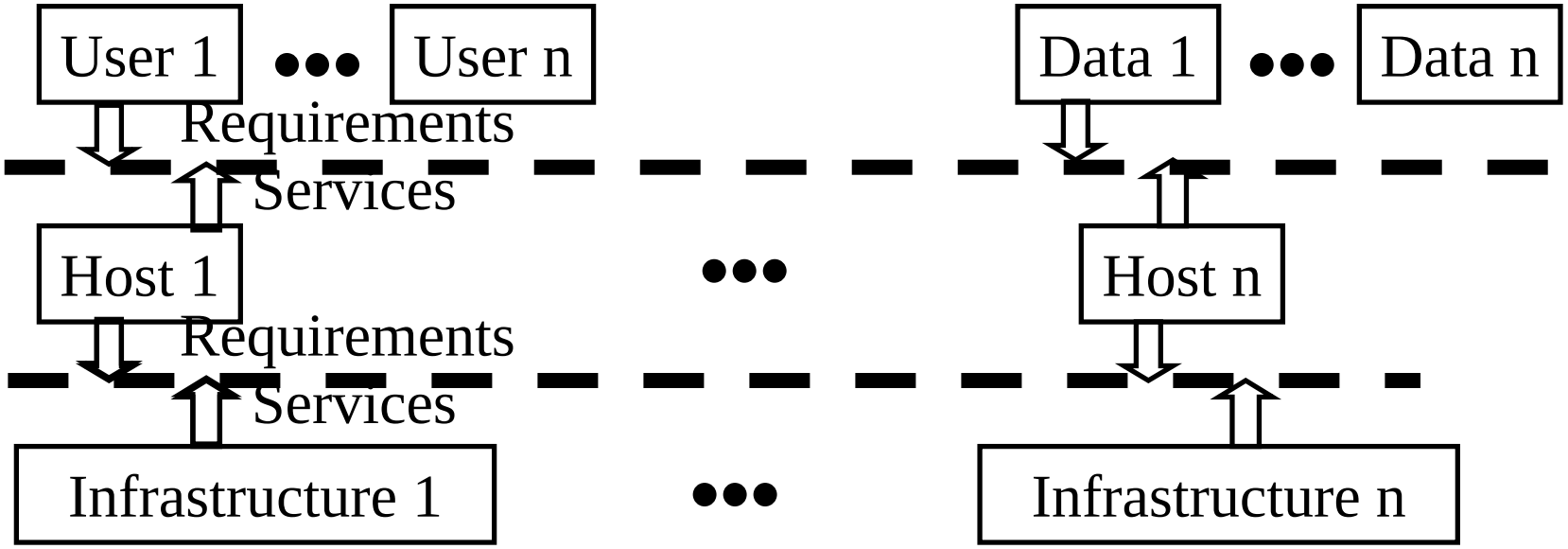
  $\Rightarrow$ Multi-Tier Ownership

4. Multi-Tier Policy Based Architecture



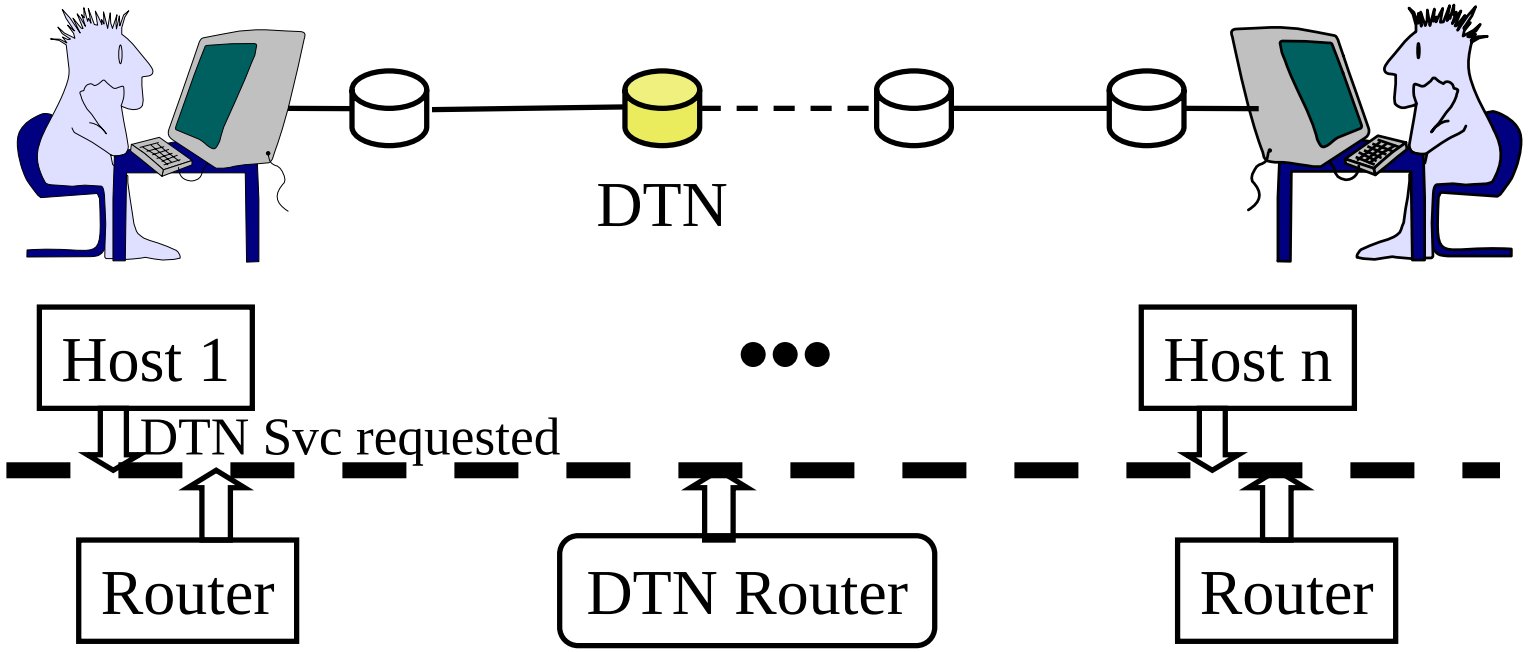
- Both Users and data need hosts for communication
- Data is easily replicable/divisible. All copies are equally good.
- Users, Hosts, Infrastructure, Data belong to different realms (organizations).
- Each object has to follow its organizational policies.

5. Multi-Tier Object-Oriented View



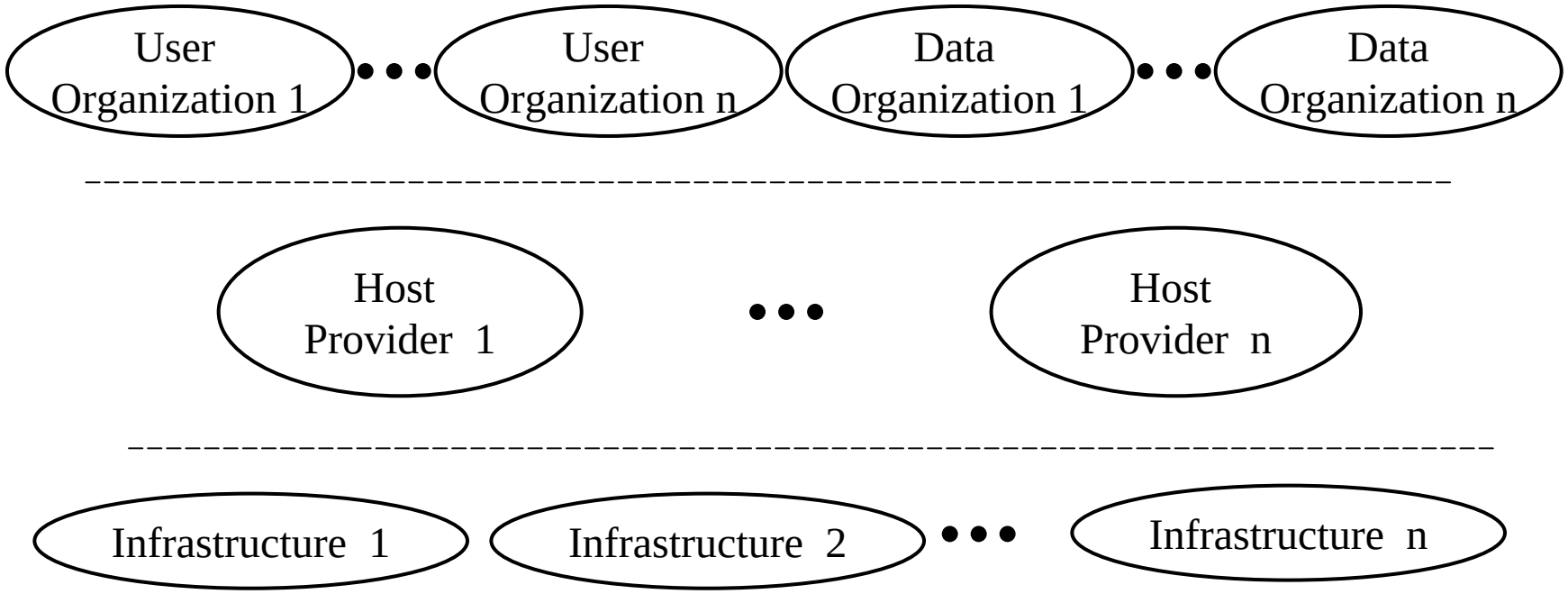
- Objects provide services. Higher tiers specify the requirements
- Tier service broker (shown by dotted line) composes a service – can negotiate with multiple realms in that tier
- Allows creating "*requirement specific networking contexts*" ⇒ **Application based networking**
- **Multi-Tier Mobility, multi-homing, virtualization**

Disruption Tolerant Network (DTN)



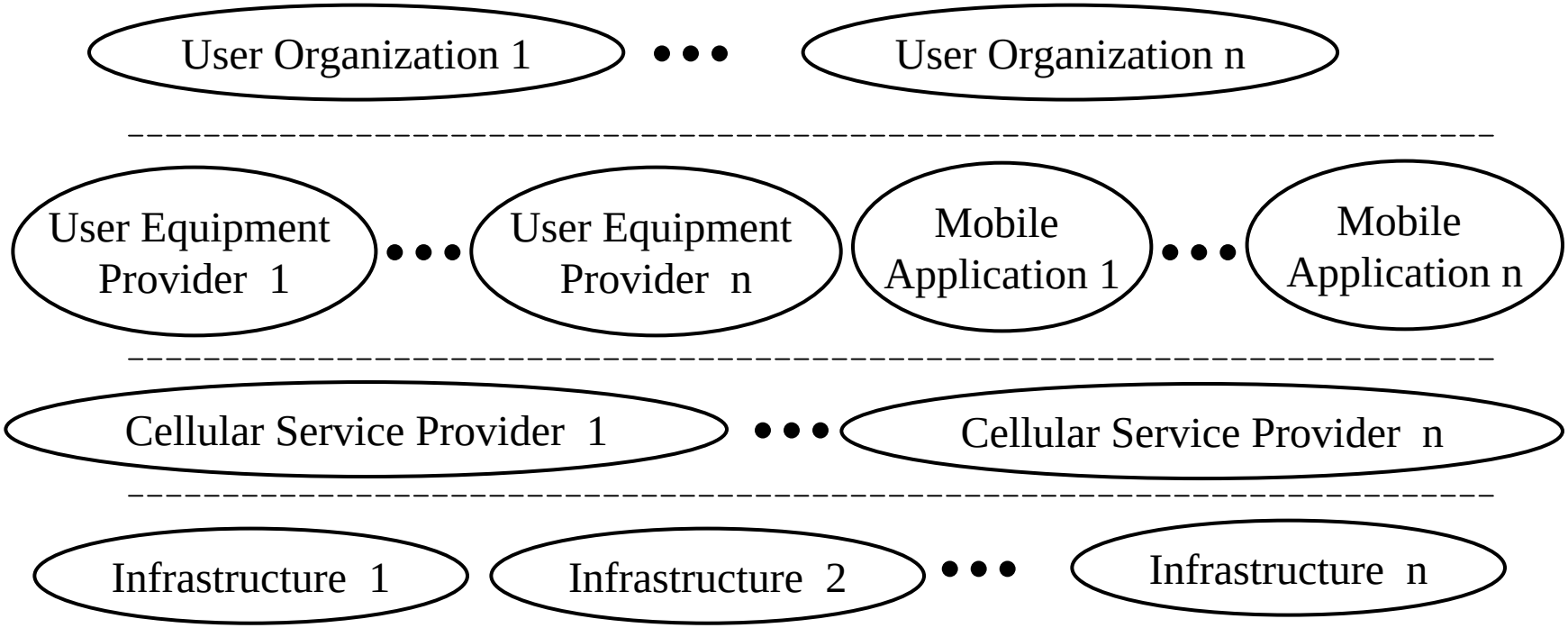
- Normally all routers on the end-to-end path should be up
- DTN-aware routers store data until it can be forwarded
- In Internet 3.0, DTN service can be advertised by DTN routers and negotiated by the service broker

Cloud Computing



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

Tiers of Cellular Networks



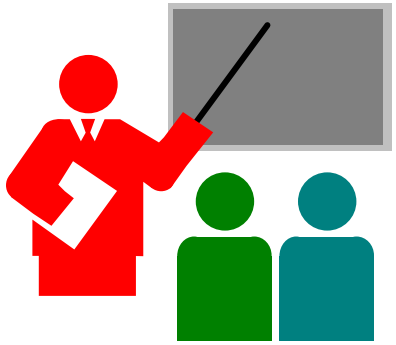
Internet 1.0 vs. Internet 3.0: Features

	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	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. Future Internet must be designed for commerce
   ⇒ Must represent organizational structure and policies
2. Different ownership/policies of users, hosts, infrastructure
   ⇒ Multi-tier, policy-based object-oriented architecture
3. Service broker architecture ⇒ Application based networking
4. Organizational services include mobility, multi-homing, …
5. Intelligence in the network ⇒ Usable by masses

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