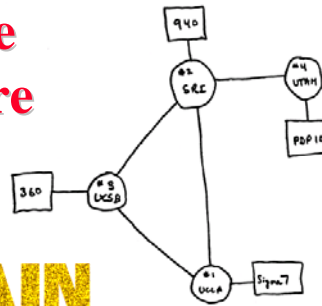


# Internet 3.0: Future Internet Architecture



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These slides and Audio recordings of this talk are at:

[http://www.cse.wustl.edu/~jain/talks/in3\\_nsf.htm](http://www.cse.wustl.edu/~jain/talks/in3_nsf.htm)



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

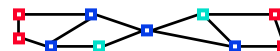
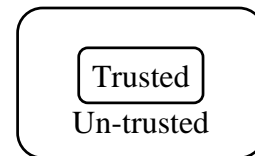
## Internet 3.0: Future Internet Architecture

- 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.  
⇒ 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.

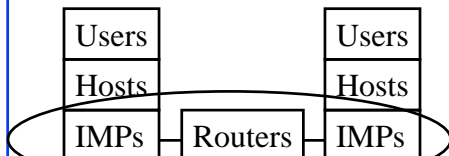


Ref: Our Milcom 2006 paper

## Internet Generations

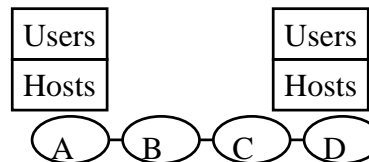
### Internet 1.0 (1969 – 1989)

- Research project
- Single ownership  
⇒ Logical Trust
- Assumes complete knowledge of the topology and resources
- Algorithmic optimality  
⇒ RIP

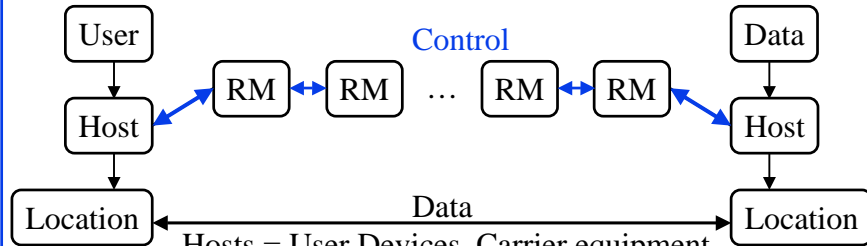


### Internet 2.0 (1989 – 2009)

- 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

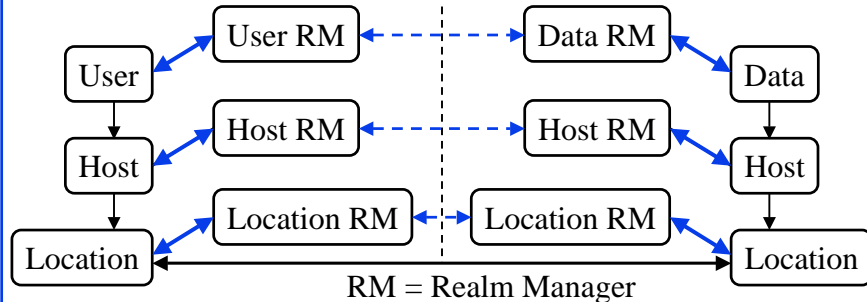
- ❑ Ref: Our Globecom 2008 paper [2]

## 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
  - ⇒ Multi-Tier Ownership

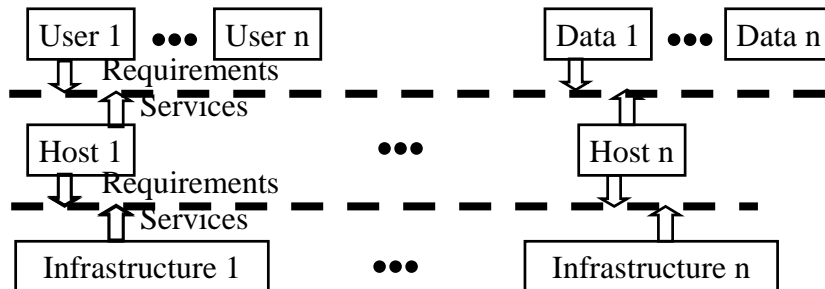


## 4. Multi-Tier Policy Based Architecture



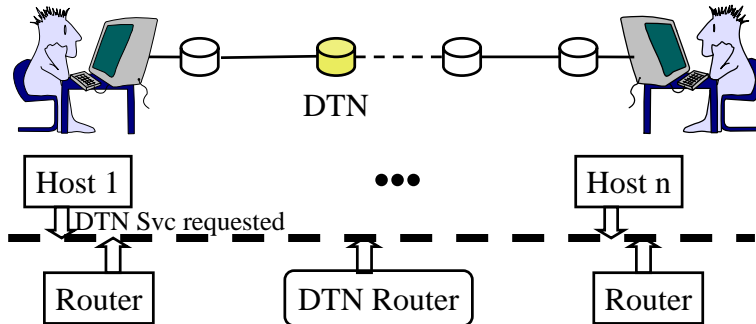
- ❑ Both Users and data need hosts for communication
- ❑ Data is easily replicable/divisible. All copies are equally good.
- ❑ Users, Hosts, Infrastructure, Data belong to different realms (organizations).
- ❑ Each object has to follow its organizational policies.

## 5. Multi-Tier Object-Oriented View



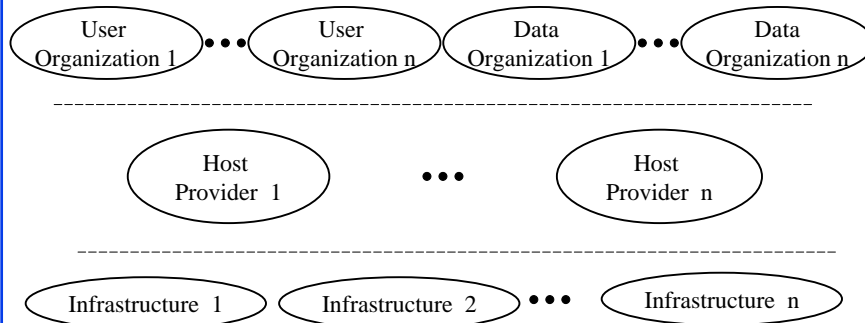
- ❑ Objects provide services. Higher tiers specify the requirements
- ❑ Tier service broker (shown by dotted line) composes a service – can negotiate with multiple realms in that tier
- ❑ Allows creating “*requirement specific networking contexts*”  
⇒ **Application based networking**
- ❑ **Multi-Tier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

## Disruption Tolerant Network (DTN)



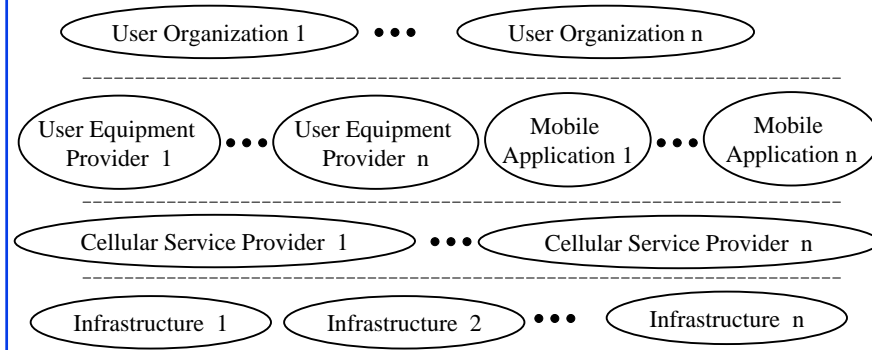
- ❑ Normally all routers on the end-to-end path should be up
- ❑ DTN-aware routers store data until it can be forwarded
- ❑ In Internet 3.0, DTN service can be advertised by DTN routers and negotiated by the service broker

## 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


	<b>Feature</b>	<b>Internet 1.0</b>	<b>Internet 3.0</b>
1.	Energy Efficiency	Always-on	Energy aware
2.	Mobility	Mostly stationary computers	Mostly mobile <i>objects</i>
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

<b>Internet 1.0 vs. Internet 3.0: Design</b>			
	<b>Design Issue</b>	<b>Internet 1.0 Solution</b>	<b>Internet 3.0 Solution</b>
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



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## 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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