2

THE PHYSICAL LAYER

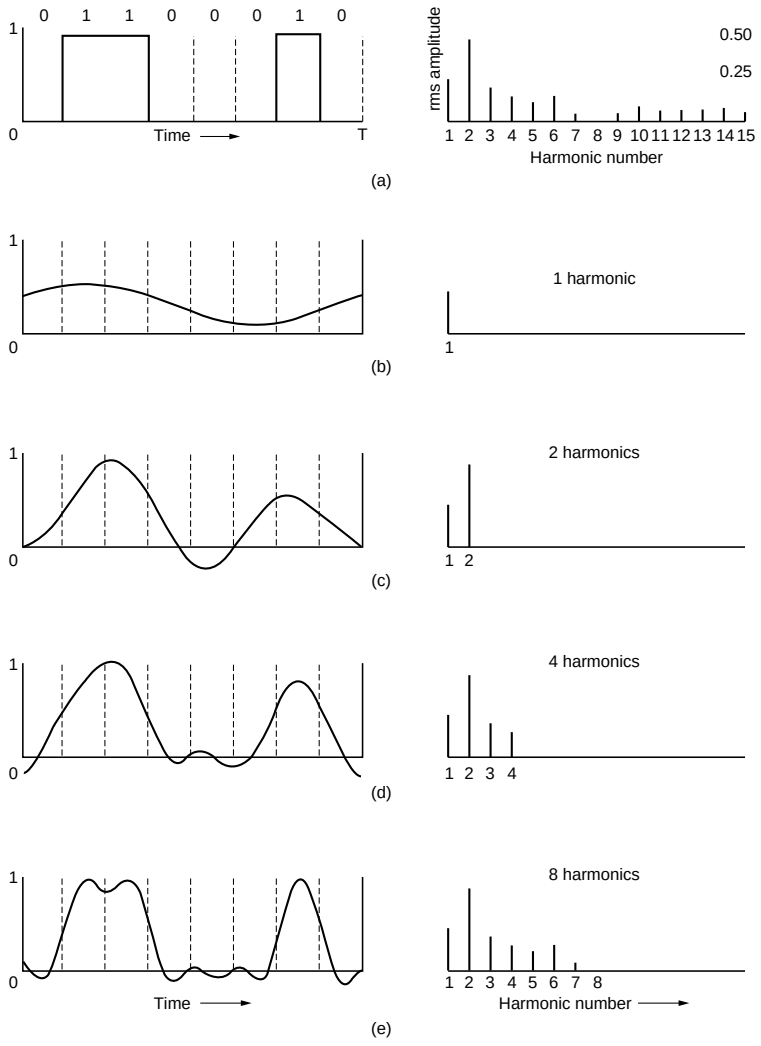

Fig. 2-1. (a) A binary signal and its root-mean-square Fourier amplitudes. (b)-(e) Successive approximations to the original signal.

Bps	T (msec)	First harmonic (Hz)	# Harmonics sent
300	26.67	37.5	80
600	13.33	75	40
1200	6.67	150	20
2400	3.33	300	10
4800	1.67	600	5
9600	0.83	1200	2
19200	0.42	2400	1
38400	0.21	4800	0

Fig. 2-2. Relation between data rate and harmonics.

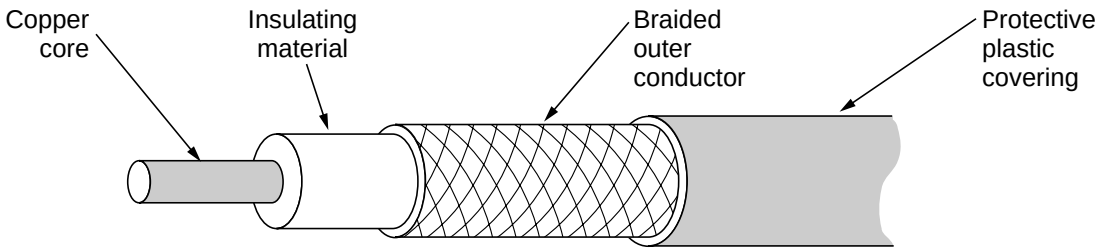

Fig. 2-3. A coaxial cable.

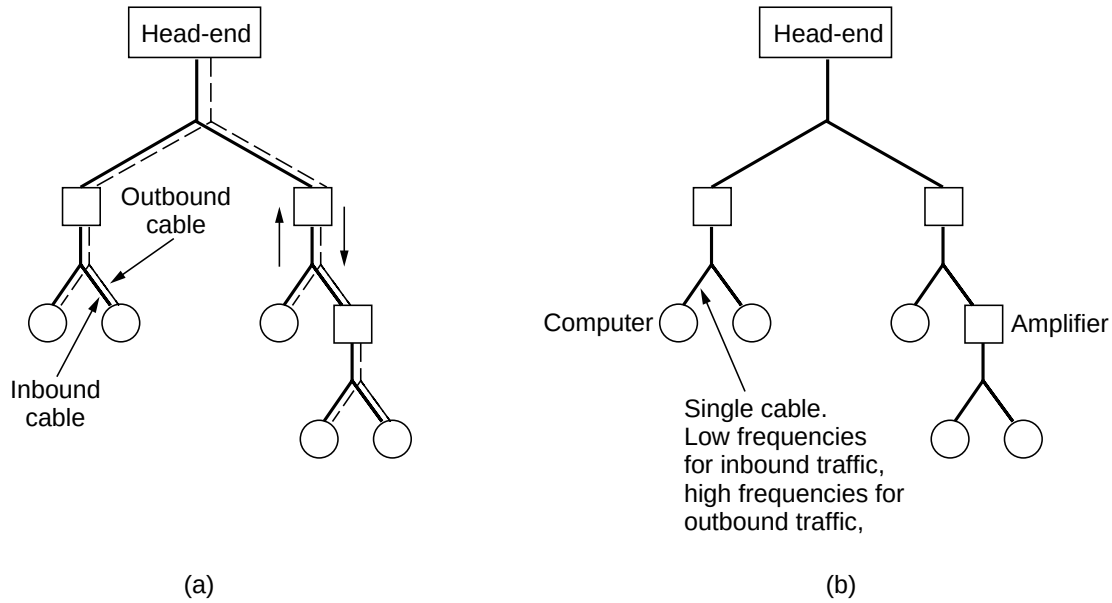

Fig. 2-4. Broadband networks. (a) Dual cable. (b) Single cable.

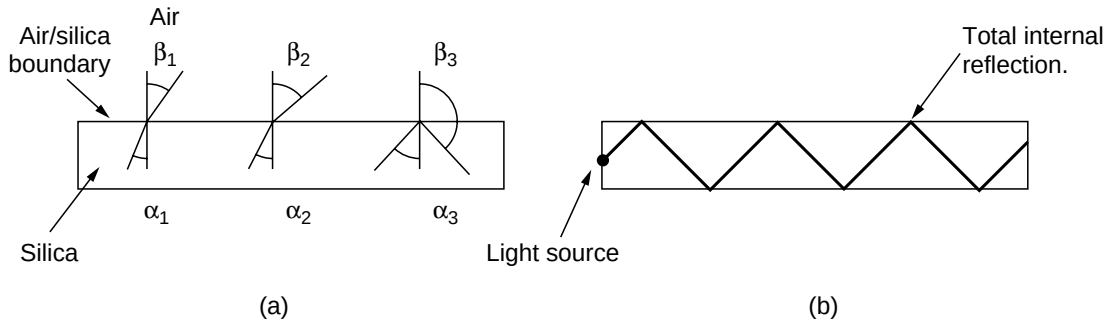

Fig. 2-5. (a) Three examples of a light ray from inside a silica fiber impinging on the air/silica boundary at different angles. (b) Light trapped by total internal reflection.

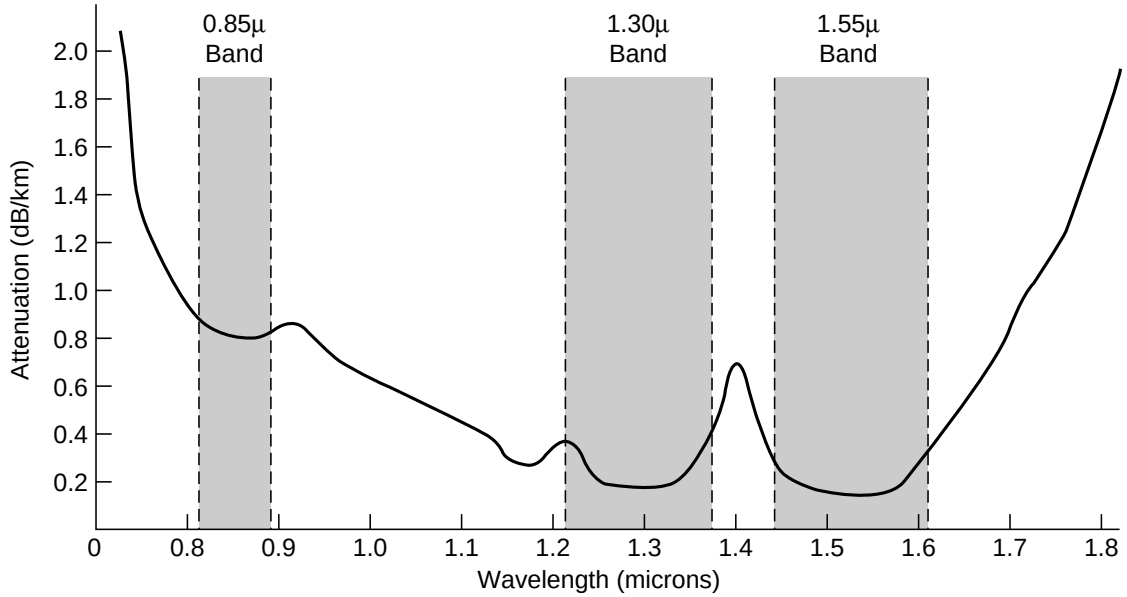

Fig. 2-6. Attenuation of light through fiber in the infrared region.

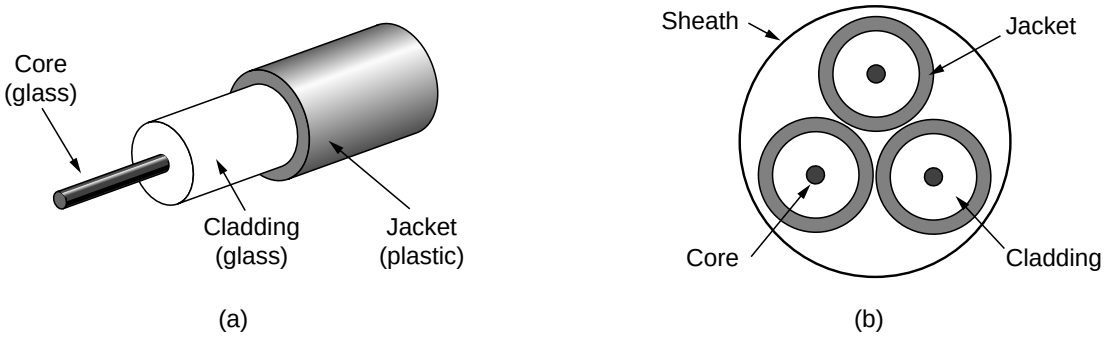

Fig. 2-7. (a) Side view of a single fiber. (b) End view of a sheath with three fibers.

Item	LED	Semiconductor laser
Data rate	Low	High
Mode	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Fig. 2-8. A comparison of semiconductor diodes and LEDs as light sources.

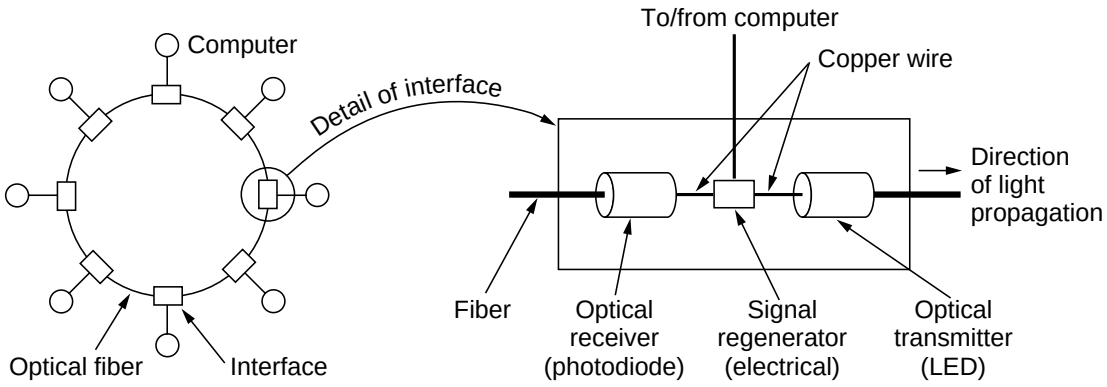

Fig. 2-9. A fiber optic ring with active repeaters.

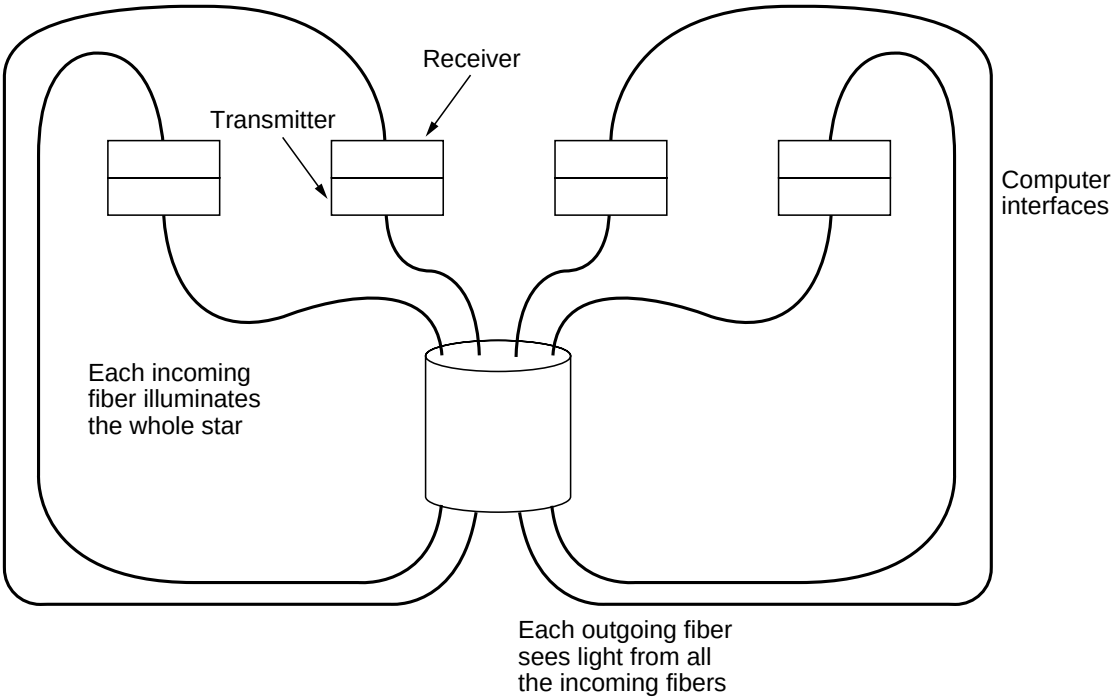

Fig. 2-10. A passive star connection in a fiber optics network.

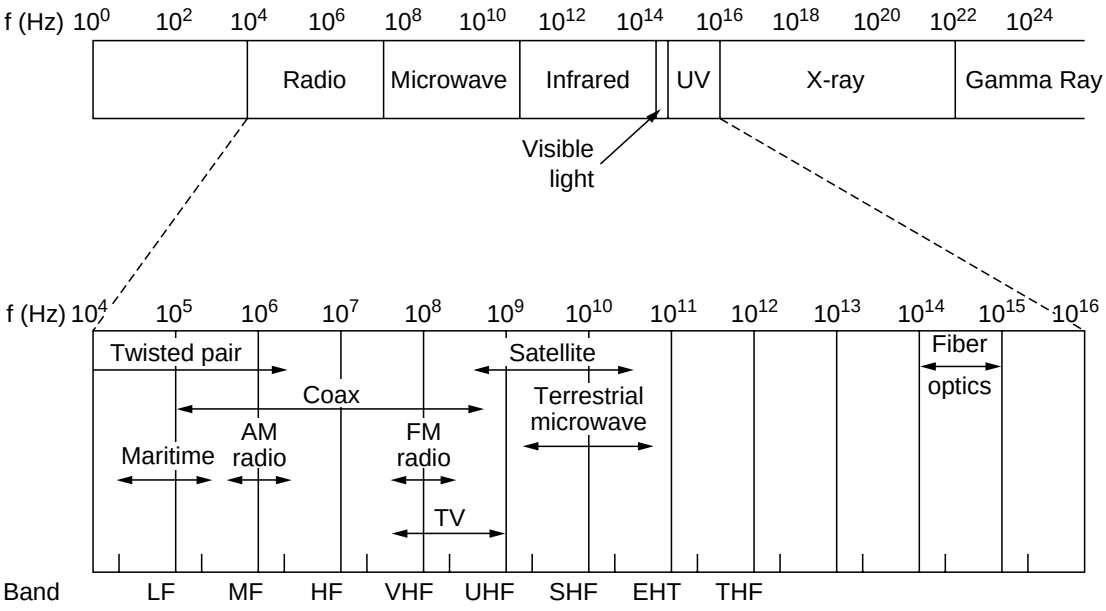

Fig. 2-11. The electromagnetic spectrum and its uses for communication.

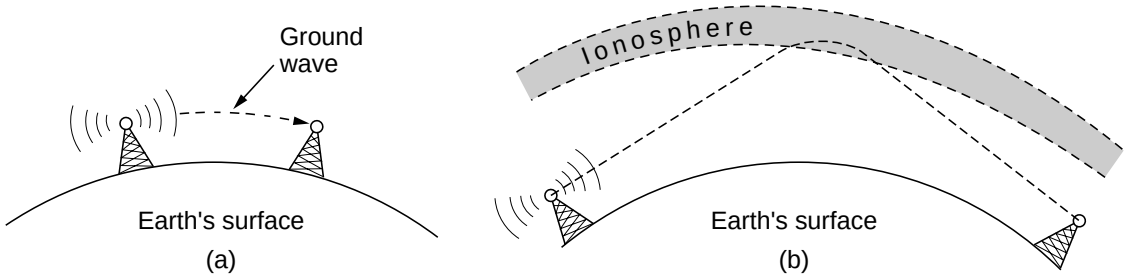

Fig. 2-12. (a) In the VLF, VF, and MF bands, radio waves follow the curvature of the earth. (b) In the HF they bounce off the ionosphere.

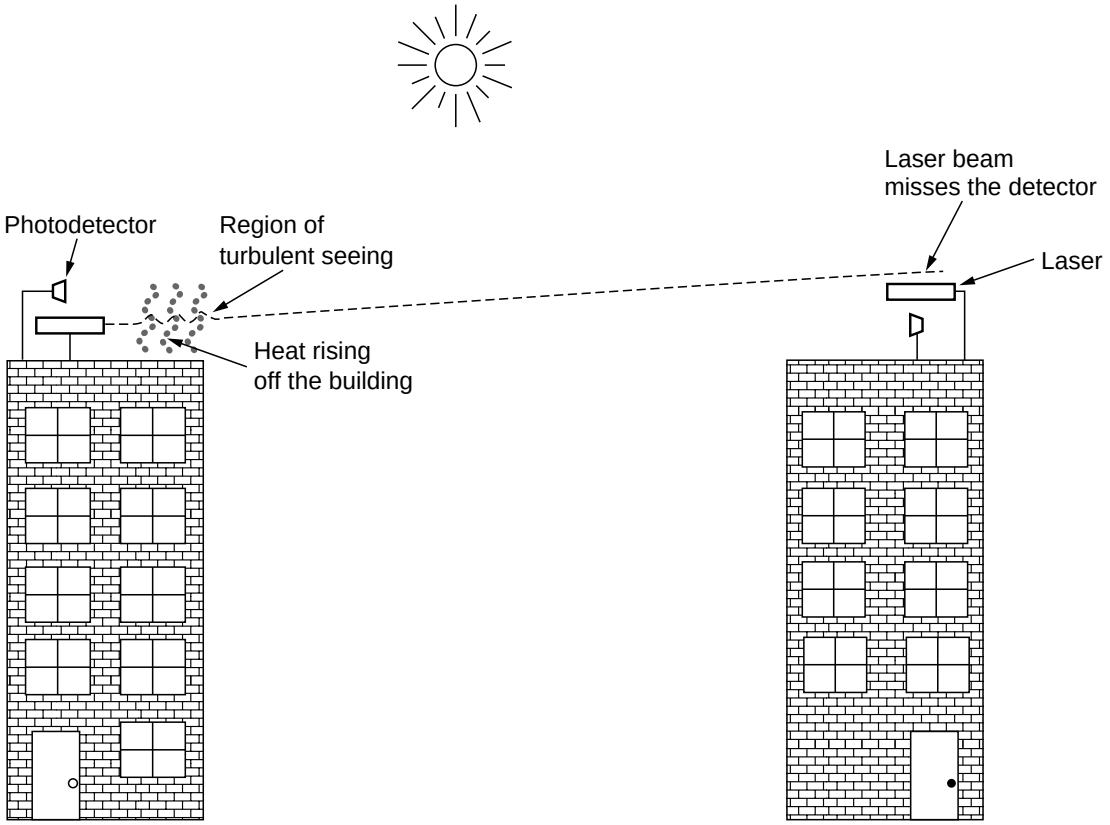

Fig. 2-13. Convection currents can interfere with laser communication systems. A bidirectional system, with two lasers, is pictured here.

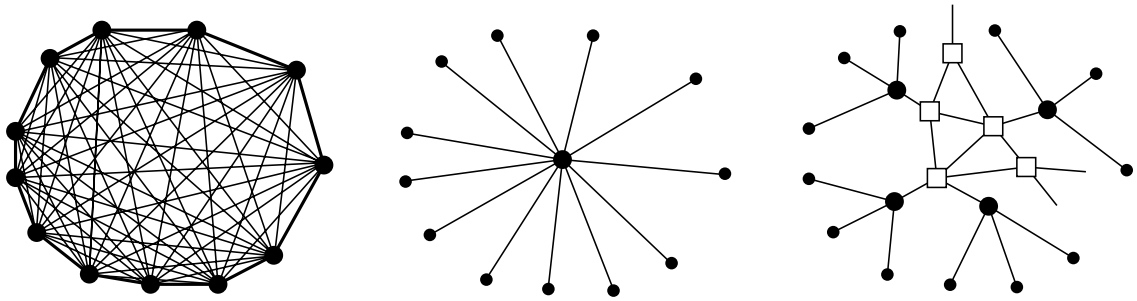

Fig. 2-14. (a) Fully interconnected network. (b) Centralized switch. (c) Two-level hierarchy.

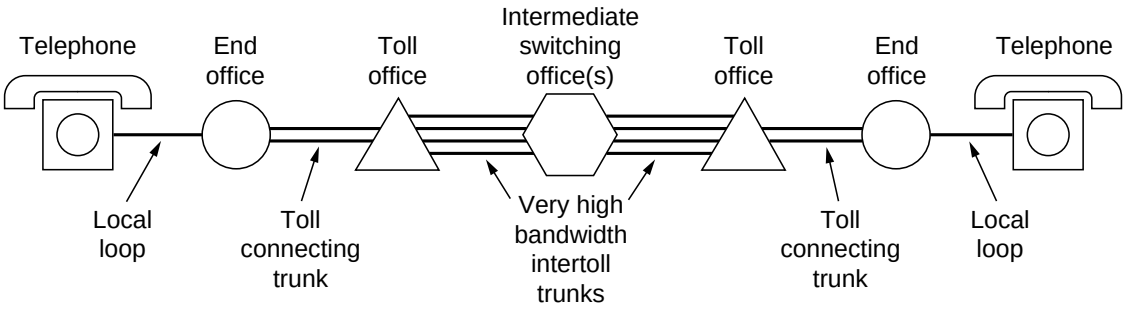

Fig. 2-15. Typical circuit route for a medium-distance call.

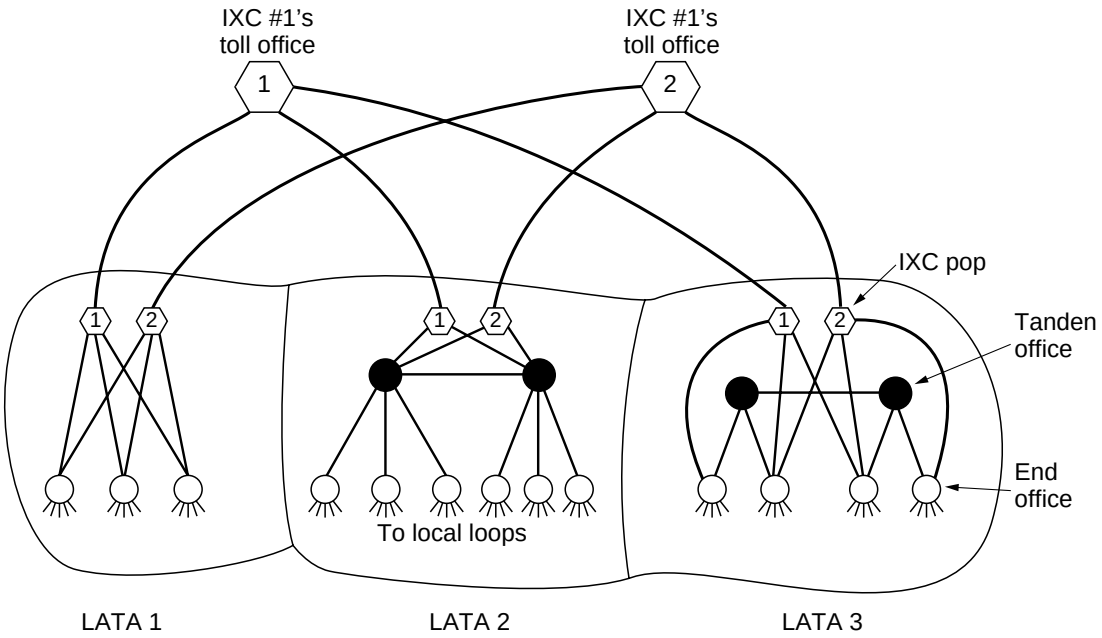

Fig. 2-16. The relationship of LATAs, LECs, and IXCs. All the circles are LEC switching offices. Each hexagon belongs to the IXC whose number is in it.

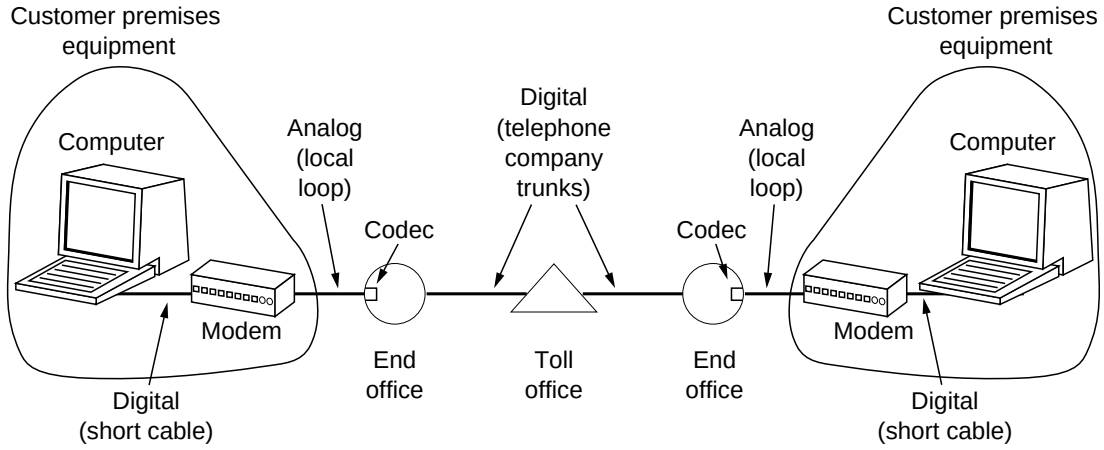

Fig. 2-17. The use of both analog and digital transmission for a computer to computer call. Conversion is done by the modems and codecs.

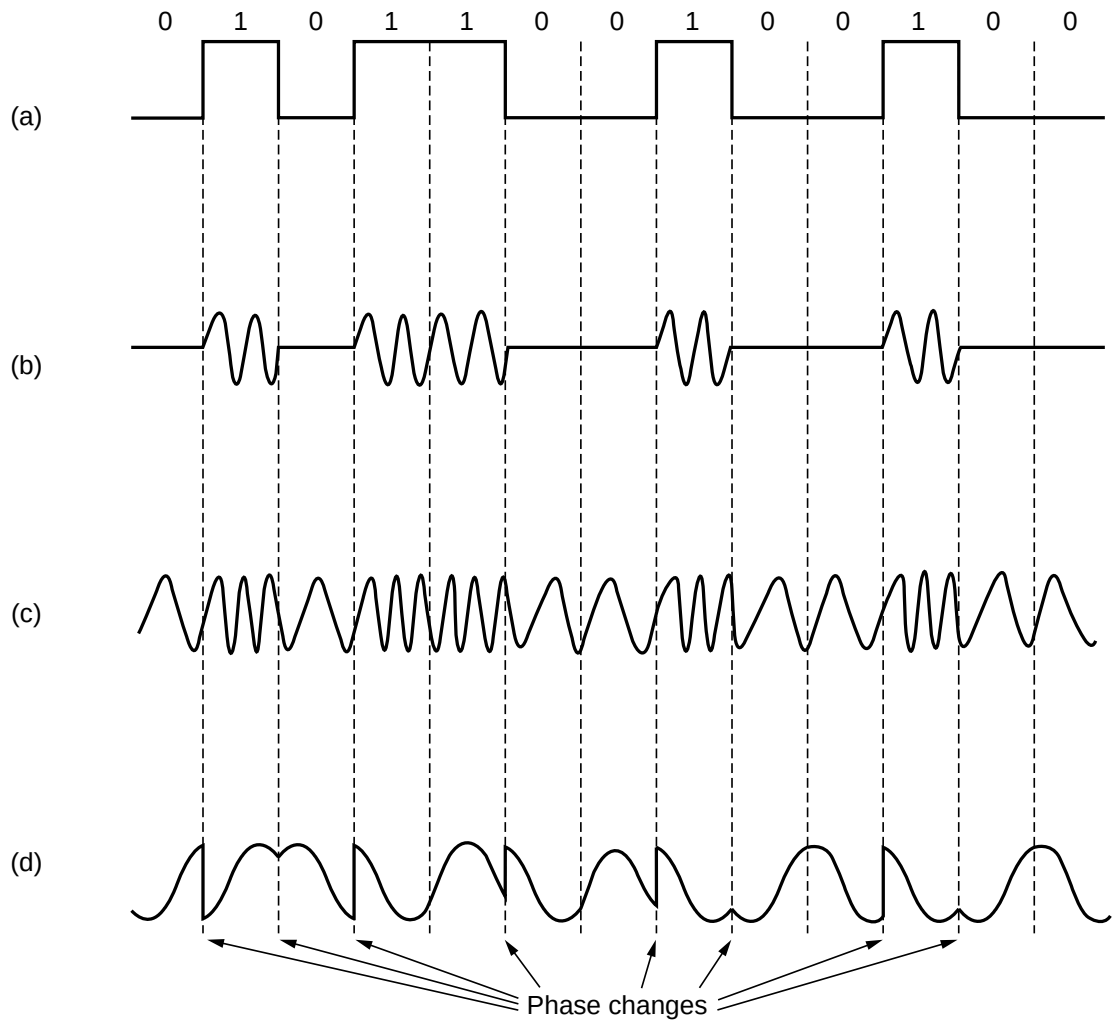

Fig. 2-18. (a) A binary signal. (b) Amplitude modulation. (c) Frequency modulation. (d) Phase modulation.

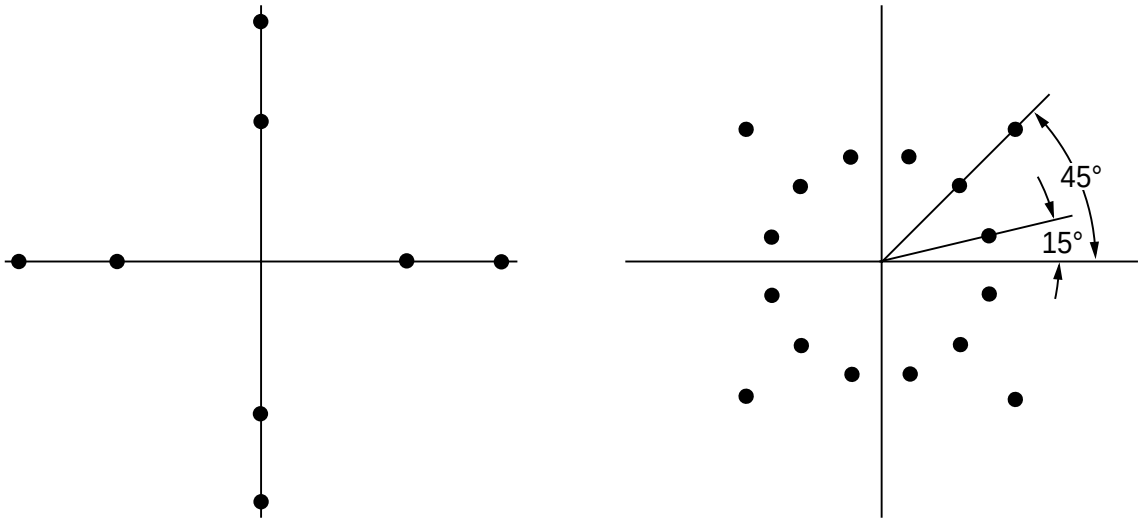

Fig. 2-19. (a) 3 bits/baud modulation. (b) 4 bits/baud modulation.

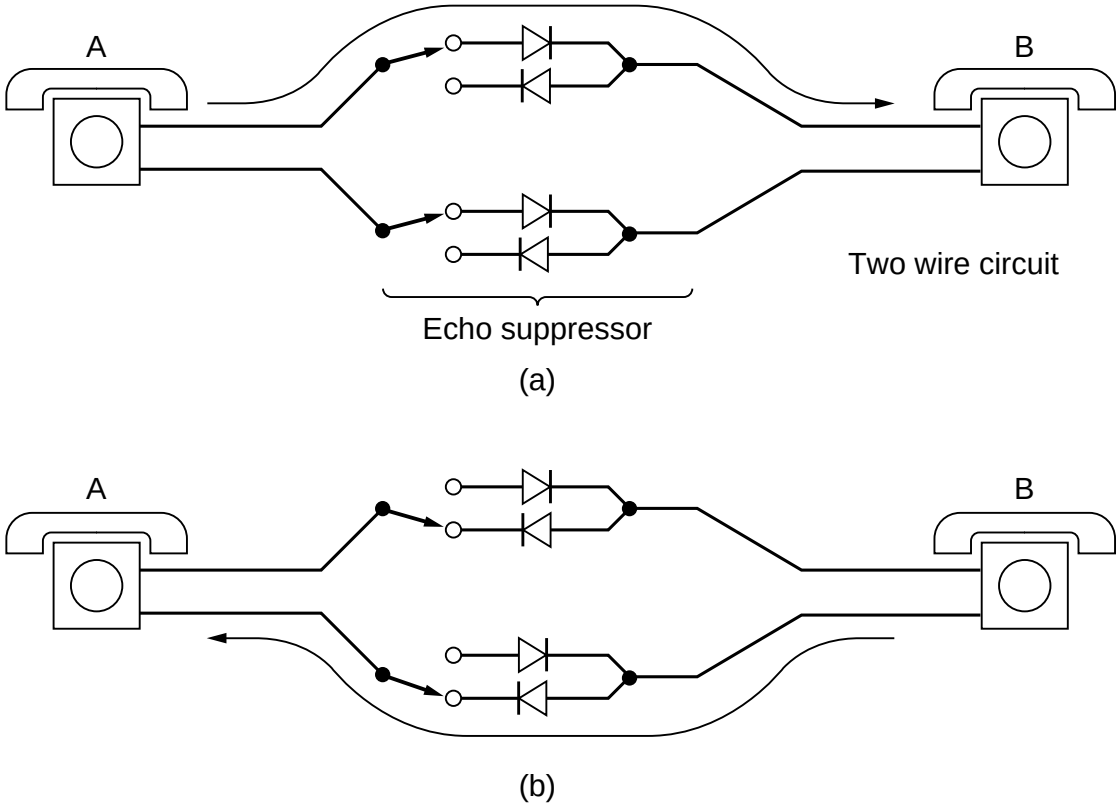

Fig. 2-20. (a) *A* talking to *B*. (b) *B* talking to *A*.

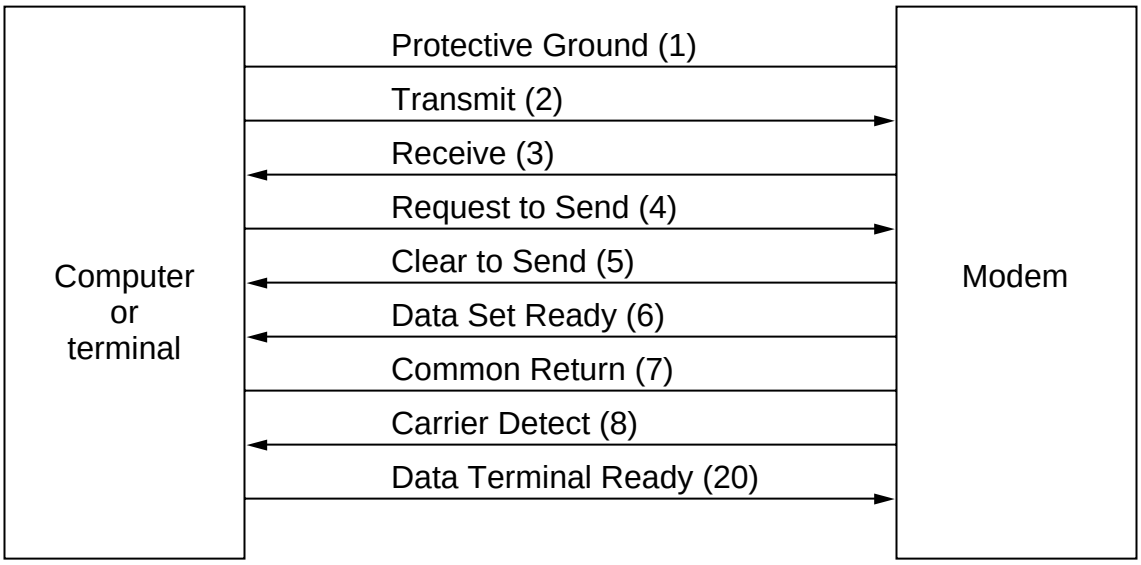

Fig. 2-21. Some of the principal RS-232-C circuits. The pin numbers are given in parentheses.

	RS-232-C			CCITT V .24			RS-449		
	Code	Pin	Circuit	Code	Pin	Circuit	Code	Pin	Circuit
	AA	1	Protective ground	101	1	Protective ground	_	1	
	AB	7	Signal ground	102	7	Signal ground	SG	19	Signal ground
							SC	37	Send common
							RC	20	Receive common
	BA	2	Transmitted data	103	2	Transmitted data	SD	4, 22	Send data
	BB	3	Received data	104	3	Received data	RD	6, 24	Receive data
	CA	4	Request to send	105	4	Request to send	RS	7, 25	Request to send
	CB	5	Clear to send	106	5	Ready for sending	CS	9, 27	Clear to send
	CC	6	Data set ready	107	6	Data set ready	DM	11, 29	Data mode
	CD	20	Data terminal ready	108	20	Data terminal ready	TR	12, 30	Terminal ready
	CE	22	Ring indicator	125	22	Calling indicator	IC	15	Incoming call
	CF	8	Line detector	109	8	Line detector	RR	13, 31	Receiver ready
	CG	21	Signal quality	110	21	Signal quality	SQ	33	Signal quality
	CH	23	DTE rate	111	23	DTE rate	SR	16	Signaling rate
	CI	18	DCE rate	112	18	DCE rate	SI	2	Signaling indicators
							IS	28	Terminal in service
				136		New signal	NS	34	New signal
				126	11	Select frequency	SF	16	Select frequency
	DA	24	DTE timing	113	24	DTE timing	TT	17, 25	Terminal timing
	DB	15	DCE timing	114	15	DCE timing	ST	5, 23	Send timing
	DD	17	Receiver timing	115	17	Receiver timing	RT	8, 26	Receive timing
Secondary Channel	SBA	14	Transmitted data	118	14	Transmitted data	SSD	3	Send data
Secondary Channel	SBB	16	Received data	119	16	Received data	SRD	4	Receive data
Secondary Channel	SCA	19	Request to send	120	19	Line signal	SRS	7	Request to send
Secondary Channel	SCB	13	Clear to send	121	13	Channel ready	SCS	8	Clear to send
Secondary Channel	SCF	12	Line detector	122	12	Line detector	SRR	2	Receiver ready
							LL	10	Local loopback
							RL	14	Remote loopback
							TM	18	Test mode
							SS	32	Select standby
							SB	36	Standby indicator

Fig. 2-22. Comparison of RS-232-C, V.24, and RS-449.

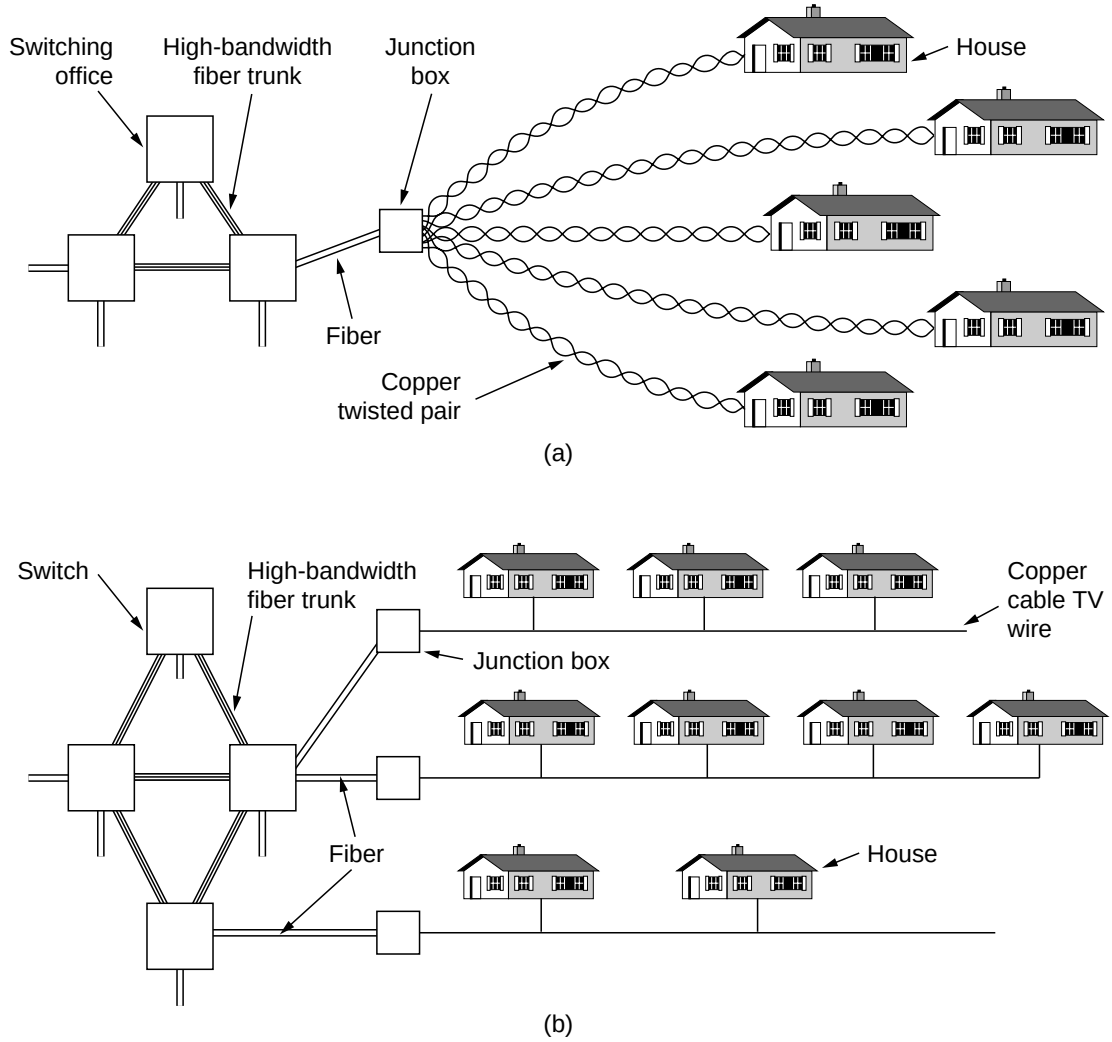

Fig. 2-23. Fiber to the curb. (a) Using the telephone network. (b) Using the cable TV network.

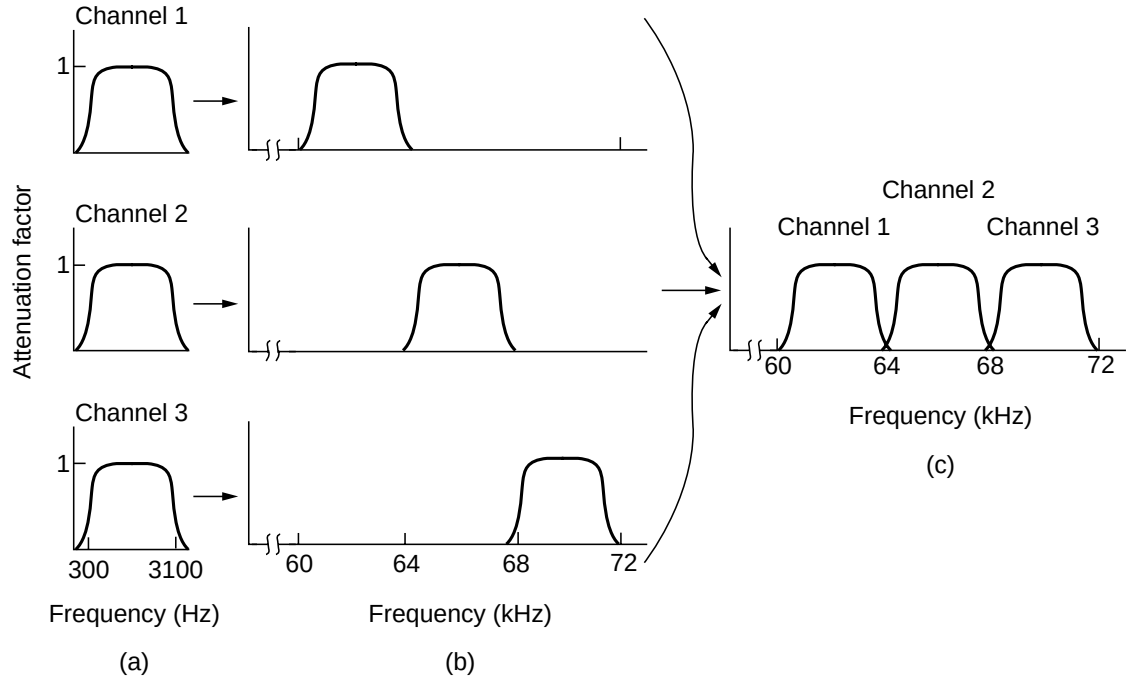

Fig. 2-24. Frequency division multiplexing. (a) The original bandwidths. (b) The bandwidths raised in frequency. (c) The multiplexed channel.

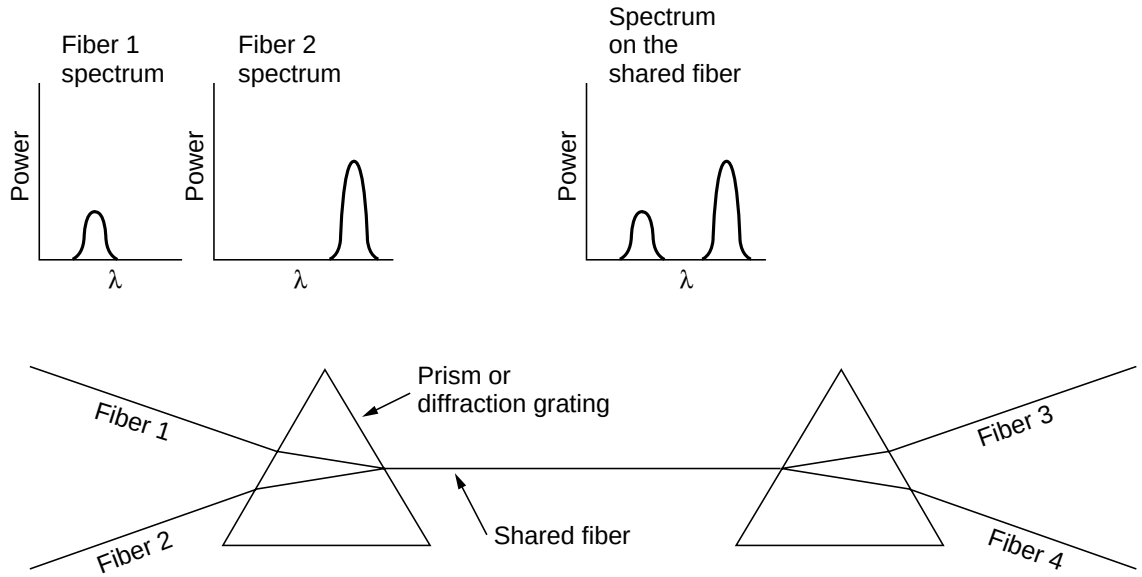

Fig. 2-25. Wavelength division multiplexing.

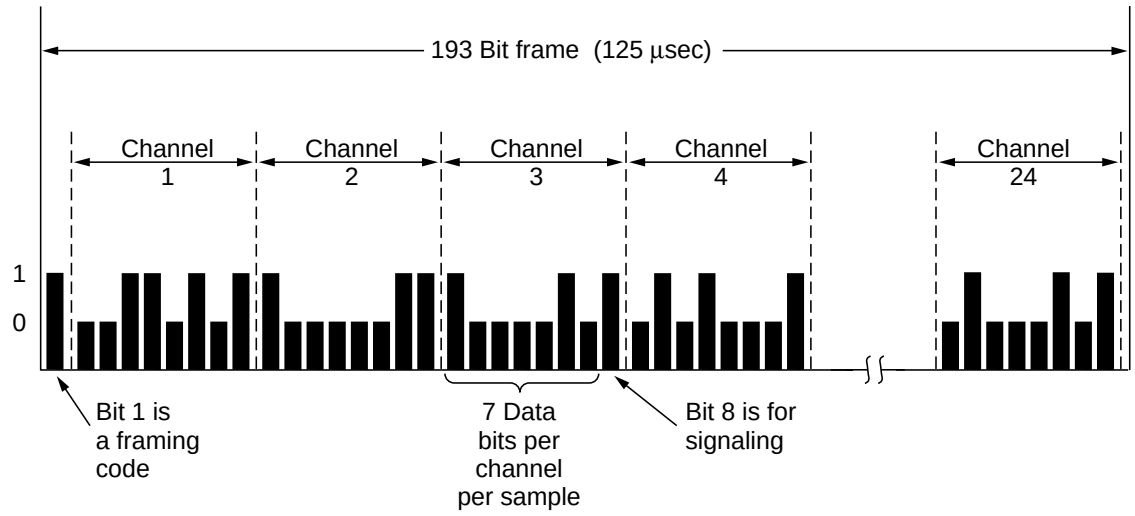

Fig. 2-26. The T1 carrier (1.544 Mbps).

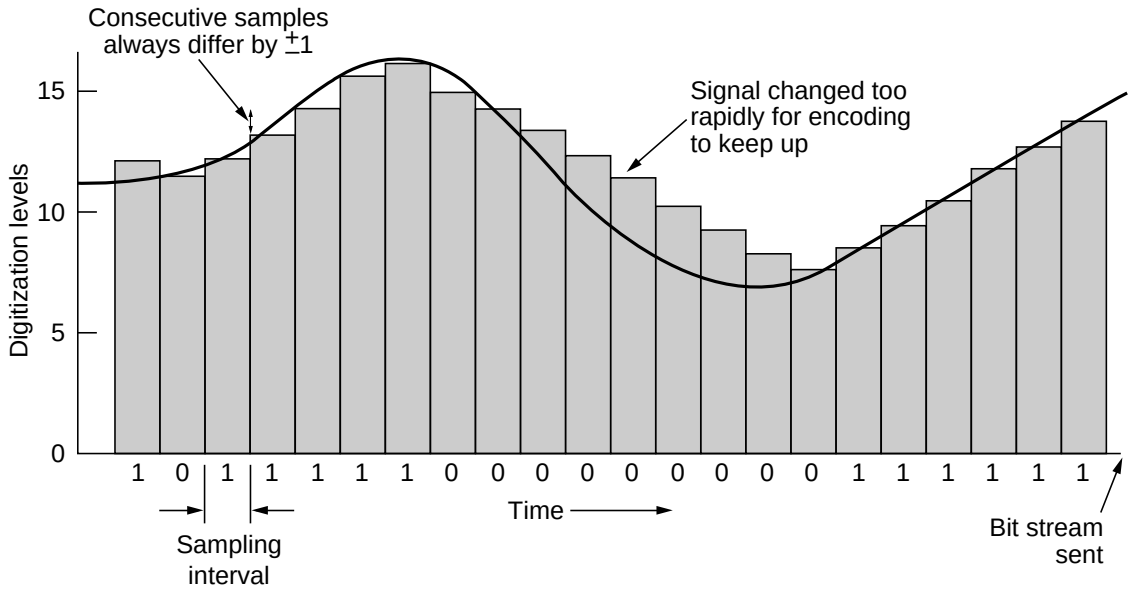

Fig. 2-27. Delta modulation.

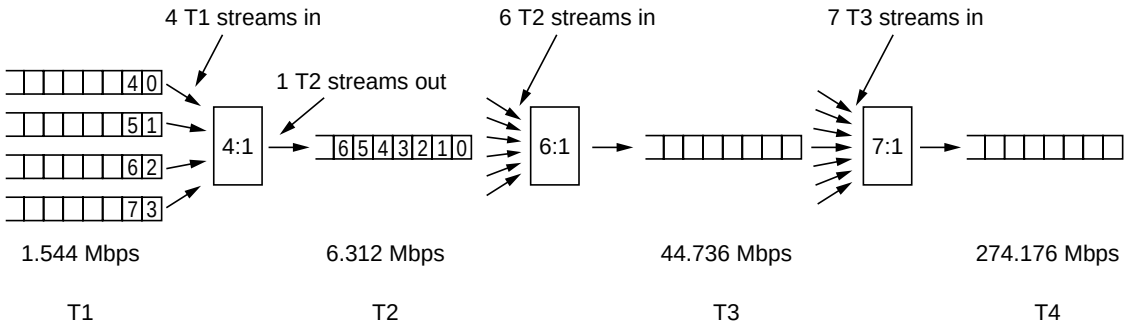

Fig. 2-28. Multiplexing T1 streams onto higher carriers.

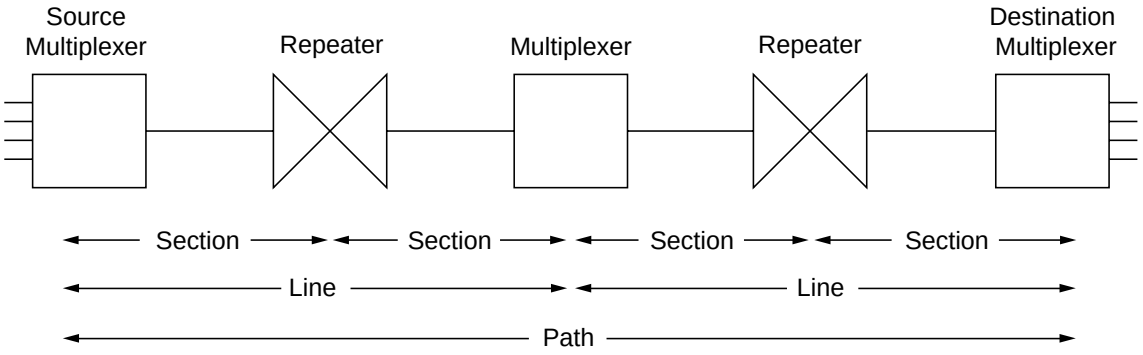

Fig. 2-29. A SONET path.

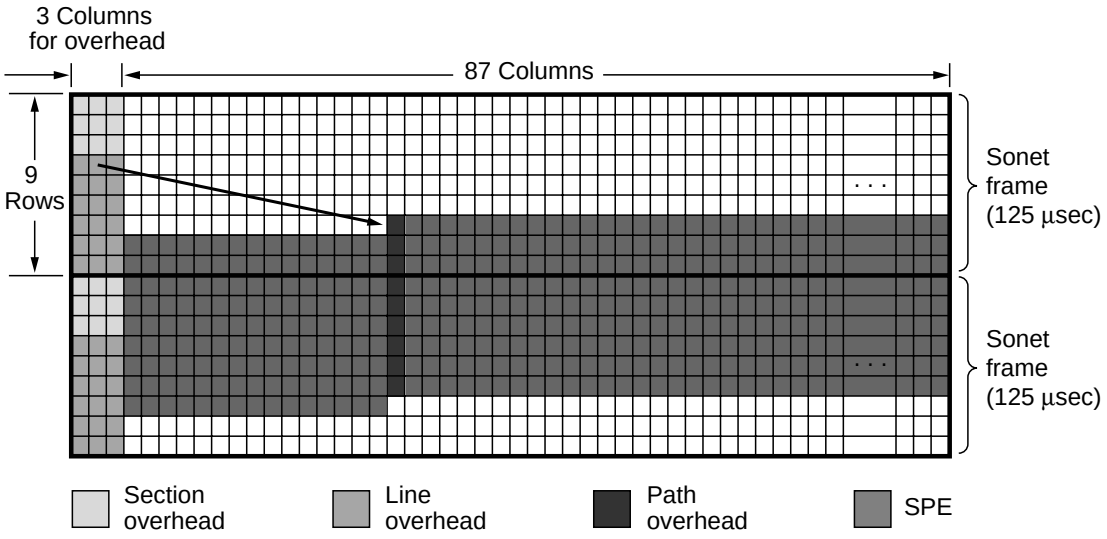

Fig. 2-30. Two back-to-back SONET frames.

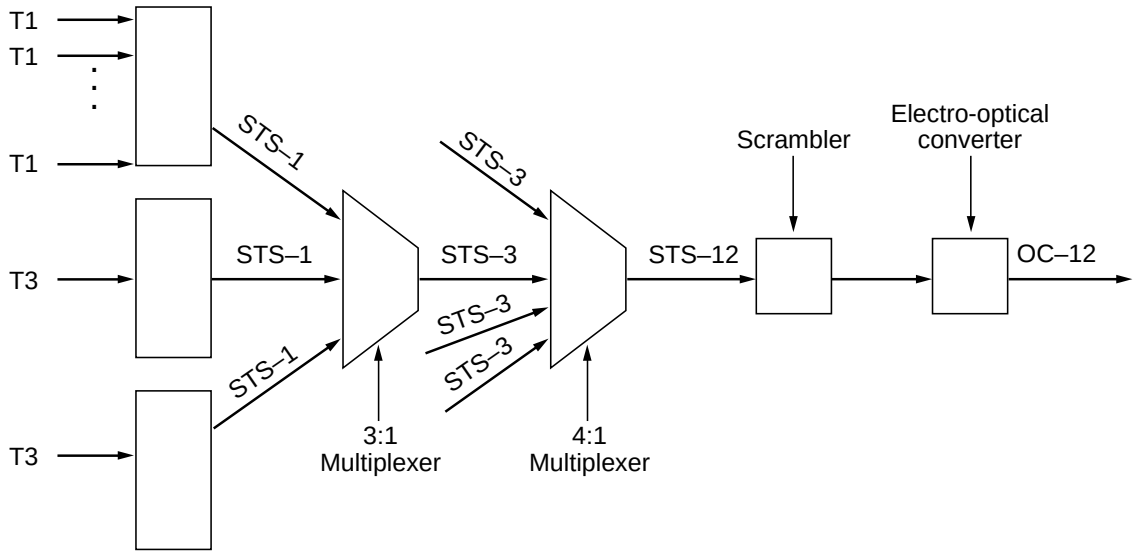

Fig. 2-31. Multiplexing in SONET.

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

Fig. 2-32. SONET and SDH multiplex rates.

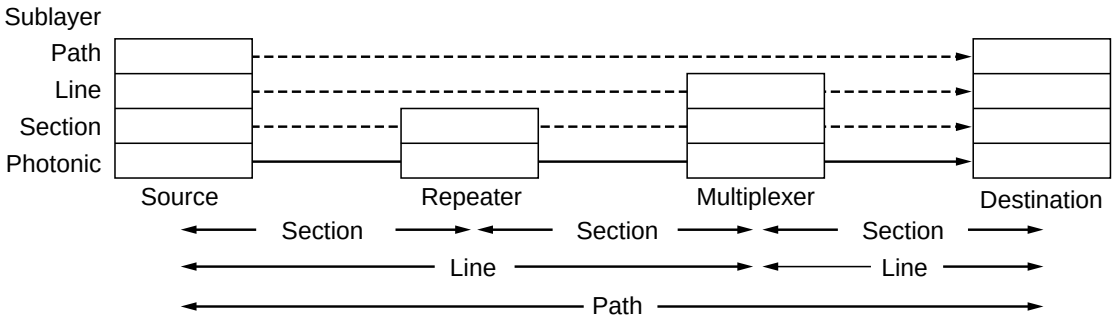

Fig. 2-33. The SONET architecture.

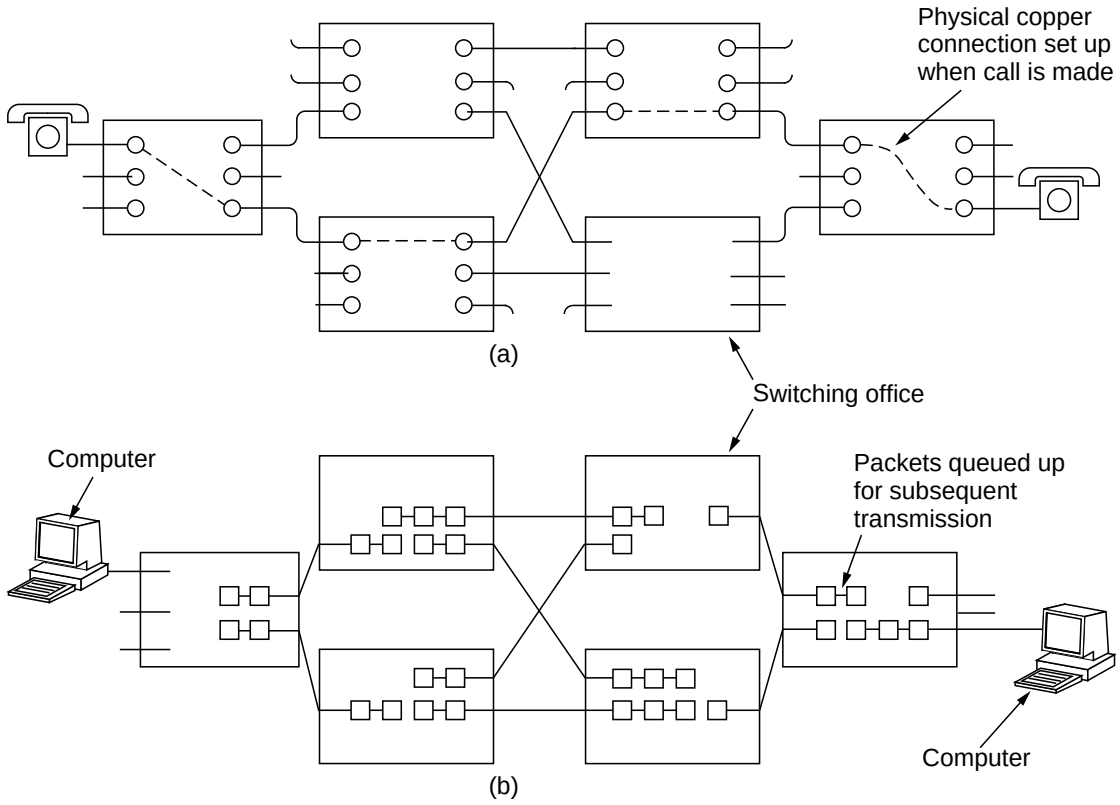

Fig. 2-34. (a) Circuit switching. (b) Packet switching.

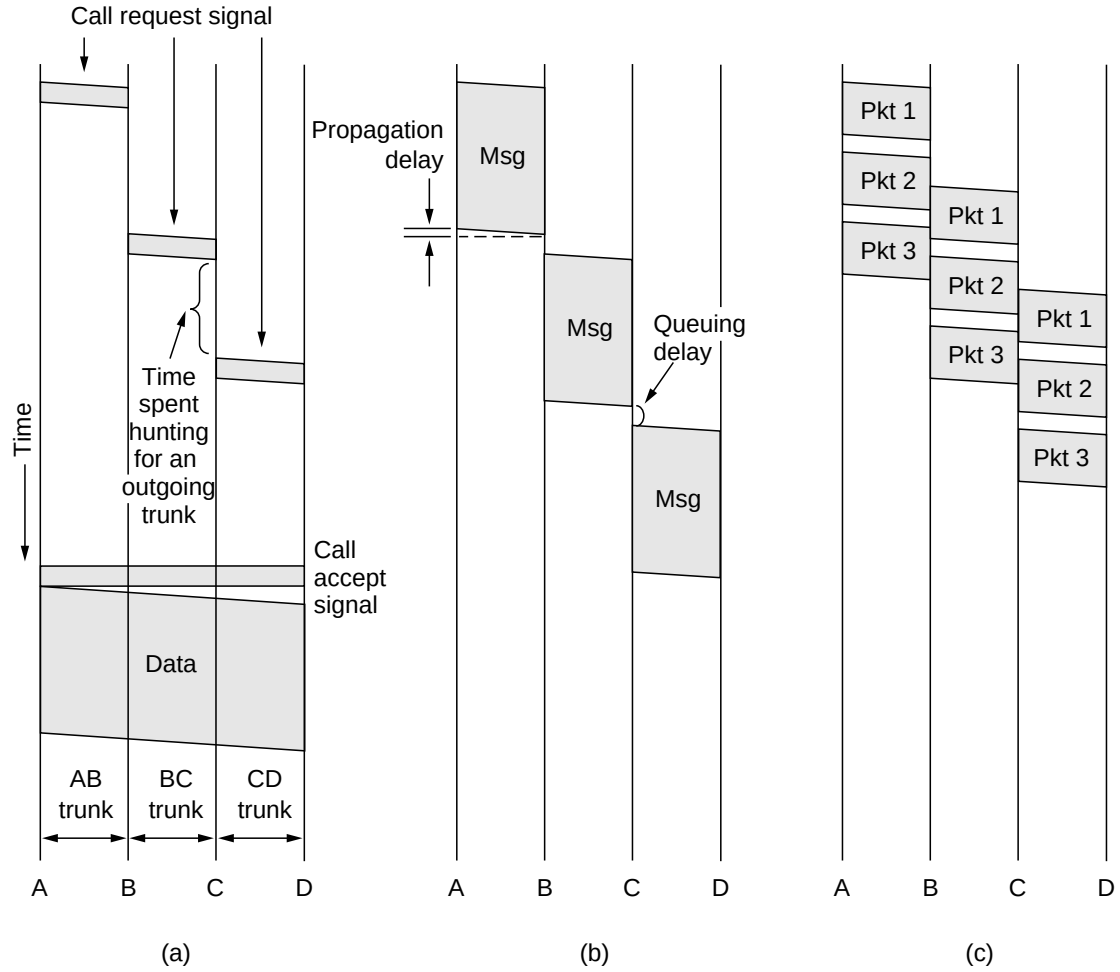

Fig. 2-35. Timing of events in (a) circuit switching, (b) message switching, (c) packet switching.

Item	Circuit-switched	Packet-switched
Dedicated “copper” path	Yes	No
Bandwidth available	Fixed	Dynamic
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Each packet follows the same route	Yes	No
Call setup	Required	Not needed
When can congestion occur	At setup time	On every packet
Charging	Per minute	Per packet

Fig. 2-36. A comparison of circuit-switched and packet-switched networks.

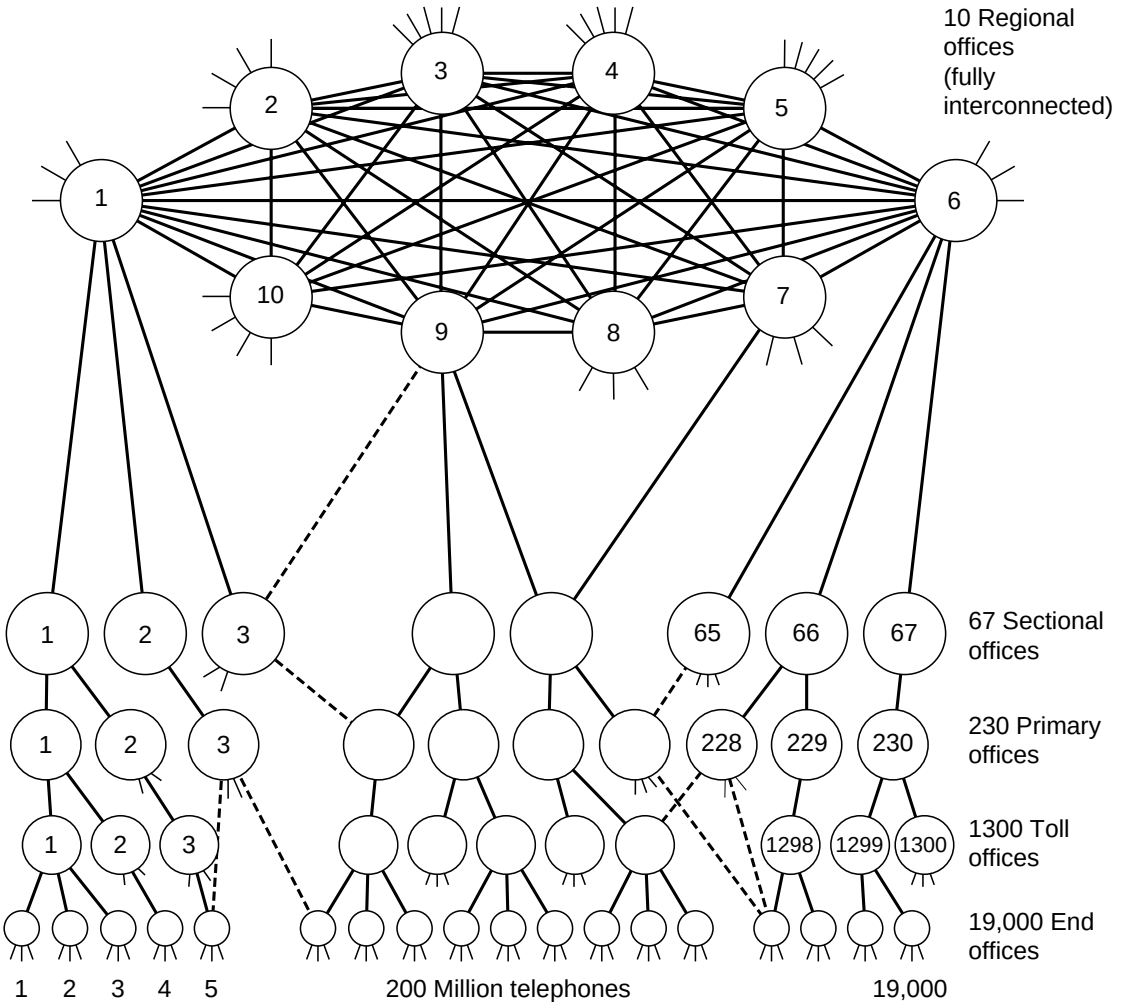

Fig. 2-37. The AT&T telephone hierarchy. The dashed lines are direct trunks.

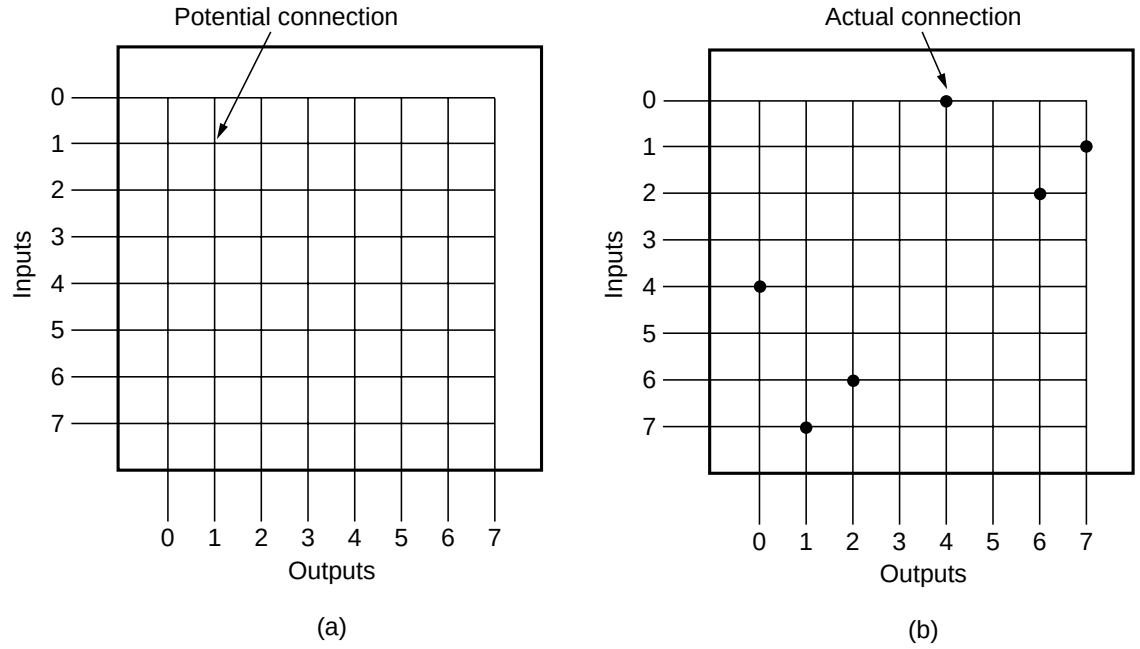

Fig. 2-38. (a) A crossbar switch with no connections. (b) A crossbar switch with three connections set up: 0 with 4, 1 with 7, and 2 with 6.

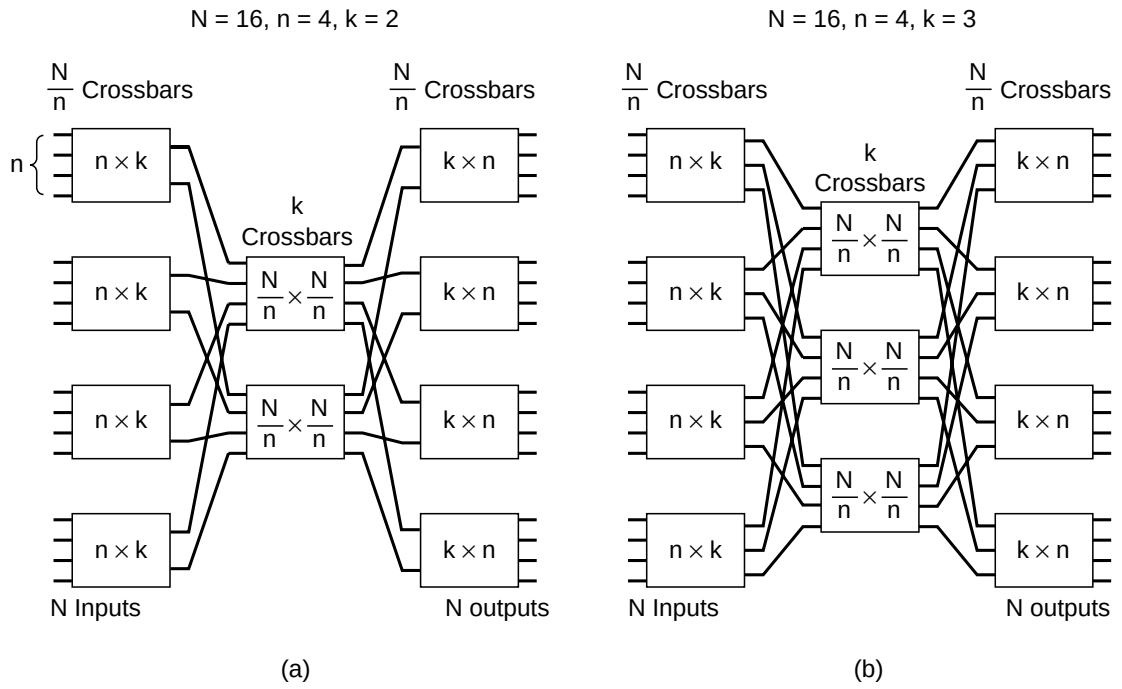

Fig. 2-39. Two space division switches with different parameters.

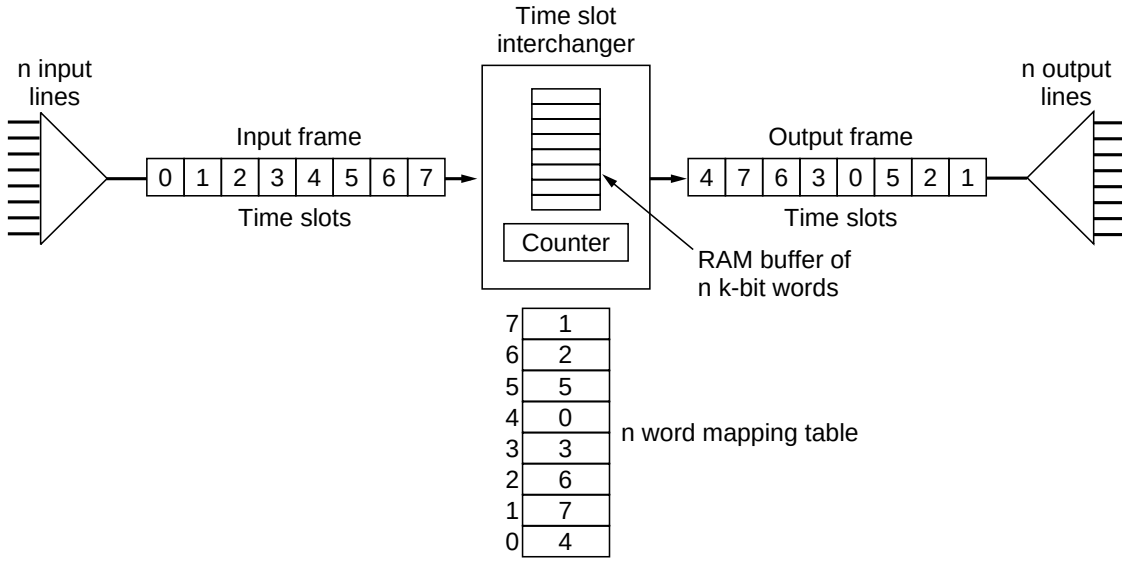

Fig. 2-40. A time division switch.

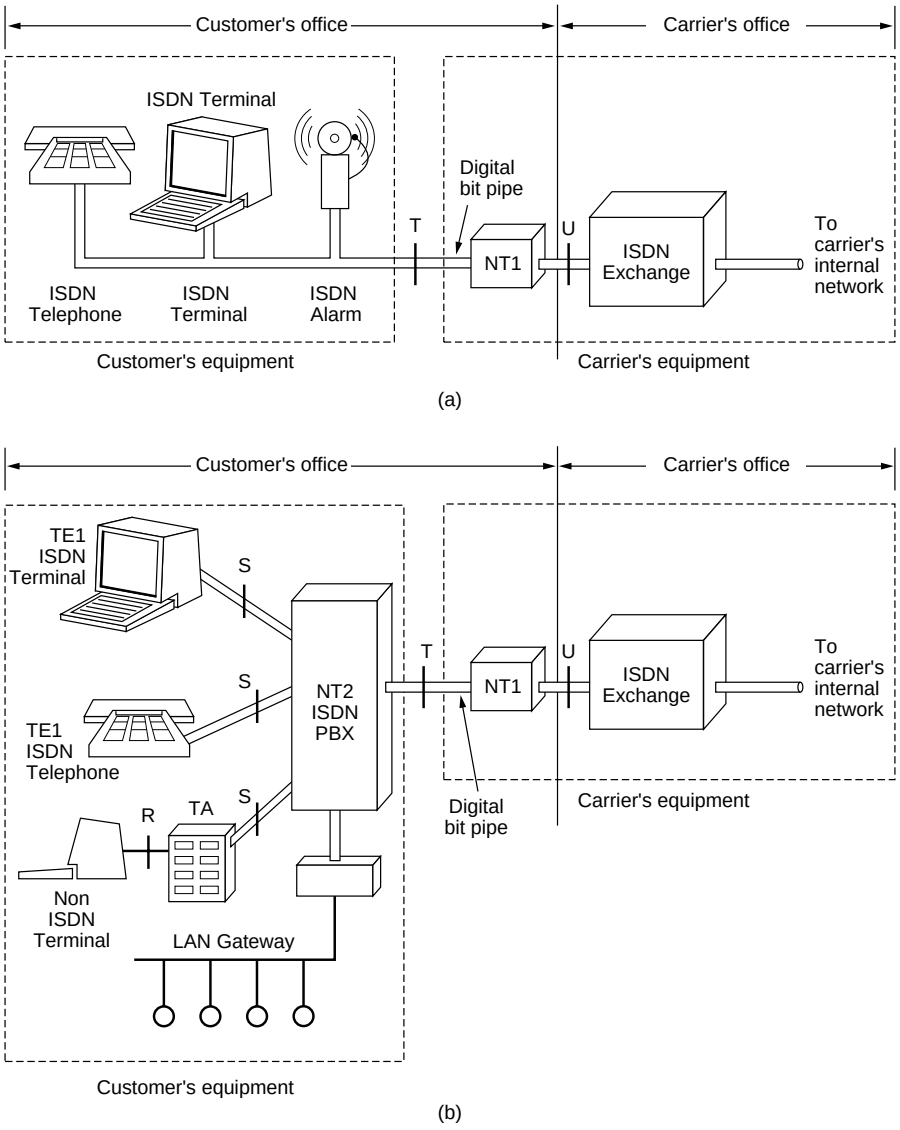

Fig. 2-41. (a) Example ISDN system for home use. (b) Example ISDN system with a PBX for use in large businesses.

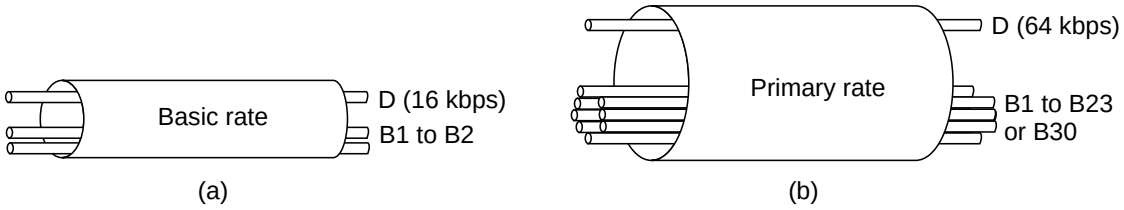

Fig. 2-42. (a) Basic rate digital pipe. (b) Primary rate digital pipe.

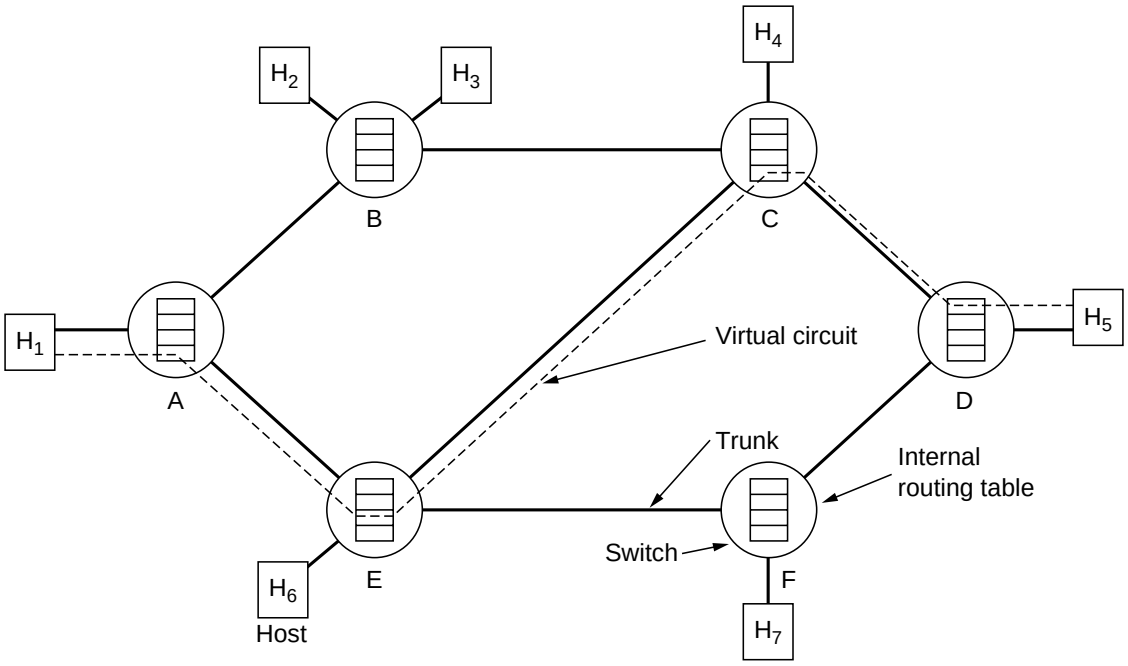

Fig. 2-43. The dotted line shows a virtual circuit. It is simply defined by table entries inside the switches.

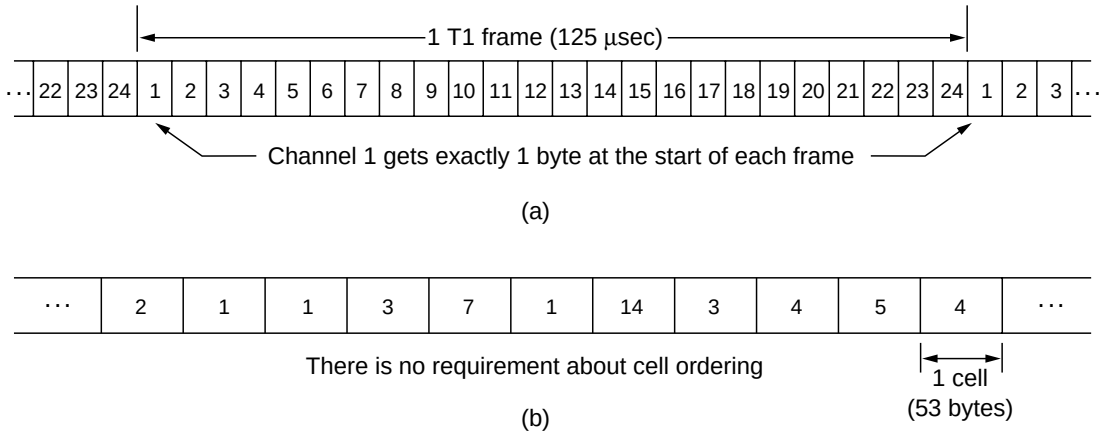

Fig. 2-44. (a) Synchronous transmission mode. (b) Asynchronous transmission mode.

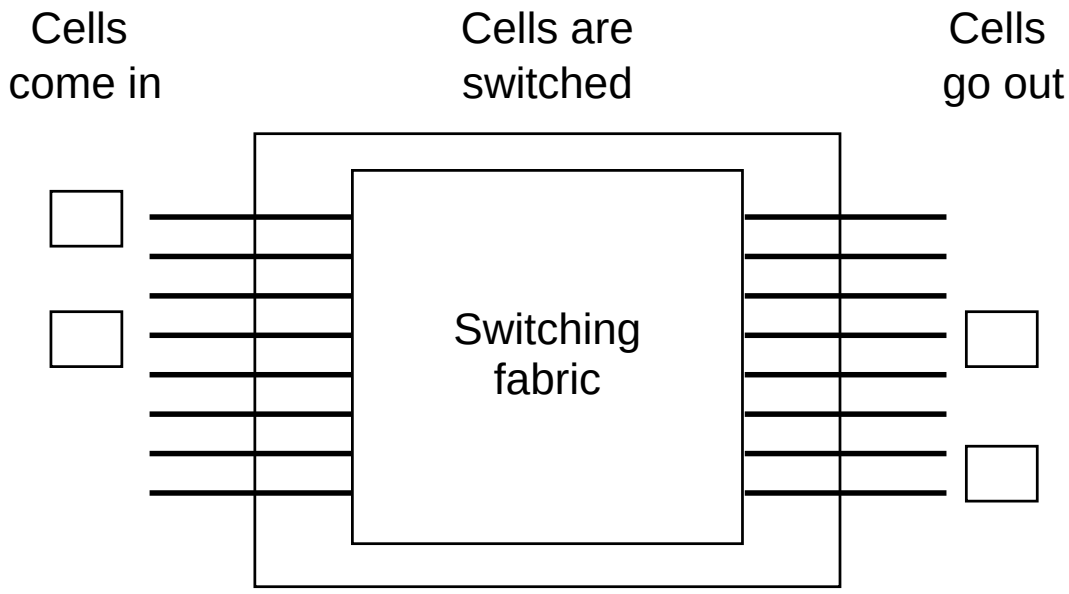

Fig. 2-45. A generic ATM switch.

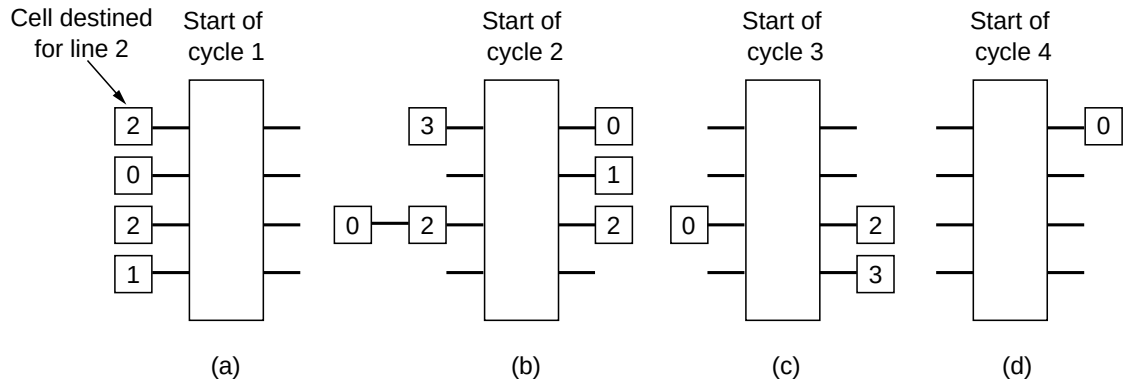

Fig. 2-46. Input queueing at an ATM switch.

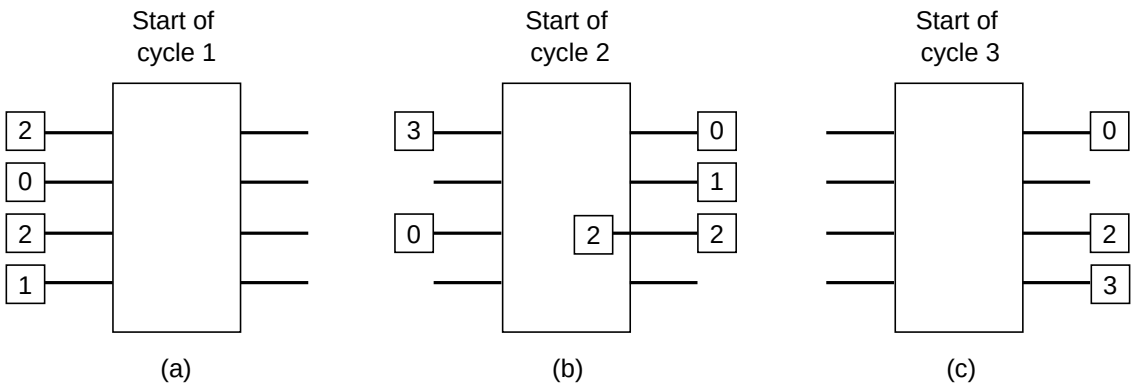

Fig. 2-47. Output queueing at an ATM switch.

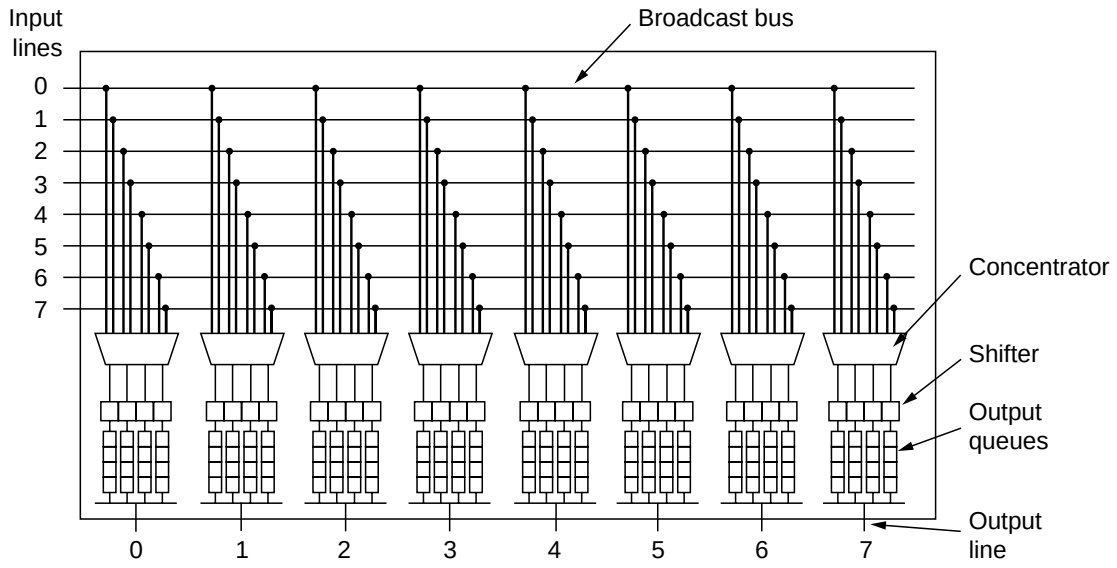

Fig. 2-48. A simplified diagram of the knockout switch.

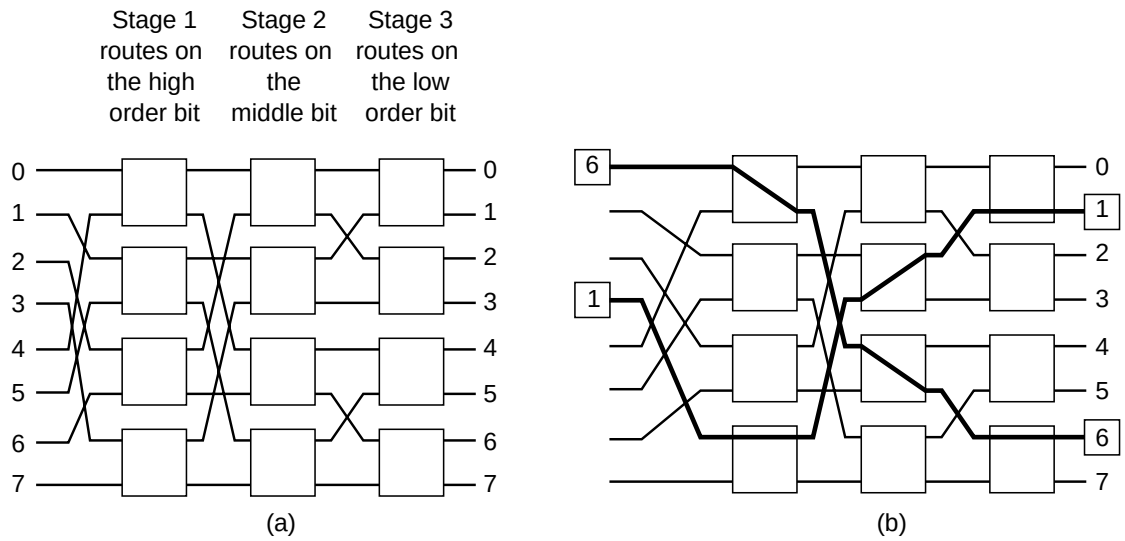

Fig. 2-49. (a) A banyan switch with eight input lines and eight output lines. (b) The routes that two cells take through the banyan switch.

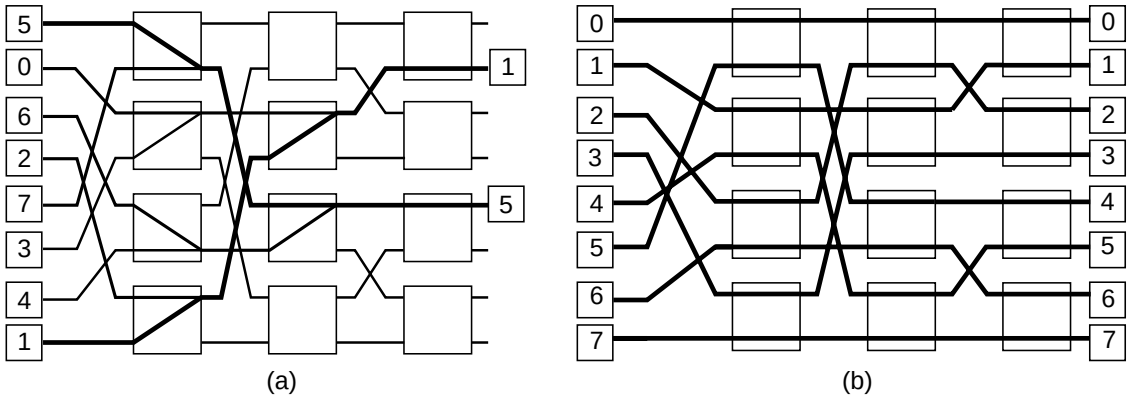

Fig. 2-50. (a) Cells colliding in a banyan switch. (b) Collision-free routing through a banyan switch.

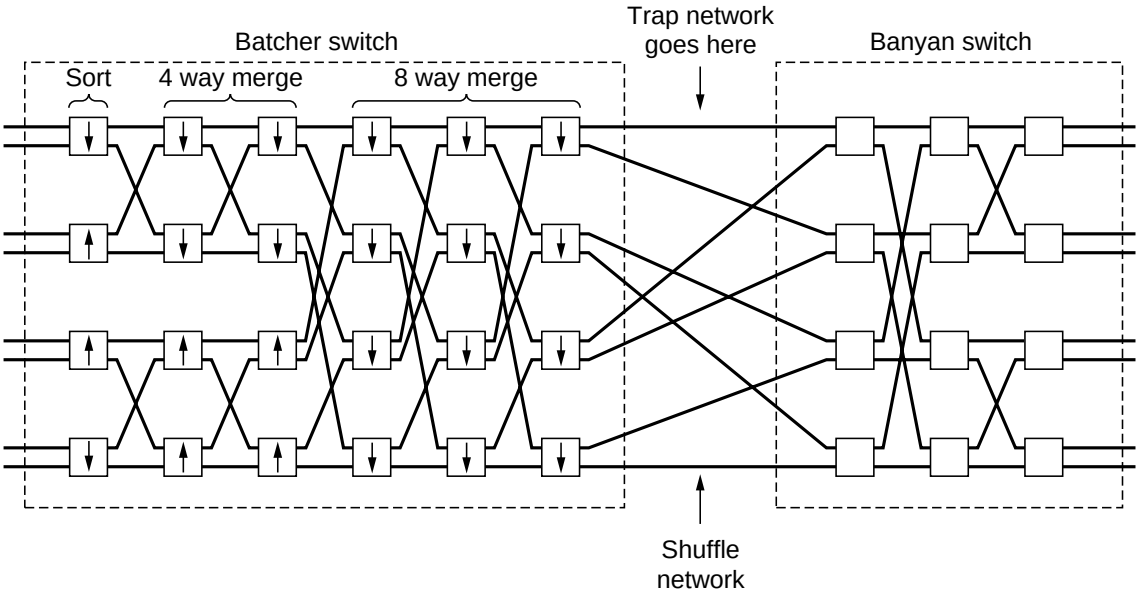

Fig. 2-51. The switching fabric for a Batcher-banyan switch.

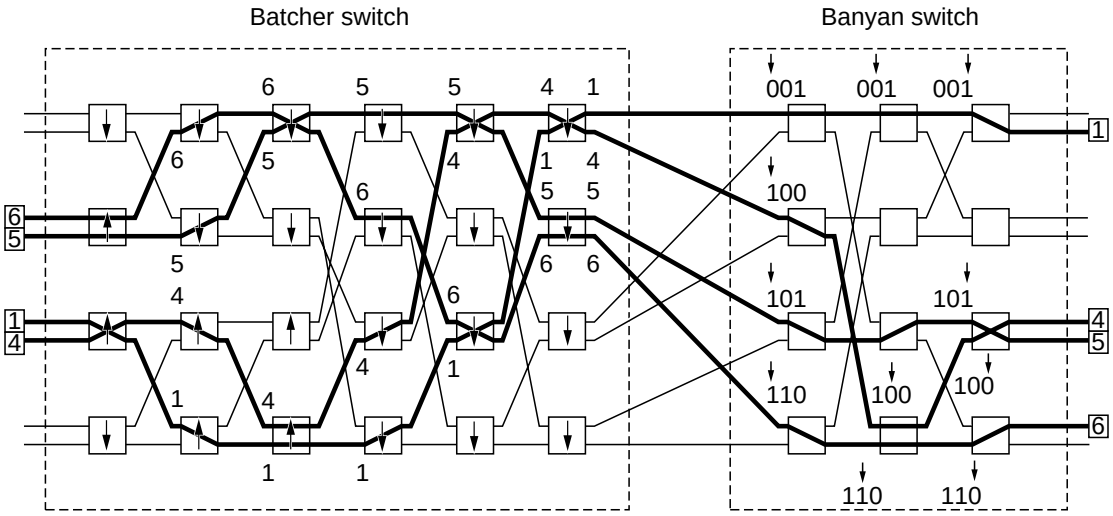

Fig. 2-52. An example with four cells using the Batcher-banyan switch.

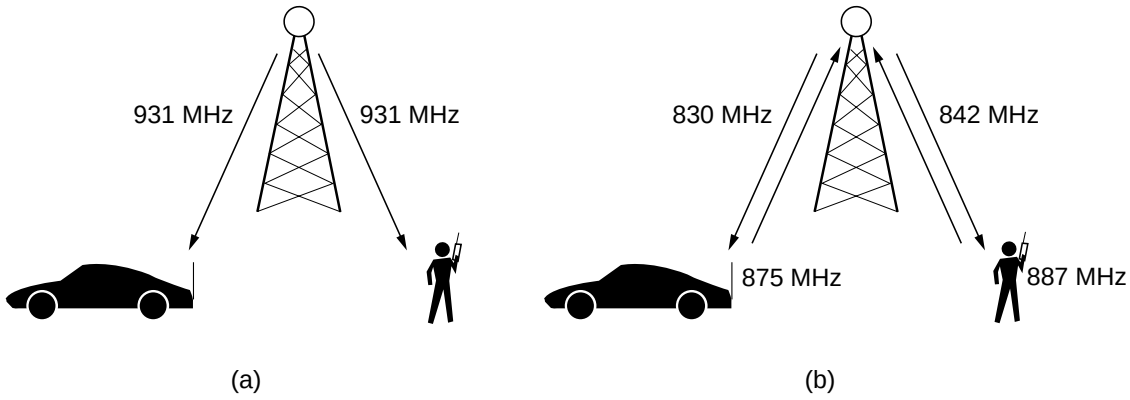

Fig. 2-53. (a) Paging systems are one way. (b) Mobile telephones are two way.

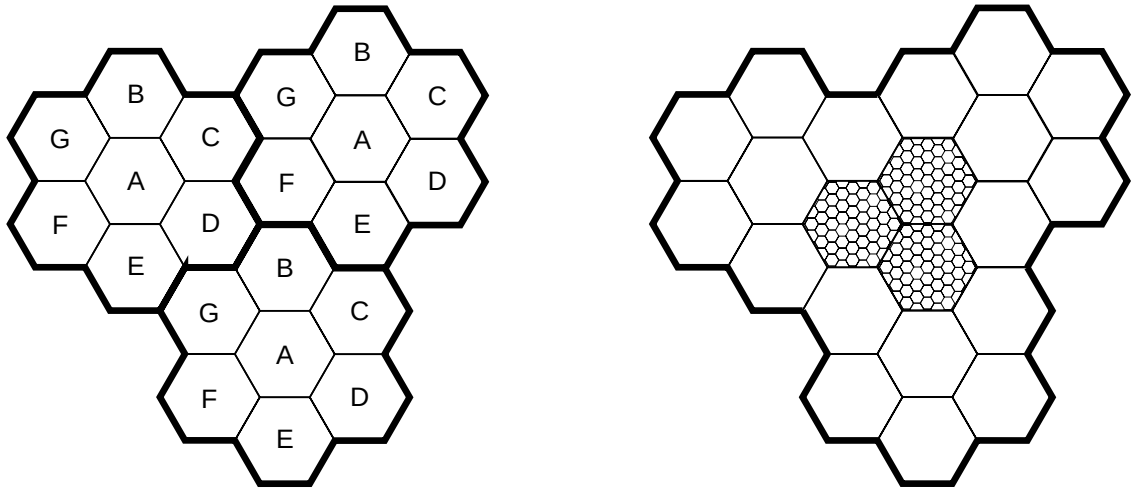

Fig. 2-54. (a) Frequencies are not reused in adjacent cells. (b) To add more users, smaller cells can be used.

Band	Frequencies	Downlink (GHz)	Uplink (GHz)	Problems
C	4/6	3.7–4.2	5.925–6.425	Terrestrial interference
Ku	11/14	11.7–12.2	14.0–14.5	Rain
Ka	20/30	17.7–21.7	27.5–30.5	Rain; equipment cost

Fig. 2-55. The principal satellite bands.

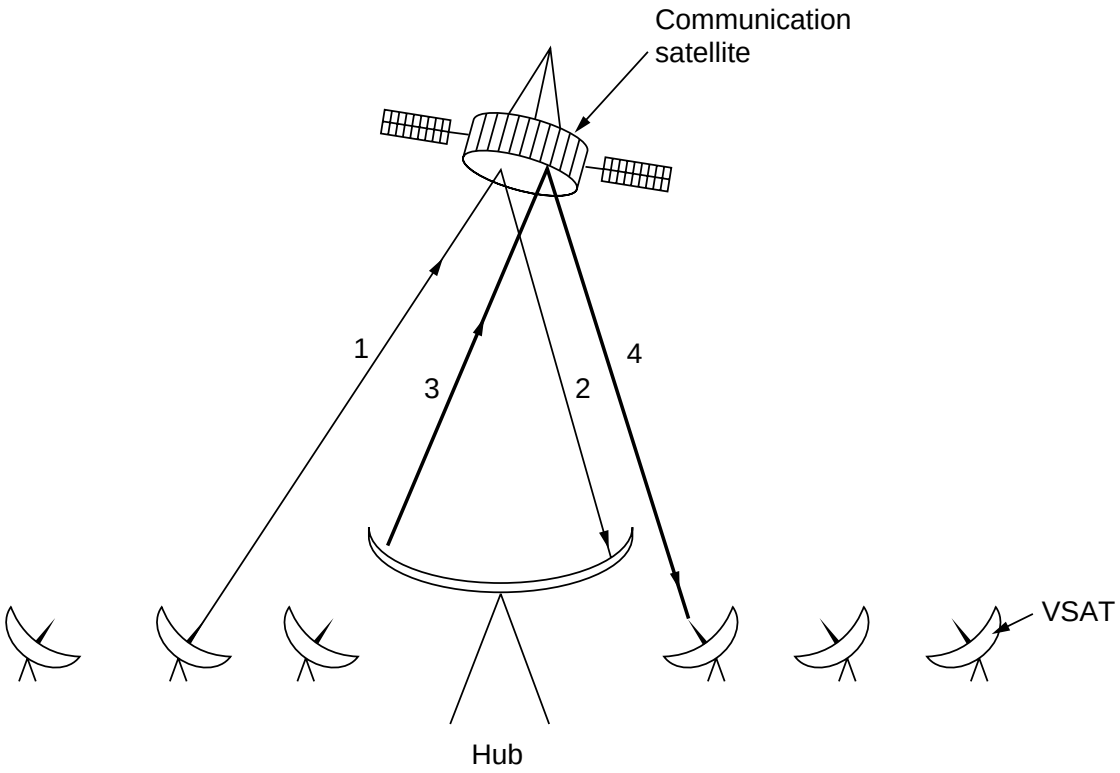

Fig. 2-56. VSATs using a hub.

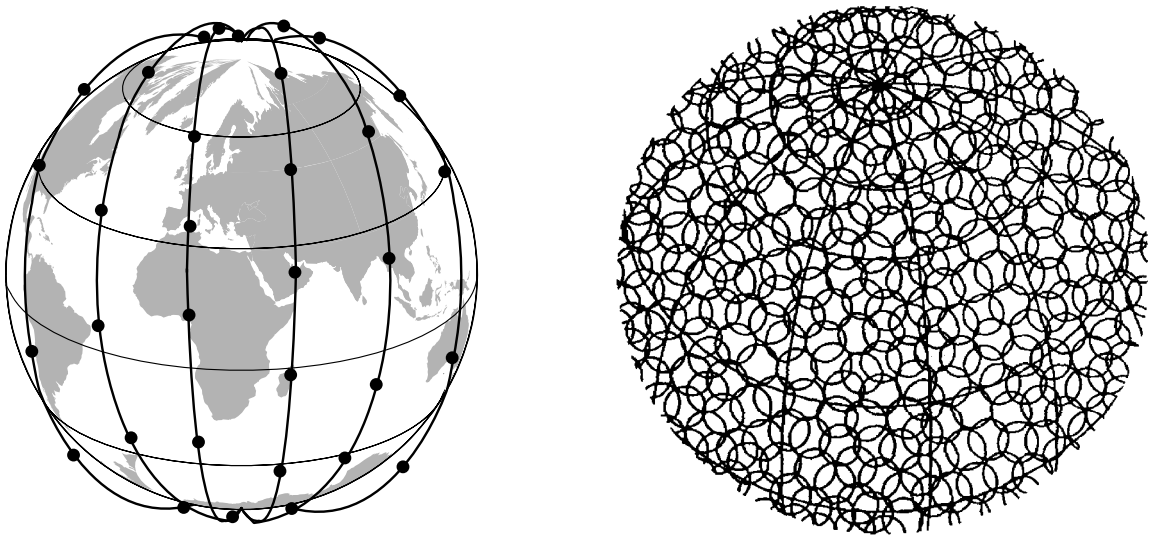

Fig. 2-57. (a) The Iridium satellites form six necklaces around the earth. (b) 1628 moving cells cover the earth.