Next Generation Internet and Wireless and Mobile Networking Research at Washington University

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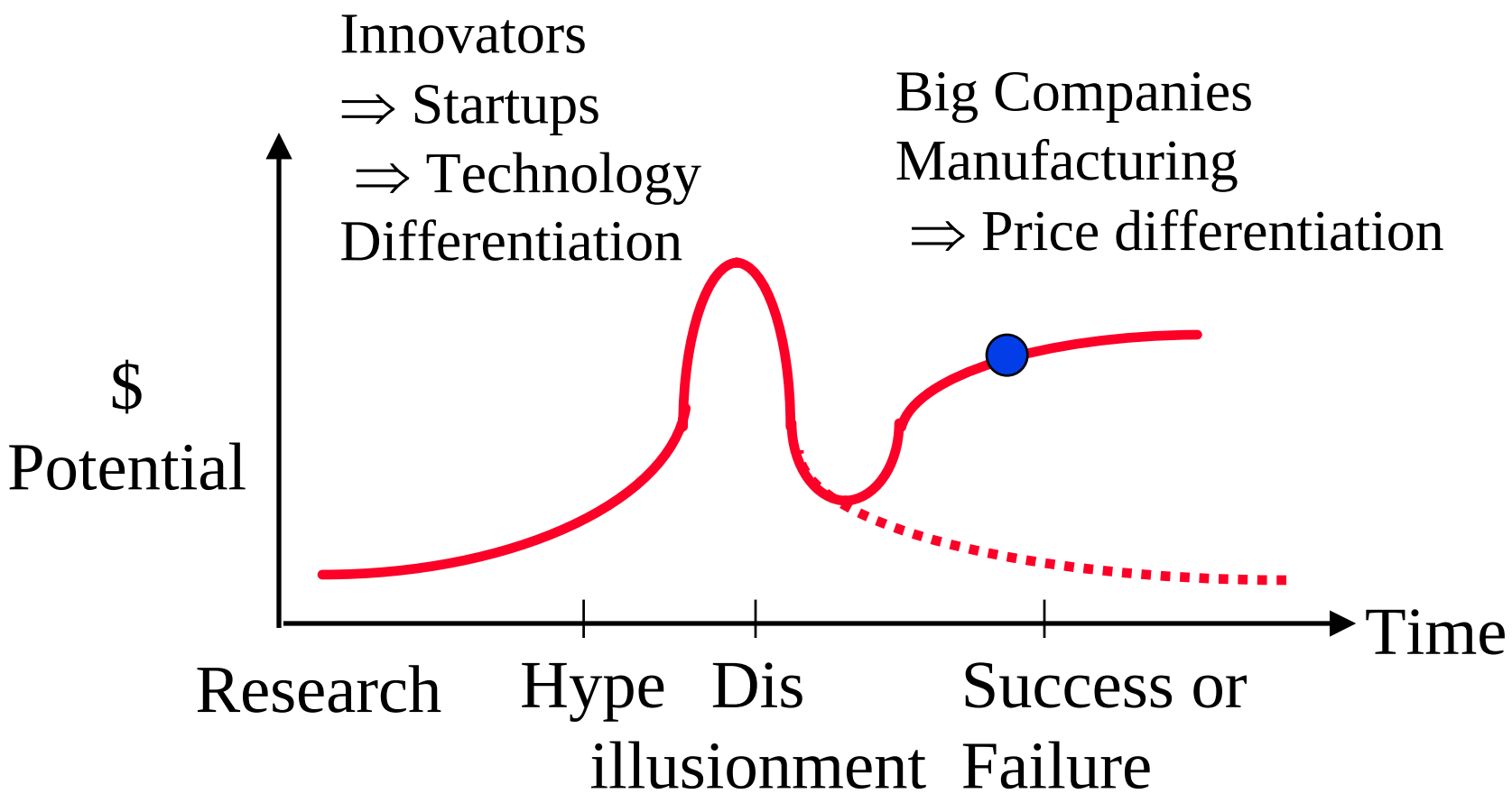
These slides are available on-line at:

http://www.cse.wustl.edu/~jain/talks/cs59108.htm

Overview

1. Life Cycles of Technologies
2. Problems with Current Internet
3. Our solution for the next generation: Internet 3.0
4. High-Speed Metro-wide wireless networking
5. Related networking research and courses

Life Cycles of Technologies



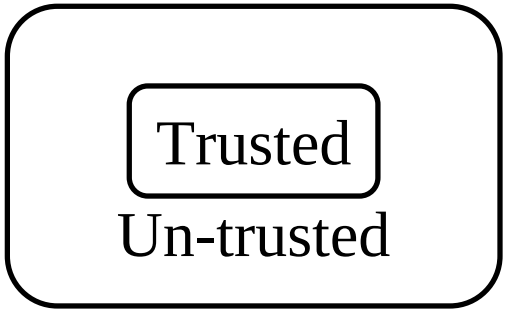
Internet 3.0

- National Science Foundation has been working on a large research and infrastructure program on next generation Internet
  - Testbed: "Global Environment for Networking Innovations" (GENI)
  - Architecture: "Future Internet Design" (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/cns/geni/
- Similar programs by research agencies in Europe, Japan, …
- Internet 3.0 is our project on the next generation of Internet
- Named by me along the lines of "Web 2.0"
- Internet 3.0 is more intuitive then GENI/FIND

Ten Problems with Current Internet

1. Security:
   Designed for research
   ⇒ Trusted systems
   Used for Commerce
   ⇒ Untrusted systems

2. Difficult to represent organizational, administrative hierarchies and relationships.
   Perimeter based.

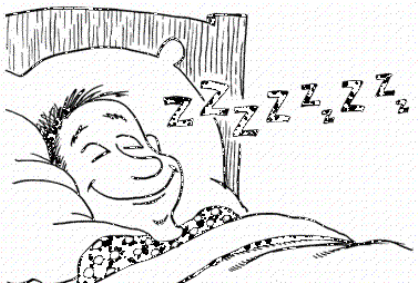


Problems (cont)

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

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

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



Ref: Our Milcom 2006 paper [1]

Names, IDs, Addresses

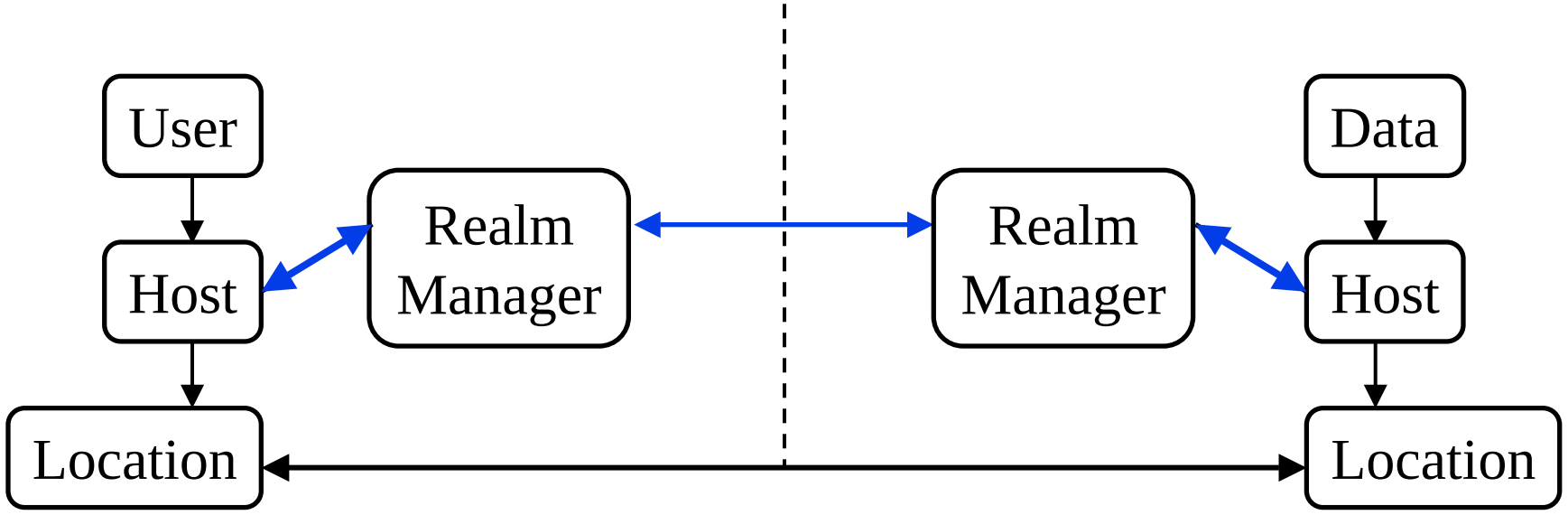
Name: John Smith

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

Id-Locator Split Architecture (MILSA)

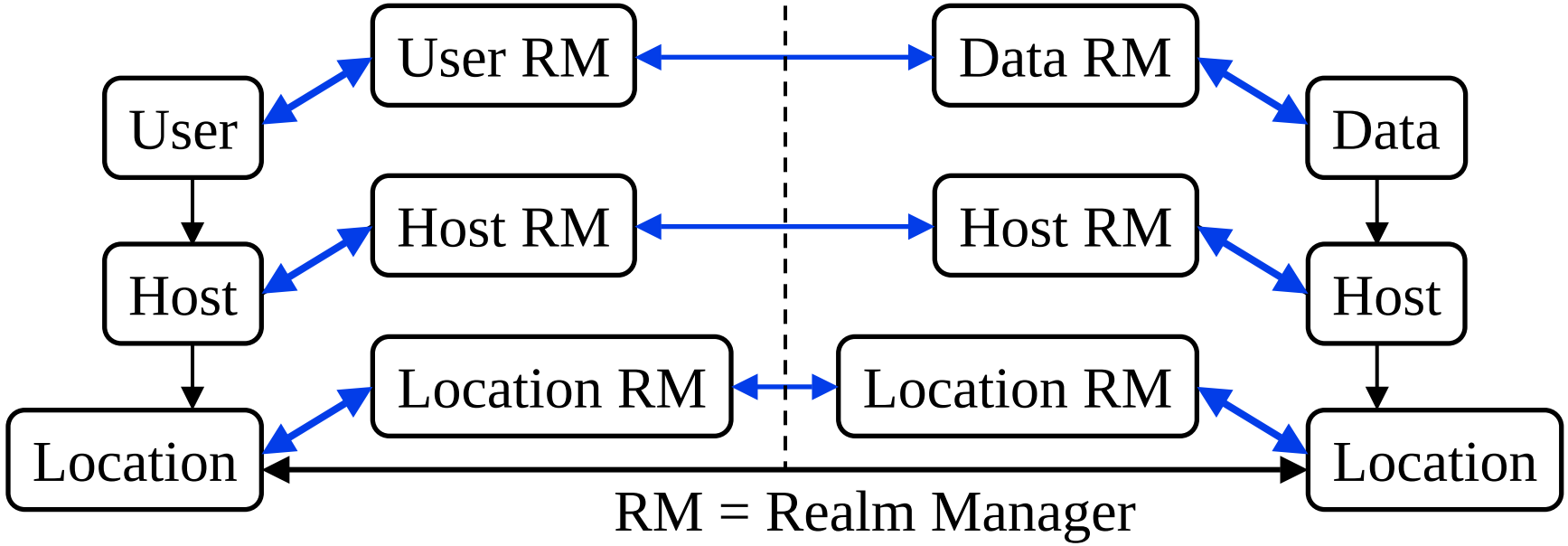


- Realm = An administrative domain
- Realm managers:
  - Resolve current location for a given host-ID
  - Allow mobility, multi-homing, location privacy
  - Enforce policies: authentication, authorization, privacy
- Ref: Our Globecom 2008 paper [2]

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 iPod 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 addresses 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) ⇒ 3-Tier virtualization
- Ref: Our PONA paper [3]

RANGI

- Routing Architecture for Next Generation Internet
- Applying Internet 3.0 ideas to current Internet
  - Most routers are still IPv4 (32 bit addresses: 128.32.56.189)
  - Border routers may use IPv6 (128 bit addresses)
- Use 128 bit IDs ⇒ Look like IPv6 addresses
  Applications and TCP bind to 128-bit IDs.
- IPv6 packets encapsulated in IPv4 if necessary
  ⇒ Core routers can use IPv4 of IPv6
- Ref: Our contribution to Internet Research Task Force (IRTF)

Key Distinction of Our Research

- Research topic of current interest to Industry
- Funded by industry partners
- Impact real-world by participating in standards organizations and industry forums:
  ATM Forum, IEEE Standards, American National Standards Institute (ANSI), International Telecommunications Union (ITU), Internet Engineering Task Force (IETF), Internet Research Task Force (IRTF), WiMAX Forum
- Work on long term as well as short term research

Impact of Our Past Research

- Reducing load on timeout ⇒ Implemented in slow start in TCP
- DECbit allows routers to indicate congestion by a bit in the packet header ⇒ Implemented in almost all networking architectures since 1984
  - Forward Explicit Congestion Notification (FECN) bit in frame relay
  - Explicit Forward Congestion Indication (EFCI) bit in ATM cells
  - Explicit congestion notification (ECN) bits in every TCP/IP packet based on our DECbit research
- Explicit Rate based feedback for Available bit rate (ABR) service in ATM Networks
- In Citeseer's top 50 "most cited authors in Computer Science"

Recent Networking Developments

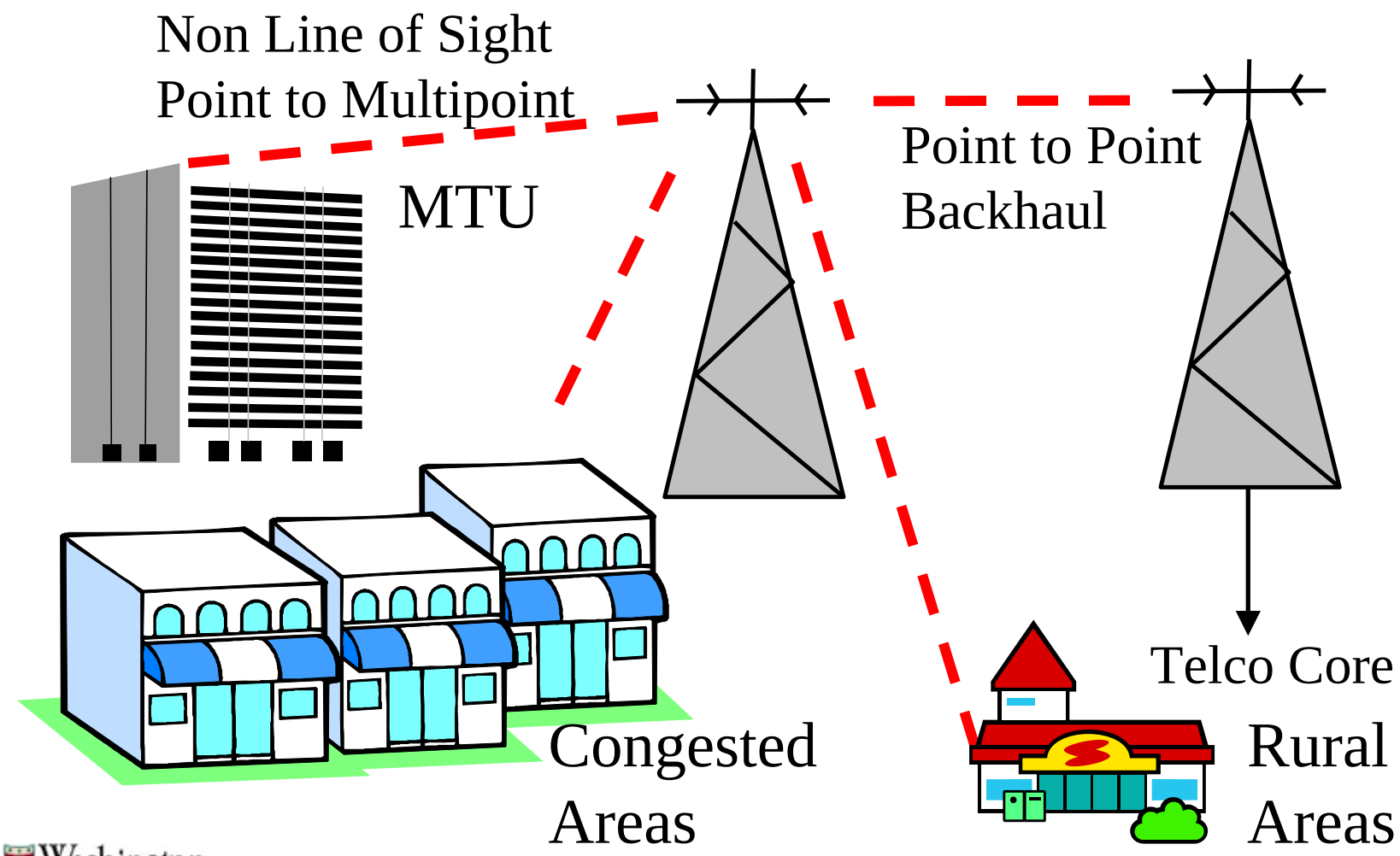
1. Wireless (WiFi) is ubiquitous (Intel Centrino)
2. More Cell phones than POTS.
   Ratio projected to be 4-to-1 by 2012.
3. Wiring more expensive than equipment
   $\Rightarrow$ Wireless Access
4. Smart Cell phones w PDA, email, video, images
   $\Rightarrow$ Mobility

Telecom Revenue

	Revenue in Billions						
	2003	2004	2005	2006	2007	2008	Annual Growth
Video	0.2	0.3	.05	1.0	1.6	2.5	65.7%
Consumer Broadband	2.8	3.5	4.0	4.2	4.6	4.8	11.4%
Consumer long distance	20.7	18.2	16.0	13.6	11.3	9.2	-15.0%
Business local	26.3	26.7	26.4	26.1	25.8	25.5	-0.6%
Business long distance	26.1	24.5	23.0	21.3	19.7	18.2	-7.0%
Business data	44.8	45.6	46.6	47.1	46.8	45.4	0.3%
Consumer local	46.9	42.2	39.0	36.2	34.0	32.3	-7.25%
Wireless	91.5	108.7	119.2	132.8	144.5	153.6	10.9%
Total	260.7	271.5	277.0	285.0	291.3	294.9	2.5%

- 48% revenues are from wireless.
- 26% of revenue from data (vs. voice)
- Source: Instat/MDR (Business Week, Feb 28, 2005)

Metropolitan High-Speed Wireless: WiMAX



IEEE 802.16 (WiMAX): Key Features

- WiMAX = Wireless Interoperability for Microwave Access ⇒ Industry group for interoperability
- Up to 50 km or Up to 70 Mbps.
- Data rate vs Distance trade off w adaptive modulation.
  ⇒ High rate near the tower.
  Lower as distance increases
- Offers non-line of site (NLOS) operation
- Hundreds of simultaneous sessions per channel
- Allows mobility
- Robust Security

Status of WiMAX

- WiBro service started in Korea in June 2006.
- Service available in Bangalore, India since 2007.
- Sprint-Nextel in 2.3/2.5 GHz with equipment supplied by Intel, Motorola, Samsung, Nokia, and LG.
  Initial deployment in Washington DC and Chicago (Sept 2008)
- More than 200 operators have announced plans for WiMAX
- About half are already trialing or have launched pre-WiMAX
- Two dozen networks in trial or deployed in APAC
- Intel has developed a multi-band WiMAX/WiFi chipset
  In laptops before the end of this year

Sample WiMAX Subscriber Stations

Alvarion

Airspan

Axxcelera

Siemens

Aperto

Redline

SR Telecom

Telsima

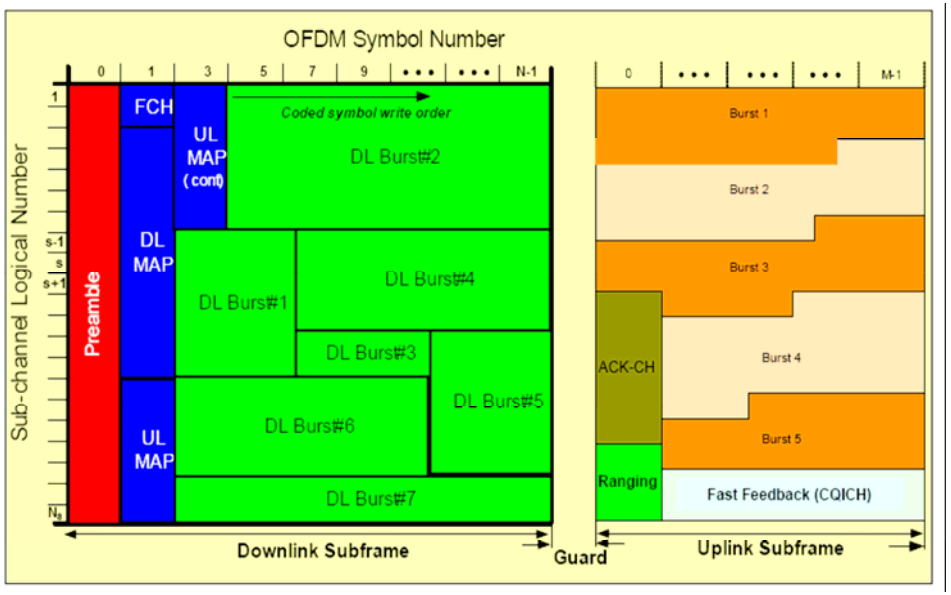
Cavemen of 2050

WiMAX Simulation Methodology

- Agreed upon by WiMAX Forum members
- Can be used by anyone to develop their own simulation
- Can be used with any modeling platform: NS-2, OPNET, …
- Specifies parameter values: ranges and default
- Specifies features and methods
- Allows comparison of performance results from different vendors
- Workloads for key applications: gaming, video streaming, VOIP, FTP, HTTP

Ref: Our paper in IEEE Wireless Magazine, October 2008 issue

Scheduling in WiMAX



- Each user is given some frequencies for some time
  - Two dimensional bin packing problem ⇒ NP-Hard
- Quality of the wireless channel is typically different for different users, and randomly changes with time (on both slow and fast time scales)
- Ref: Our paper in IEEE J-SAC, Feb 2009

Mobile Video Modeling

- MPEG4 compressed video frame sizes can be modeled as a time series
- Seasonal Auto-Regressive Integrated Moving Average (ARIMA) model for Mobile Video
- One model that seems to fit many movies
- Developing a workload generator for use in WiMAX simulation studies
- Ref: Our SAM paper

Related Networking Research at Wash U

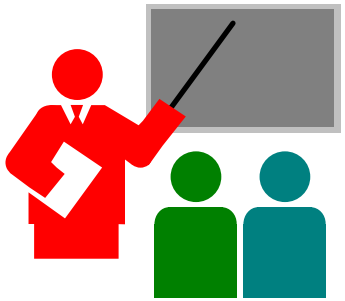
- High-Speed Router for GENI: Allows multiple virtual routers with different protocols (Prof. Jon Turner)
- Embedded Networking: Multi-core communication (Prof. Patrick Crowley)
- Traffic Management and Congestion Control (Prof. Sergey Gorinsky)
- Sensor networking (Prof. Chenyang Lu)

Ref: See respective professor's website for more details

Networking Courses at WUSTL

1. CSE 473: Introduction To Computer Networks
2. CSE 471T: Communications Theory And Systems
3. CSE 521S: Wireless Sensor Networks
4. CSE 570A: Reinventing The Internet
5. **CSE 571S: Network Security – Spring 2009**
6. CSE 572S: Signaling And Control In Communication Networks
7. CSE 573S: Protocols For Computer Networks
8. **CSE 574S**: Advanced Topics In Networking (**Wireless Networks**)
9. CSE 577M: Design And Analysis Of Switching Systems
10. CSE 578A: Multimedia Computing And Networking
11. CSE 7703: Research Seminar On Networking

Overall Summary



1. Both short term and long-term research
   Of interest to industry.
2. Active participation industry forums and standards
3. Internet 3.0 architecture, naming, and routing
4. Wireless performance modeling
5. WiMAX scheduling
6. Mobile application characterization

References

- Audio/Video recordings and podcasts of several networking classes are available:
  - CSE 473: Introduction to Computer Networks, http://www.cse.wustl.edu/~jain/cse473-05/index.html
  - CSE 571S: Network Security, http://www.cse.wustl.edu/~jain/cse571-07/index.html
  - CSE 574S: Wireless Networks, http://www.cse.wustl.edu/~jain/cse574-08/index.html

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

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4. Raj Jain, Chakchai So-In, and Abdel-Karim Al Tamimi, "**System Level Modeling of IEEE 802.16e Mobile WiMAX Networks: Key Issues**," IEEE Wireless Magazine, October 2009.
5. Chakchai So-In, Raj Jain, Abdel-Karim Tamimi, "**Scheduling in IEEE 802.16e Mobile WiMAX Networks: Key Issues and a Survey**," IEEE Journal on Special Areas in Communications (JSAC), Feb 2009.
6. A. Tamimi, R. Jain, C. So-in, "SAM: A Simplified Seasonal ARIMA Model for Mobile Video over Wireless Broadband Networks," Proceedings of IEEE International Symposium on Multimedia (ISM2008), December 15-17, 2008, Berkeley, California, USA, http://www.cse.wustl.edu/~jain/papers/sam.htm