Hot Topics in Networking Research for Carrier Network Evolution

RAJ JAIN

Washington University in Saint Louis
Saint Louis, MO 63130
Jain@cse.wustl.edu

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These slides are available on-line at:

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

1. What networking will be in 2020?
2. Important issues and challenges
3. Our own research projects

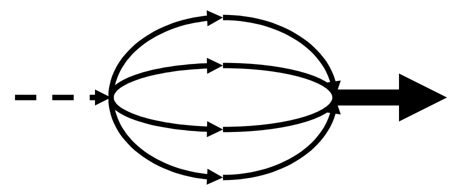
2012: Where are we now?

- At the knee of Mobile Internet age (paradigm shift)
  - Computing (IBM 360) ⇒ Mini-computing (PDP11) ⇒ Personal Computing (Desktop, PC+MAC) ⇒ Laptops ⇒ Netbooks ⇒ Smart Phones + Tablets
- Most valued companies in the stock market are generally those that lead the paradigm shift
  - Automotive (General Motors) ⇒ Electrical (GE, Edison Electric) ⇒ Networking (Cisco + 3Com in 80's) ⇒ Internet (Netscape + Yahoo in 90's) ⇒ Mobile Internet (Apple +MS+ Google, 2010's)
- Note: Apple ≠ PC (MAC) company
  - Google ≠ search engine
- Also Social Networking (Facebook), Internet Retail (Amazon)

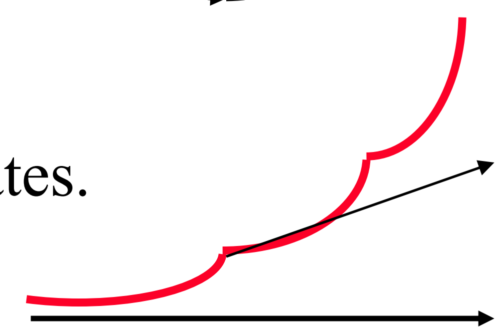
5 Future Predictors

1. **Miniaturization**: Campus $\Rightarrow$ Datacenter $\Rightarrow$ Desktop $\Rightarrow$ Laptop $\Rightarrow$ Pocket $\Rightarrow$ Multi-functional Pocket device
2. **Mobility**: Static $\Rightarrow$ Mobile (1 km/hr) $\Rightarrow$ Mobile (100 km/hr) $\Rightarrow$ Mobile (600 km/hr)
3. **Distance**: PAN (5m) $\Rightarrow$ LAN (500 m) $\Rightarrow$ MAN (50 km) $\Rightarrow$ WAN (500 km)
4. **Applications:** Defense $\Rightarrow$ Industry $\Rightarrow$ Personal
5. **Social Needs**: Energy, Environment, Health, Security

- Broadening and Aggregation: Research $\Rightarrow$ Many Solutions $\Rightarrow$ One Standard $\Rightarrow$ General Public adoption, e.g., Ethernet



- Non-Linearity: Progress is not linear. It is exponential and bursty.
  Most predictions are linear $\Rightarrow$ underestimates.



2020

- Multifunctional Device:
  - 2004 (Palm): Phone, Contacts, Wrist watch, Calendar, Games
  - 2012 (iPhone): Video Phone, News paper, Banking, Shopping, Navigation, Camera
  - 2020 (**jPhone**): Health monitor, home energy controller, 3D Video conferencing, 3D Navigation, … ⇒ Security
- jPhone = Compute power of a 2012 high-end desktop
- Multiple Interfaces: WiFi, 2G/3G, Bluetooth, LTE/WiMAX, USB, Ethernet but **collaborative** optimization

Issues in Networking Research

List based on our interests and projects:

1. Security
2. Mobile Networking
3. Energy and Networking
4. Health and Networking
5. Multimedia Networking
6. Emergency Communications
7. Next Generation Internet: Internet 3.0

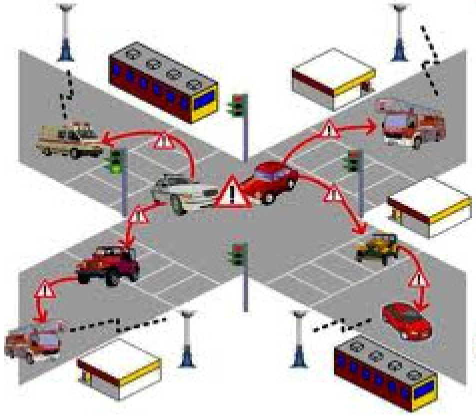
Short term + Medium Term + Long Term **Research Investment**

1. Security

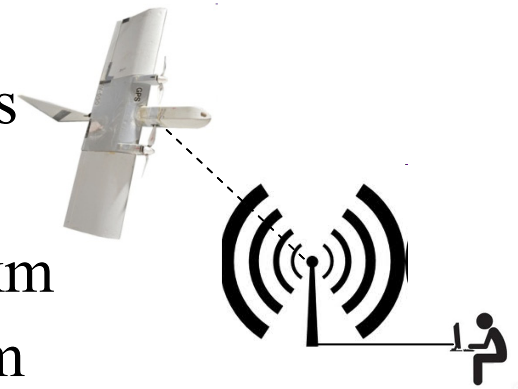
- Cyber Warfare: Nation States are penetrating other nations computers ⇒ 5th domain of warfare (after land, sea, air, space)
- USA UK, China, Russia, Israel, North Korea have cyber command centers
- Cloud computing ⇒ new cloud security issues
- Application service providers (ASPs), Cloud Computing Service Providers (CSPs), Internet Service Providers (ISPs), and Users ⇒ separate **trust domains**.

2. Mobile Networking

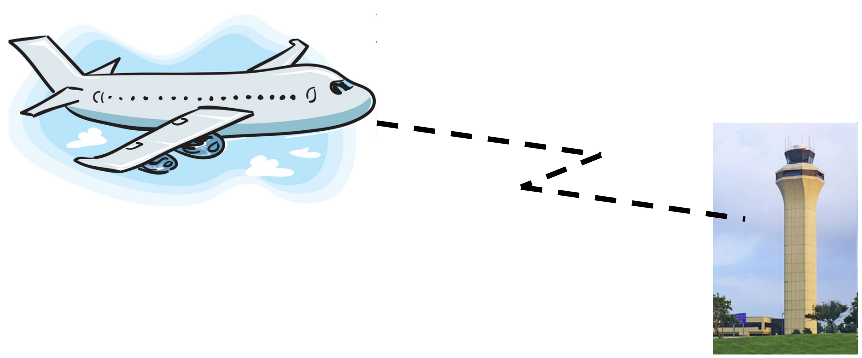
- Starting your download at office and continuing it at home is an example of wired mobility
- Cellular phone networks are designed for mobility but Internet protocol is not.
- Vehicular networking ⇒ Mobile Ad-hoc networking



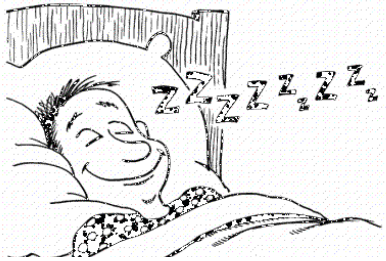
Aeronautical Datalinks (WUSTL)



- Unmanned Aircrafts: Border patrol, Drones
- Very long distances:
  - Wi-Fi covers 100m. WiMAX covers 5km
  - Aeronautical links need to cover 360 km
    - Limited Power ⇒ High bit error rate
- Very High Mobility:
  - WiMAX/LTE is designed for 60-120 km/hr
  - Aeronautical links need to cover 600 nm/hr (1080 km/hr)



3. Energy Efficient Networking



- Original Internet design assumed all hosts are up all the time
- Computer Industry produces as much green house gases as the airlines industry
- Energy Efficient Ethernet
- Delay-Tolerant Networking: Routers store data if the next hop is down
- Mobile phones are already energy efficient $\Rightarrow$ Can benefit from energy efficient **backhaul**
- Smart mobile devices can help in savings energy by location sensing and control

Modeling for Green Buildings (WUSTL)

- Commercial and residential buildings use 71% of electricity and 39% of energy

- Commercial building ⇒ Usage independent of personnel, time, or outside weather (≈Computers energy used was not affected by utilization)

- Plan to study residential buildings. Develop automatic control strategies
- Mobile smart phones for location and control

- **Collaboration** with Energy department

4. Health and Networking (WUSTL)

- Health monitoring, remote diagnostics, …
- Ultra-wide band (UWB) is also good for precise positioning and 3D imaging
- A **multi-disciplinary team** of computer scientists, electrical engineers, physics, biotech engineers, and medical doctors working to apply UWB for health

Single discipline ⇒ Multi-disciplinary research

5. Multimedia Networking

- jPhone will be the center of any time any where entertainment
- Numerous challenges in improving video delivery with least wireless bandwidth

Mobile Video Modeling (WUSTL)

- 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
- Developed a workload generator for use in WiMAX simulation studies
- Ref: WUSTL High-Definition Video Trace Library http://www.cse.wustl.edu/~jain/sam/index.html

6. Emergency Communications (WUSTL)

- Tsunami in Japan ⇒ Worldwide awareness on emergency communications
- US National Science Foundation issued a call for "RAPID" research about lessons from Japan
- WUSTL is studying Emergency warning systems
- Current 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

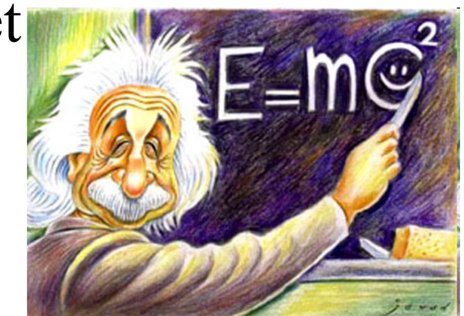
7. Next Generation Internet: Internet 3.0

- 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

Trend: Moore's Law

- Computing Hardware is cheap
- Memory is plenty

⇒ Storage and computing (Intelligence) in the net



Energy	⟷	Matter
Space	⟷	Time
Communication in Space	⟷	Communication in Time

Rural India

- Link
- Storage (USB, Caching,…)

Next Gen nets will use storage in networks, e.g., DTN, CCN

Trend: Declining Revenues in Transport

- Telecom carriers' disappearing revenues in basic transport
- New opportunities in apps and Intelligent transport

2000 FedEx Trucking

2010 FedEx Office Distribution Centers, Email, …

Future of ISPs is to go beyond best effort trucking services

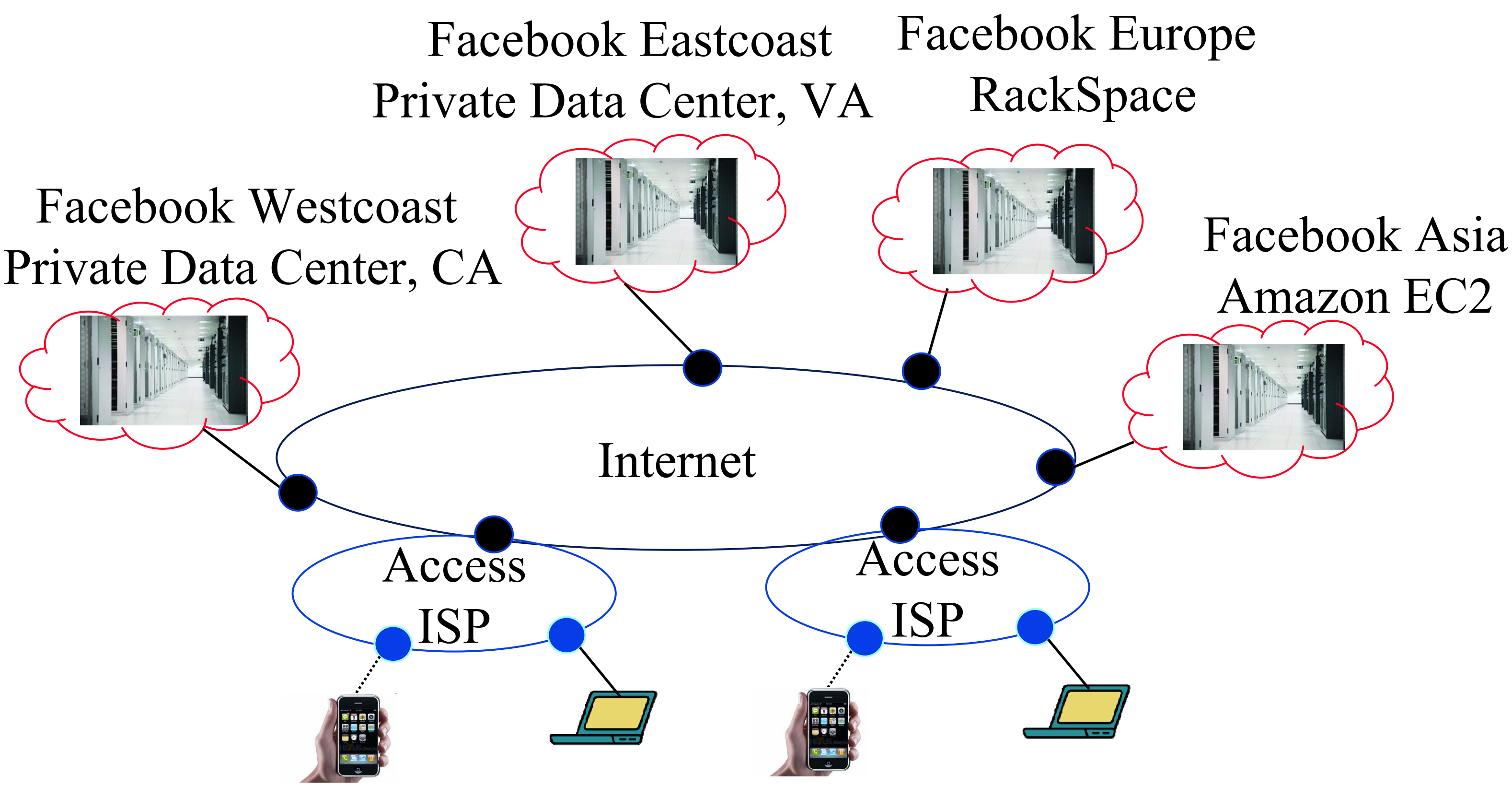
Trend: Profusion of Services

- 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

Ref: Top 500 sites on the web, http://www.alexa.com/topsites

Ten Key Features that Services Need



End User Hosts

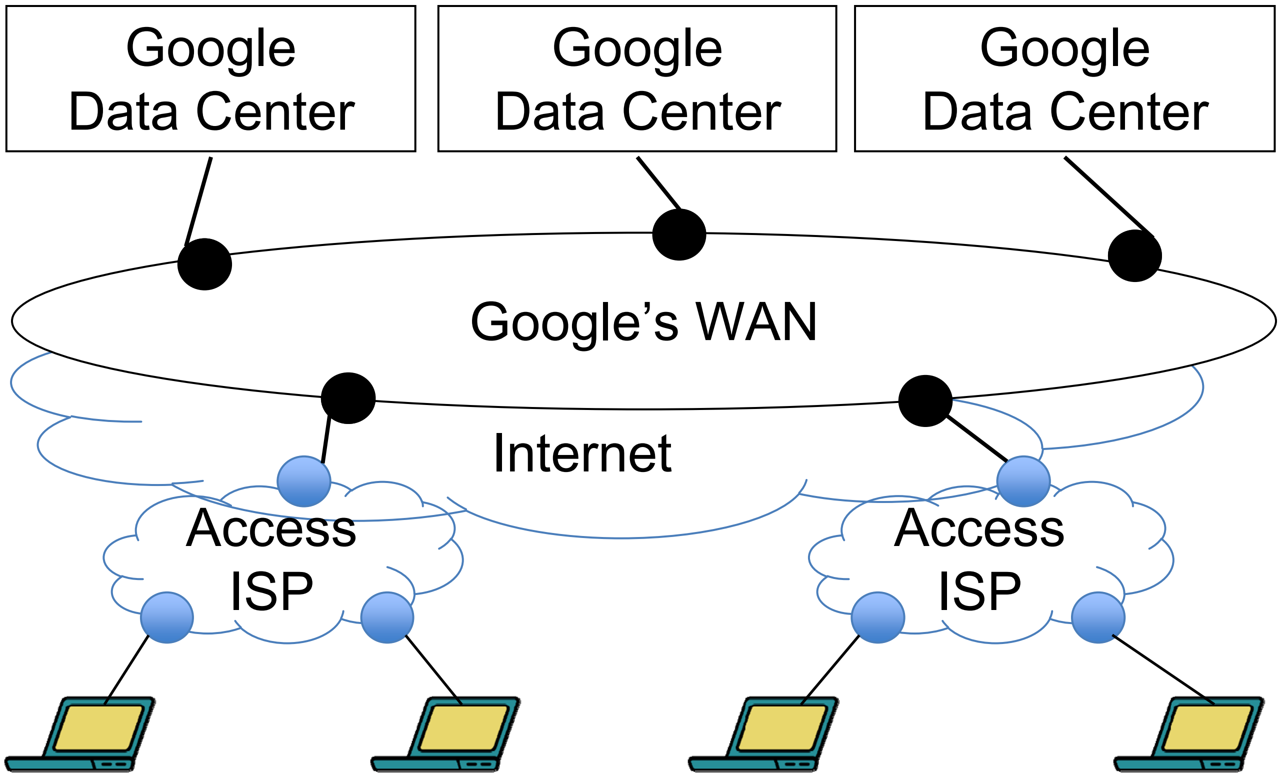
1. **Replication**: Multiple datacenters appear as one
2. **Fault Tolerance**: Connect to B if A is down

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 ⇒ Networking as a Service
6. **User Mobility**: Gaming/Video/… should not stop as the user moves
7. **Security**: Provenance, Authentication, Privacy, ...
8. **Service composition**: Services using other services
9. **Customization**: Every service has different needs
10. **Flow or Packet based forwarding**: Movies, Storage Backup, …
    ATMoMPLS, TDMoMPLS, FRoMPLS, EoMPLS, …
    Packets in Access, Flows in Core

Trend: Private Smart WANs

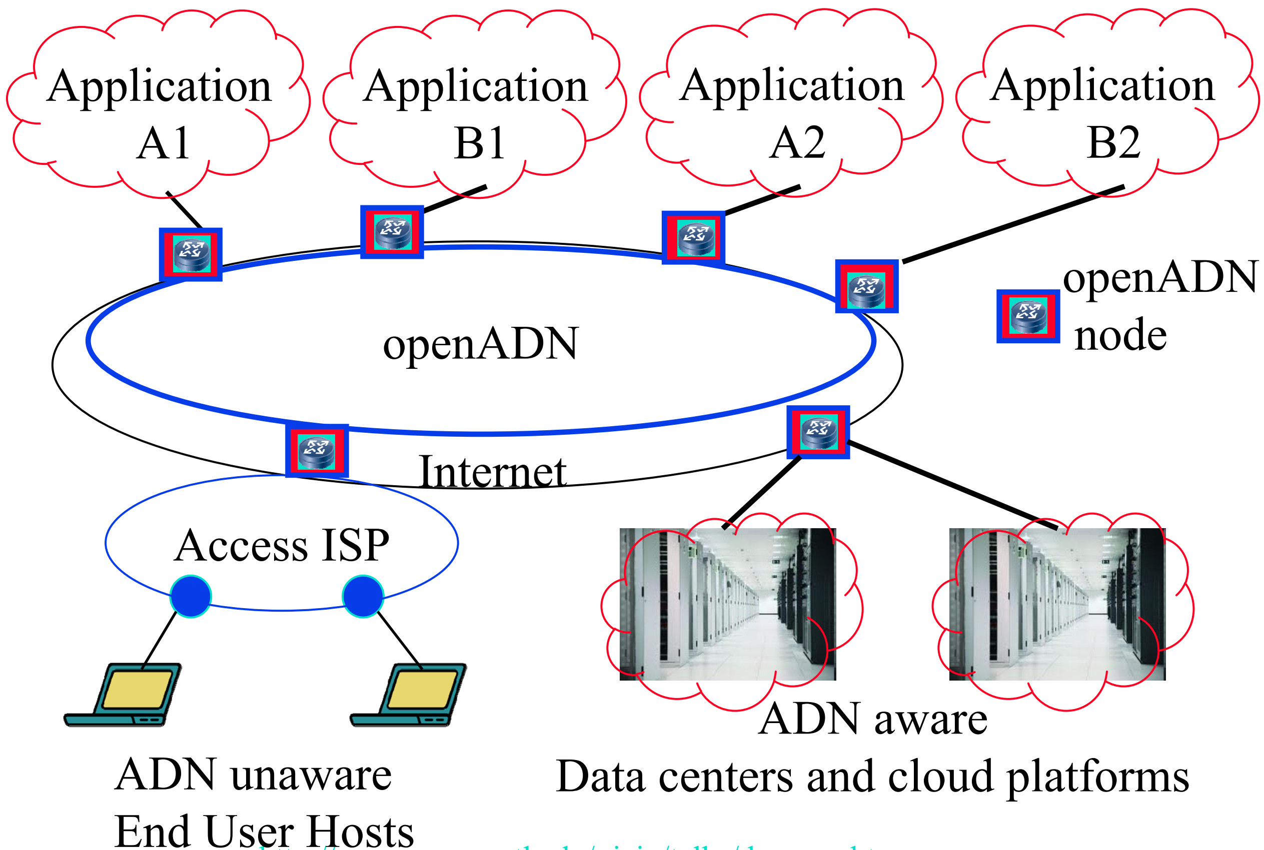
- Services totally avoid the Internet core ⇒ Many private WANs
- Google WAN, Akamai ⇒ Rules about how to connect users



Opportunity for ISPs to offer these types of WAN services

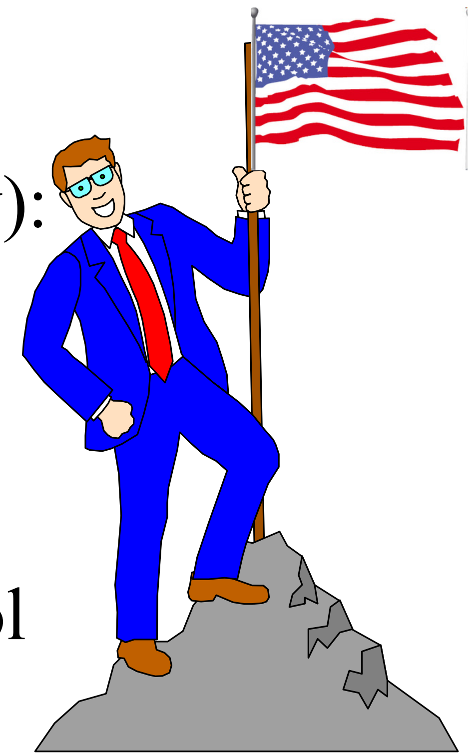
OpenADN

- High-Speed application delivery on a shared network
- Allows ASPs to quickly setup services



Five Architecture Design Principles

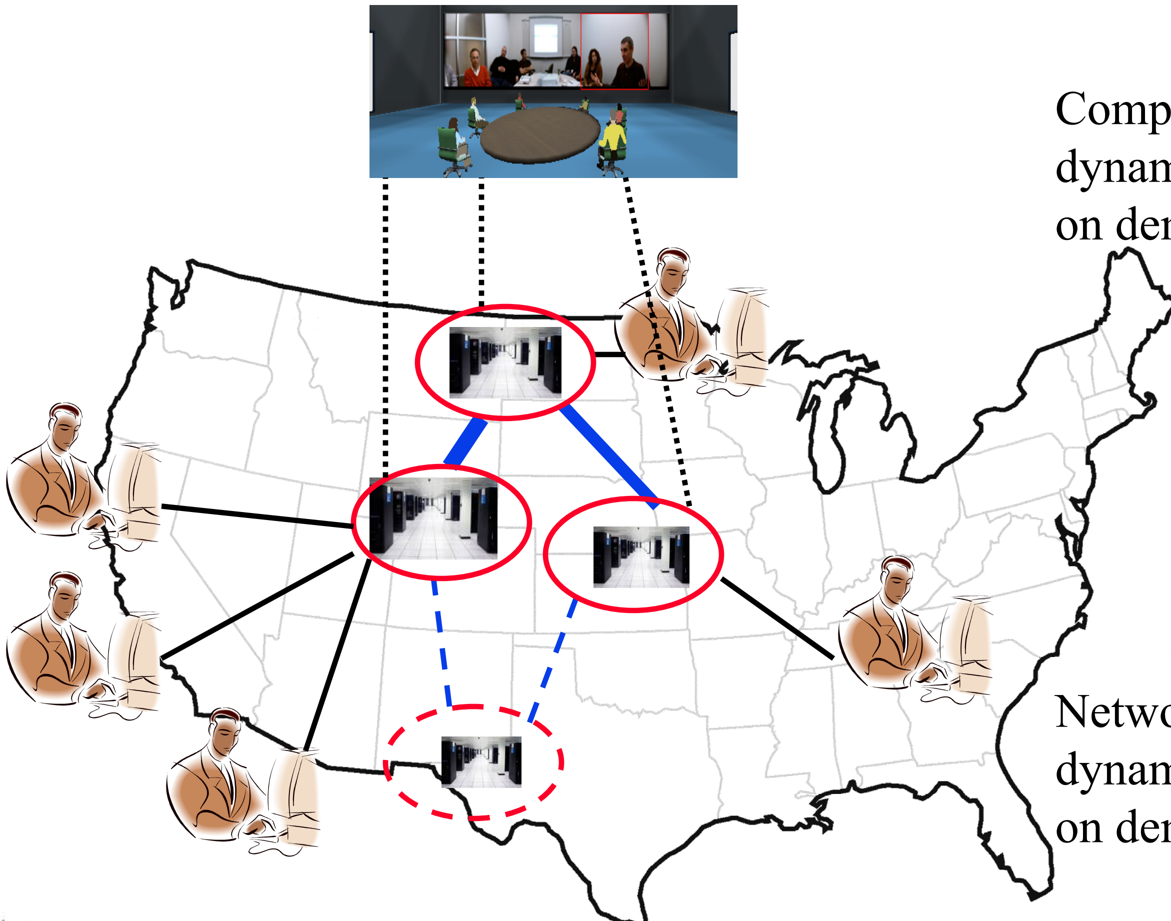
1. Evolution not replacement.
2. Coexistence (Backward compatibility): Old on New. New on Old
3. Incremental Deployment
4. Economic Incentive for first adopters
5. Customization without loosing control (No active networks)



Most versions of Ethernet followed these principles. Many versions of IP did not.

Application 1: Telecom Services

- IP Multimedia, Video Conferencing, Gaming, …



Computing resources dynamically optimized on demand

Networking resources dynamically optimized on demand

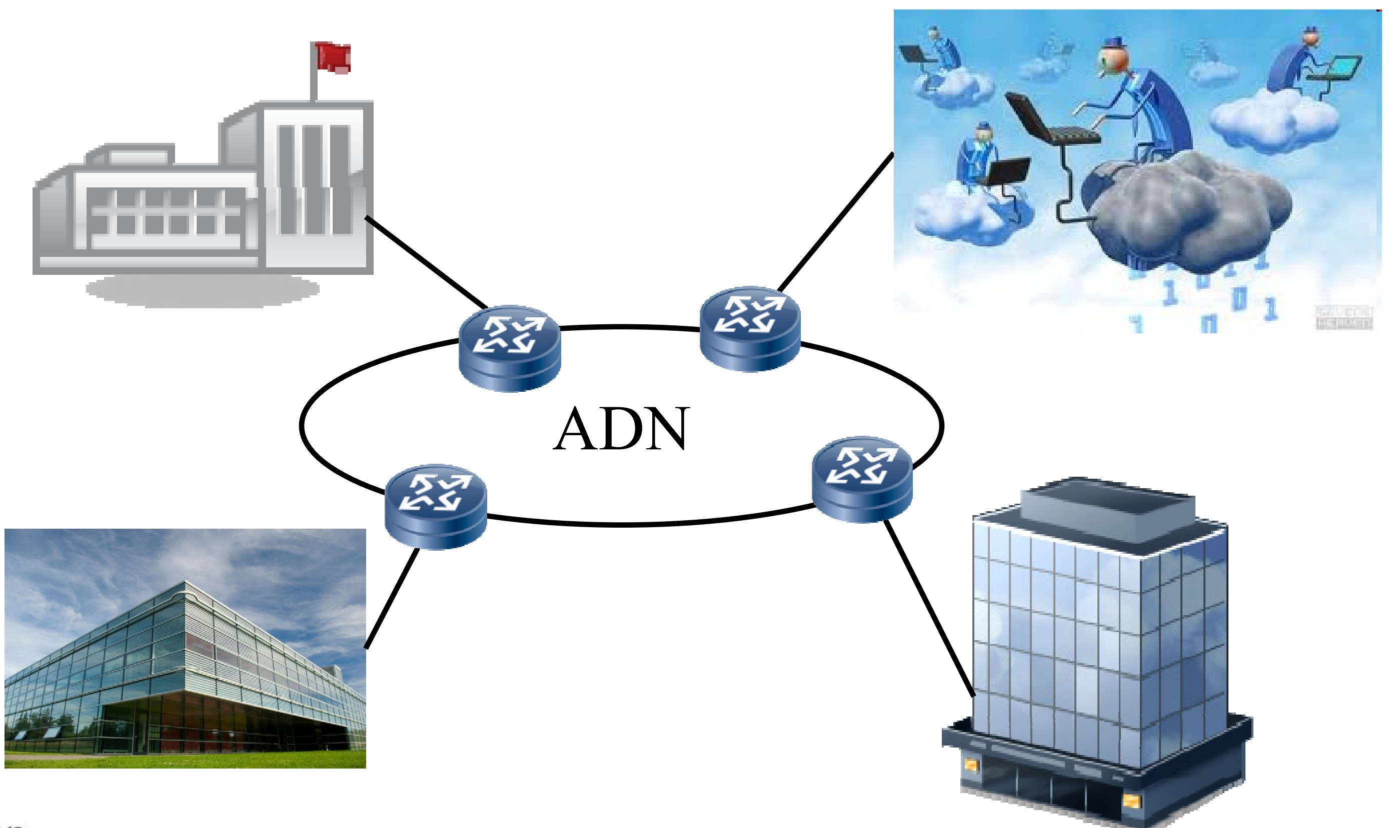
Application 2: Critical Infrastructure

- Defense, Power Grid, Water supply, Gas Supply, …
- Security + Customization
  ⇒ Multiple services can share a single ADN



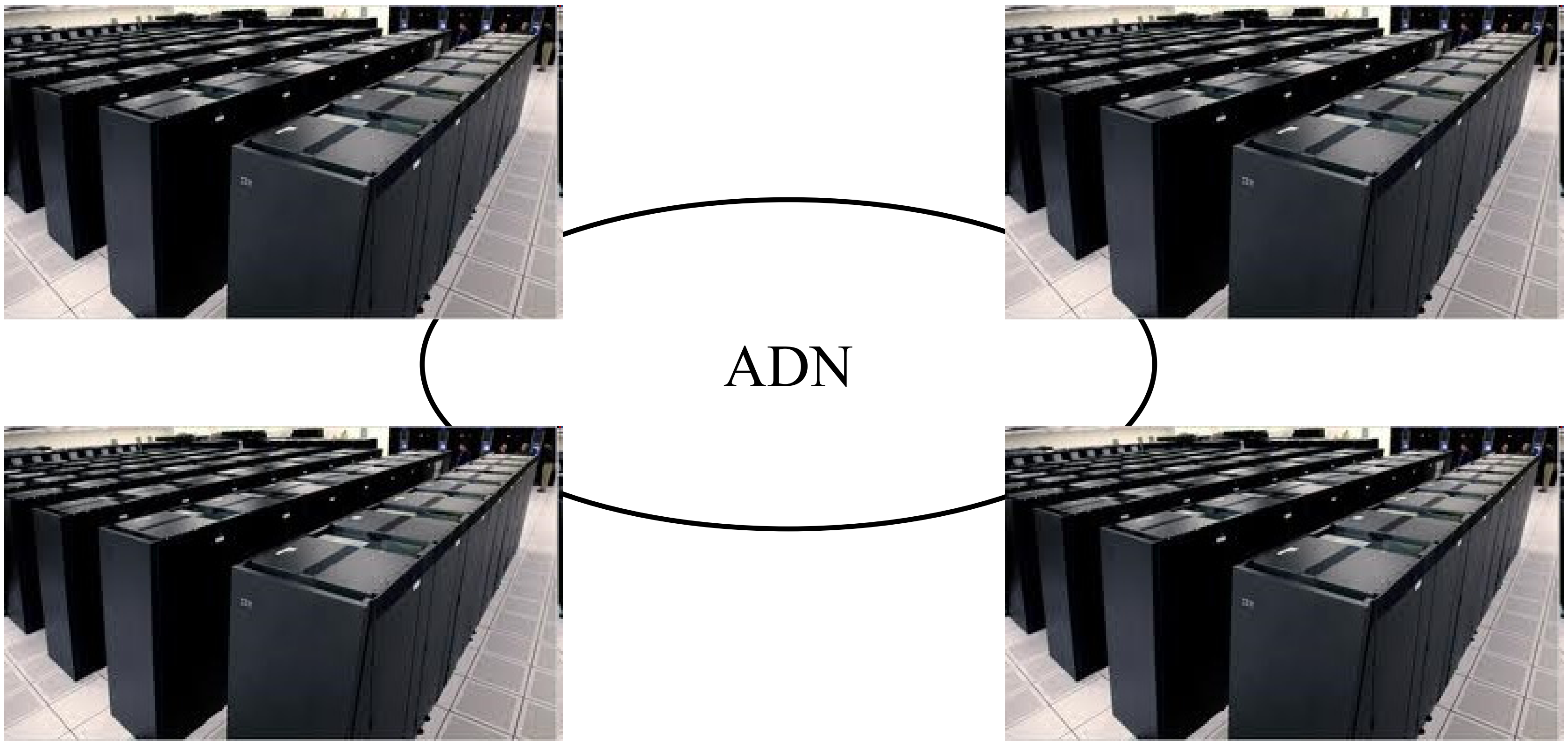

Application 3: Public + Private Clouds

- Multiple sites (including cloud computing) with rules for traffic handling



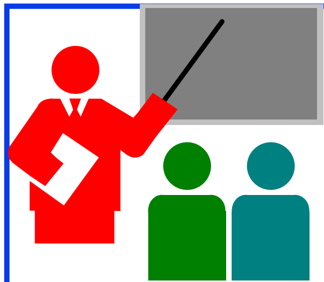
Application 4: Scientific Computing

- Distributed computing using high-speed networking,
- National Knowledge Network



Application 5: Datacenter

- Multiple services and clients in a datacenter
- ADN design is good for short distance too



Summary

1. Peak of **mobile internet** paradigm shift
2. Miniaturization, Mobility, Distance, Applications, Social needs help predict the future
3. Key issues: Security, mobility, energy efficiency, health applications, multimedia, …
4. Profusion of **multi cloud-based applications** on the Internet. Application services need replication, fault tolerance, traffic engineering, security, …
5. **OpenADN** provides these features in a multi-cloud environment with backward compatibility, incremental deployment

Application Delivery: Opportunity for ISP's