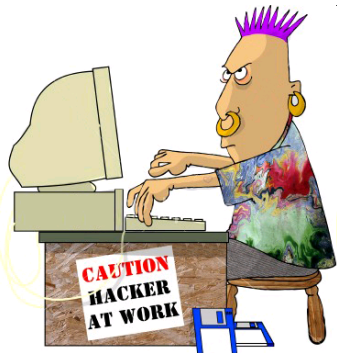


# Introduction to Computer Networking: Trends and Issues



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A talk given to "CS 131R: Computer Science I" Class  
October 4, 2011

These slides are available on-line at:

<http://www1.cse.wustl.edu/~jain/talks/cs13111.htm>



1. Why study networking?
2. Current Issues in Networking
3. Our research projects
4. Related networking research and courses

# Why Study Computer Networking?

- ❑ Networking is the “plumbing” of computing
- ❑ Almost all areas of computing are network-based.
  - Distributed computing
  - Distributed databases
  - Distributed storage
  - Robotics
  - Distributed Games
- ❑ Fast growing field
- ❑ Job Opportunities: Google, Facebook, eBay, Microsoft, Cisco, HP, Intel, ...



# Stone Age to Networking Age

- ❑ Stone, iron, ..., automotive, electricity, telephone, jet plane, ..., networks caused a fundamental change in our life style



- ❑ No need to get out for
  - Office
  - Shopping
  - Entertainment
  - Education
- ❑ Virtual reality will satisfy your needs for
  - ❑ Games
  - ❑ Tourism
  - ❑ Socialization

# Current Issues in Networking

1. Network Security
2. Mobile Networking
3. Wireless Networking
4. Energy Efficient Networking
5. Multimedia Networking
6. Datacenter Networking
7. Next Generation Internet

Note: These topics are based on current activity in industry groups like Internet Engineering Task Force (IETF), Internet Research Task Force (IRTF), and Institution of Electrical and Electronic Engineering (IEEE)

# 1. Network Security

- ❑ No authentication:
  - DNS attack: All YouTube traffic went to a black hole in Pakistan [Domain Name System (DNS) is used to convert names like [www.youtube.com](http://www.youtube.com) to Internet Protocol (IP) Addresses, e.g., 128.23.45.56]
- ❑ Phishing: Enter personal information on fake websites
- ❑ Spam
- ❑ Cyber warfare



# Phishing

- ❑ Emails from banks and financial services leading to fake websites, e.g., <http://www.bankofamerica.com> may actually point to <http://hackers.com>
- ❑ Students in our Network Security course setup fake “free public wireless” service. Can grab passwords.



**Fake  
Public  
Wireless**



**Real  
Public  
Wireless**

# SPAM

- ❑ 200 Billion messages/day  
88-90% of all emails sent
- ❑ 81% of spam is about pharmaceutical drugs
- ❑ Cost businesses \$100 Billion in 2007
- ❑ CAN-SPAM act of 2003
- ❑ Sent through Botnets of infected computers



Ref: [http://en.wikipedia.org/wiki/Email\\_spam](http://en.wikipedia.org/wiki/Email_spam)



# Cyber Warfare

- ❑ Nation States are penetrating other nations computers  
5<sup>th</sup> domain of warfare (after land, sea, air, space)
- ❑ In 2009, US set up a cyber command
- ❑ UK, China, Russia, Israel, North Korea have similar centers
- ❑ Pentagon spent more than \$100 million in first half of 2009 in repairing damages from cyber attacks.

In Nov 2010, hackers calling themselves “Indian Cyber Army” attacked Pakistani Websites. In Dec 2010, “Pakistan Cyber Army” attacked Indian Central Bureau of Intelligence.

Ref: [http://en.wikipedia.org/wiki/Cyber\\_war](http://en.wikipedia.org/wiki/Cyber_war)



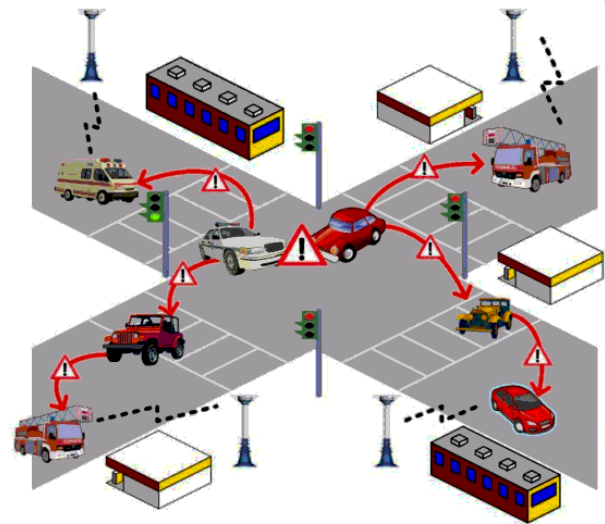
## 2. Mobile Networking

- ❑ Smart Phones (iPhone, Blackberry, Android Phones), Net books, Laptops  
⇒ Mobile computers
- ❑ Mobility: Keep your networking session connected regardless of your location
- ❑ Mobile ≠ Wireless.  
Starting your download at office and continuing it at home is an example of wired mobility
- ❑ Cellular phone networks are designed for mobility but Internet protocol is not.



# 3. Wireless Networking

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  
⇒ Wireless Access
4. New Developments:
  - 4G: 1Gbps Metropolitan Area Networks (LTE-Advanced, WiMAX V2)
  - Vehicular Networking (802.11p)
  - Ad-hoc Wireless Networks
  - TV Band (700 MHz) networking
  - Audio/Video over Wi-Fi (802.11aa)





# 5. Multimedia Networking

## □ Trends:

- Audio/Video over networks
- Entertainment on cellular phones
- Home Entertainment
- Movies on Demand
- YouTube

## □ Issues:

- Timing and synchronization
- Peer to peer streaming
- Stream reservation
- Media caching





# 6. Datacenter Networking

## □ Cloud Computing:

- Applications through Internet (Google Docs)
- Computing through Internet (Amazon EC3)
- Storage and backup through Internet



## □ Issues:

- Inter-Cloud Provider Networking: High-speed links on demand
- Policy, Security, QoS issues (Multi-organizational ownership)

## □ Data Center Networking: Ethernet optimized for data centers

- Congestion control at Multi-Gigabit Speeds
- Micro-seconds transaction delays

# 7. Next Generation Internet: Internet 3.0

- ❑ Internet 1.0: Before Commercialization
  - First twenty years (1969-1989)
  - No Security, Optimal routing
- ❑ Internet 2.0: After Commercialization
  - 1989-2009
  - Security, Policy based routing: ISP
- ❑ Internet 3.0:
  - The next 20 years
  - How would you design the networks, if you were to design it today
  - All leading universities all over the world are working on a “clean-slate” design
  - Internet 3.0 is the name of our clean-slate research program



# Our Research Projects

1. Internet 3.0: Architecture for the Next Generation Internet
2. Communication and Modeling for Green Buildings
3. Communications for Emergency Situations
4. Next Generation Wireless Networks
5. Aeronautical Networks



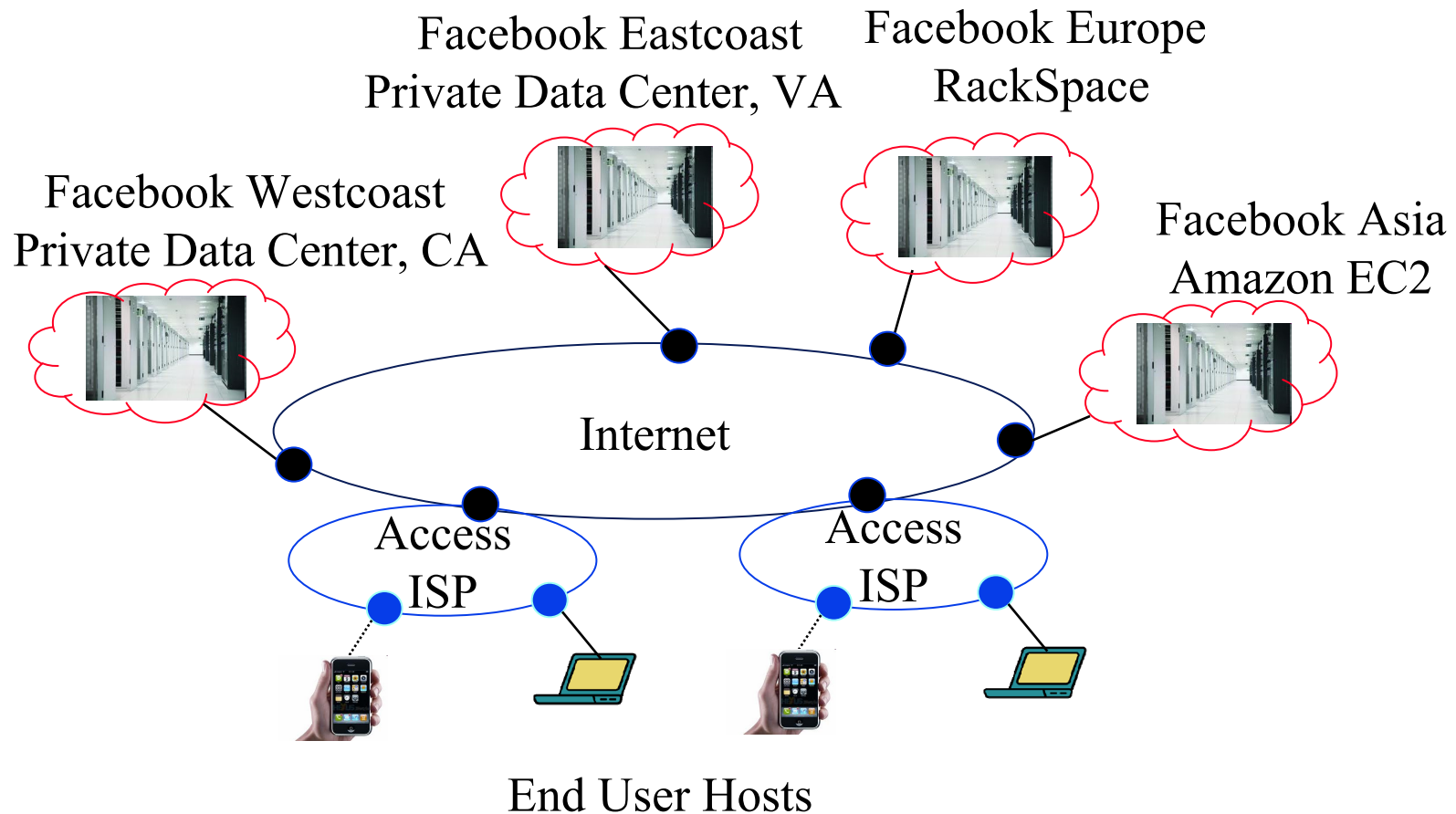
# Trend: Profusion of Services



- ❑ Almost all top 50 Internet sites are services [Alexa]
- ❑ Smart Phones: iPhone, Android Apps
  - ⇒ New globally distributed services, Games, ...
  - ⇒ More clouds, ...

**Networks need to support efficient service setup and delivery**

# Ten Key Features that Services Need



1. **Replication:** Multiple datacenters appear as one
2. **Fault Tolerance:** Connect to B if A is down

## Key Features (Cont)

3. **Load Balancing:** 50% to A, 50% to B
4. **Traffic Engineering:** 80% on Path A, 20% on Path B
5. **Server Mobility:** Move service between clouds  
**Dynamic Setup**  $\Rightarrow$  Networking as a Service
6. **User Mobility:** Gaming/Video/... should not stop as the user moves
7. **Security:** Provenance, Authentication, Privacy, ...

## 2. Modeling for Green Buildings

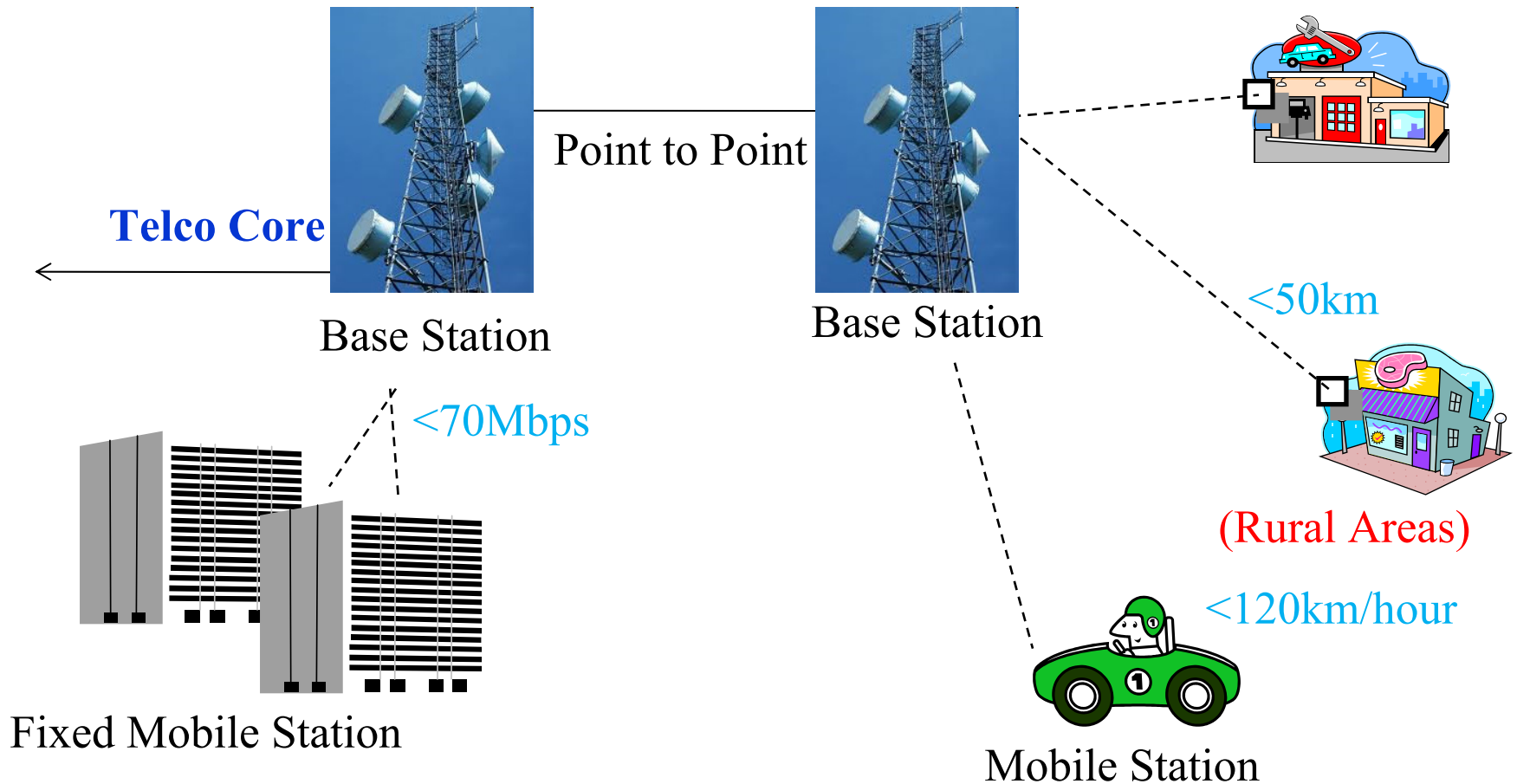
- ❑ Commercial and residential buildings use 71% of electricity and 39% of energy
- ❑ Some monitors available but do not use common network
- ❑ Commercial building studied for 6 months  
Usage independent of personnel, time, or outside weather
- ❑ Plan to study residential buildings. Model. Develop automatic control strategies
- ❑ Mobile phones for location and control
- ❑ Clouds for storage, model, and coordination

### 3. Communications for Emergency Situations

- ❑ Emergency warning systems: Based on radio and television ⇒ Office workers not accessible
- ❑ Need cellular warning systems
- ❑ What if towers are damaged?  
Can we use WiFi modes for communication?
- ❑ Goals:
  - Study cellular usage and problems data from Japan  
March earthquake
  - Develop strategies for a cellular EEW for US

# 4. Next Generation Wireless

## Best of WiFi + Cellular



# WiMAX and LTE: Key Features

- ❑ WiMAX = Wireless Interoperability for Microwave Access  $\Rightarrow$  Industry group for interoperability
- ❑ Long Term Evolution (LTE)
- ❑ Up to 50 km or Up to 70 Mbps.
- ❑ Data rate vs Distance trade off w adaptive modulation.  
 $\Rightarrow$  High rate near the tower.  
Lower as distance increases
- ❑ Both are 3.5G technologies
- ❑ 1 Gb/s in the next generation  $\Rightarrow$  4G



# Cavemen of 2050





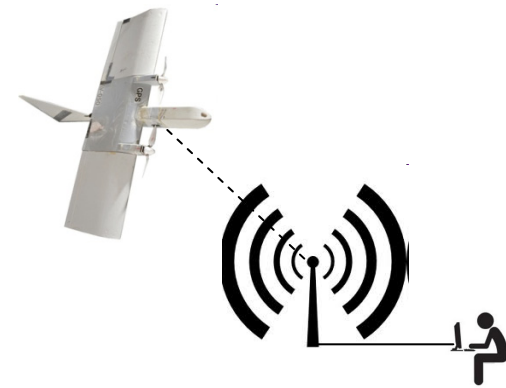
# Mobile Video Modeling

- ❑ 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



# Aeronautical Datalinks: Challenges

- ❑ Very long distances:
  - Wi-Fi covers 100m. WiMAX covers 5km
  - Aeronautical links need to cover 360 km
    - ❑ Limited Power  $\Rightarrow$  High bit error rate
- ❑ Very High Mobility:
  - WiMAX is designed for 60 km/hr
  - Aeronautical links need to cover 600 nm/hr (1080 km/hr)
- ❑ Unmanned Aircrafts: Border patrol, Drones



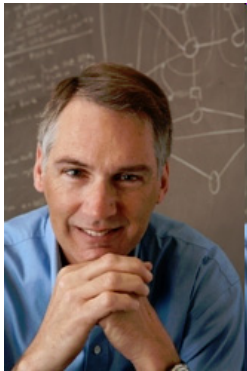
# Key Distinction of Our Research

- ❑ 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

# Networking Courses at WUSTL

1. **CSE 473: Introduction To Computer Networks** (every fall)
2. CSE 521S: Wireless Sensor Networks
3. CSE 537S: Mobile Computing
4. **CSE 571S: Network Security** (Fall 2011)
5. ESE 572S: Signaling and Control in Communications Networks
6. CSE 573S: Protocols For Computer Networks
7. **CSE 574S: Wireless and Mobile Networking** (Spring 2010)
8. CSE 577M: Design And Analysis of Switching Systems
9. CSE 7700: Research Seminar On Networking and Communications

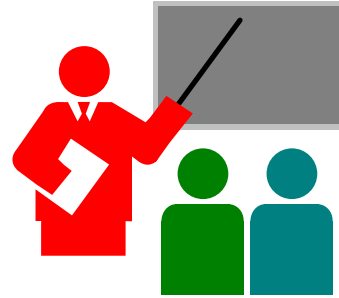
# Other Networking Faculty at WUSTL



1. Prof. Jonathan Turner, <http://www.arl.wustl.edu/~jst/>
2. Prof. Patrick Crowley, <http://www.arl.wustl.edu/~pcrowley/>
3. Prof. Chenyang Lu, <http://www.cs.wustl.edu/~lu/>

Please see respective web pages for additional networking research.

# Summary



1. Computer networking is the backbone of all computing  $\Rightarrow$  Cyber age
2. Key Issues: Security, Mobility, Energy, datacenters
3. Wireless is the major source of carrier revenue  $\Rightarrow$  Significant growth in Wireless networking
4. Profusion of services on the Internet. Services need replication, fault tolerance, traffic engineering, security, ...
5. OpenSDN provides these features with rule-based delegation, support for legacy nodes, data-control plane separation

# References

- ❑ Audio/Video recordings and podcasts of several of our classes are available on-line for everyone:
  - CSE 473: Introduction to Computer Networks,  
<http://www1.cse.wustl.edu/~jain/cse473-11/index.html>
  - CSE 571S: Network Security,  
<http://www1.cse.wustl.edu/~jain/cse571-11/index.html>
  - CSE 574S: Wireless Networks,  
<http://www1.cse.wustl.edu/~jain/cse574-10/index.html>
  - CSE 567: Computer Systems Analysis  
<http://www1.cse.wustl.edu/~jain/cse567-11/index.html>
- ❑ See <http://www1.cse.wustl.edu/~jain/papers.html> for a list of our papers