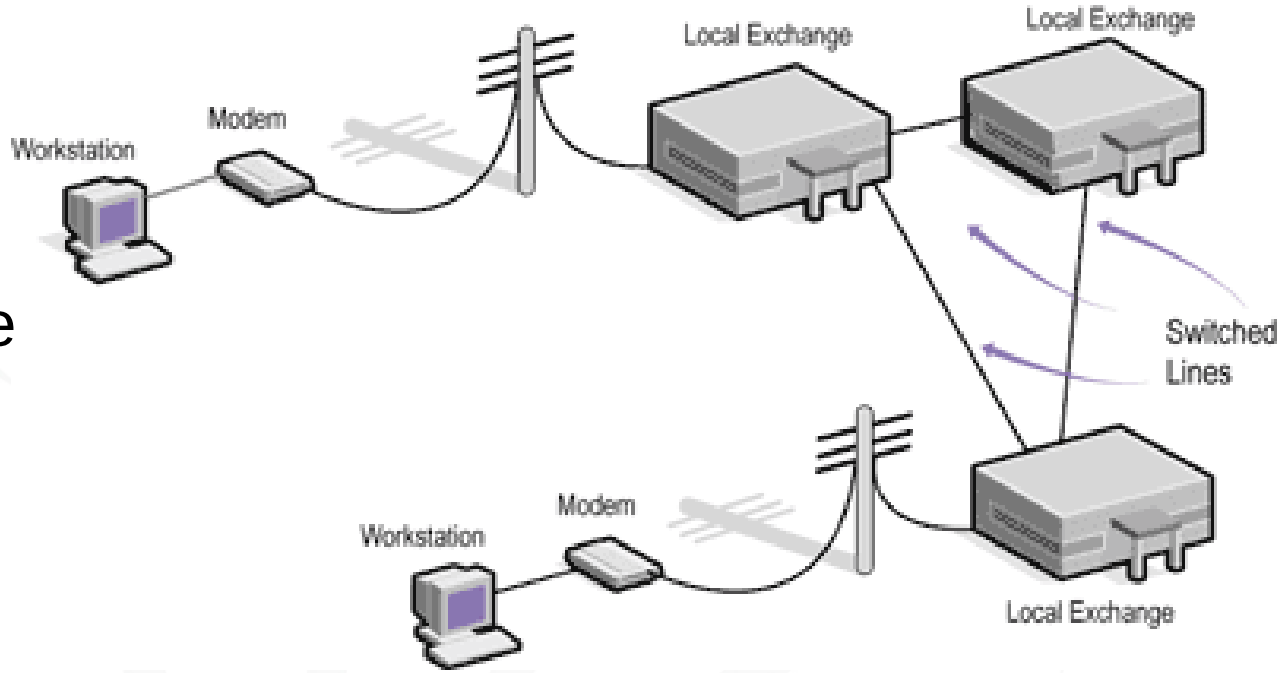
Integrated Services Digital Networks (ISDN)

Digital Subscriber Loop (xDSL)

Circuit Switching: Dial-up Point to Point

- Intelligent network of phone switches
- physical connection - “wire equivalent”



- Routing is external to communication of data
  - Call setup phase - Point to point circuit established using phone #,
  - Circuit is established, then data is transferred
- Analog or Digital, PSTN or ISDN

Circuit Switching: Dial-up Point to Point

- Advantages
  - Ubiquitous – mobile workforce
  - Security
- Disadvantages
  - Call setup delay
  - Low data rate
  - Maintaining modem pools
  - Phone service & long distance charges
  - Blocking

Circuit Switching: ISDN - Integrated Services Digital Network

- Attempt to integrate data, video, voice service
- Digital last mile, utilizing PSTN infrastructure
- Most common form: Basic Rate – 144 kbps
  - 2 “quick dial” phone lines - 64 kbps each, inverse multiplexing (bonding, multilink)
  - 16 kbps control channel, always on
- Problem – pay for connect time, too expensive
- Common uses –
  - backup to a leased line
  - Video conf. – no latency, not shared, no routing

Circuit Switching: Leased Lines - Permanent Circuit Switching

- Addressing is external – Circuit ID, static route
- Monthly rate based on distance and data rate
- Pros
  - Always on
  - High bandwidths available
  - Secure
- Cons
  - Inefficient – TDM
  - Expensive
  - Managing multiple lines in a complex network

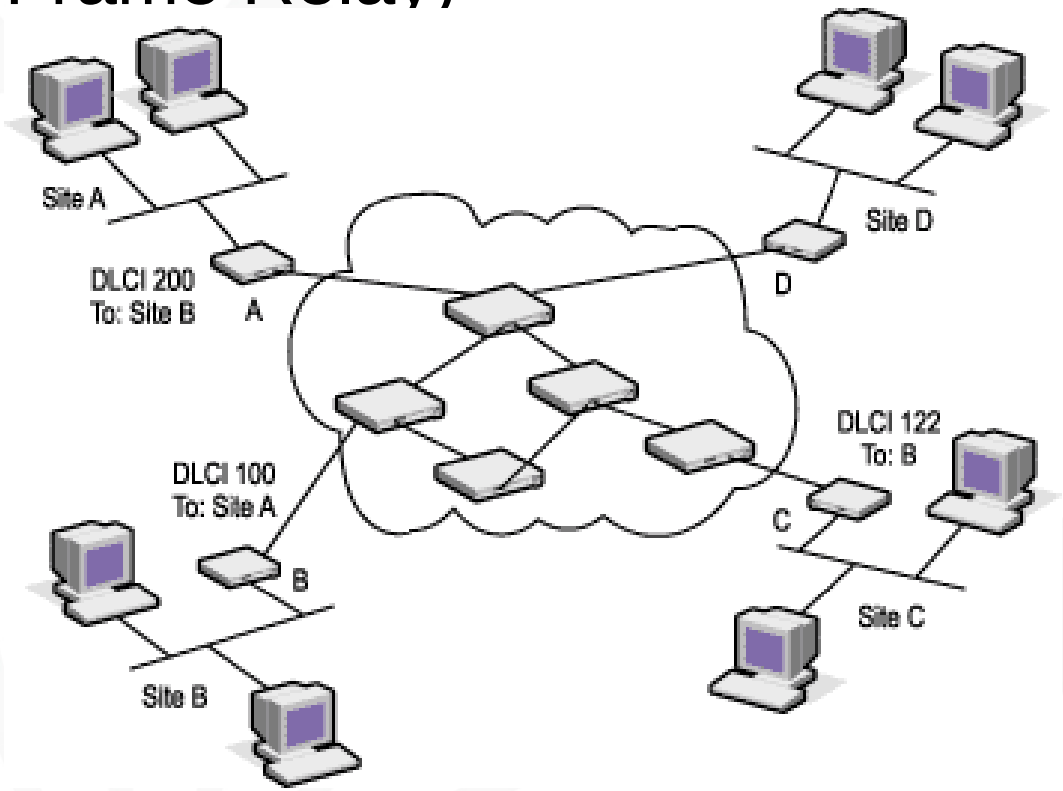
Circuit Switching: Leased Lines

- Layer 1 technology – wire equivalent
- T-Carrier - Copper cable
  - T-1 - 1.544 Mbps
  - T-3 - 44.7 Mbps
- Optical Carrier - Fiber optics cable
  - OC-1 - 51 Mbps,
  - OC-3 - 155 Mbps,
  - OC-12 - 622 Mbps,
  - OC-48 - 2.4 Gbps

Packet Switched Data Networks

- Lower costs - shares circuits using STDM – data link layer (i.e. ATM, Frame Relay)

- Mesh of point to point circuits
- Intelligent nodes address frames
- Store and forward switches buffer frames from many sources and relay along a path



Sharing Bandwidth: Private vs. Public

- Private network
  - All nodes are owned by one company
  - All the circuits are dedicated to traffic from one company
- Semi-Private Networks – Value Added Network
  - All traffic is from a small set of companies
  - Broker dealers for NASDAQ, automotive suppliers, EFT – Electronic Funds Transfer
- Public Networks
  - Traffic is a mix of companies of which you have no control over. (Sprint, Verizon, Worldcom …)
- Internet

Benefits - Private vs. Public

- Private network - (Hospitals)
  - Pros
    - Best security – circuits terminate on premises
    - Total control over performance
  - Cons
    - Management – it is costly and difficult to manage the packet switched network
    - Inefficient
- Value Added Network
  - Good security, good control over performance
  - Homogenous group with like interests
  - Shared costs, economies of scale

WAN Products

- DSL
- Frame Relay
- ATM
- Virtual Private Networks (VPNs)

WAN Alternatives

Technology	Bandwidth	Switching Mode
Leased Line	56 Kbps - 1.5 Mbps (for T1) 45 Mbps (T3)	Circuit
ISDN	64 Kbps - 1.92 Mbps	Circuit
xDSL	600 Kbps - 51.84 Mbps receive 64 Kbps - 2.3 Mbps send	Packet
X.25	Up to 64K	Packet
Frame Relay	56 Kbps - 1.5 Mbps (for T1) 45 Mbps (T3)	Packet
ATM	25 Mbps, 100 Mbps, 155 Mbps, 622 Mbps, 2.488 Gbps	Packet (cell)

Evolution of WAN Protocols – Changing Technologies and Requirements

- X.25 – old technology designed to give low speed terminal access across error prone analog lines
- Frame Relay – newer technology optimized for data transfer between computers, takes advantage of improvements in transport technology to streamline X.25
- ATM – designed to be the one network for data, voice and video, takes advantage of fiber optic

POTS, Satellite Phone

- Switched access, 1200 and 300 bits/s
  - Very long RTD, on the order of 400 ms
  - Fax almost works
  - Calls are $3-5 per minute
- Switched access, 300-9600 bits/s
  - Very long RTD, on the order of 400 ms
  - Throughput depends on aiming accuracy
  - Calls are about $10 per minute

POTS, ISDN

- Switched network, 64,000 and 128,000 bits/s (Voice over Data)
  - Price variation is still broad
  - Per-minute charges on ISDN data calls
- Leased-line, 128,000 bits/s
  - Price variation still broad
- RTD short, 30 ms
- Up to 10 km without repeaters now available
- Limit used to be 5 km

Consumer Broadband

- Cable-TV modems
- Digital Subscriber Line (DSL) service
- Wireless Internet
- Satellite Internet

Evolution of Communications

Narrowband	**Voice, low speed data Wide area coverage 10-to-100 kbps**
Wideband	**Higher speed data, images Wide area coverage 100-to-1000 kbps**
Broadband	**Integrated voice, high speed data, full motion colour video 1-to-100 Mbps (and greater)**

Telecom Speeds

BPS	Abbr.	Term	Technologies
1,000,000,000,000	1 tbps	Terabits	Optical fiber potential
1,000,000,000	1 gbps	Gigabits	Microwave LANs, OC-48, ATM, Gigabit Ethernet
100,000,000	100 mbps	Megabits	OC-12, ATM, T4, OC-3, Faster Ethernet, infrared
10,000,000	10 mbps	Megabits	T3, E3, frame relay, Ethernet, Wireless LANs, cable modem
1,000,000	1 mbps	Megabits	T2, infrared LAN, stationary 3G wireless, E1, DSL, T1
100,000	100 kbps	Kilobits	Wireless local loop, mobile 3G Wireless, ISDN, 2G wireless
10,000	10 kbps	Kilobits	Modems (56K), 2.5G wireless
1,000	1 kbps	Kilobits	2G wireless, infrared LAN

Broadband Technologies

ADSL

DSL

Cable Modem

Satellite

Power Line Technology

HFC

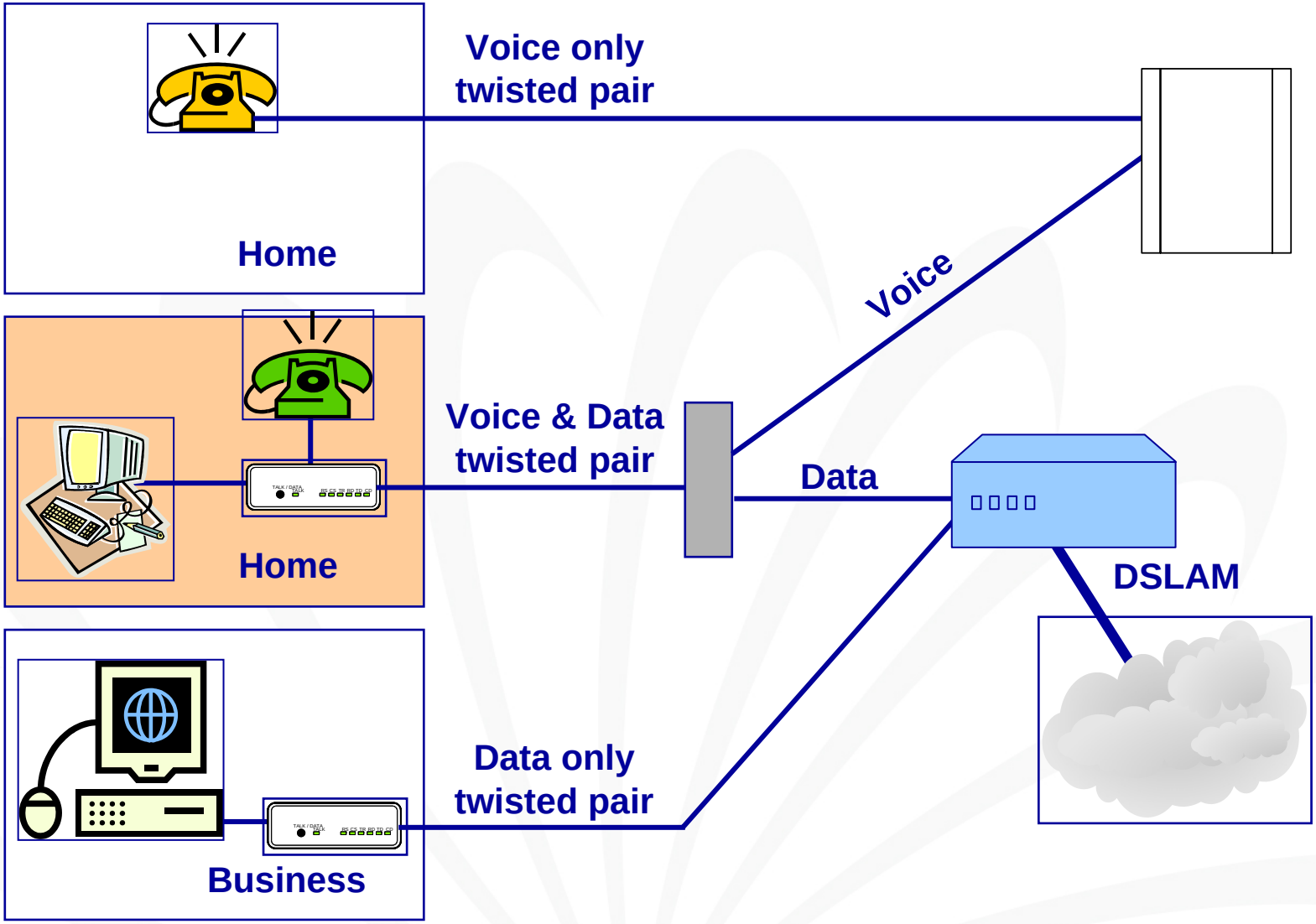
ADSL/xDSL

- Asymmetric Digital Subscriber Line
- ADSL is becoming widely known
  - Broadband to the home
  - Currently expensive and poorly supported
- Uses current copper telephone cable
- Sends signals at higher frequencies
  - Not affected by telephone calls?!

ADSL

- Special ‘modem’ required
- Fast speeds (varies by provider but 128kbps is a commonly used figure)
- Continuous, always on connection
- This is likely to be a very important technology in the next few years.
- Solves the ‘last mile’ problem to home

xDSL Architecture



xDSL Family

Service	Explanation	Download	Upload	Mode of Operation
ADSL	Asymmetric DSL	1.5--8.192 Mbps	16—640 Kbps	Different up and down speeds, one pair wire
CDSL	Consumer DSL	1 Mbps	16—160 Kbps	Now ratified as DSL-lite (G.Lite). No splitters. One pair wire.
HDSL	High-data rate DSL	1.544 Mbps	1.544 Mbps	Symmetrical services. Two pairs of wire.
VDSL	Very High data rate DSL	13—52 Mbps	1.5—6.0 Mbps	Fiber needed and ATM probably used.

Broadband ISDN

Dominant ideas in the early 80's

- Convergence of telecommunication networks
  - Telephone
  - Cable TV
  - Data
- Dominant application: Video On Demand
  - High Definition TV: 155 Mb/s
  - Four different programs per home

ISDN

- Integrated Services Digital Network
- Telecomms solution for Voice + Data
- Uses existing copper infrastructure
- Physical and data-link layers
- Circuit Switching

ISDN

- Control (D) and Data (B) channels
  - Control 16kbps, Data 64kbps
  - Basic Rate = 2B+1D
  - Primary Rate = 30B + 1D (2Mbps)
- ISDN is common in businesses and home as it is a relatively cheap option and it allows voice and data simultaneously

Broadband ISDN

The situation in the 90's

- **HDTV**
  - Broadcasters not willing to invest in HDTV
  - Public prefers diversity over technical quality
  - Video on demand can't compete with video rental
- **Digital Signal Processing**
  - Video compressed into 1.5 Mb/s
  - XDSL allows up to 6 Mb/s over copper local loop
- **Internet**
  - Explosive success of cheap, low quality but very diversified universal communications network

Broadband ISDN: Design Specifications

- **Dominated by the HDTV requirements**
  - 600 Mb/s throughput to every home
    - Fiber to the home
    - Simple protocols implemented in hardware
  - Guaranteed Quality of Service
    - Connection oriented protocol
- **General purpose network**
  - HDTV, LDTV, Voice, Data
    - Different service classes
  - Very low data-rate applications (meter reading)
    - Multiplexing of very different data-rates
    - Low multiplexing overhead

Commercial Broadband

- Leased Lines
  - Digital Subscriber Line
  - T1
  - E1
  - T3
  - Faster
- Frame Relay

HDSL

- Can replace G.703 T1 service
- Bandwidth up to 2 megabits/s
- Cable lengths to 5 km

VDSL

- Asymetrical rates
  - 13 to 52 megabits/s downstream
  - 1.2 to 2.3 megabits/s upstream
- Up to 1 km
- RTD not documented