Computer Networking: Recent Developments, Trends, and Issues

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These Slides are available at
http:/www.cse.wustl.edu/~jain/talks/ieee0509.htm

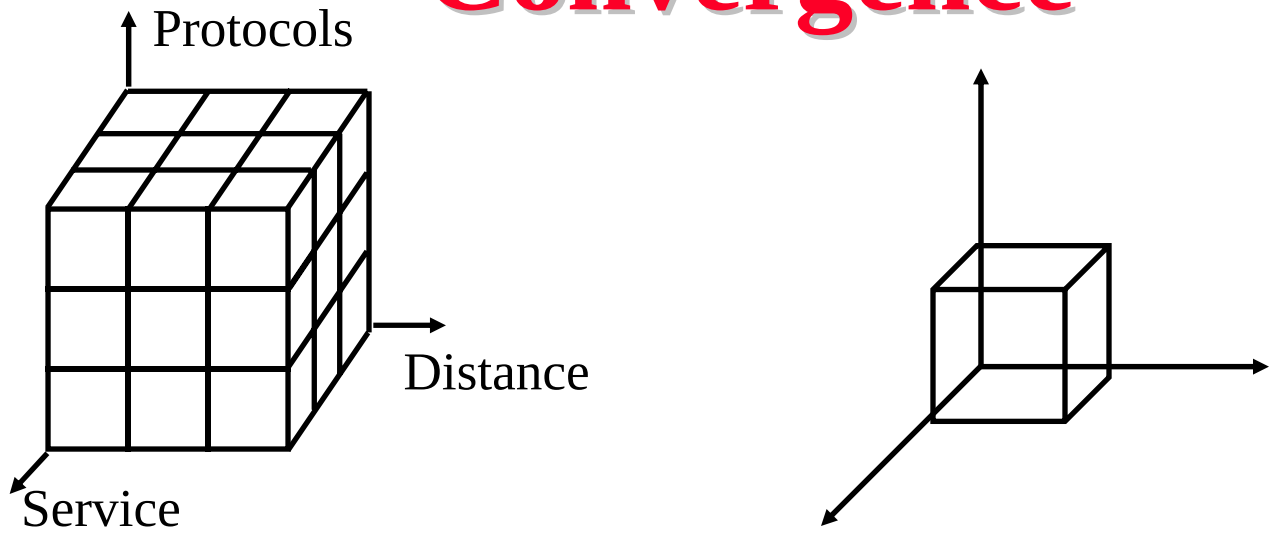
Bird's Eye View of Networking

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

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.

Convergence



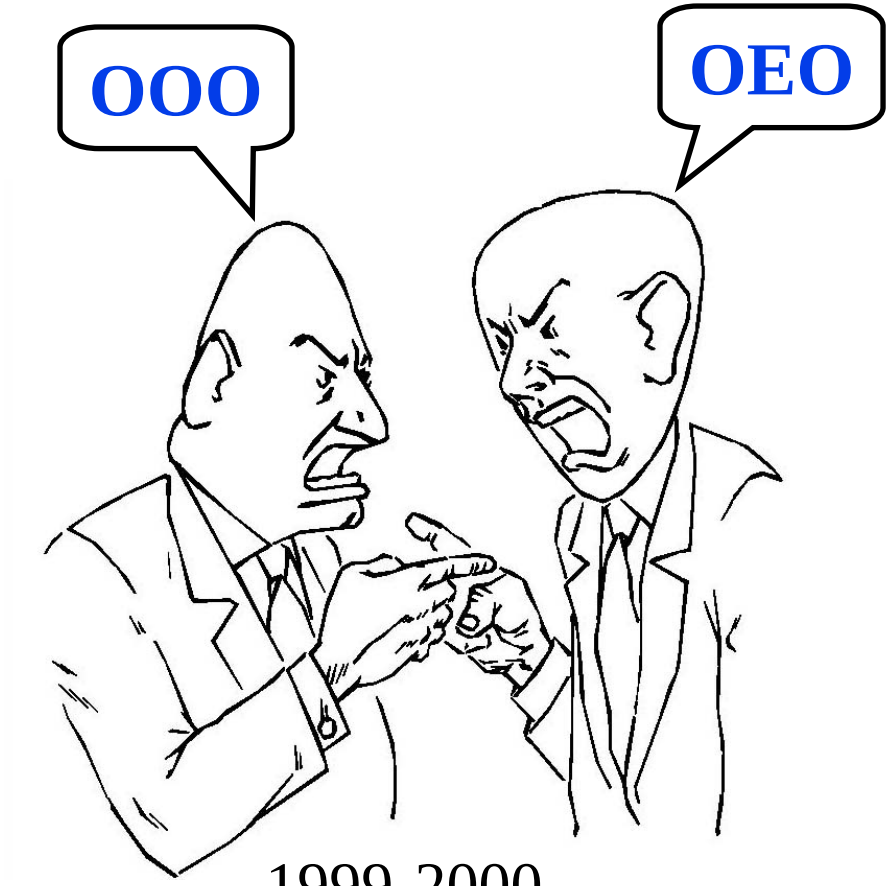
- Distance: LAN vs MAN
- Services: Data, Voice, Video
- Phy: Circuit switched vs Packet switched
- L2 Protocols: Ethernet and SONET
- L3 Protocols: IP
- HTTP: Hyper-Application Access protocol

Core Networks

- Higher Speed/λ: 10 Gbps to 40 Gbps to 160 Gbps
- Longer Distances/Regens: 600 km to 6000 km
- More Wavelengths: 16 λ's to 160 λ's

- 1 Fiber = 160 λ x 40 Gbps = 6.4 Tbps
  = 1 kbps x 6 Billion = 1 kbps/person

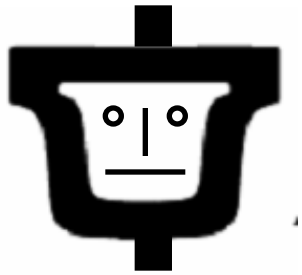
Optical vs Electrical Switching

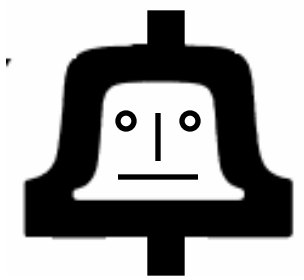


1999-2000

Key Issue: Monitoring

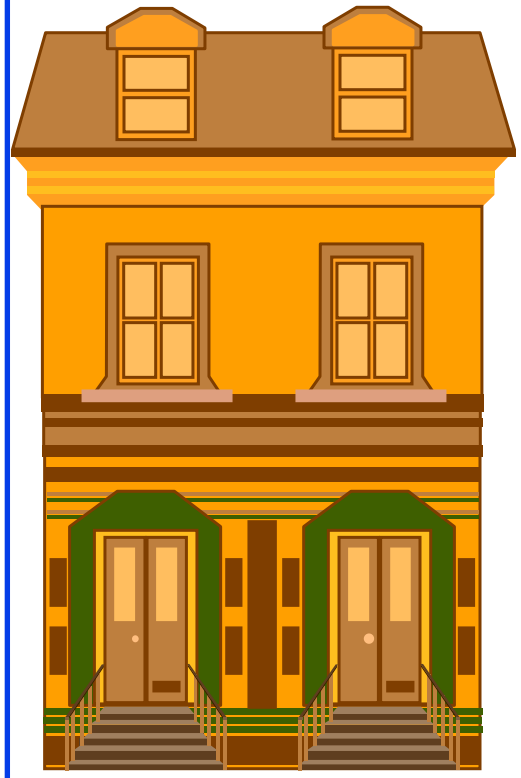
Ethernet: 1G vs 10G Designs

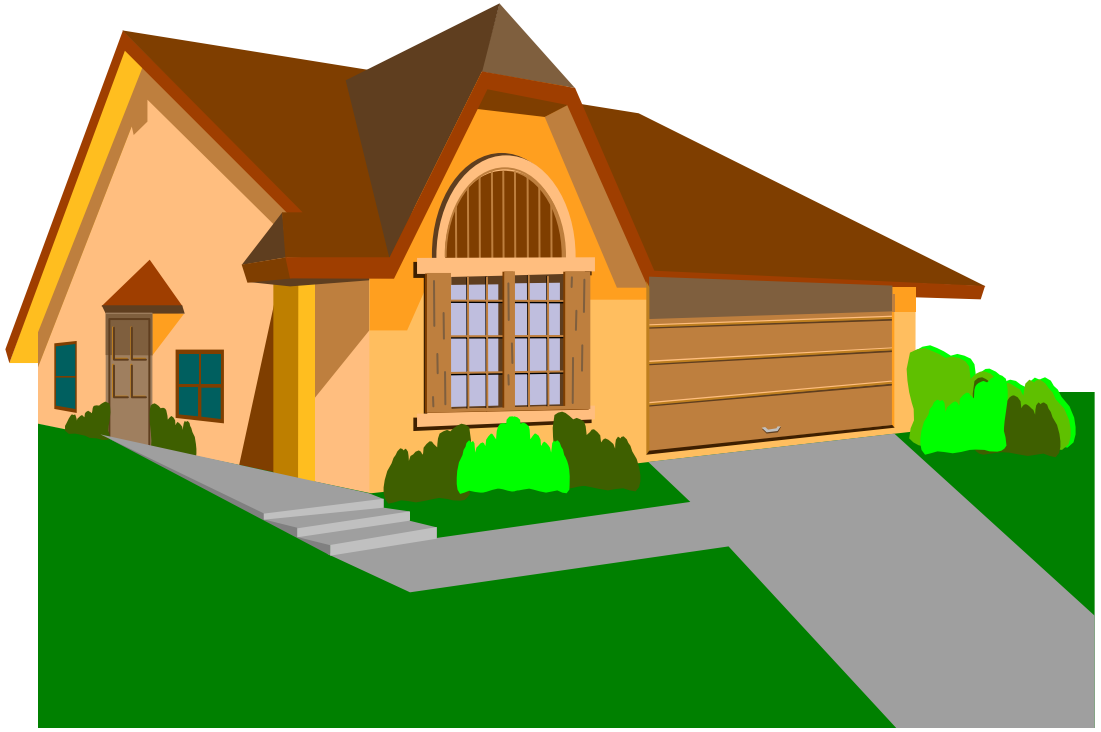




1G Ethernet	10G Ethernet
❑ 1000 / ~~800~~ / ~~622~~ Mbps **Single** data rate	❑ 10.0/9.5 Gbps **Both** rates.
❑ **LAN** distances only	❑ LAN and **MAN** distances
❑ No Full-duplex only ⇒ **Shared** Mode	❑ Full-duplex only ⇒ **No Shared** Mode
❑ Changes to **CSMA/CD**	❑ **No CSMA/CD** protocol ⇒ No distance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

Old House vs New House





- New needs:

  Solution 1: Fix the old house (cheaper initially)

  Solution 2: Buy a new house (pays off over a long run)

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)

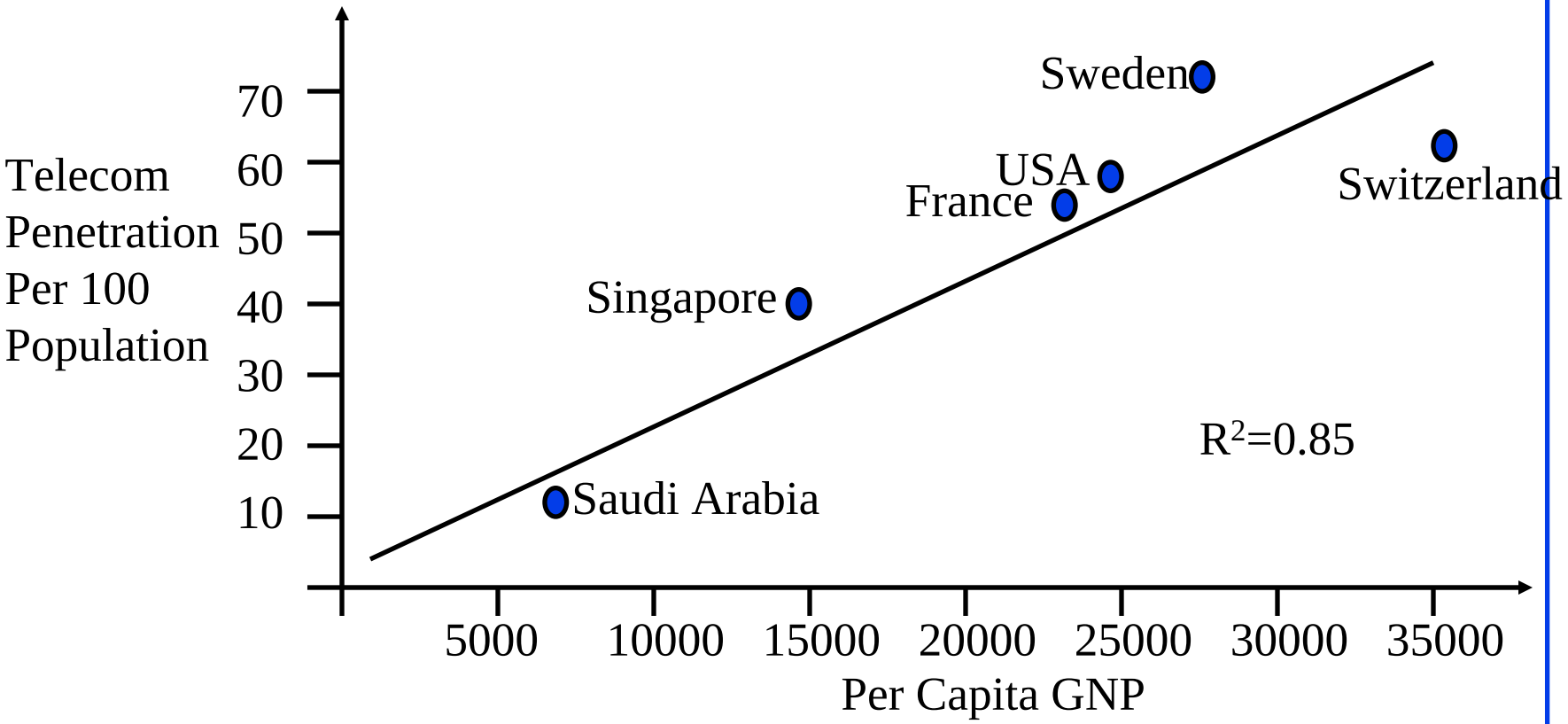
Requirements for Success

- 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)

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)

Telecom and Economic Development



- Fundamental correlation between GDP growth and teledensity

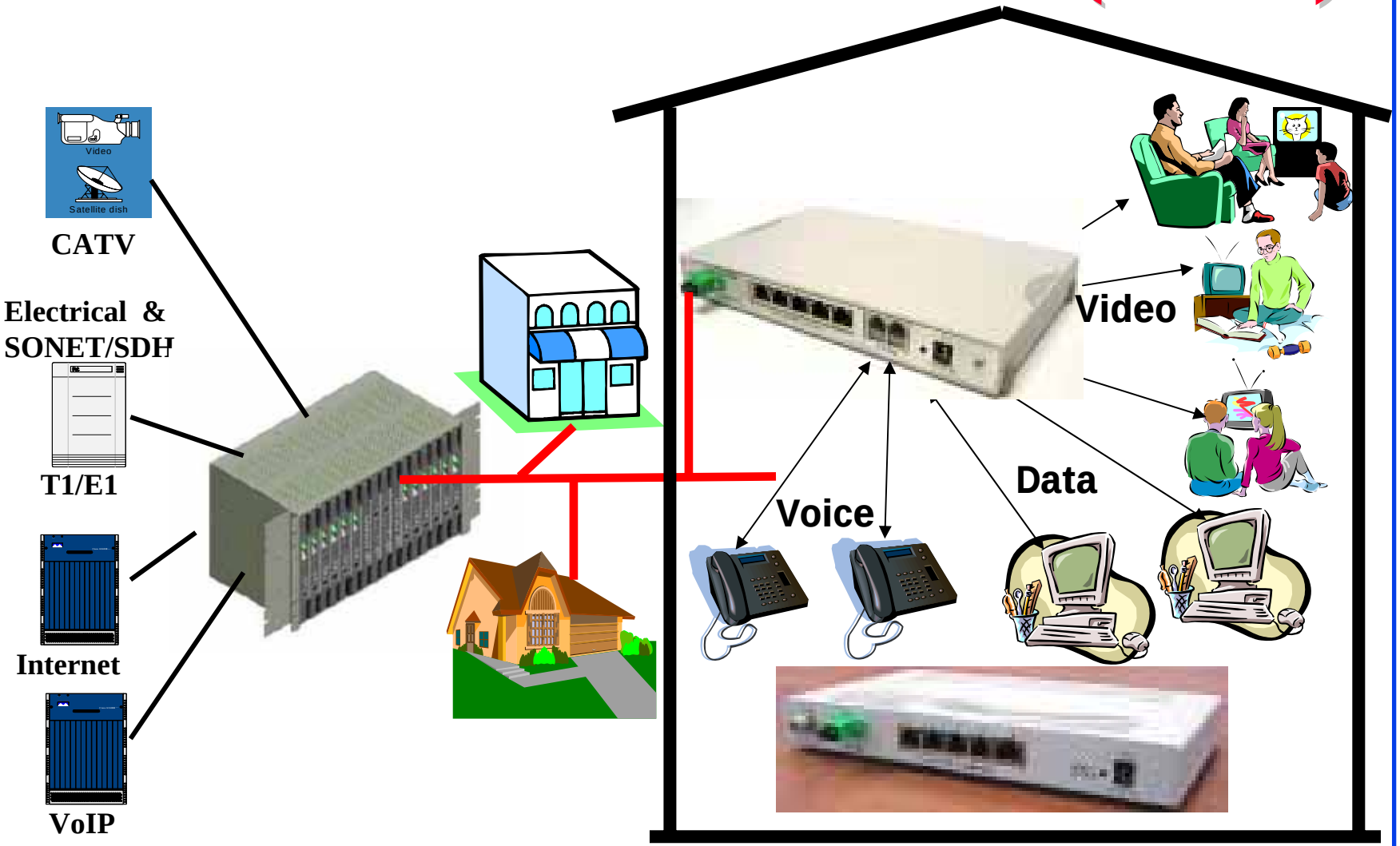
Source: ITU

Access Networks

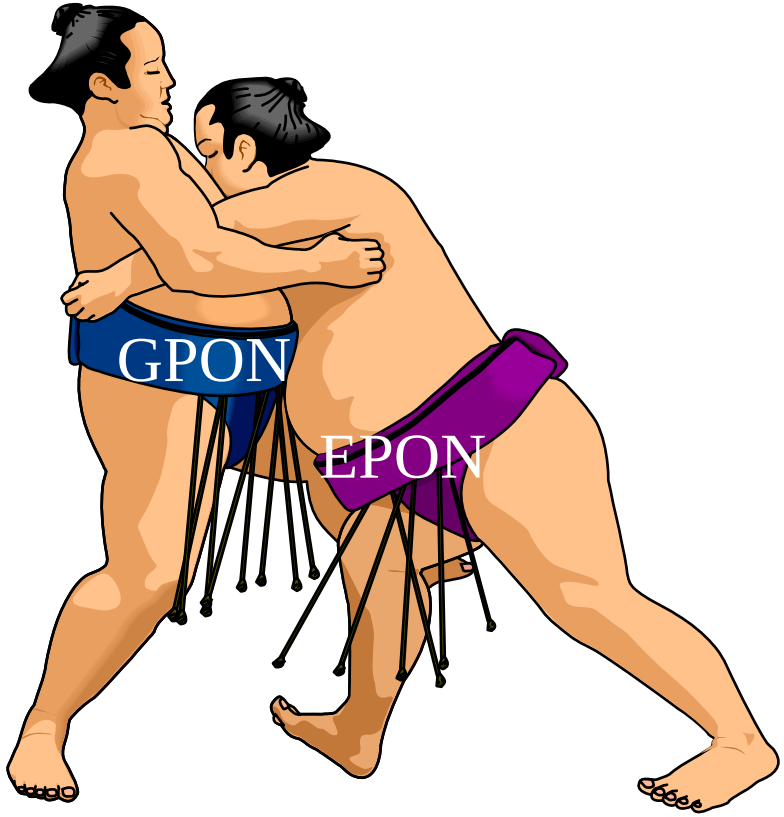
- 63.84 M DSL subscribers worldwide. 2003 growth rate of 77.8% is more than the peak growth rate of cellular phones.
- By Q3'04, 19M Cable Modems, 12M DSL in USA [Leichtman Research]
- All countries are racing to a leadership position in broadband
- Digital-Divide ⇒ 30M subs@10Mbps, 10M@100Mbps in Japan 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)



EPON vs GPON



- Low-cost optics and high volume ⇒ EPON is much cheaper. EPON being planned by US Community networks and by carriers in Japan, Korea, China

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)

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,

Cantenna

- 13,000 Free WiFi access nodes and growing
- 12db to 12db can-to-can shot can carry an 11Mbps link well over ten miles
- Ref: http://www.netscum.com/~clapp/wireless.html

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

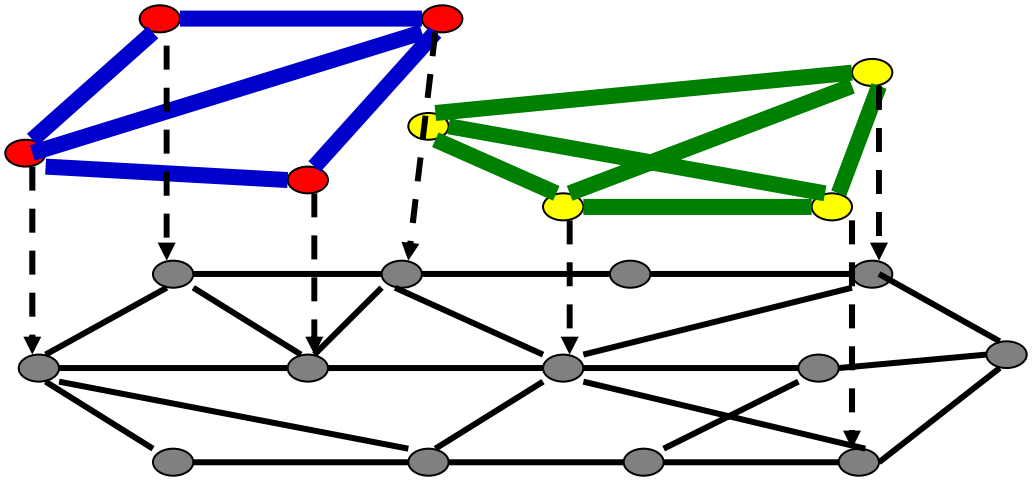
Research Areas

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, multicasting, multimedia
3. **Sensor Networks**: Large scale, Energy efficient
4. **Distributed Computing Networks** (Grids): Grid computing, Grid Storage
5. **Security:** Firewalls, key management, attacks

Disruption Tolerant Networking

- Frequent Disconnection due to mobility, power outage (Military Ad hoc networks)
- Regular or unpredictable disconnections (LEO satellites)
- Very high delay networks (Inter-planetary networks)
- Aka Delay Tolerant/Difficult/challenged/disconnected/ Intermittent networks
- DTN routers need storage but not unlimited
- End-to-end retransmissions not desirable
- Congestion management in DTNs
- Path selection and scheduling in DTNs
- Ref: DTN IRTF

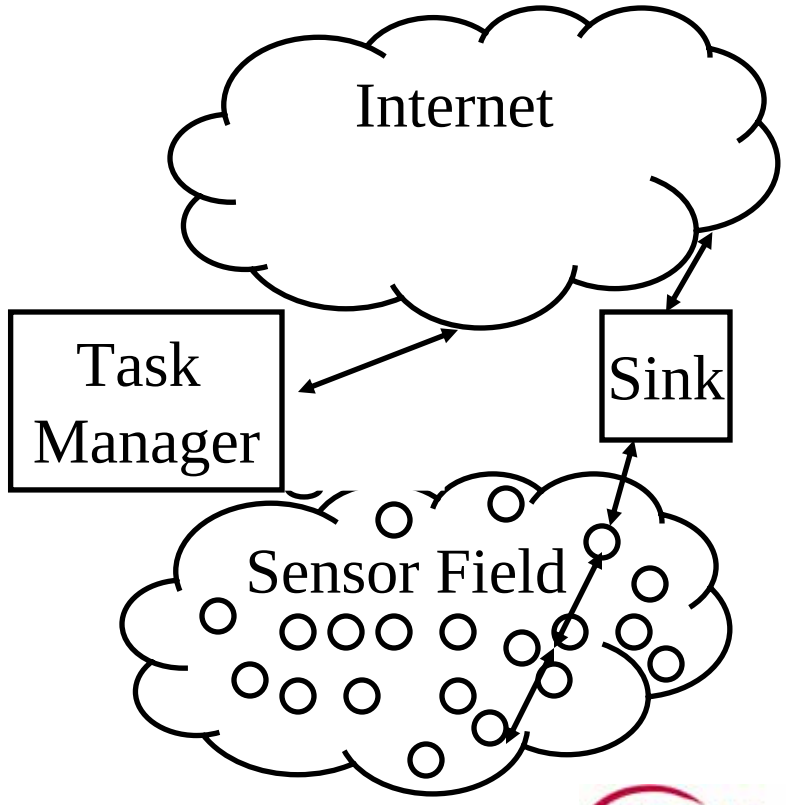
Overlay Networking



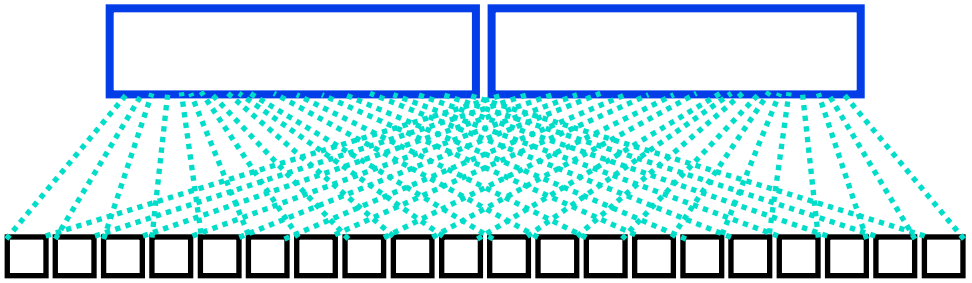
- Networking over Networking
  - Heterogeneity: Multiple L1/L2/L3 technologies
  - Scalability: Multiple Domains
  - Performance: Application level optimization
- Peer-to-peer networking, Video Overcasting,
- Issues: QoS, Routing, multicast, anycast, Secure communication over insecure net

Sensor Networks

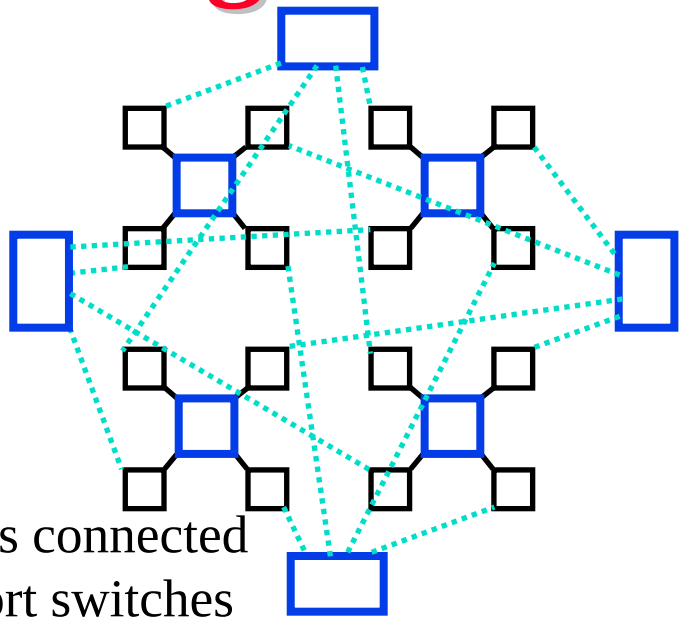
- A large number of **low-cost**, **low-power**, **multifunctional**, and small sensor nodes consisting of sensing, data processing, and communicating components
- Key Issues:
  1. Scalability
  2. Power consumption
  3. Fault tolerance
  4. Network topology
  5. Transmission media
  6. Cost
  7. Operating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



Grid Networking



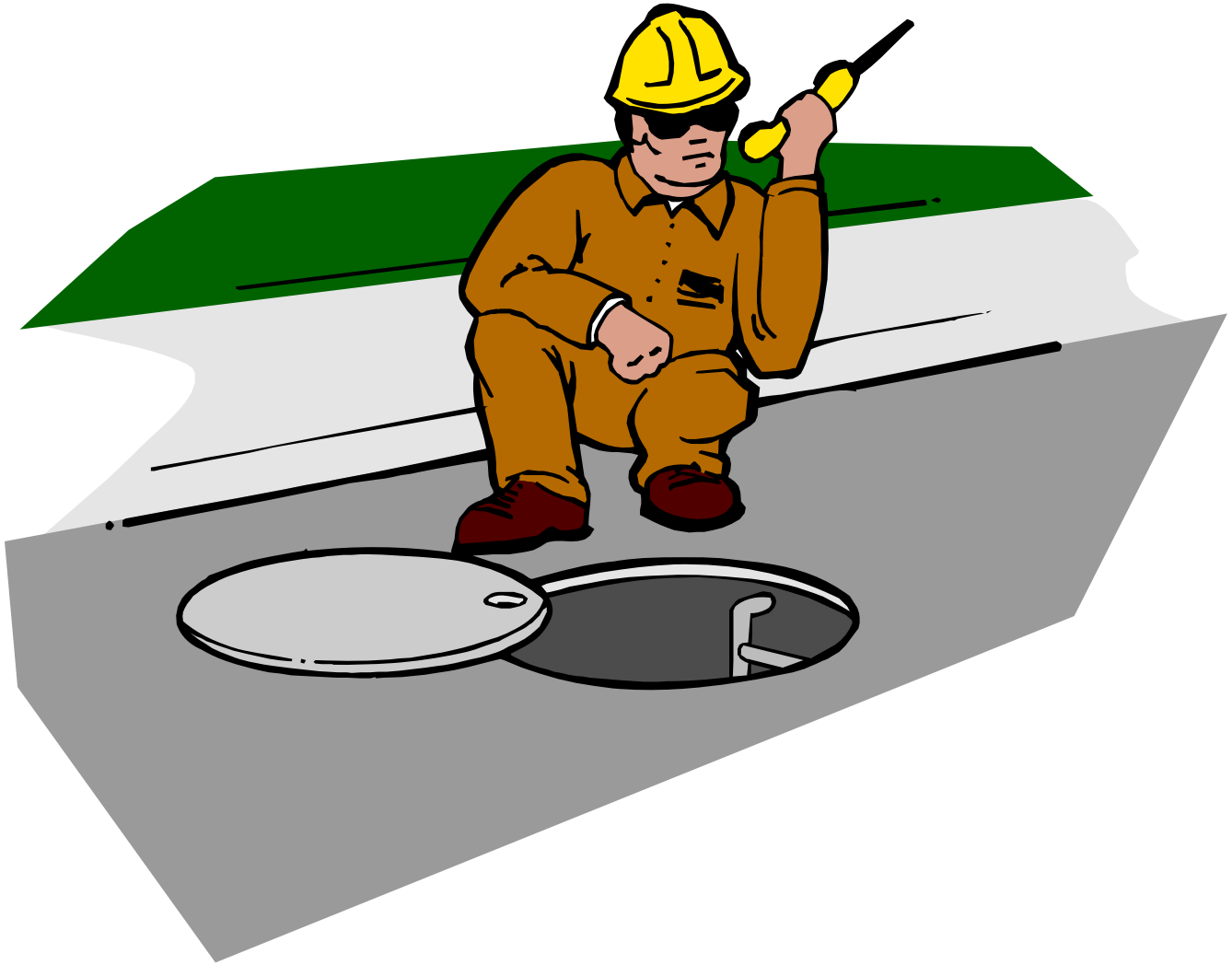
16 Storage nodes connected with two 16-port switches



16 Storage nodes connected with eight 4-port switches

- Grid Computing: High-speed LAN/WAN ⇒ Distributed computing
- Grid Storage: Storage connected in a grid
- Grid = Connectivity to two nodes in one or more dimensions
- Grid Storage: Every node is connected to two 4-port switches. More reliable, less bottleneck, scalable.
- Ref: www.grids-center.org

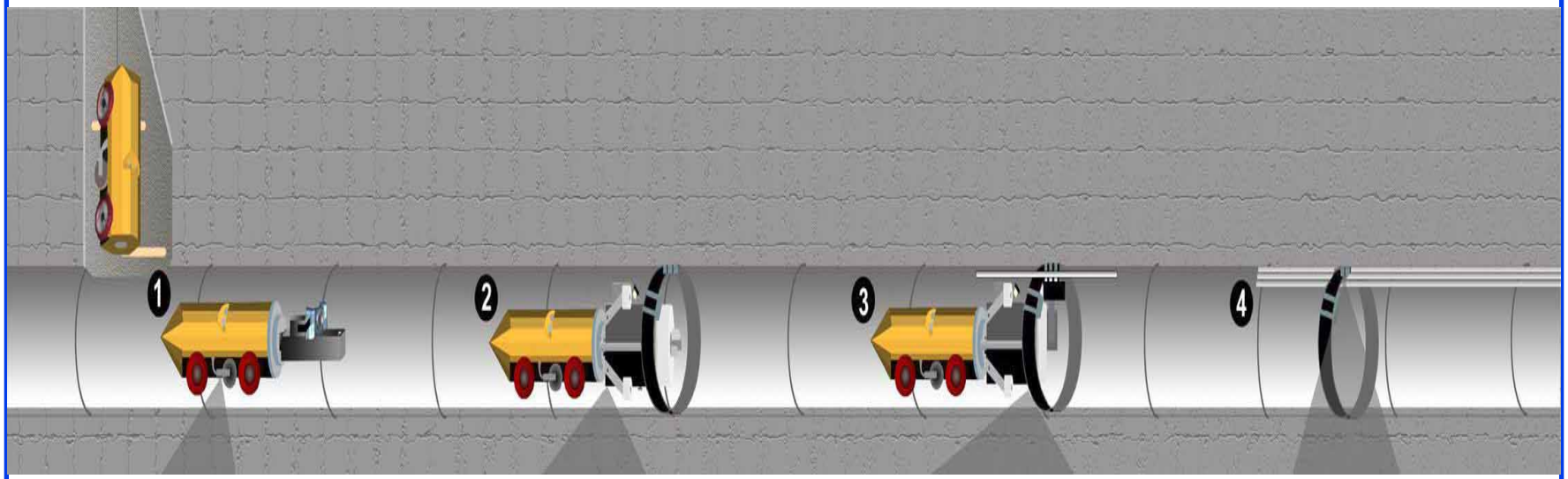
Sewer Networking



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

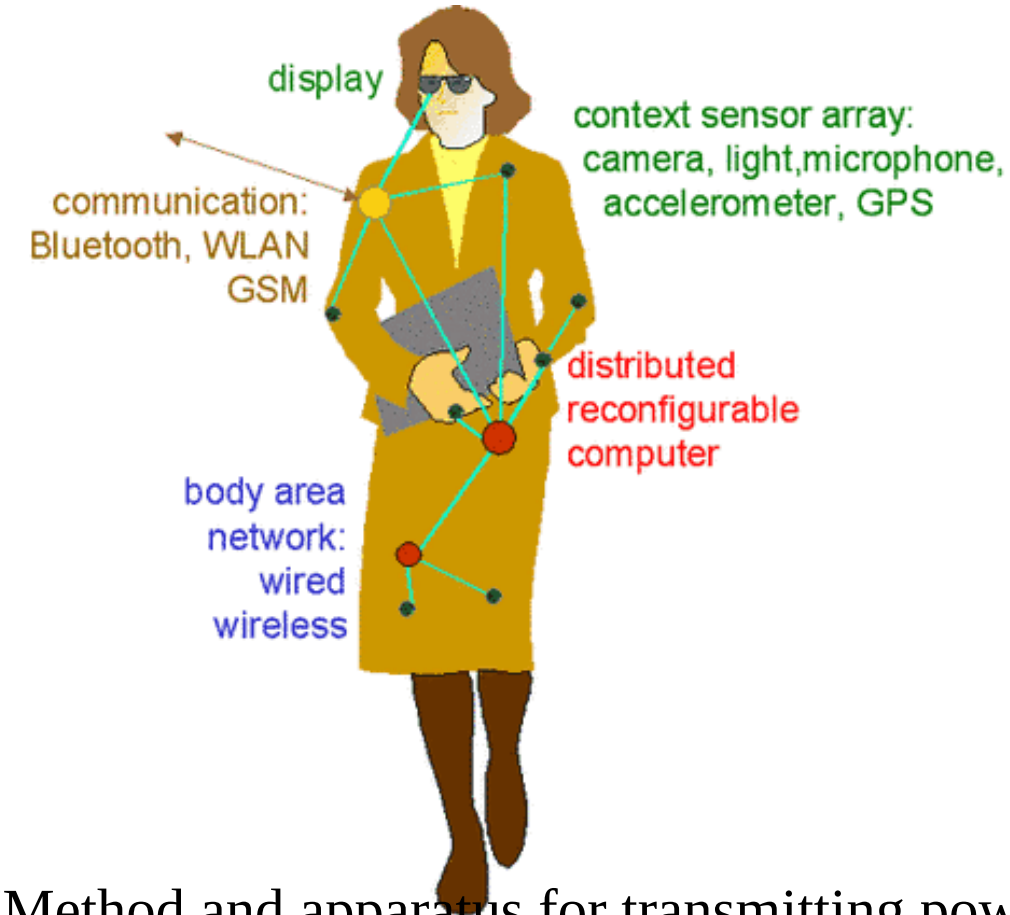
FAST Installation



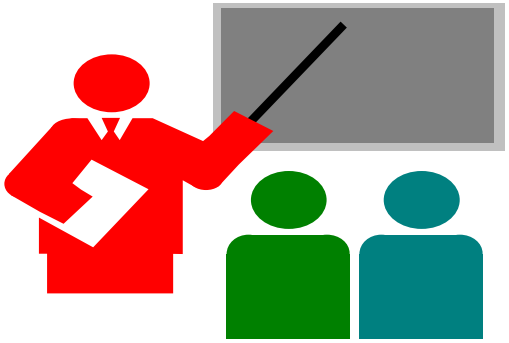
1. Robots map the pipe
2. Install rings
3. Install ducts
4. Thread fibers

Fast Restoration: Broken sewer pipes replaced with minimal disruption

Body Area Networks (BANs)



- Microsoft, "Method and apparatus for transmitting power and data using the human body," US Patent 6,754,472, June 22, 2004.



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

Thank You!