CS 55231
Internet Engineering

Kent State University
Dept. of Math & Computer Science

LECT-4b

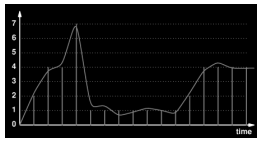
Long Distance Digital Connection Technology

Digital Telephone

- Long before computer communication came into being, telephone companies developed digital communication technology.
- Telephone industries have devised complex long distance digital communication technology.
- Most computer communication rides on the digital communication lines provided by the telephone carriers.
- Key Difference: Synchronous Communication:
  - system designed to move data at a precise rate.

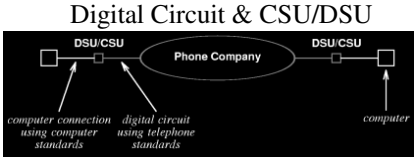
Pulse Code Modulation

- Human voice is digitized and sent as a digital signal.
- How many times it should be sampled?
  - Human voice has frequencies up to 4KHz.
  - Nyquest's theorem suggest that for accurate reproduction it must be sampled two times faster at a rate of 8000 times per second or precisely once in every 125 microsecond.
  - Each sample is sampled at 0-255 levels.
  - A voice channel requires to carry 8x8000 =65Kbps data.



What if the network is not synchronous, such as delay at a junction is traffic dependant?

Digital Circuit & CSU/DSU



- To send computer data over telephone line, the asynchronous data must be converted into the right synchronous telephone standards.
- Data service Unit/ Channel Service Unit.
  - CSU handles line diagnostics, termination, control current surge, lightening, etc.
  - It prevent too many 1's!
  - DSU handles the computer side. It can use RS-232 (for less than 56K rate) or some other standard.

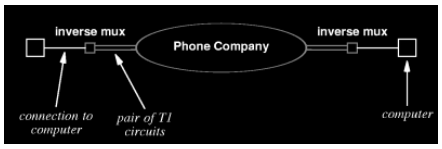
DS Telephone Standards

Name	*Bit Rate (Mbs)*	*Voice Circuits*	*Location*
	.06400	1	
T1	1.5440	24	North America
T2	6.3120	96	North America
T3	44.736	672	North America
E1	2.0480	30	Europe
E2	8.4448	120	Europe
E3	34.368	480	Europe

- These are sometime called DS levels. DS refers to Digital Signal Level Standard. T defines the multiplexing mechanism.

Capacity Adjustments

- Fractional Capacity
  - available at rates such as 64Kbps, 128Kbps, 9.6Kbps, 4.8Kbps, etc.
  - These are Time Division Multiplexed on T1.
- Intermediate Capacity
  - What if you need 2 T1?
  - Inverse Multiplexer
  - Separate CSU/DSU are required for each line.



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Highest Capacity Circuits

Standard Name	Optical name	Bit Rate	Voice Circuits
STS-1	OC-1	51.840	810
STS-3	OC-3	155.520	2430
STS-12	OC-12	622.080	9720
STS-24	OC-24	1244.160	19440
STS-48	OC-48	2488.320	38880
STS-192	OC-192		

- Synchronous Transport Protocols (STS) represent trunk circuits.
- OC is a special version of the standards for fibers.
- OC-3C means single fiber 155 Mbps while OC-3 may require three fibers.

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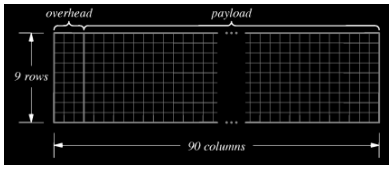
SONET

- Synchronous Optical Network frames carry these data.



- The frame size is circuit dependent.
  - STS-1 contains 810 8-bit octates,
  - STS-3 holds 2430 8-bit octates.

How the size is determined?

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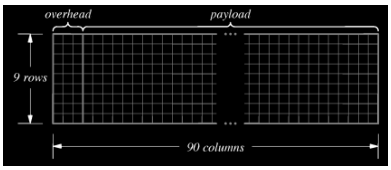
SONET (contd)



- One Frame must be sent in every 125 microsecond.
  - At STS-1 rate, 51.840 Mbps, exactly 6480 bits=810 octates need to be carried in 125 microsecond.
- Synchronous multiplexing
  - multiplexing without introducing delay.
- SONET is used for Point-to-Point data comm. But it can be used in other ways as well, such as in FDDI ring.

How the size is determined?

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Local Subscribers Line

- Leased lines provides the ability to send data across long distance.
- But, before Internet can be ubiquitous the problem of reaching every house hold have to be solved.
- Local Loop;
  - the last mile or a local subscribers carrier line connecting the phone company central office (CO) with the subscriber's place of business.
- Despite the dial-up modems, progress, the need of bandwidth has grown even faster.
- The voice bandwidth and signal-to-noise ratio dictates the ultimate limit of simple modems.

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ISDN

- Integrated Service Digital Line
  - One of the first effort to provide large scale digital service.
  - Uses the same twisted-pair copper wire as telephones, no need to special wiring or equipment.
  - Offers 2B+D channels. B for digitized voice or compressed video.D for control.
  - Bandwidth 64+64+16=144 Kbps + (16 signaling).
  - The two Bs can be combined into one
  - Uses TDM over single pair of wire.
- ISDN is an old technology and faces extinction from improved modems and other technologies.

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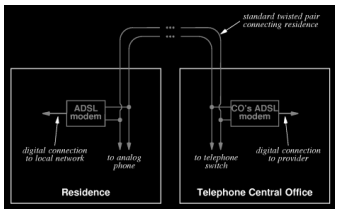
Asymmetric Digital Subscribers Line (ADSL)

- It has more download and smaller upload bandwidth.
  - 6.144 Mbps Down + 576 Kbps Up + 64 Kbps (control Up)
- It keeps the telephone as well.



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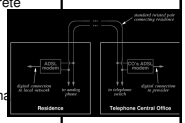
How ADSL Works

- Telephone lines are not designed for such high data rate!
- It does everything to evade interference.
  - Combines FDM an Inverse Multiplexing known as Discrete Multi-tone Modulation (DMT).
  - Divides the bandwidth into 286 sub-channels
  - assigns 255 down and 31 upstream.
  - Conceptually a separate modem runs on each of them.
  - Carriers are spaces 4.1325 KHz apart to avoid cross-cha interference.
  - It also does not use frequency from 0-4KHz. To avoid voice.
  - Each modem also tracks the error rate and adjusts the modulation scheme (quantization levels etc) dynamically with the noise in the sub-channels.
  - Does not guarantee a capacity, but is the best effort depending on the cable quality and local interference.
  - Effective rate varies in 32Kbps-6.4mbps DN/32-640 Kbps UP



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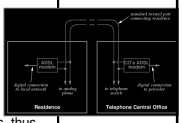
Other xDSLs

- Symmetric DSL (SDSL)
  - inverse ADSL is not easy to find so best choice for server farms.
  - Uses a somewhat different encoding technology.
- High rate DSL(HDSL)
  - 1.544 Mbps both directions.
  - Does it by restricting to shorter distances.
  - Requires two pairs of twisted pairs.
  - A one pair variant is HDSL2.
  - It can survive bridge-tap
  - Fails gracefully, works at half capacity when one wire fails, thus provides reliability to businesses.
- Very High DSL (VDSL)
  - 52 Mbps!
  - Requires special concentrator devices to be inserted in between.
- ADSL G.LITE
  - ITU standard for 1.5 Mbps/ 512Kbps (December 1999)



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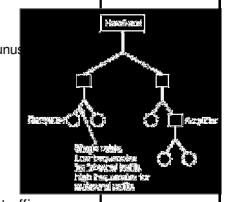
Cable Modem

- Cable Modem
  - A coax is better carrier than twisted pair.
  - CATV available at 80% residential units in USA.
  - Currently 1-450 MHz band is in use (can take upto ~1 GHz)
  - Divided into 6MHz television sub-channels.
  - Amplifies signal in the neighborhood.
  - A very good download broadcast media with high unus capacity.
- Limitations:
  - The FDM does not scale.
  - Capacity is divided by customers.
  - Unidirectional architecture
    - no upstream channel
    - amplifiers in between are unidirectional too.
- Basic Cable Modems use Telephone for upstream traffic
  - Can offer up to 3-10 Mbps download speed



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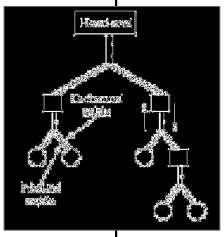
Hybrid Fiber Coax (HFC)

- HFC uses a hybrid cable with fiber and coax
  - Fiber carries main data while coax carries individual subscribers data.
    - Will require massive rewiring
    - new fiber-coax interface equipment,
    - bi-directional amplifiers
- How it works
  - uses combination of TDM and FDM
  - 1-50 MHz up, 40-450 MHz down (6MHz channels), 450-750 MHz down digital communication.
  - TDM groups customers according to neighborhood.
  - Asymmetric to customers like ADSL.
  - 3-10 Mbps/ 128 Kbps-10 Mbps upload



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Alternatives

- Satellite
  - Uses Satellite for Downlink and telephone for uplink
- Cellular Like Wireless

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▲ High scores are best.
▼ Low scores are best.
Bold type denotes first place.

	Straight FTP Throughput (Kbps) ▲	Monthly Service Fee	Cost per Mbps* ▼
ANALOG V.90			
Concentric Network San Francisco	20.9	$19.95	$977
CABLE			
@ Home Fremont, CA	222.8	$39.95	$184
@Home Sarasota, FL	434.9	$39.95	$94
MediaOne Arlington, MA	263.6	$39.95	$155
MediaOne Atlanta	532.8	$39.95	$77
MediaOne Boxford, MA	**613.1**	$39.95	**$67**
MediaOne Elmhurst, IL	581.9	$39.95	$70
Optimum Online Westport, CT	383.0	$39.95	$107
DSL			
Bell Atlantic Leonia, NJ	406.8	$59.95	$151
Bell South Atlanta	534.5	$59.95	$115
Brainstorm/Covad Foster City, CA	84.5	$00.00	$1,091
Sirius/Covad San Francisco	140.6	$149.00	$1,085
SATELLITE			
DirecPC Tampa, FL	223.2	$49.99	$229

* Based on monthly service charges.

BETTER ▶

Source: PC Magazine, April 1999

Current Options

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