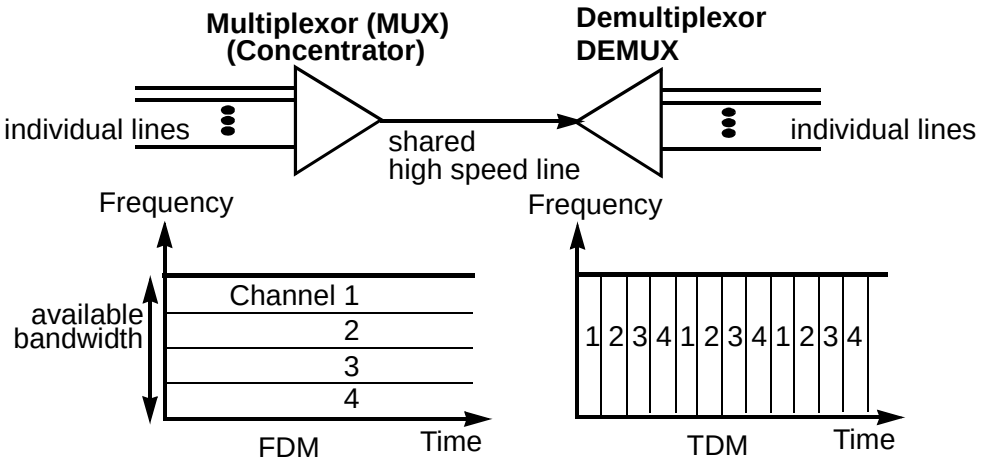
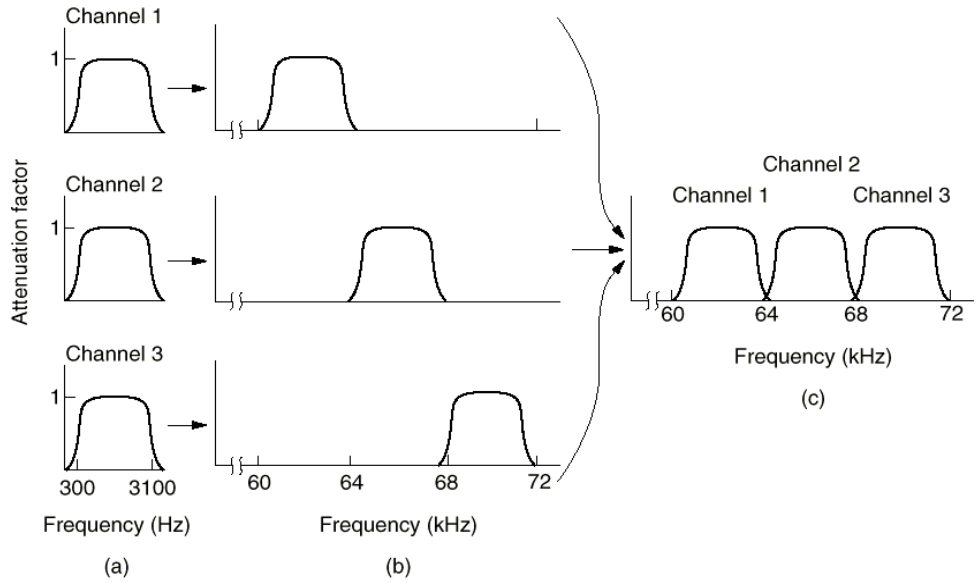
Evolution of Switching Techniques

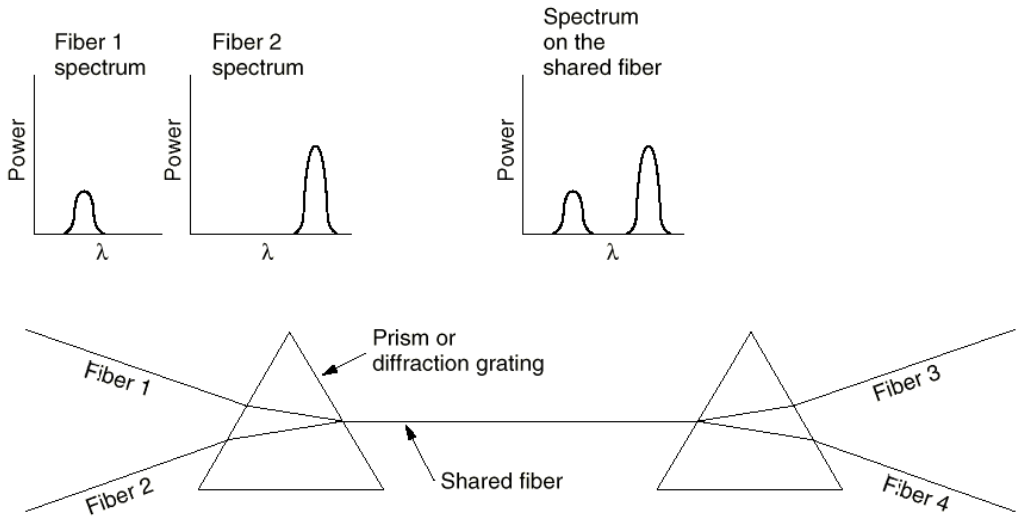
1. Dedicate Channel. Separate wire frequency division multiplexing (FDM) time division multiplexing (TDM)



Frequency Division Multiplexing (FDM)



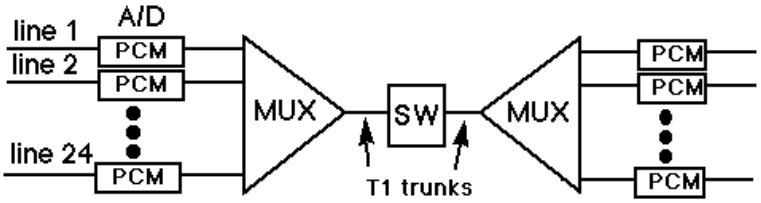
Wavelength Division Multiplexing

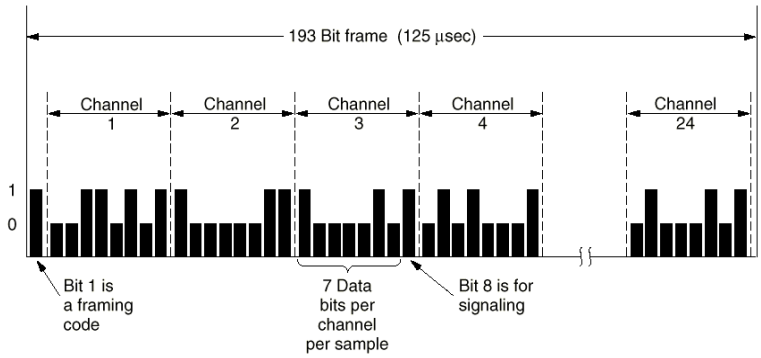


Impact of WDM

- Many big organizations are starting projects to design WDM system or DWDN (Dense Wave Division Mutiplexing Network). We may see products appear in next three years.In Fujitsu and CCL/Taiwan, 128 different wavelengthes on the same strand of fiber was reported working in the lab.
- We may have optical routers between end systems that can take one wavelenght signal, covert to different wavelenght, send it out on different links. Some are designing traditional routers that covert optical signal to electronical signal, and use time slot interchange based on high speed memory to do the switching, the convert the electronic signal back to optical signal.
- With this type of optical networks, we will have a virtual circuit network, where each connection is assigned some wave length. Each connection can have 2.4 gbps tremedous bandwidth.
- With inital 128 different wavelength, we can have about 10 end users. If each pair of end users needs to communicate simultaneously, it will use 10*10=100 different wavelength.
- There is an issue of protocol layering. Should we have IP/DWDN directly, or IP/Sonet/DWDN? No one is talking about IP/ATM/Sonet/DWDN.

T1 and PCM



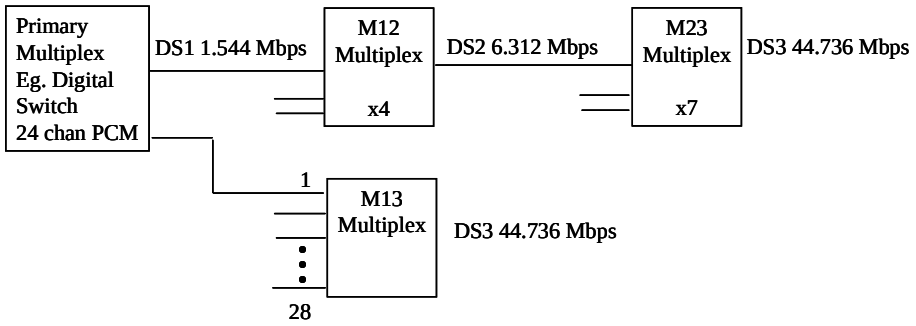


T1 frame Structure

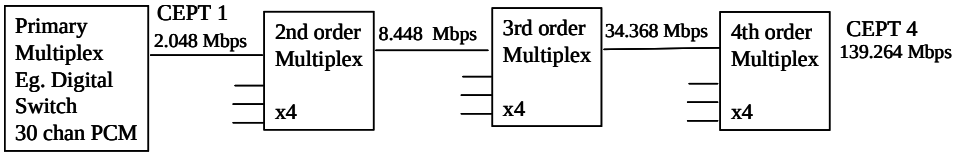
Every 6 frames it steals one bit from each channel for signalling purpose. What is the impact of this design on data comm.?

Basic Digital Hierarchies

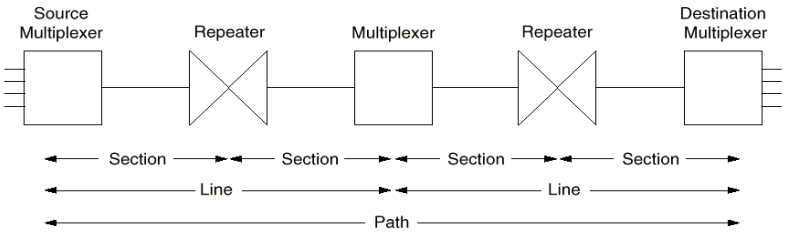
North American Digital Hierarchy



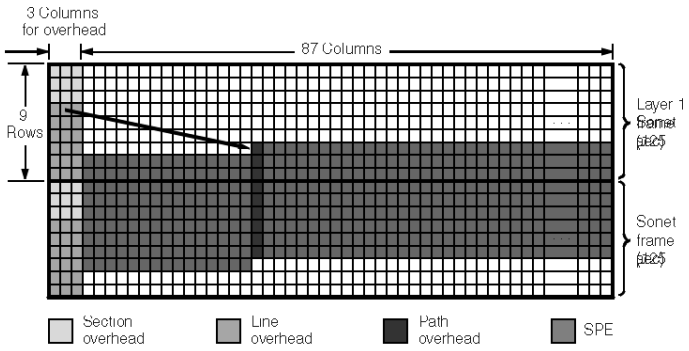
European Digital Hierarchy



SONET (Synchronous Optical NETwork)



Dual ring is a common topology for SONET.



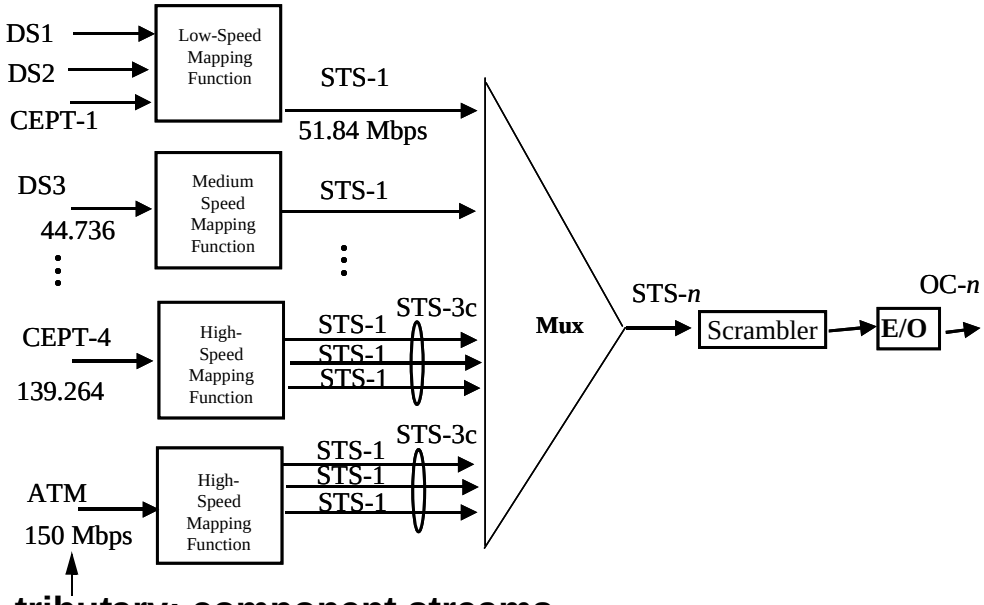
SPE: synchronous payload data
This is STS-1 frame with 9x90 bytes (51.84 Mbps).
STS-3 frame has 9x270 bytes (155.52 Mbps).
Frame rate is 8000 per second.

SONET and SDH Multiplex Rate

SDH (Synchronous Digital Hierarchy) STS (Synchronous Transport Signal)

SONET		SDH	Data Rate (Mbps)		
Electrical	**Optical**	**Optical**	**Gross**	**SPE**	**User**
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28		

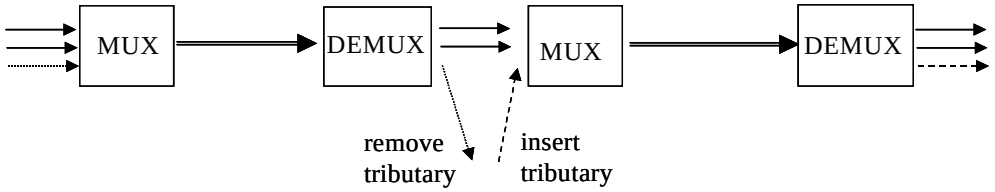
SONET Multiplexing



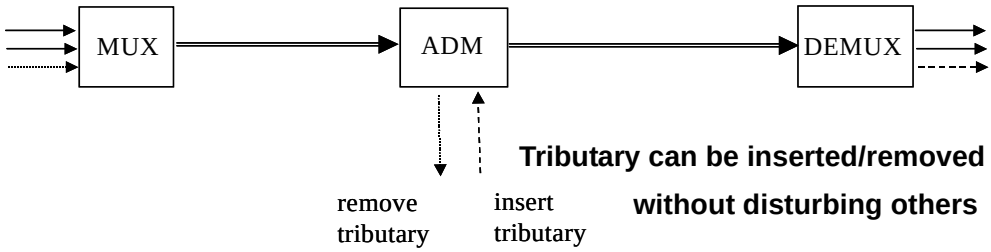
tributary: component streams

SONET Add-Drop Multiplexor (ADM)

(a) pre-SONET multiplexing

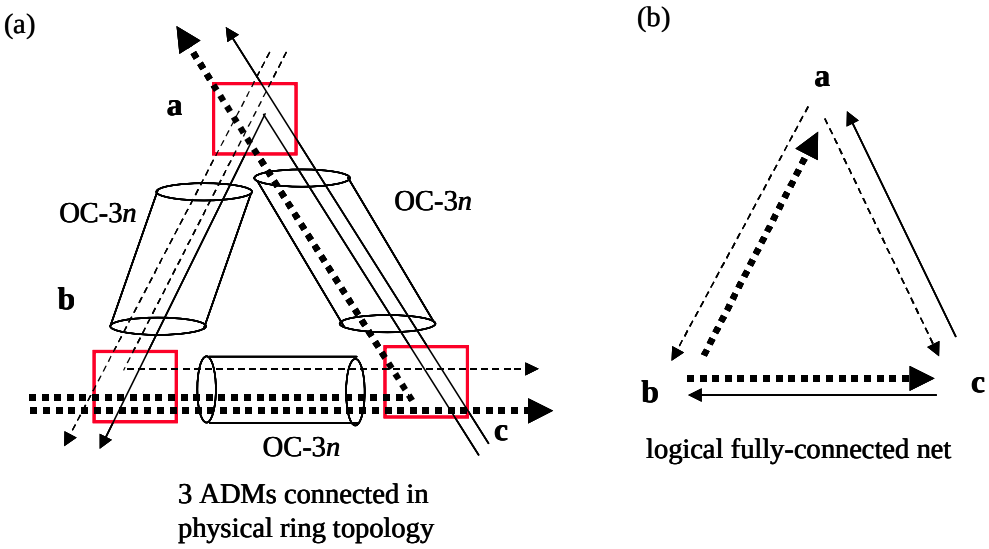


(b) SONET Add-Drop multiplexing



Tributary can be inserted/removed without disturbing others

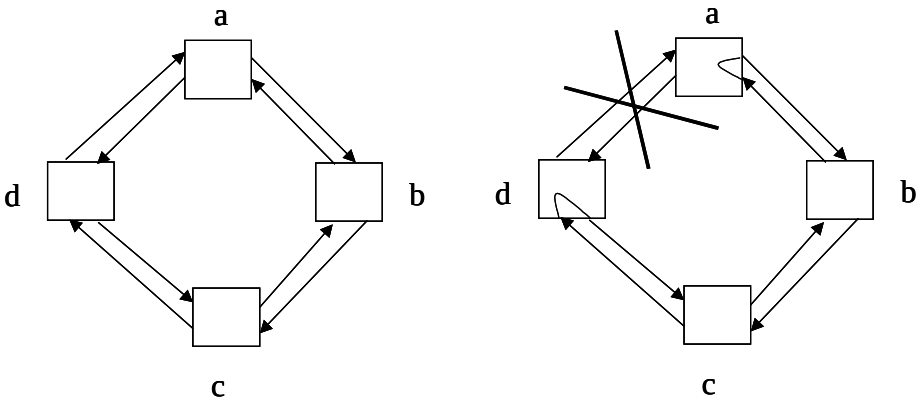
Configure Logical Networks Using ADM



3 ADMs connected in physical ring topology

logical fully-connected net

SONET Self-Healing Ring

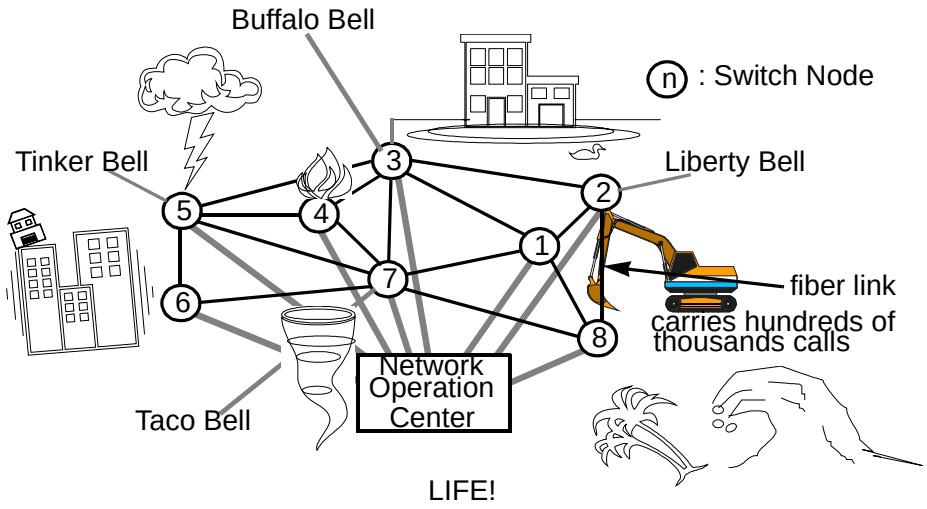


restoration can be done in 50 msec

(a) Dual ring

(b) Loop-around in response to fault

What is the Network Restoration Problem?

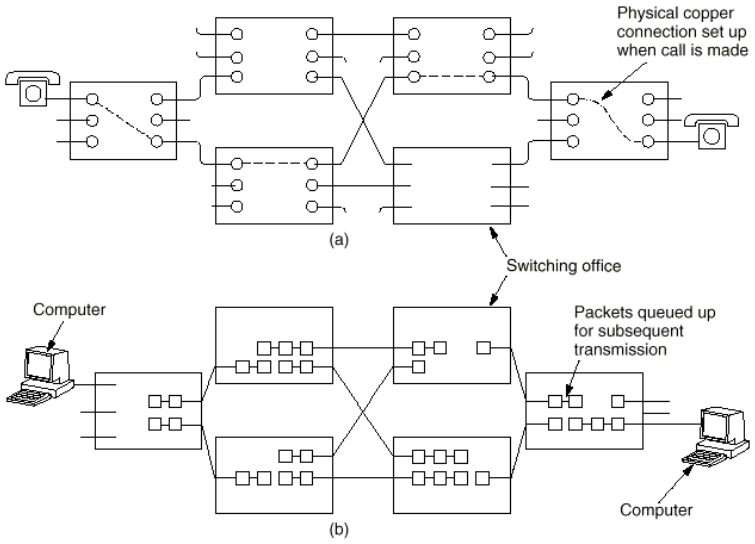


- Types of Failures: Channel, Link, Node, Area, and Transient Failures.
- Network Restoration: Process of recovering from network failures.
- Types of Restoration Approaches: Centralized, Distributed, Hierarchical.

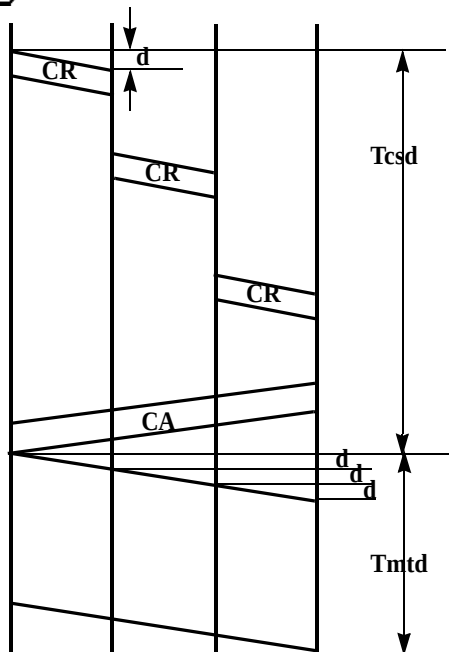
Evolution of Switching Techniques

2. Circuit Switching
   using FDM or TDM with demand (dynamic channel assignment)
   e.g. old telephone networks, satellites.
   difficulties in handling computer data traffic:
   - demand assignment per "message" ⇒ relative long set-up time.
   - demand assignment per "session" ⇒ low utilization.
3. Message Switching
   with data concentrator for long distance high-speed line
   also called statistical multiplexing or
   ATDM (Asynchronous Time-Division Multiplexing)
   used in stored-and-forward network.
   Note: addresses needed to identify messages.
4. Packet Switching
   variable size messages from host segmented into small packets.
   advantages—simultaneous parallel path possible;
   pipelining in multihop network.
   Problems— disassembly, reassembly, sequencing, support real-time traffic.

Circuit Switching vs. Packet Switching: Network



Delay Analysis of a Circuit Switch Network

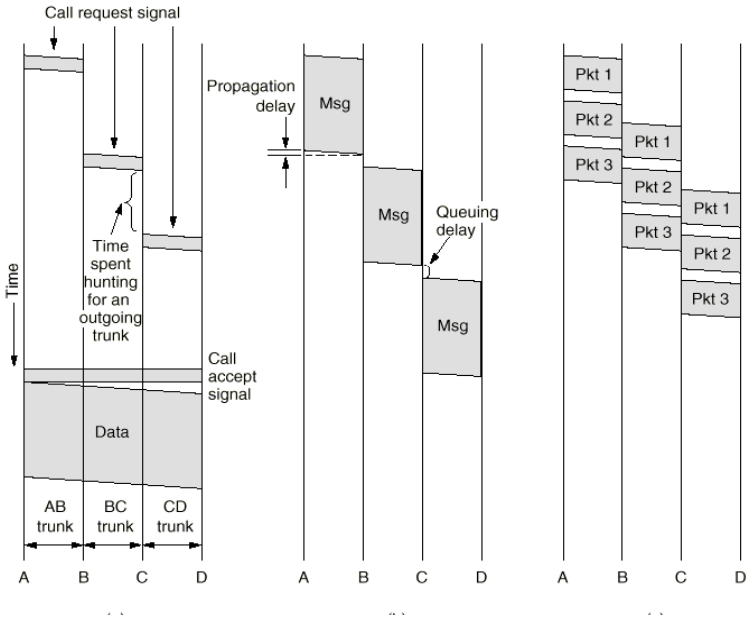


d: propagation delay
CR: Call Request message
CA: Call Accept message
Tcsd: Total call setup delay
Tmtd: Total message transmission
L: message length (bits)
b: transmission speed (bps)

Assume all hops of the same b an
then Total circuit switching delay=
Tcsd + Tmtd
= Tcsd + (3d + L/b)

→no. of hops+1

Timing Analysis of Ckt SW, Msg SW and Pkt SW



Important Network Design Parameters for Analyzing Network Performance

Propagation delay refers to how long it takes for a bit to traverse a link. It depends on the distance and the signal propagation speed.

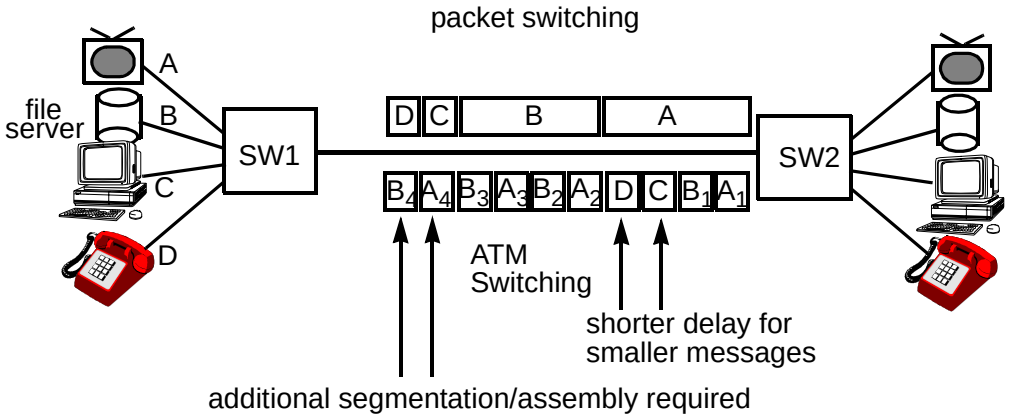
Example: 10km distance, $2*10^8$ m/sec propagation speed.

Propagation delay = distance / signal propagation speed
Transmission delay = message size / transmission speed
Queueing delay depends on

- how many requests on the queue and
- how fast the node can process them.

Evolution of Switching Techniques

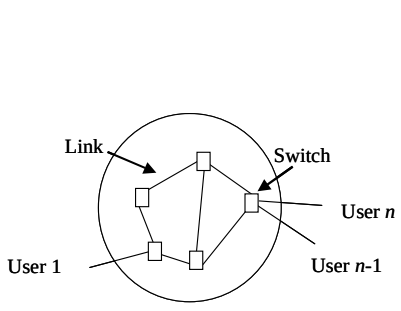
5. Cell Switching
   chop messages into tiny fixed size packets called ATM cell (53 bytes)
   ATM: Asynchronous Transfer Mode
   advantages—much better response time of small message traffic
   provision for guarantee bandwidth ⇒ support real-time traffic.
   disadvantages—too much overhead; (5 bytes header).

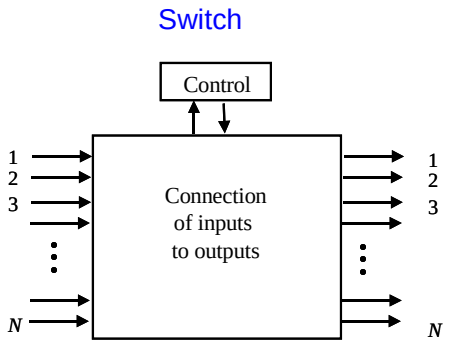


Network with Links and Switches

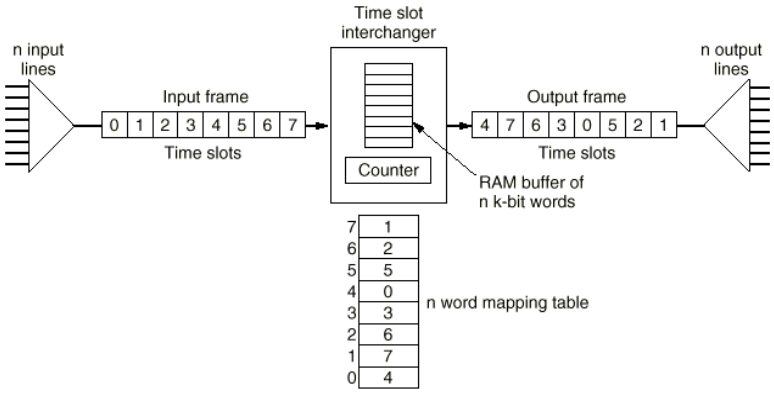
Switches can be divided into two classes:

- Space-division switches: provide separate physical connections between inputs and outputs (ports).
- Time-division switches: network flow are time-division multiplexed streams.





Time Division Switch



Time division switch is used in the circuit switching systems.

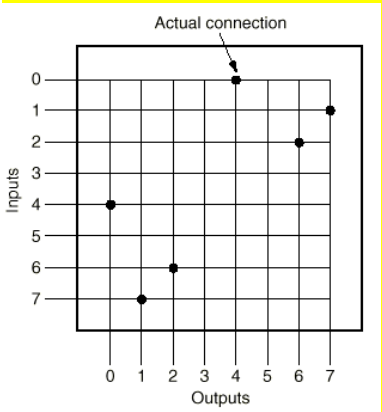
How to set up a connection through the time division switch?

What is the relationship between the memory access time (T) of RAM buffer and the number of slots/channels (n) in the frame, assuming a frame period of 125 μsec (8000frames/sec)?

Time Division Switch

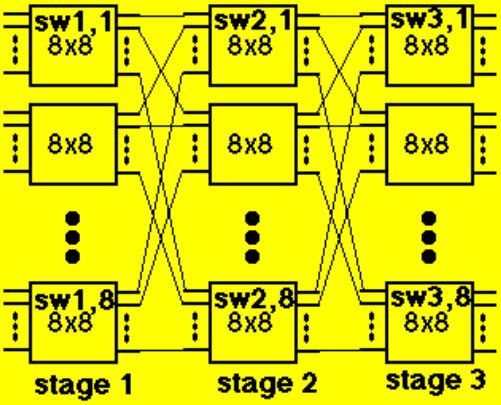
- Here we assume this a telephony network where frames (big or small) are sent at 8000 frames/sec frame rate, i.e., 125 μsec per frame.
- A separate signaling (call setup) channel is used to tell the switch which pairs of users are trying communicate each other. It results in the mapping table content shown above. Here the mapping table shows (channel0 talks to channel 4, channel1 to channel7, channel2 to channel6)
- There are two basic ways to implement this time slot interchange:
- Sequential write to RAM, random read out of RAM:
  In this approach, channel data are written to the RAM sequentially, i.e., data of the first channel is written to the first word of the RAM.
  After all data is in, the data in RAM are read according to the mapping table to form the outgoing frame. For example, the first time slot of the outgoing frame is filled with the 4th word of RAM, the 2nd time slot is filled with 7th word.
- Random write to RAM, sequential read out of RAM:
  In this approach, the time slot data in the incoming frame are written to the RAM “randomly” according to the mapping table. After all data is in, the data in RAM are read sequentially to form the outgoing frame.
- The outgoing frame cannot be sent until the whole incoming frame is read.

Crosspoint Switch and Multistage Switch



A 8x8 crosspoint switch

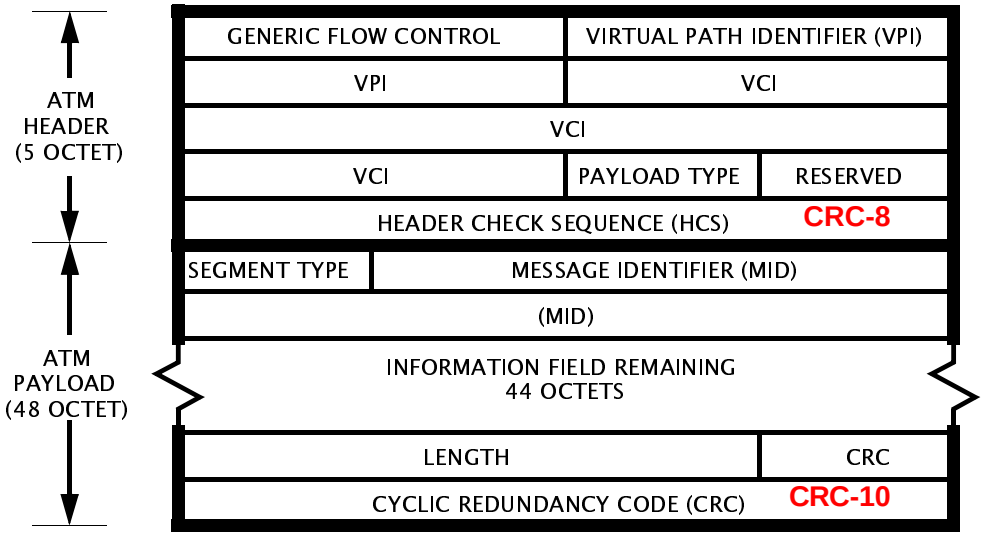
How many crosspoints are needed in this switch?



A 3-stage switch

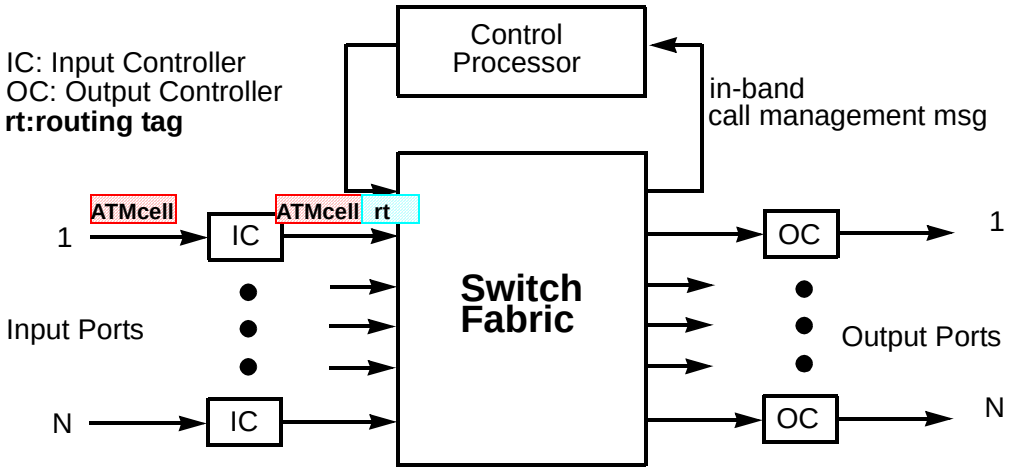
Why 3-stage? Why not 2-stage?

ATM **53 Byte** Cell Structure



ATM Switch Structure

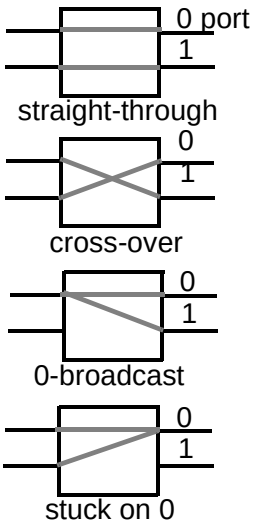
IC: Input Controller
OC: Output Controller
rt:routing tag



Control Processor: connection management, bandwidth allocation, maintenance.
IC: cell buffering, VCI/VPI translation, cell filtering, ATM policing, cell alignment, and output port contention resolution.
OC: cell buffering, VCI/VPI translation for multicast cells.

Space Division Switching Elements
2x2 Switches

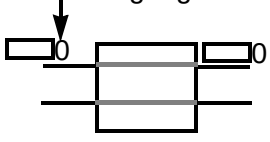
Possible States of 2x2 Sw



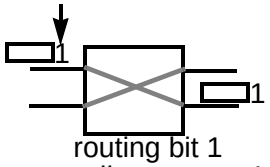
Self-Routing
Using routing tag of cell
to select the 2x2 Sw state

2x2 configure as router

bit in routing tag

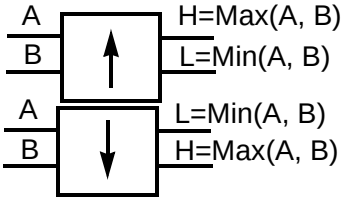


route bit 0
cell go to port 0



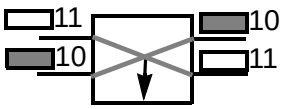
routing bit 1
cell go to port 1

bitonic
2x2 configure as sorter

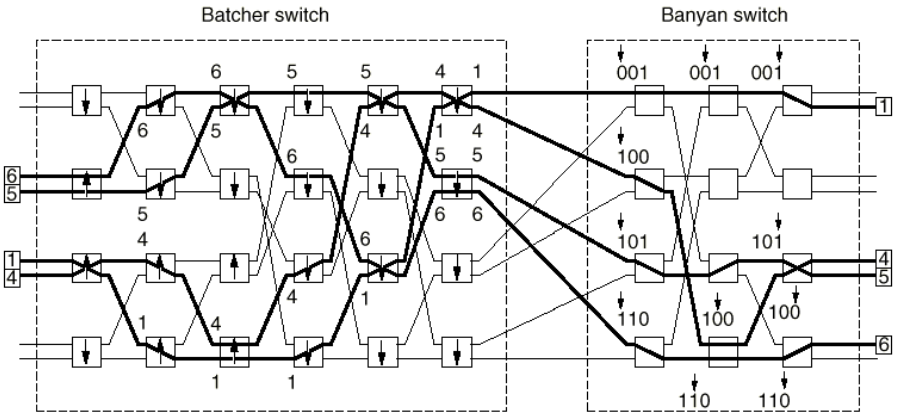


arrow point to the port to receive bigger routing tag

11>10
set 2x2 to cross-over state



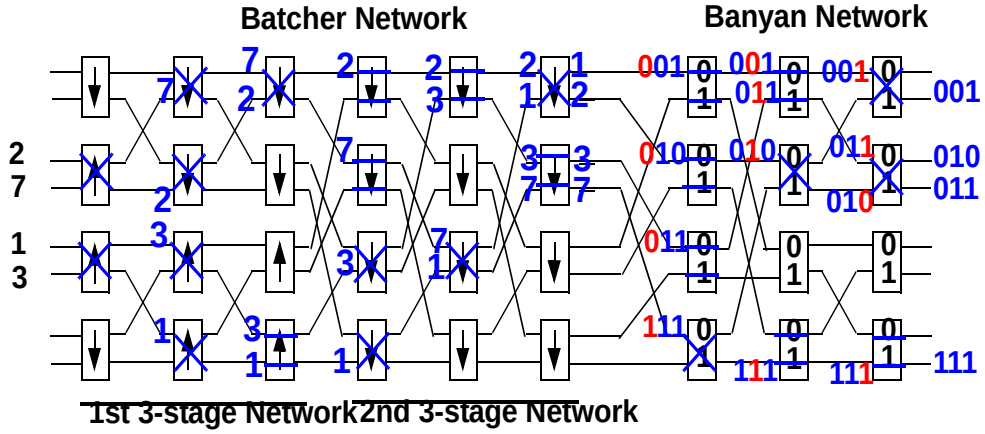
Cell Routing in A Batcher-Banyan Switch



Those lines without input cell is assume to have very large routing tag value.
Batcher sorting switch sorts the cells according to the routing tag values.
For this work, in a given cycle, no two cells go to the same output port.
The nth stage of banyan switch interprets the nth bit of routing tags as routing bit.

Exercise Cell Switching

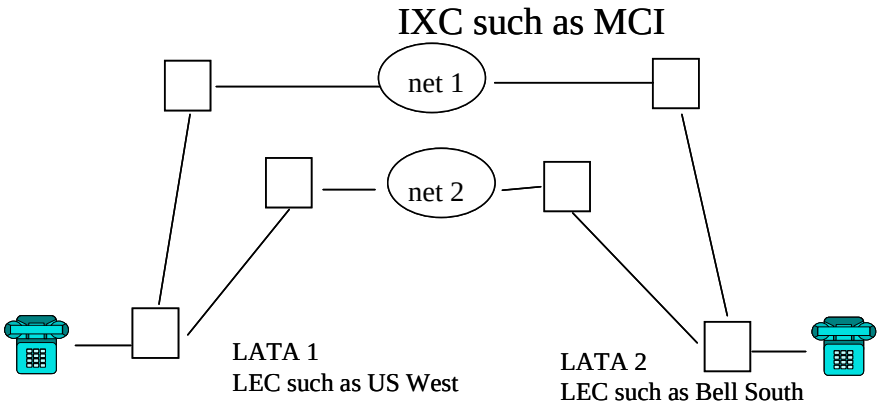
Prob. 3. Batcher-Banyan Switch. Draw the 2x2 element configurations along the



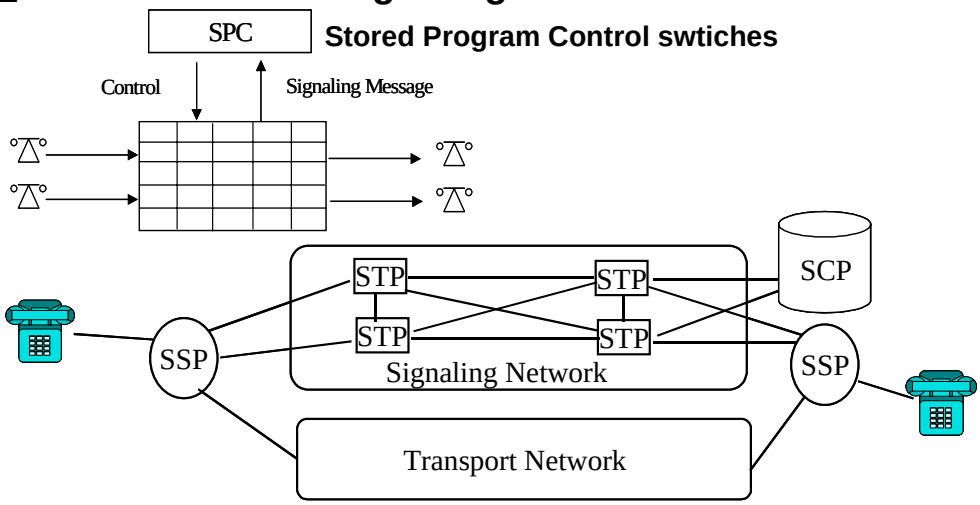
routes for those 4 cells.

Telephone Network: LEC(RBOC), IXC

- Local Exachnage Carriers (LECs) consist of Regional Bell Operating Companies (RBOCs).
- Interexchnage Carriers (IXCs) consist of AT&T, MCI, Sprint.
- LATA: Local Access and Transport Area operated by LECs.
- IXC has POP (point of presence) in some LATA switches.

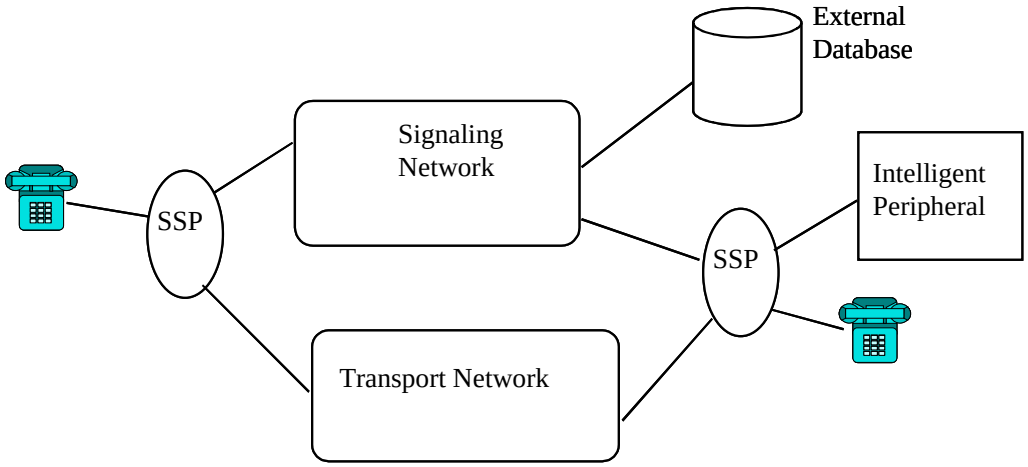


Signaling Network



SSP = Service switching point (signal to message)
STP = Signal transfer point (message transfer)
SCP = Service control point (processing)

Intelligent Networks

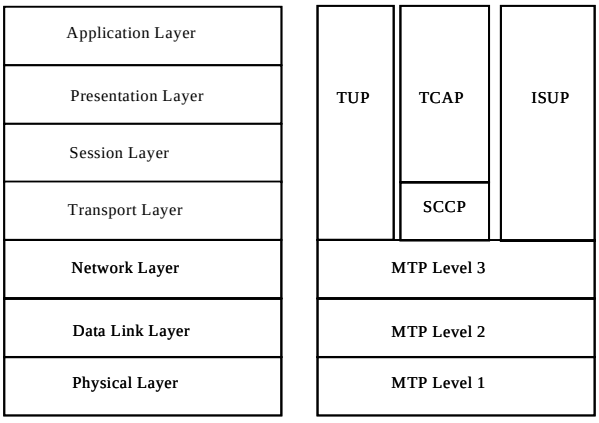


Provides services using enhanced signaling networks.

- Caller ID, voice mail, voice recognition, call screening, call back...

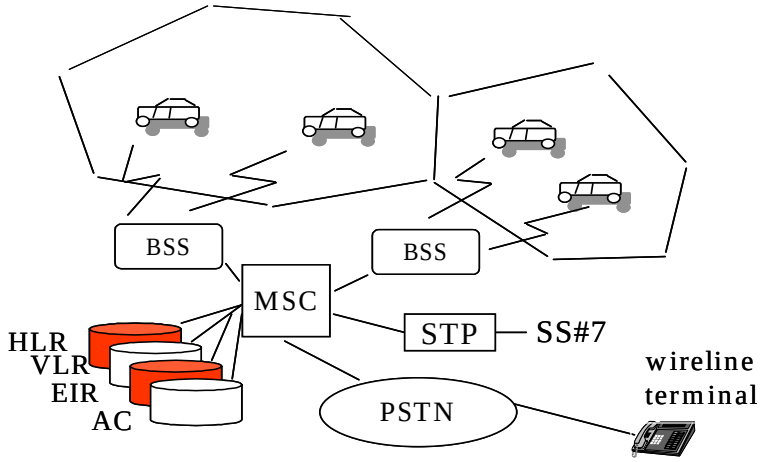
Signalling System #7

a packet network that control the setting up, managing, and releasing of telephone call. It also supports, IN, mobile cellular networks, and ISDN.



It has its own layering called part and related message format.
It is used by a cellular network to communication with LECs or IXCs.

Components of Cellular Networks



AC = authentication center
BSS = base station subsystem
EIR = equipment identity register
HLR = home location register
MSC = mobile switching center
PSTN = public switched telephone network
STP = signal transfer point
VLR = visitor location register

Paging System vs. Cellular Phone System

one way communication vs. two way communications
Some companies to offer integrated system that provides both services.
Advanced paging system can relay email/bulletin board messages.

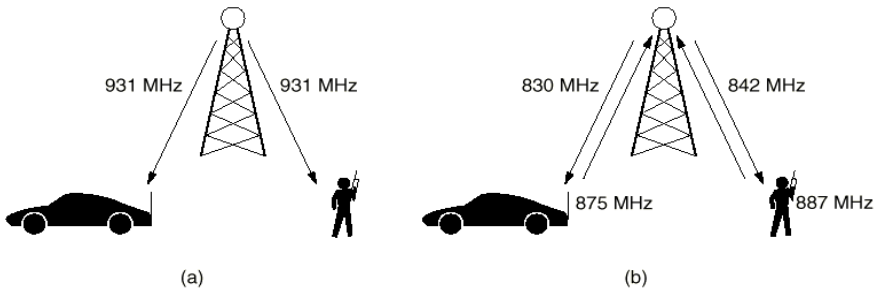


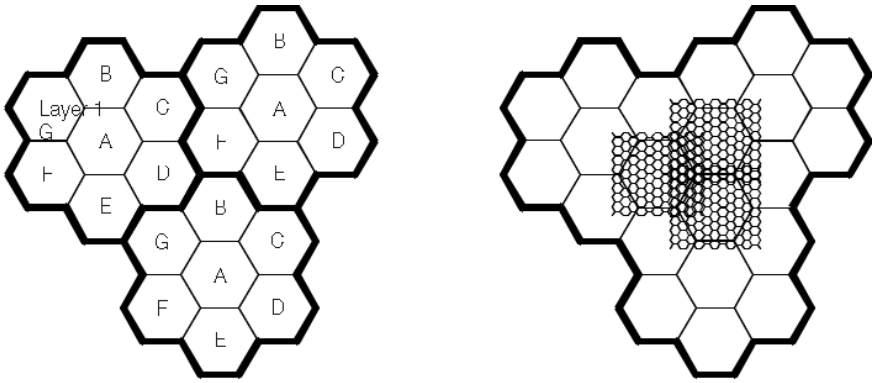
Fig. 2-53. (a) Paging systems are one way. (b) Mobile telephones are two way

Advanced Mobile Phone System (AMPS)

invented by Bell Lab. and deployed in US in 1982.

10-km cell. Mobile phone put out 0.6 watts; transmitter in cards are 3 watts.

AMPS uses 832 full duplex channels. 832 simplex channels from 824-849, another 832 simplex channels from 869-894MHz. Each channel is 30kHz wide. FDM is used. They are divided into two carriers (B-side and A-side).



AMPS Call Management

Registration: (register once every 15 minutes)

- When a cellular phone is switched on, it scans 21 control channels, picks the strongest one, broadcasts the 32 bit serial number and 34 bit telephone number (10 bits for 3 digit area code, 24 bits for 7 digit subscriber number), in digital form, multiple times with ECC code.
- Base station hears the registration msg, keeps record, and inform the customer's home MTSO(Mobile Telephone Switching Office).

Making cellular call:

- Enter number in keypad and press SEND button. The destination phone number and its ID are sent over the shared access channel. If collision occurs, retry it later.
- Base station relays info to MTSO, which allocate idle channel, and make phone call to destination.

Incoming call to a cellular phone:

- a packet first sends to the callee's home MTSO to find out its current location.
- a packet then sends to the current base station, which broadcasts on the paging channel for the called phone.
- When the called phone responded, a voice channel is assigned and rings.

Personal Communications Services (PCS)

- Use CDMA (Code Division Multiplexing Access).
- Microcell (50-100 meters) 0.25 watt light weight terminal.
- Small base station, toaster size, called telepoints, on top of telephone/light pole.
- Use 1.7-2.3 GHz spectrum.
- FCC auction off licenses to use PCS spectrum in 1994-5. Get 7.7 billion dollars.
- The original users in the spectrum needs to be relocated. Who should pay that?

Iradium Project

- Use 77 LEO (low earth orbit) satellites.
- Revised to 66 LEO, 1628 moving cells.
- Provide world-wide telecommunication services among hand-held devices using those LEO satellites.
- The coverage areas of PCS or Current Cellular systems are limited. You pay more for access if you are not in the area of your subscriber.

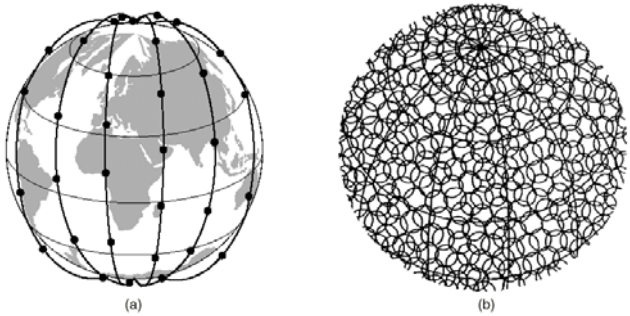


Fig. 2-57. (a) The Iridium satellites form six necklaces around the earth. (b) 1628 moving cells cover the earth.