Computer Networking: Recent Developments, Trends, and Issues

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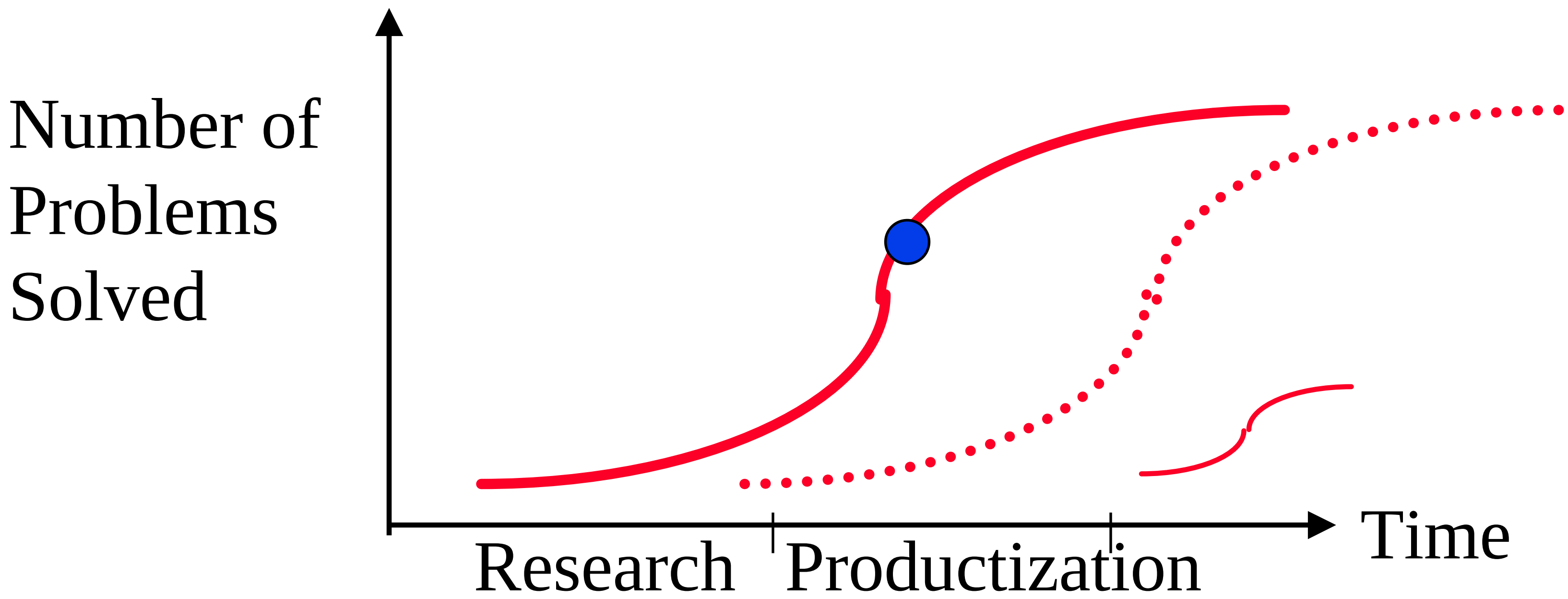
- Impact of Networking
- Life Cycle of Networking Technologies
- Top 10 Developments of 2004
- Optical Networking Developments: Core, Metro, Access
- Networking Technologies: Failures vs Successes
- Wireless Networking: Issues

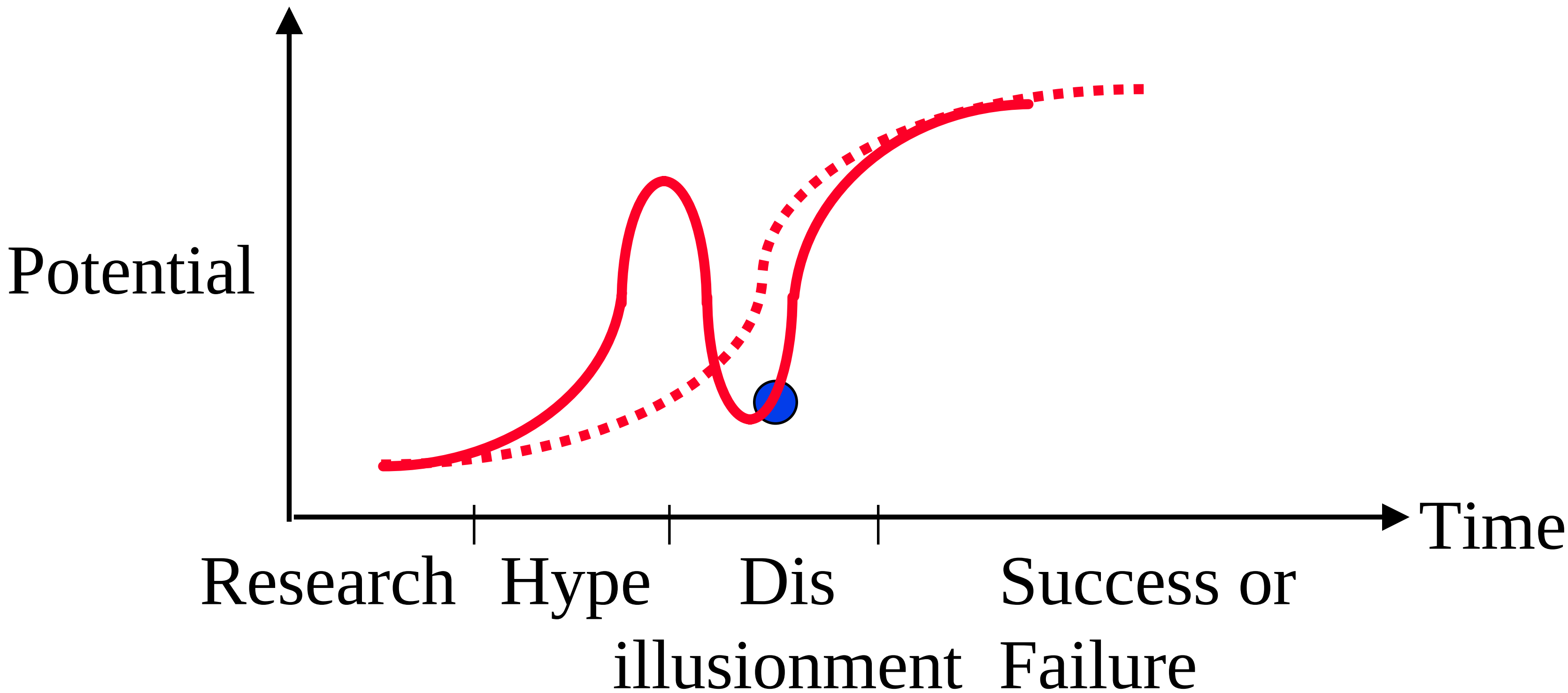
Trend: Back to ILECs

1. CLECs to ILECs
   ILEC: Slow, steady, predictable.
   CLEC: Aggressive, Need to build up fast
   New networks with newest technology
   No legacy issues
2. Back to Voice
   CLECs wanted to *start* with data
   ILECs want to *migrate* to data
   ⇒ Equipment that support voice circuits but allow packet based (hybrids) are more important than those that allow only packet based

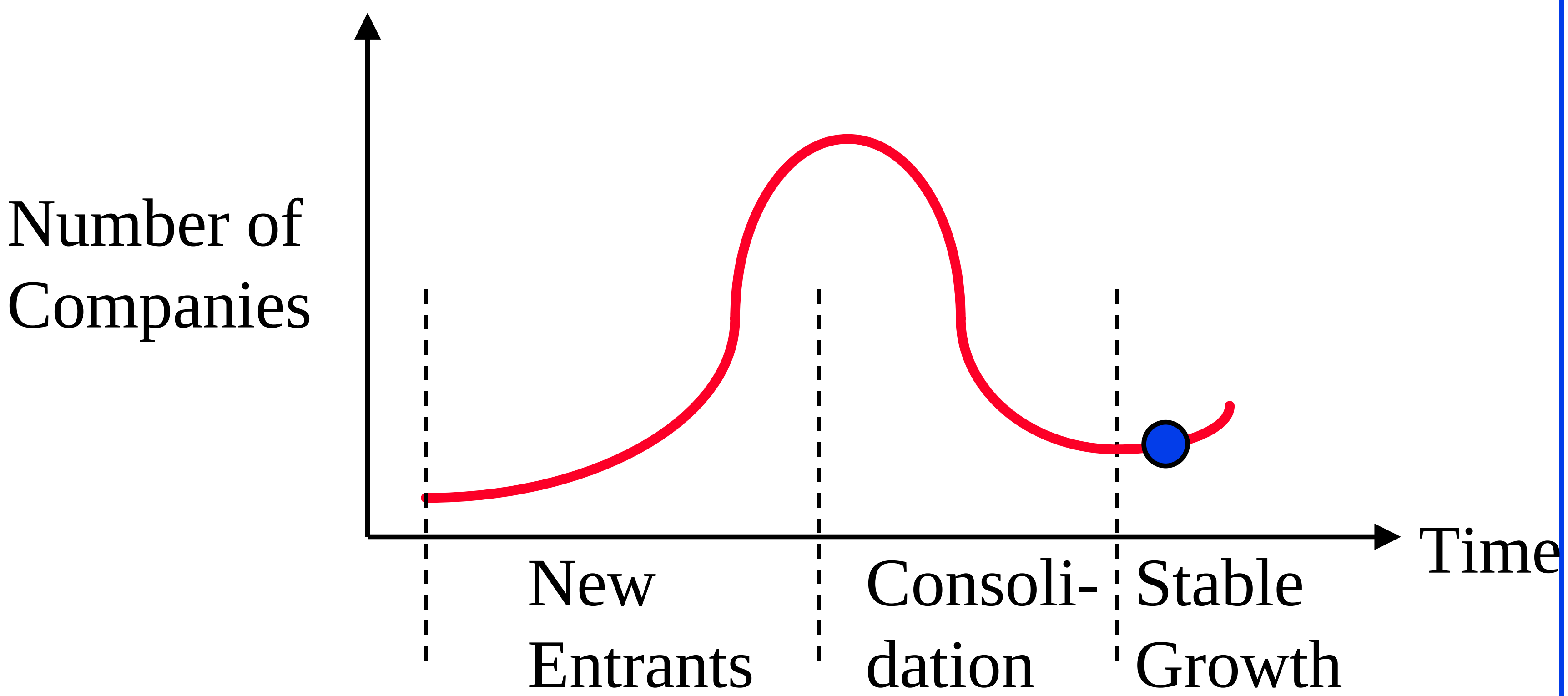
Life Cycles of Technologies



Hype Cycles of Technologies



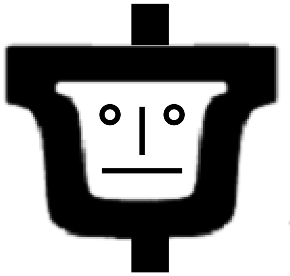
Industry Growth

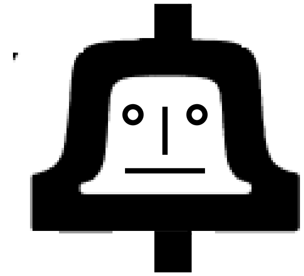


Top 10 Developments of 2004

1. Large investments in Security
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
5. Fiber is creeping towards home
6. Ethernet extending from Enterprise to Access to Metro …
7. Wiring more expensive than equipment ⇒ Wireless Access
8. Multi-Protocol Label Switching for traffic engineering
9. Voice over Internet Protocol (VOIP) is in the Mainstream
10. Multi-service IP: Voice, Video, and Data

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

SONET/SDH vs Ethernet

Feature	SONET	Ethernet
Payload Rates	51M, 155M, 622M, 2.4G, 9.5G	10M, 100M, 1G, 10G
Payload Rate Granularity	Fixed	√Any
Bursty Payload	No	√Yes
Payload Count	One	√Multiple
Protection	√Ring	Mesh
OAM&P	√Yes	No
Synchronous Traffic	√Yes	No
Restoration	√50 ms	Minutes
Cost	High	√Low
Used in	Telecom	Enterprise

SONET/SDH vs Ethernet: Remedies

Feature	SONET	Ethernet	Remedy
Payload Rates	51M, 155M, 622M, 2.4G, 9.5G	10M, 100M, 1G, 10G	10GE at 9.5G
Payload Rate Granularity	Fixed	√Any	Virtual Concatenation
Bursty Payload	No	√Yes	Link Capacity Adjustment Scheme
Payload Count	One	√Multiple	Packet GFP
Protection	√Ring	Mesh	Resilient Packet Ring (RPR)
OAM&P	√Yes	No	In RPR
Synchronous Traffic	√Yes	No	MPLS + RPR
Restoration	√50 ms	Minutes	Rapid Spanning Tree
Cost	High	√Low	Converging
Used in	Telecom	Enterprise	

Enterprise vs Carrier Ethernet

Enterprise

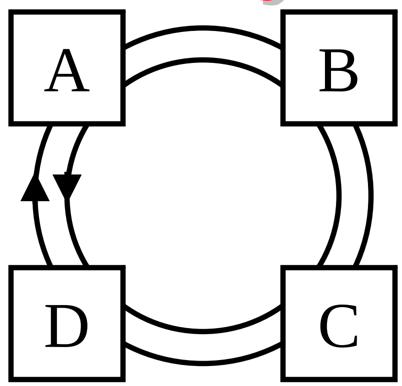
- Distance: up to 2km
- Scale:
  - Few K MAC addresses
  - 4096 VLANs
- Protection: Spanning tree
- Path determined by spanning tree
- Simple service
- Priority ⇒ Aggregate QoS
- No performance/Error monitoring (OAM)

Carrier

- Up to 100 km
- Millions of MAC Addresses
- Millions of VLANs Q-in-Q
- Rapid spanning tree (Gives 1s, need 50ms)
- Traffic engineered path
- SLA. Rate Control.
- Need per-flow QoS
- Need performance/BER

No 100 Mbps Ethernet switches with Q-in-Q, Rate control, Priority

RPR: Key Features



- Dual Ring topology
- Supports broadcast and multicast
- Packet based ⇒ Continuous bandwidth granularity
- Max 256 nodes per ring
- MAN distances: Several hundred kilometers.
- Gbps speeds: Up to 10 Gbps
- Too many features and alternatives too soon (702 pages)

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 $\Rightarrow$ Evolution
- High Performance
- Killer Applications
- Timely completion
- Manageability
- Interoperability
- Coexistence with legacy LANs
  Existing infrastructure is more important than new technology

Laws of Networking Evolution

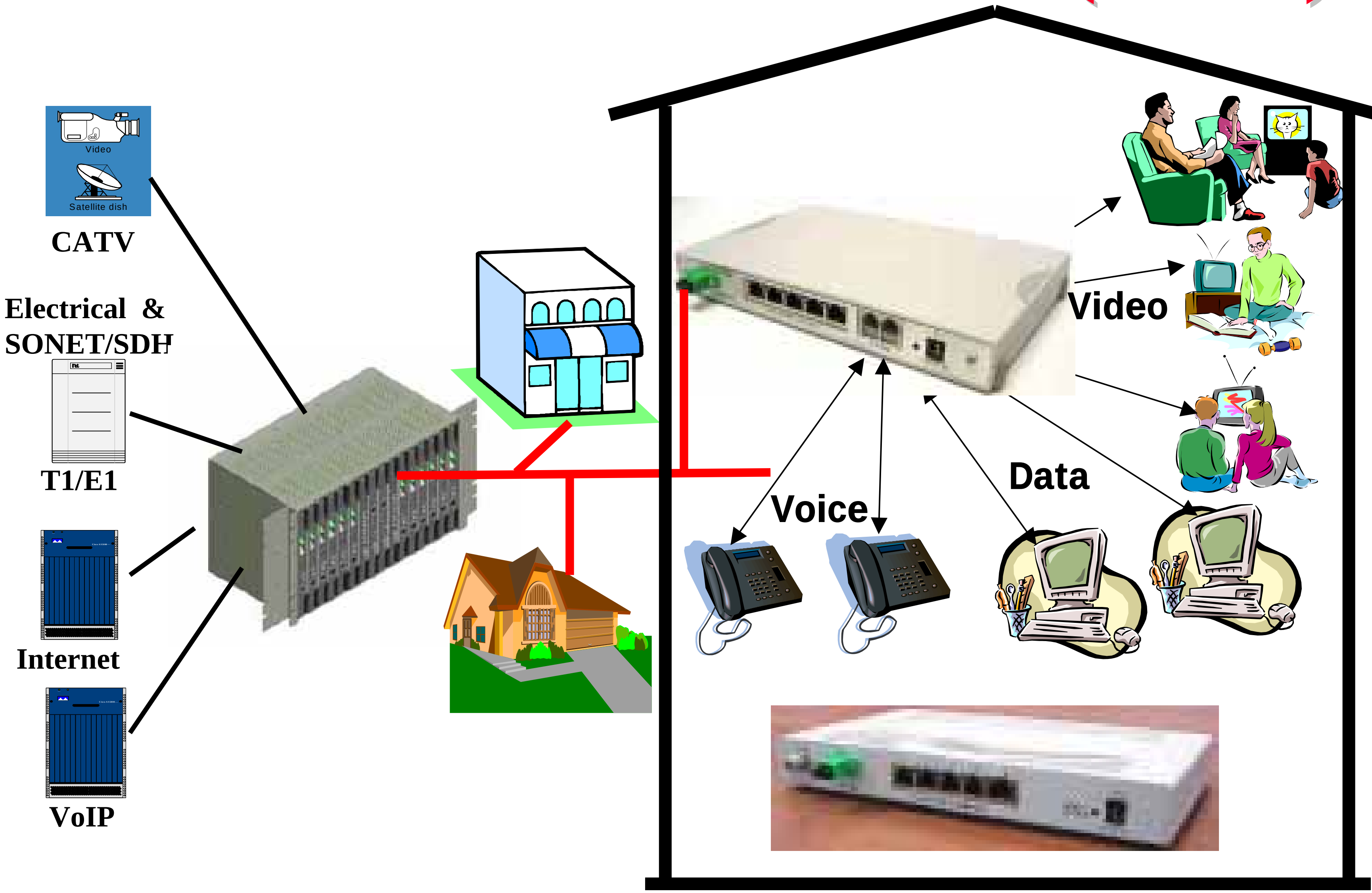
1. Existing infrastructure is more important then deploying new technology
   - ❑ Ethernet vs ATM, IP vs ATM
   - ❑ Exception: Killer technology, immediate savings
2. Modifying existing protocol is more acceptable than new protocols
   - ❑ TCP vs XTP
   - ❑ Exception: New applications (VOIP – SIP, MEGACO, …)
3. Traffic increases by a factor of X/year
   Total revenue remains constant (or decreases)
   $\Rightarrow$ Price/bps goes down by $\cong$ X/year (X = 2 to 4)

Access Networks

- 63.84 M DSL subscribers worldwide. 2003 growth rate of 77.8% is more than the peak growth rate of cellular phones.
- All countries are racing to a leadership position in broadband
- Digital-Divide ⇒ 30M subs@10Mbps, 10M@100Mbps in Japan by 2005
- Telecom epicenter has moved from NA+Europe to Asia Pacific

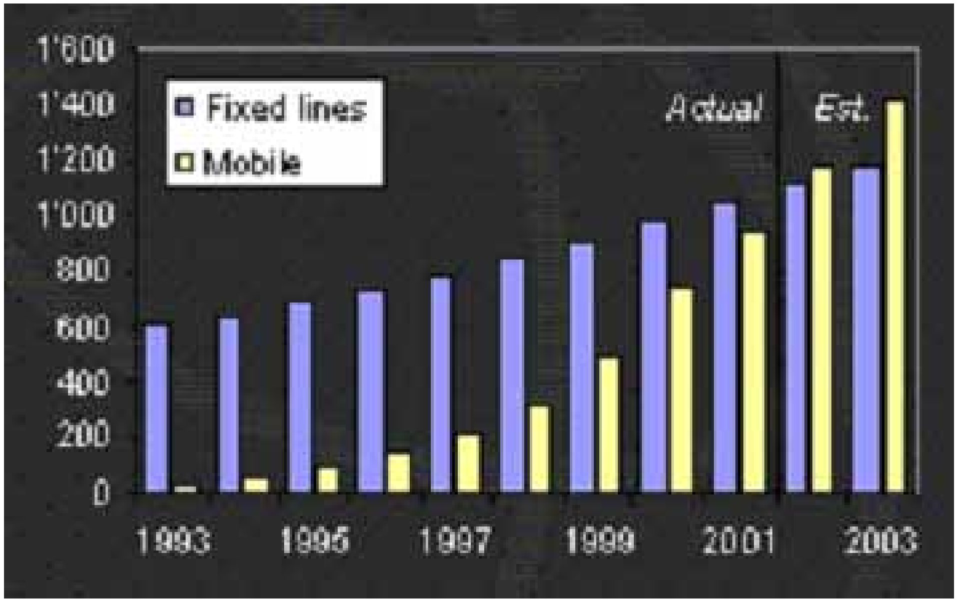
Rank	Country	DSL per 100 Phones	Rank	Country	DSL per 100 Phones
1	South Korea	28.3	6	Israel	14.5
2	Taiwan	19.8	7	Denmark	14.2
3	Belgium	16.7	8	Finland	13.6
4	Hong Kong	16.1	9	Singapore	13.4
5	Japan	15.7	10	France	12.1
			32	USA	5.6

Ethernet to the First Mile (EFM)



Mobility

- 1.35 Billion Mobile subscribers vs 1.2 Billion Fixed line subscribers at the end of 2003 [ITU]
- 70% of internet users in Japan have mobile access
- Vehicular mobility up to 250 Km/h (IEEE 802.20)

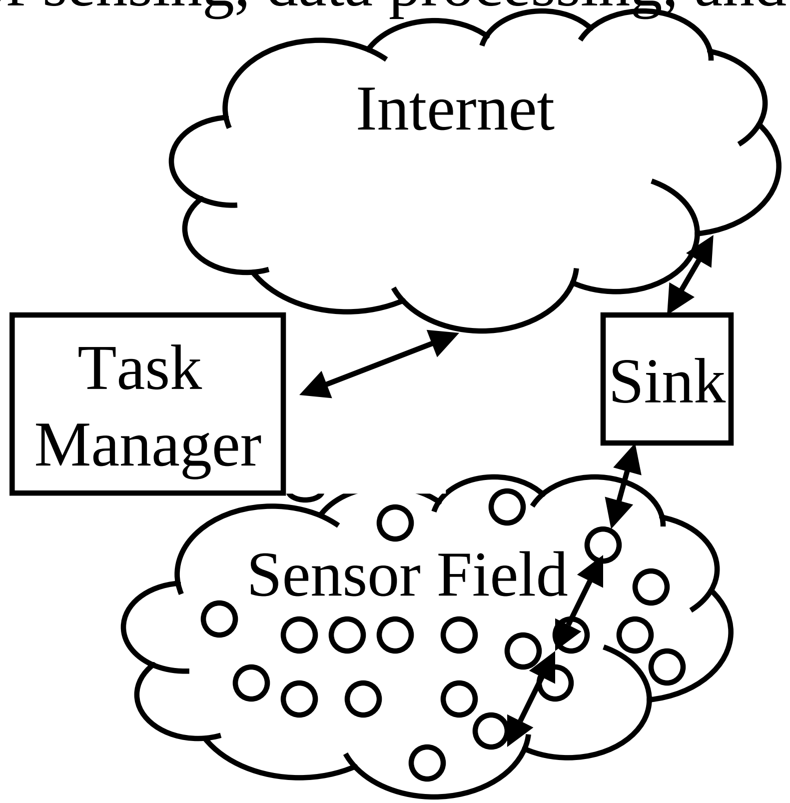


Wireless Issues

- Security (IEEE 802.11i)
- Higher Data rate (IEEE 802.11n, 100 Mbps, using Multiple-input multiple-output antennae)
- Longer distance (WiMAX, >1Mbps to 50 km)
- Seamless Networking ⇒ Handoff (IEEE 802.21)
- Mobility (IEEE 802.20)
- Automated RF management (Cell sites)
- Large scale networks (RFID, Sensors)

Sensor Networks

- Person-to-person comm ⇒ Machine-to-Machine Comm
- A large number of **low-cost**, **low-power**, **multifunctional**, and small sensor nodes consisting of sensing, data processing, and communicating components
- Key Issues:
  1. Scalability
  2. Power consumption
  3. Fault tolerance
  4. Network topology
  5. Transmission media
  6. Cost
  7. Operating environment
  8. Hardware constraints



Top Networking Research Topics

1. Security
2. Large scale wireless networks (RFID, Sensors)
3. Mobility
4. High-Speed wireless
5. Network-based computing (Grid computing)
6. Optical packet switching

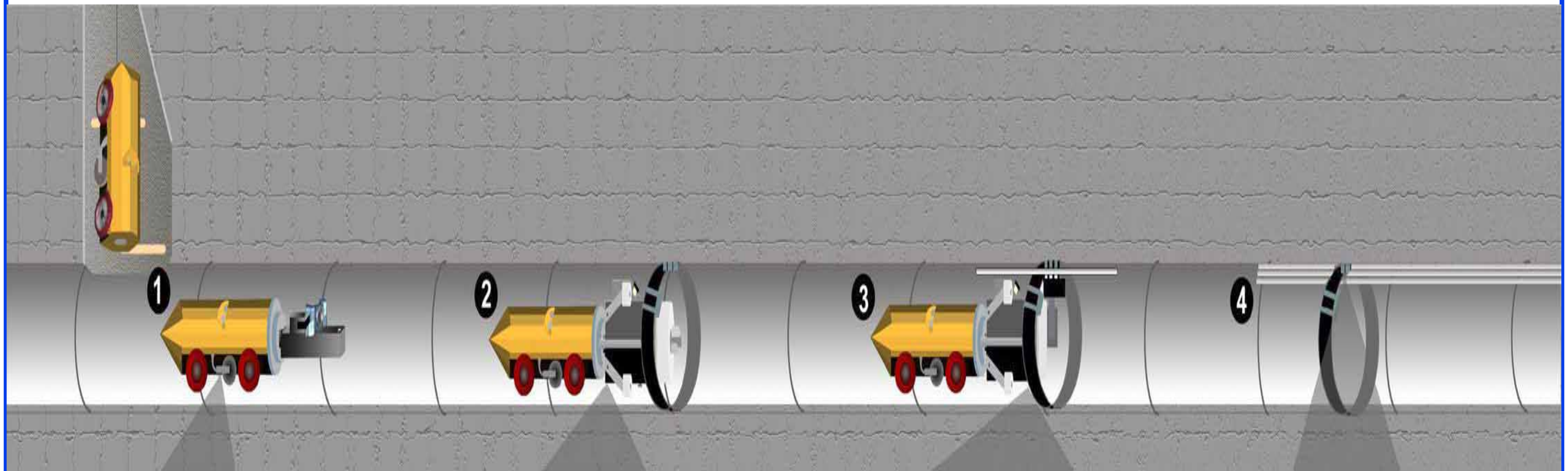
Recent Funding Opportunities

- $40M from NSF on networking research. Two focus areas:
  - Programmable wireless networks
  - Networking of sensor systems
- NIST SBIR:
  - S/w Tools For IEEE 1451-Based Smart Sensor Networks
  - Secure Ad Hoc Wireless Networks
- DOE $400M
  - Massively parallel computing
  - Lightweight operating systems for parallel computers
- DARPA:
  - Internet Control Plane
  - All-optical Packet Router $18M

Fiber Access Thru Sewer Tubes (FAST)

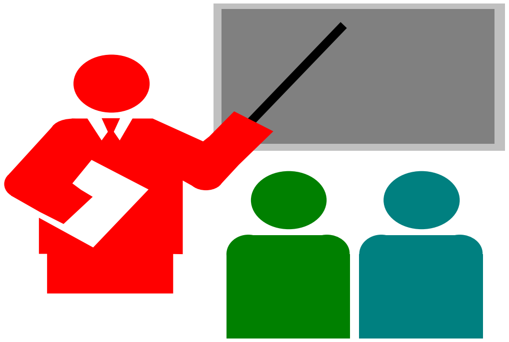
- Right of ways is difficult in dense urban areas
- Sewer Network: Completely connected system of pipes connecting every home and office
- Municipal Governments find it easier and more profitable to let you use sewer than dig street
- Installed in Zurich, Omaha, Albuquerque, Indianapolis, Vienna, Ft 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. Hype Cycles of Technologies
   ⇒ Recovering from the bottom
2. Core market stagnant. Metro and Access more important.
3. SONET vs Ethernet in Metro. Need carrier grade Ethernet.
4. Low cost is the key to success of a technology
5. FTTH is finally happening. EPON will lead.
6. Key issues in Wireless are Security and Mobility

Networking Trends: References

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