Computer Networking: Recent Developments, Trends, and Issues

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These Slides are available at

http:/www.cse.ohio-state.edu/~jain/talks/wustl05.htm

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1. Industry Trends
    1. Top 10 Networking Developments of 2004
    2. Networking Technologies: Failures vs Successes
2. Research Trends
    1. Top 5 Networking Research Topics
    2. Recent DARPA/NSF Funding Opportunities
3. My Research

Top 10 Networking Developments of 2004

1. Large investments in Security: Message Aware Networking
   ⇒ All messages scanned by security gateways
2. Wireless (WiFi) is spreading (Intel Centrino)
3. More Cell phones than POTS.
   Smart Cell phones w PDA, email, video, images ⇒ Mobility
4. Broadband Access is growing faster than cell phones
   Fiber is creeping towards home
5. Ethernet extending from Enterprise to Access to Metro …
6. Wiring more expensive than equipment ⇒ Wireless Access
7. Multi-Protocol Label Switching for traffic engineering
8. Voice over Internet Protocol (VOIP) is in the Mainstream
9. Multi-service IP: Voice, Video, and Data
10. Terabyte/Petabyte storage (Not VoD) ⇒ High-Speed Networking
    Grid Storage. Desktop search.

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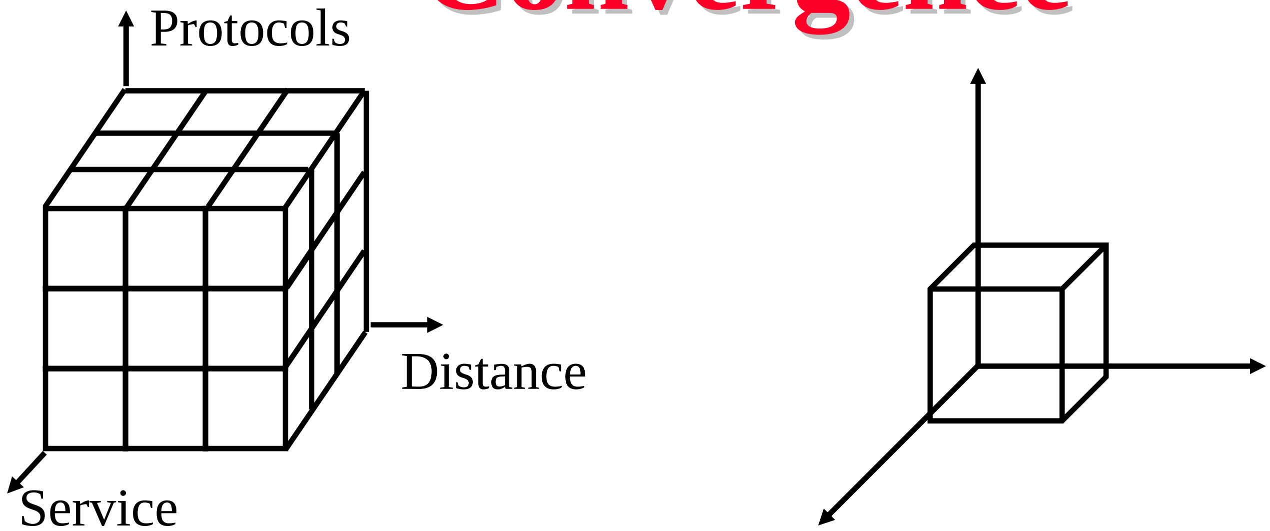
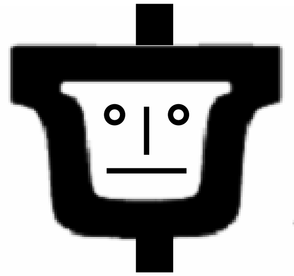
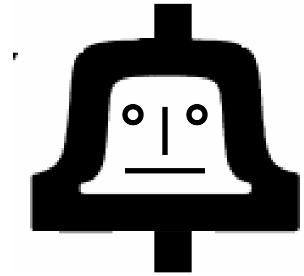
Convergence



- Distance: LAN vs MAN
- Services: Data, Voice, Video
- Phy: Circuit switched vs Packet switched
- L2 Protocols: Ethernet and SONET
- L3 Protocols: IP
- HTTP: Hyper-Application Access protocol

Ethernet: 1G vs 10G Designs





1G Ethernet	10G Ethernet
❑ 1000 / ~~800~~ / ~~622~~ Mbps **Single** data rate	❑ 10.0/9.5 Gbps **Both** rates.
❑ **LAN** distances only	❑ LAN and **MAN** distances
❑ No Full-duplex only ⇒ **Shared** Mode	❑ Full-duplex only ⇒ **No Shared** Mode
❑ Changes to **CSMA/CD**	❑ **No CSMA/CD** protocol ⇒ No distance limit due to MAC ⇒ *Ethernet* End-to-End

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Networking: Failures vs Successes

- 1980: Broadband (vs baseband) Ethernet
- 1984: ISDN (vs Modems)
- 1986: MAP/TOP (vs Ethernet)
- 1988: Open System Interconnection (OSI) vs TCP/IP
- 1991: Distributed Queue Dual Bus (DQDB)
- 1994: CMIP (vs SNMP)
- 1995: FDDI (vs Ethernet)
- 1996: 100BASE-VG or AnyLan (vs Ethernet)
- 1997: ATM to Desktop (vs Ethernet)
- 1998: Integrated Services (vs MPLS)
- 1999: Token Rings (vs Ethernet)

Requirements for Success

- Low Cost: Low startup cost ⇒ Evolution
- High Performance
- Killer Applications
- Timely completion
- Manageability
- Interoperability
- Coexistence with legacy networks
  Existing infrastructure is more important than new technology (IPv4 vs IPv6, Overcast vs IP multicast)

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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%

- Long distance is disappearing.
- Most of the revenues are going to be from wireless.
- Source: Instat/MDR (Business Week, Feb 28, 2005)

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Wireless Industry Trends

- Wireless industry is stronger than wireline. Particularly strong growth in developing countries.
- 48% of global telco revenues coming from wireless
- 26% of wireless revenues coming from data (vs voice)
- Past: Voice, email, SMS, Ring tones
- Present: Push, Gaming, Pictures, Instant Messaging
- Future: Music, Video, Location, Remote monitoring, m-commerce
- Long Term: Video telephony, remote enterprise applications, remote management, Multiparty collaboration,

Wireless Issues

- Security (IEEE 802.11i)
- Higher Data Rates:
  - Ultra-wide band (vs Bluetooth)
  - Wireless USB
  - Multiple In Multiple Out (MIMO) antennas: IEEE 802.11n
- Longer distance (WiMAX, >1Mbps to 50 km)
- Seamless Networking ⇒ Handoff (IEEE 802.21)
- Mobility (IEEE 802.20)
- Multimedia over Wireless: Media center extenders, VOIP/Video over cell phones
- Channel congestion in license-exempt band

10 Challenges of Networking

1. **Size**: 4 nodes ⇒ 100 M nodes ⇒ 4B people ⇒ 4T appliances
2. **Distance**: USA ⇒ Worldwide ⇒ Interplanetary ⇒ WAN ⇒ LAN ⇒ PAN
3. **Speed**: 128 kbps ⇒ 10Mbps ⇒ 10Gbps ⇒ 1.6 Tbps
4. **Criteria**: Least cost ⇒ Policy based (Traffic Mgmt), Power
5. **Traffic**: Delay-tolerant Data, real-time voice and video, storage and computing
6. **Trust**ed nodes ⇒ Secure, virus proof, spam proof, …
7. Stationary Nodes ⇒ **Mobile** Nodes ⇒ Mobile Networks
8. Stable Links ⇒ Continuous **disruption**, long outages, Varying quality
9. Single ownership ⇒ Multiple Domains ⇒ **Hierarchies** of ownership
10. **Heterogeneity**: Single technology ⇒ Multiple L1/L2/L3

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Research Areas

1. **Disruption Tolerant Networking**:
 Frequent Disconnection due to mobility, power outage, DTN nodes have limited storage
2. **Overlay Networking**: Virtual Networks, P2P, Application level optimization
3. **Sensor Networks**: Large scale, Energy efficient
4. **Distributed Computing Networks** (Grids): Grid Storage
5. **Security**

2004-05 DARPA BAAs

- **QoS**:
  - Switch architectures capable of end-to-end streams with **QoS** guarantees
  - Network **storage and caching** protocols for reducing long-haul communications loads
  - Cross-disciplinary approach to **modeling, analysis, and simulation** of wireless networks
  - Connectionless **wireless** networks.
  - **Situation-Aware Protocols** In Edge Network Technologies (SAPIENT): Auto-adapt protocols for application and network conditions.
- **Distributed Computing Networks**
  - Interconnecting heterogeneous systems through high speed network technology
  - Intelligent Metacomputing Center (computing via high performance networks)
  - Global Information **Grid** (Optical, satellite, wireless networks)
  - Gigabit stream access to remote assets over commercial networks
- **Security:**
  - Network Attack Traceback
  - Cyber Security Research and Development
  - Trustworthy computing in **mobile** environments
  - Host based security manager support
  - WAN firewalls and proxies for asymmetric data flows and speeds in excess of 5Gbps
  - Microprocessor/computing architectures to support secure computing
- **Optical:**
  - Fiber optics **sensor** technology
  - Wavelength division networking and soliton technology

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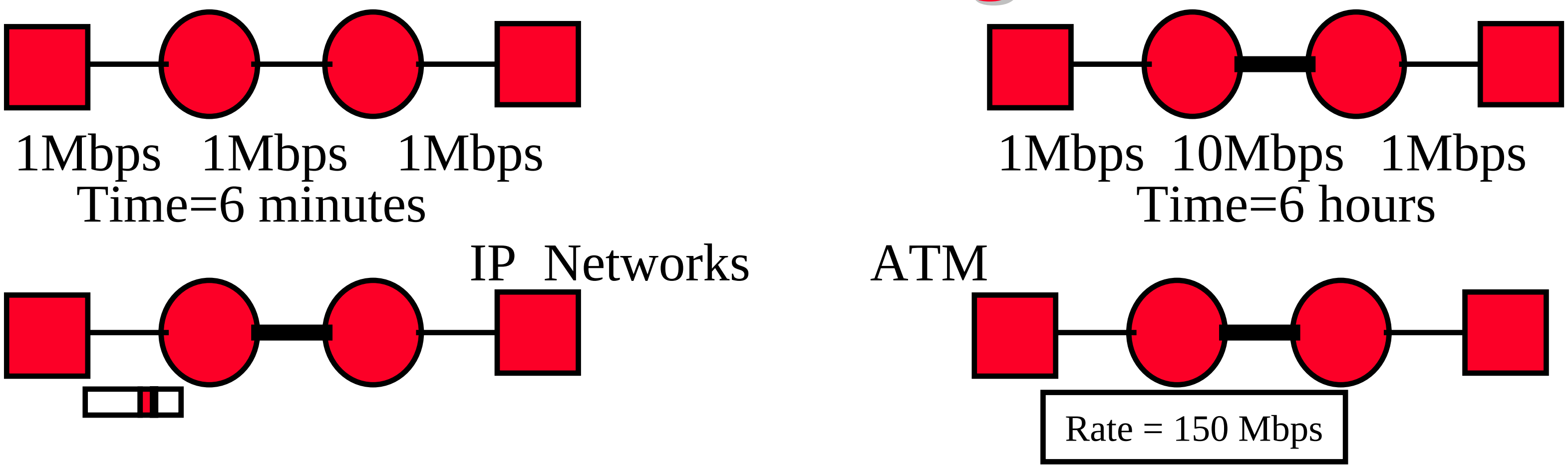
My Research Projects

1. Traffic Management in Wireless Networks
2. Traffic Characterization in Broadband Wireless Networks
3. QoS Issues and Traffic Policing Mechanisms for Multimedia over Wireless
4. Sensor Networks Routing
5. Sensor Networks Transport Protocol
6. Disruption Tolerant Wireless Networks

Wireless Networking Research at OSU

- In collaboration with Electro-science laboratory of EE Dept (Experts in Antenna design and wireless modem communications)
- Dynamically adapt to measured error characteristics:
  - Media Access Protocol
  - Transport protocol (retransmissions)
  - Hand-off strategies
- Modem design for optimal higher-layer performance
- $1.5M Funded by NSF

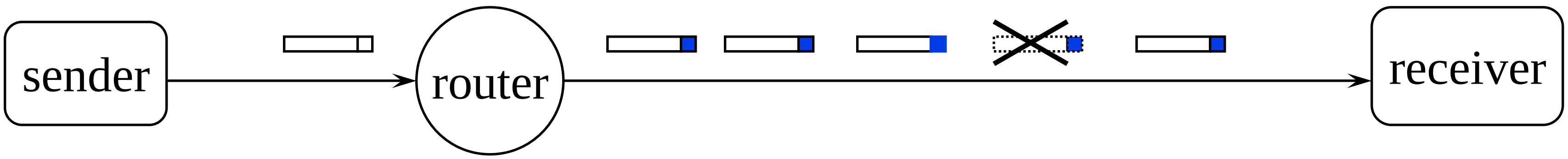
Traffic Management



- Original TCP/IP: Throughput goes down with a high-speed link
- Timeout: Reduce the TCP window to one on a timeout
- DECbit: Routers set a bit when congested.
  Additive increase and multiplicative decrease (AIMD)
- Slow-start based on Timeout and AIMD
- Forward Explicit Congestion Notification (FECN) in Frame Relay Networks
  Explicit Forward Congestion Indication (EFCI) in ATM Networks
- Explicit Rate in ATM networks
- ECN Bits in TCP/IP packets: Based on DECbit concepts (1999)

Traffic Management in Wireless

Problem: High-error rate ⇒ Packet loss ≠ Congestion

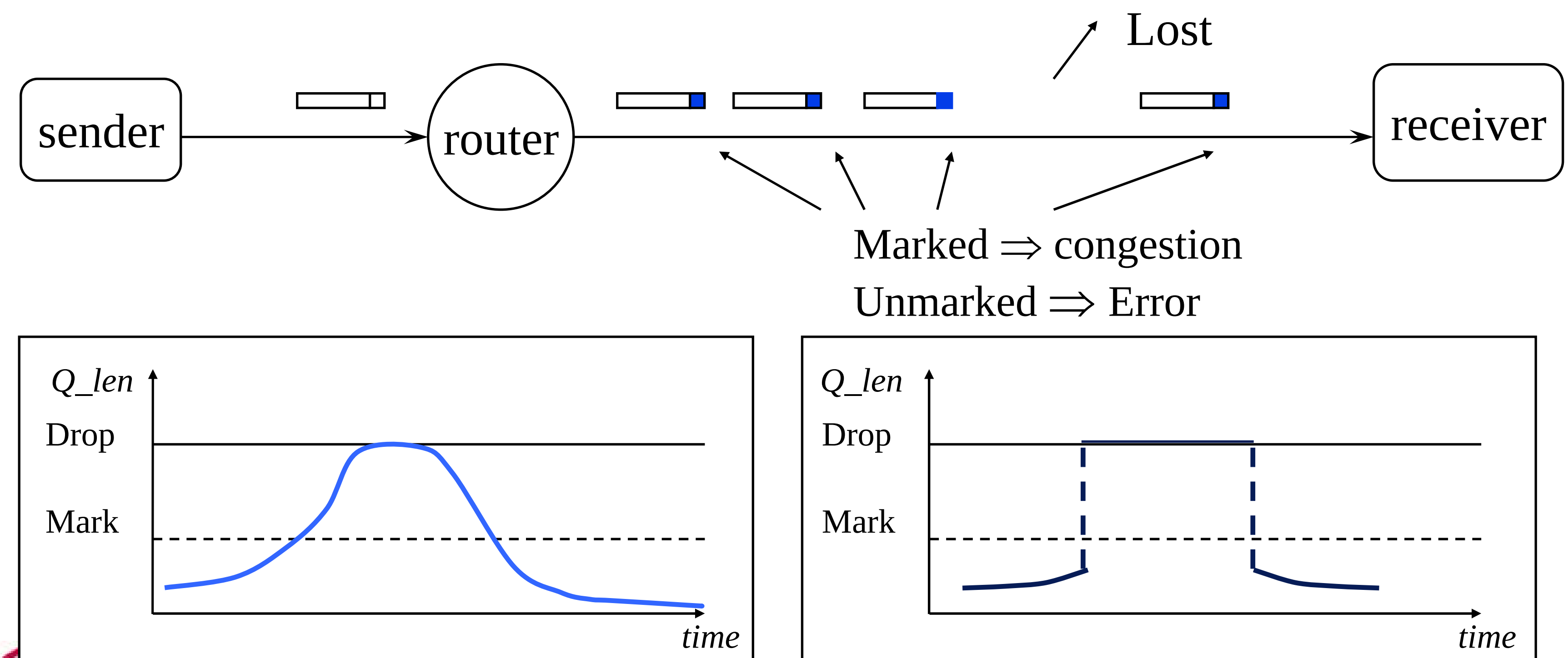


Desired Attributes of the Solution:

1. Must maintain TCP's end-to-end semantics: A packet is acked only after received by the final destination.
2. Modifications must be local: Only Base Staton (BS) and Mobile Host (MH) are in the control of wireless service provider. Cannot change all locations that MH visits.
3. Must apply to two-way traffic: MH can be both a sender and a receiver.
4. Wireless links can be at the end or in the middle (satellite links)

Congestion Coherence

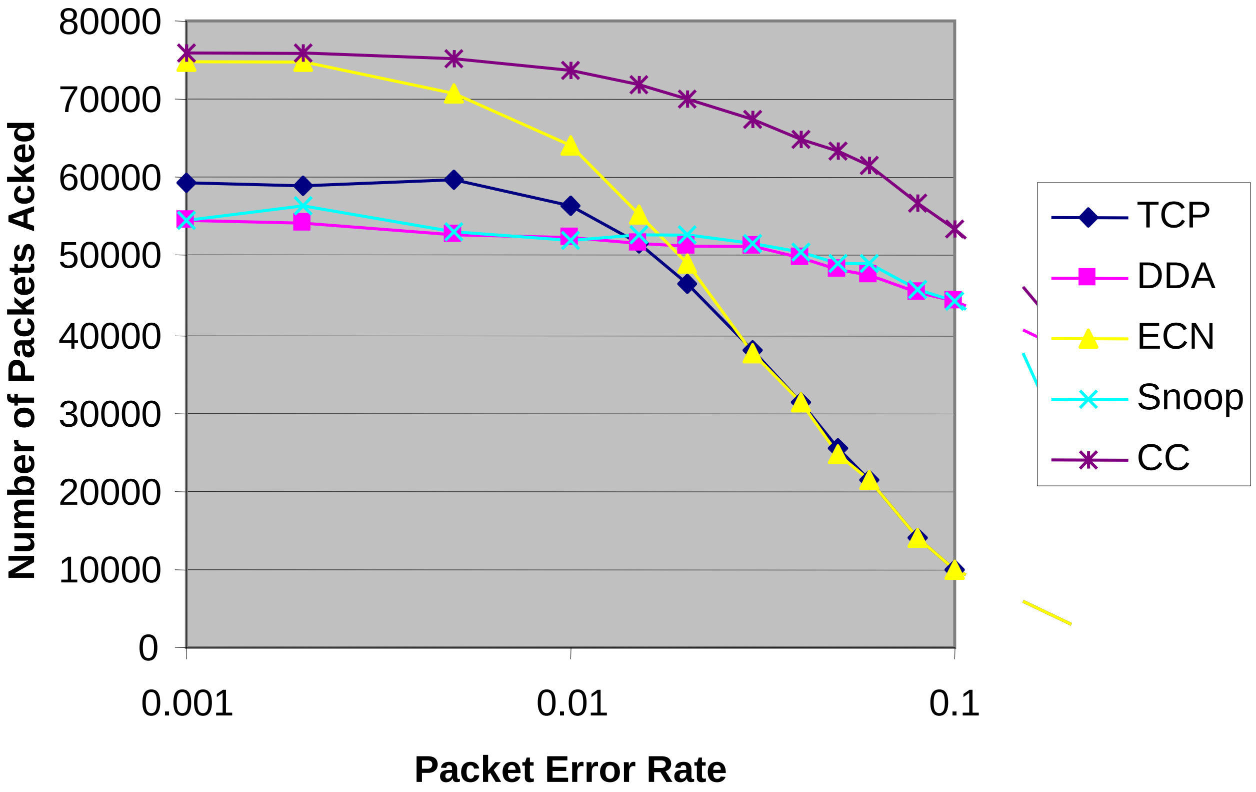
- Congestion does not happens nor disappear suddenly:
  - Before congestion reaches the point where a packet has to be dropped, some packets must have been marked.
  - After a packet is lost, some packets will be marked.



Congestion Coherence Algorithm

- Link layer acks and retransmissions at all wireless nodes.
- **Receiver**:
  - Out-of-order packets received check ECN bits.
  - If any packet marked, send duplicate acks Otherwise, defer the duplicate acks.
  - If expected packet arrives, drop deferred dupacks.
  - If the packet times out, release all deferred dupacks.
- **Sender**:
  - When the third duplicate acks arrives, MH checks the ECN-ECHO bits.
  - If any of thee duplicate acks carry an ECN-ECHO, MH retransmits the lost packet and reduces the window. Otherwise, TCP defers the retransmission.
  - When the expected ack arrives, cancel the deferred retransmission.
  - If the expected ack does not arrive in certain period of time then MH starts the deferred retransmission.

Goodput

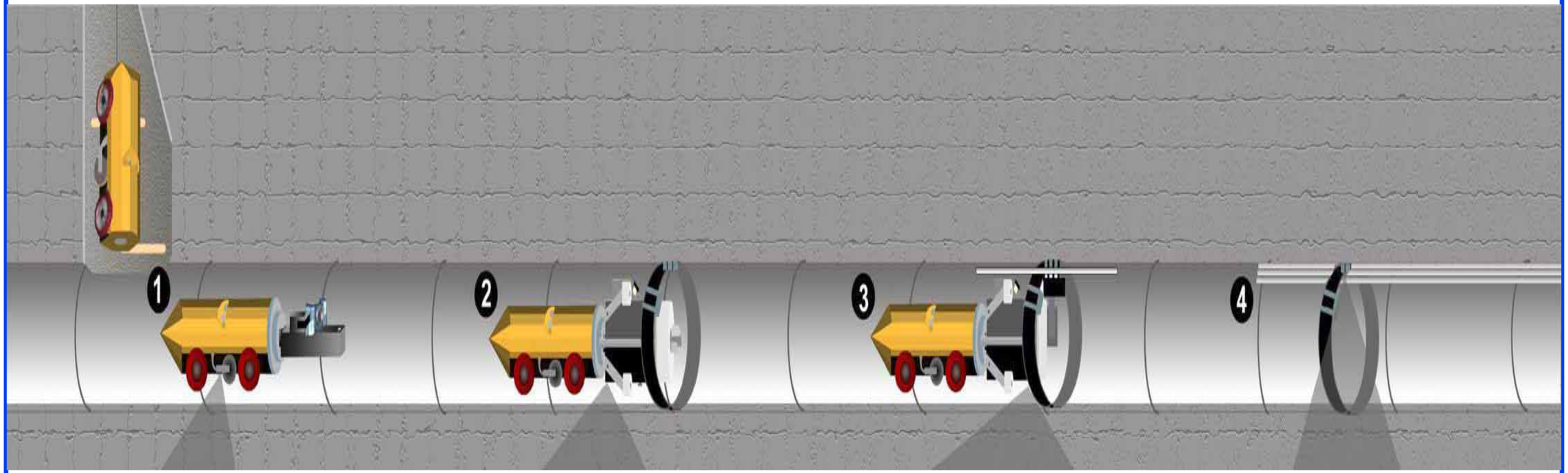


- Congestion Coherence provides the highest throughput

Fiber Access Thru Sewer Tubes (FAST)

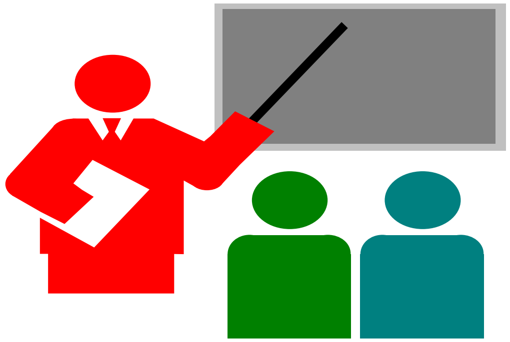
- Right of ways is difficult in dense urban areas
- Sewer Network: Completely connected system of pipes connecting every home and office
- Municipal Governments find it easier and more profitable to let you use sewer than dig street
- Installed in Zurich, Omaha, Albuquerque, Indianapolis, Vienna, Ft Worth, Scottsdale, ...
- Corrosion resistant inner ducts containing up to 216 fibers are mounted within sewer pipe using a robot called Sewer Access Module (SAM)
- Ref: http://www.citynettelecom.com, NFOEC 2001, pp. 331

FAST Installation



1. Robots map the pipe
2. Install rings
3. Install ducts
4. Thread fibers

Fast Restoration: Broken sewer pipes replaced with minimal disruption



Summary

1. Networking is infrastructure and is now widely deployed.
   Evolution is more like to succeed than revolution.
2. Growing research opportunities in networking.
   Research areas and types of solutions required are different.
   All basic assumptions are being changed.
3. Wireless is where the action is. MIMO is in. CSMA/CD is out.
   L1:Wireless, L5-L7:Applications, L2-L4: Large scale
4. Key issues in Wireless are: Security, Mobility, and high-speed

Networking Trends: References

- References on Networking Trends, http://www.cse.ohio-state.edu/~jain/refs/ref_trnd.htm
- References on Optical Networking, http://www.cse.ohio-state.edu/~jain/refs/opt_refs.htm
- References on Residential Broadband, http://www.cse.ohio-state.edu/~jain/refs/rbb_refs.htm
- References on Wireless Networking, http://www.cse.ohio-state.edu/~jain/refs/wir_refs.htm