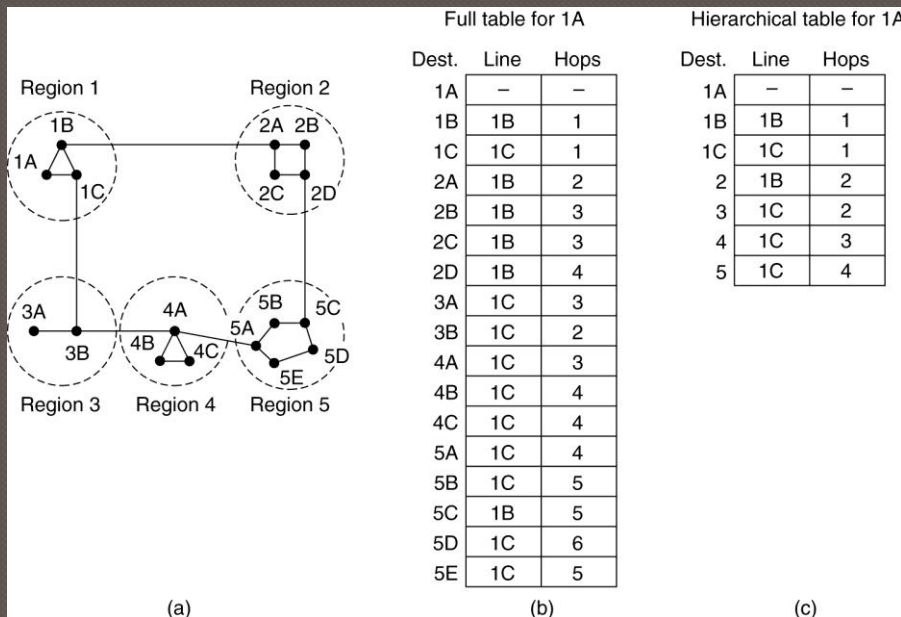


Chapter 5

The Network Layer (cont.)

Hierarchical Routing

2-level example: 1C is used to route any packet going out from Region 1 to Region 3, 4 and 5; line 1B is used for Region 2.



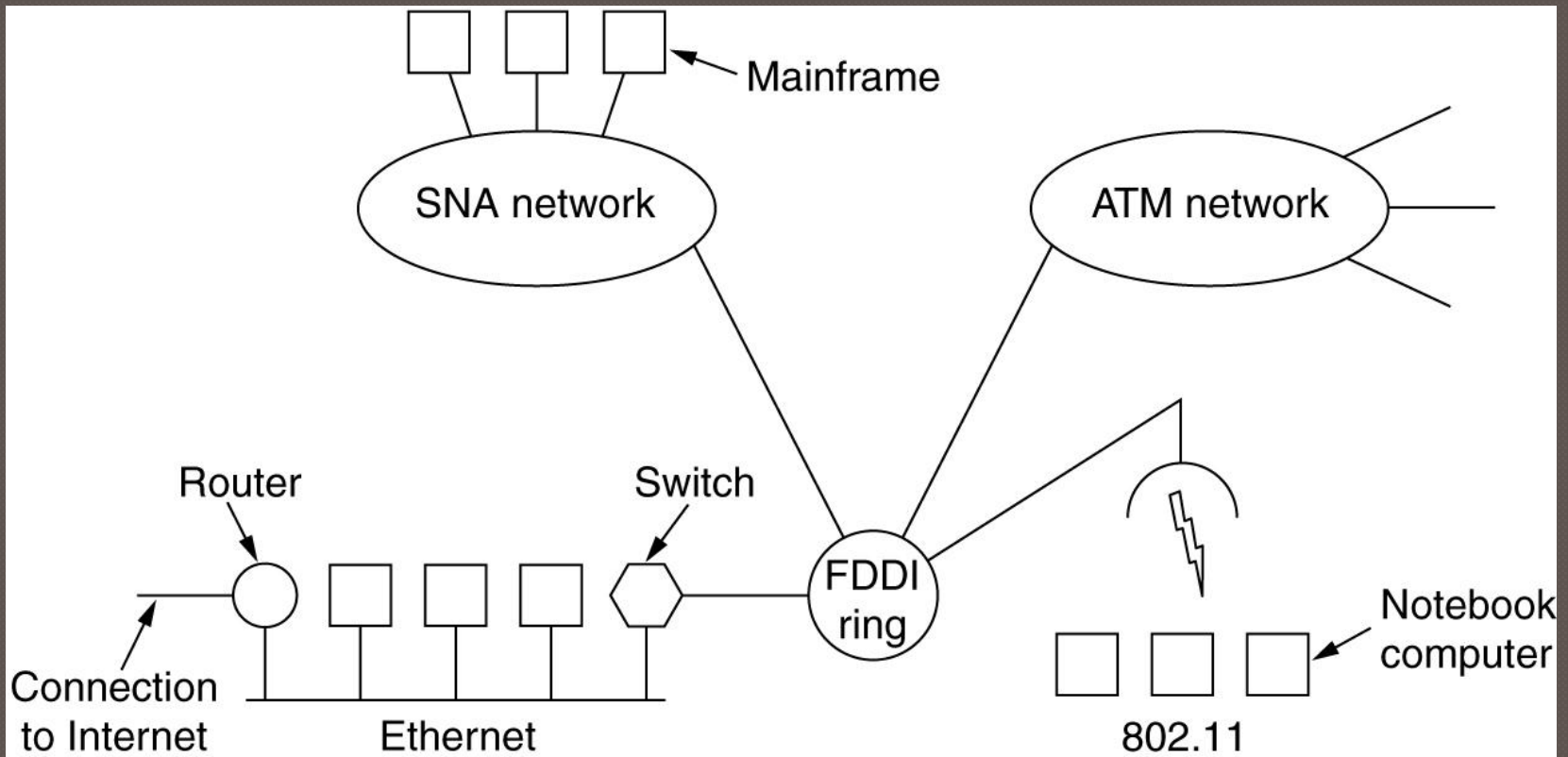
- Advantages:
 - Smaller tables
- Disadvantages:
 - increased path length for some traffic

Internetworking

- How Networks Differ
- How Networks Can Be Connected
- Concatenated Virtual Circuits
- Connectionless Internetworking
- Tunneling
- Internetwork Routing
- Fragmentation

Connecting Networks

A collection of interconnected networks.

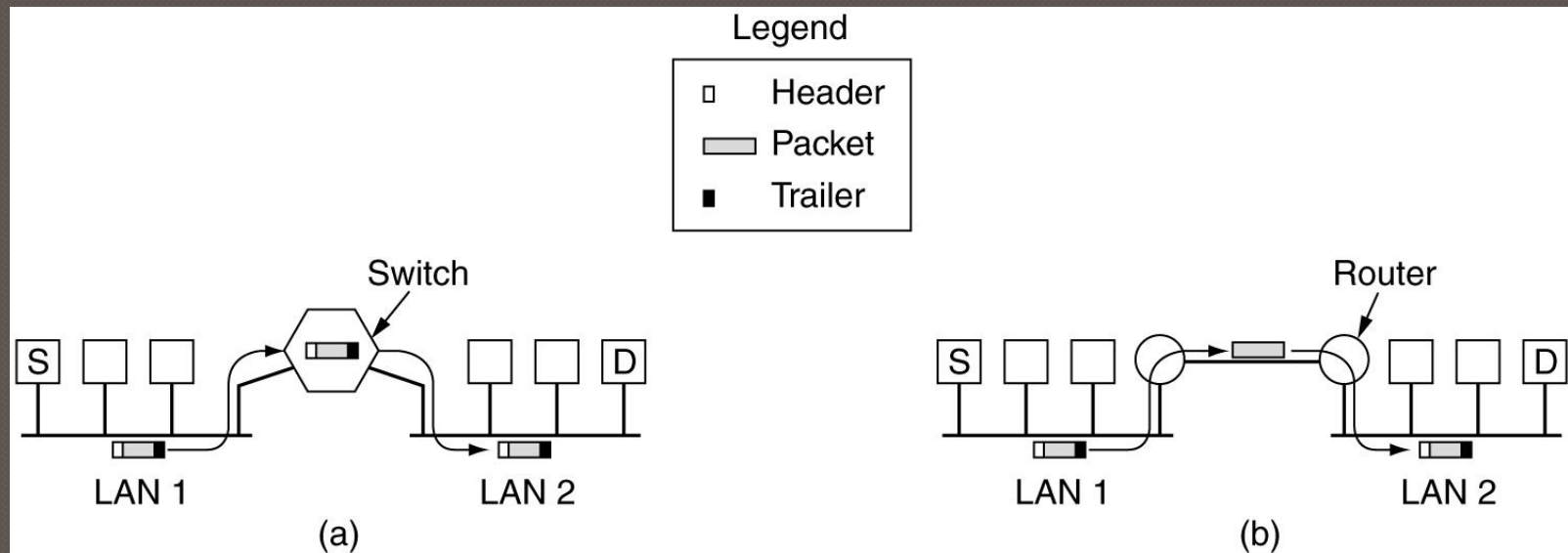


How Networks Differ

Item	Some Possibilities
Service offered	Connection oriented versus connectionless
Protocols	IP, IPX, SNA, ATM, MPLS, AppleTalk, etc.
Addressing	Flat (802) versus hierarchical (IP)
Multicasting	Present or absent (also broadcasting)
Packet size	Every network has its own maximum
Quality of service	Present or absent; many different kinds
Error handling	Reliable, ordered, and unordered delivery
Flow control	Sliding window, rate control, other, or none
Congestion control	Leaky bucket, token bucket, RED, choke packets, etc.
Security	Privacy rules, encryption, etc.
Parameters	Different timeouts, flow specifications, etc.
Accounting	By connect time, by packet, by byte, or not at all

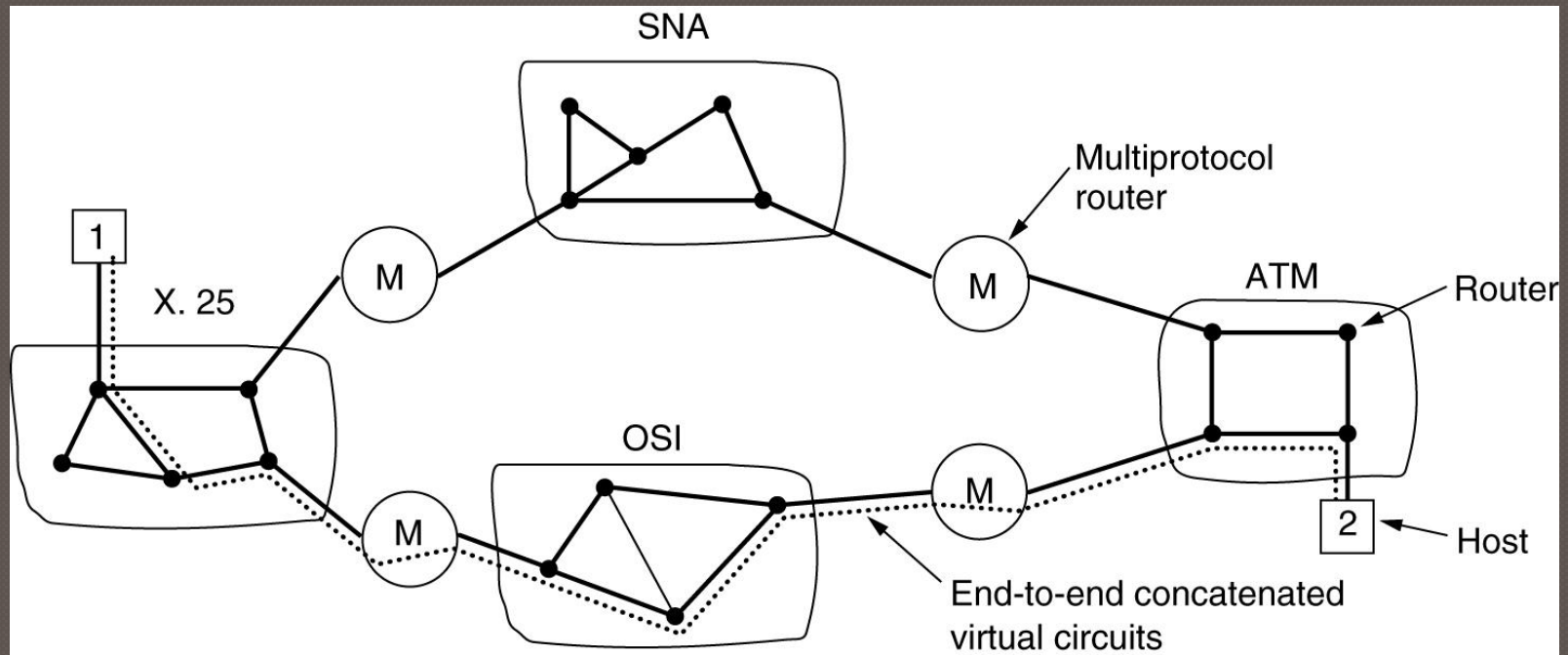
Some of the many ways networks can differ.

How Networks Can Be Connected



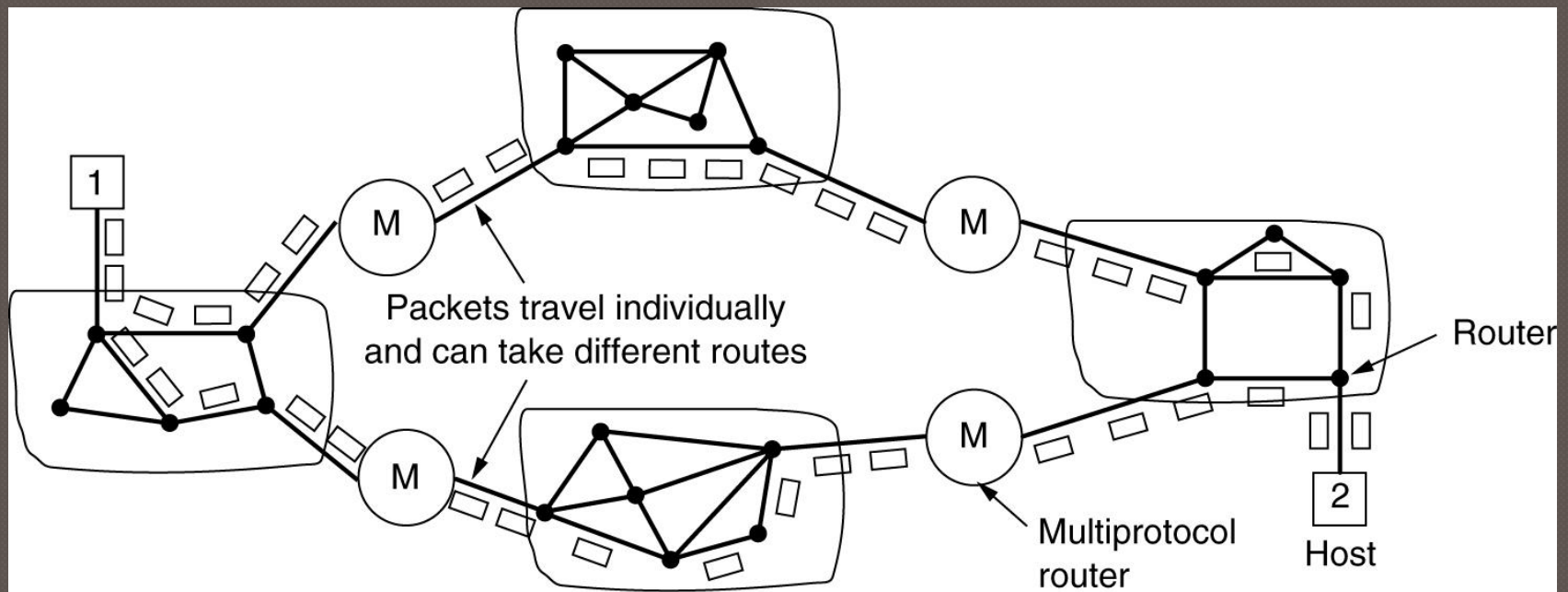
- (a) Two Ethernet networks connected by a switch.
- (b) Two Ethernet networks connected by routers.

Concatenated Virtual Circuits



Internetworking using concatenated virtual circuits.

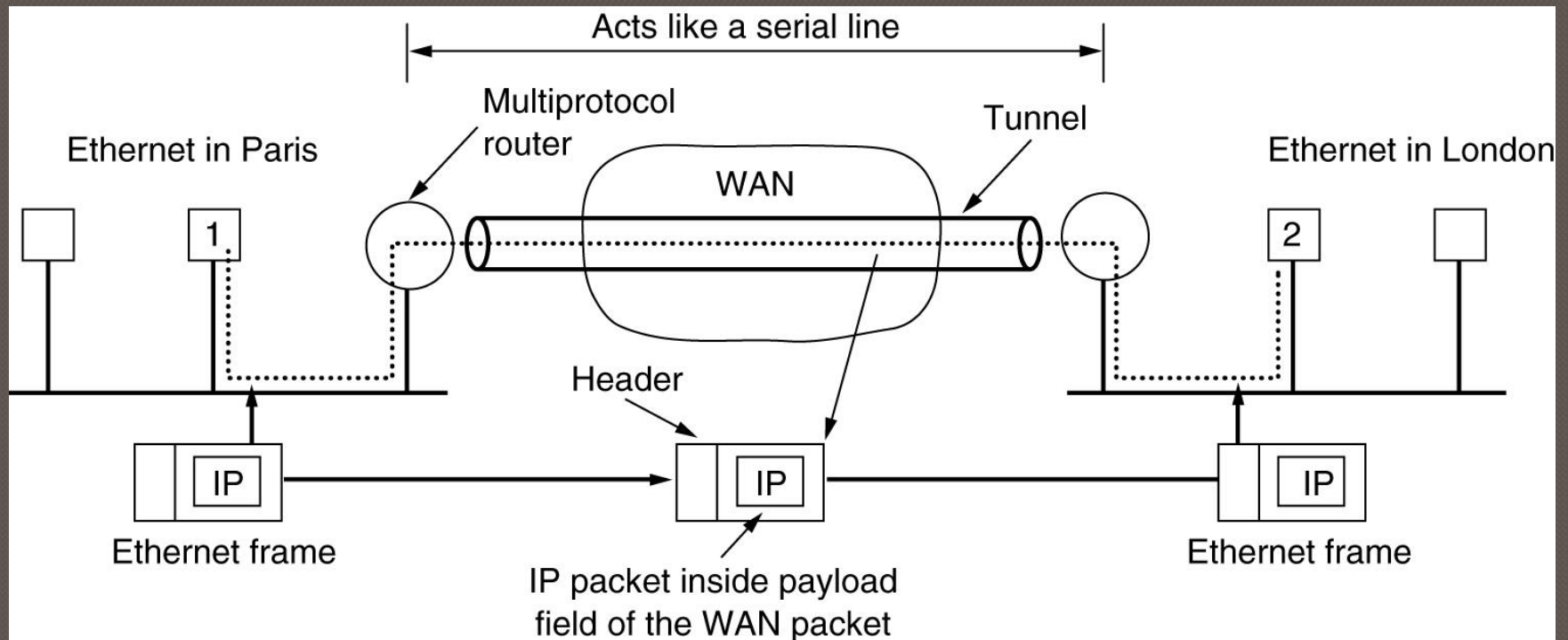
Connectionless Internetworking



A connectionless internet.

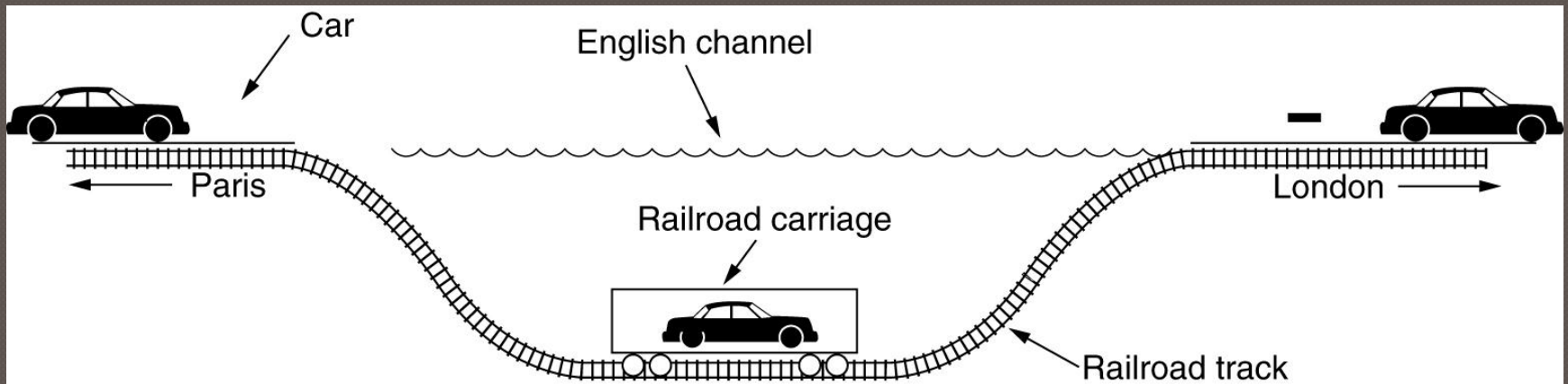
Tunneling

Tunneling a packet from Paris to London.



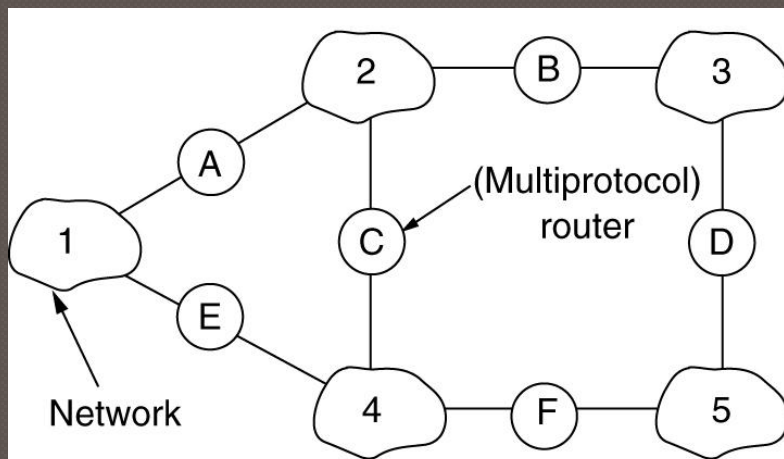
Tunneling (2)

Tunneling a car from France to England.

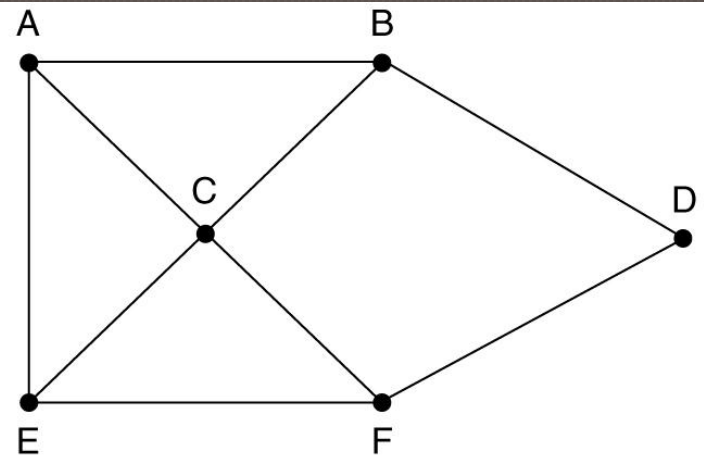


Internetwork Routing

(a) An internetwork. (b) A graph of the internetwork.



(a)



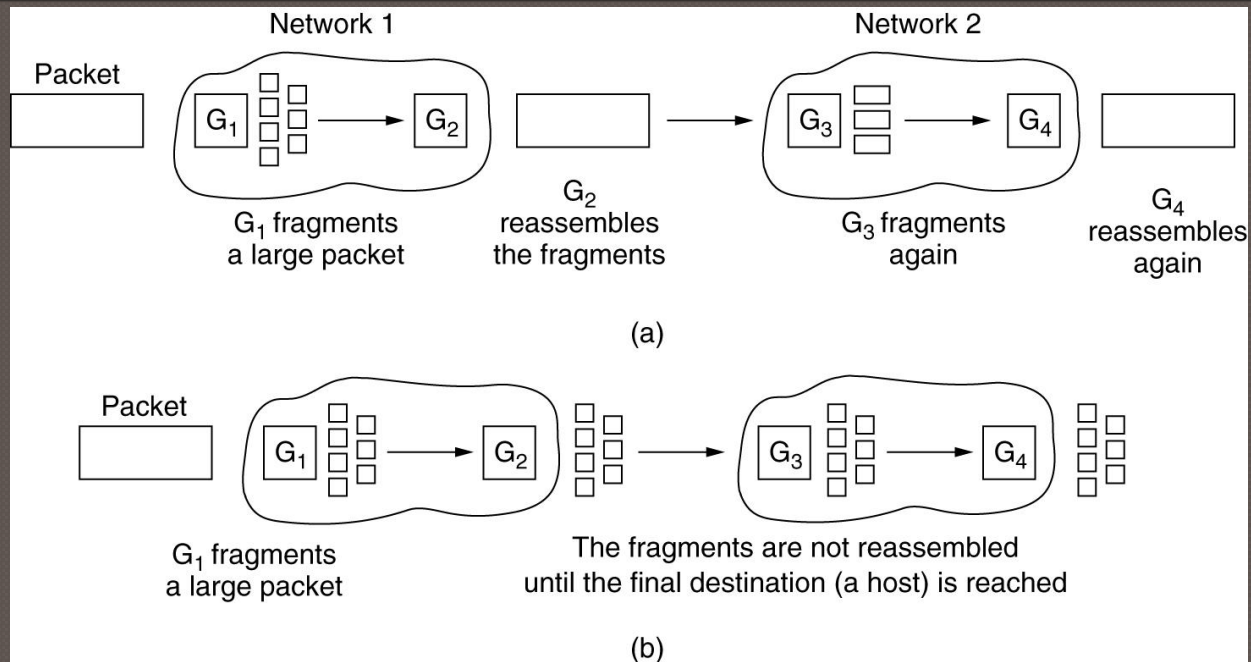
(b)

Fragmentation

Network Imposed Limitations:

- HW limitations (ex. Ethernet frame size)
- OS (ex. All buffers are 512 bytes)
- Protocols (ex no. of bits in the packet length field)
- Compliance with (inter)national standards
- Desire to reduce error-induces retransmissions
- Desire to prevent one packet from occupying the channel too long
- Net designer are not free to choose the max packet size they wish
 - Range: 48 bites (ATM cell) – 65, 515 bytes (IP packet)

Fragmentation



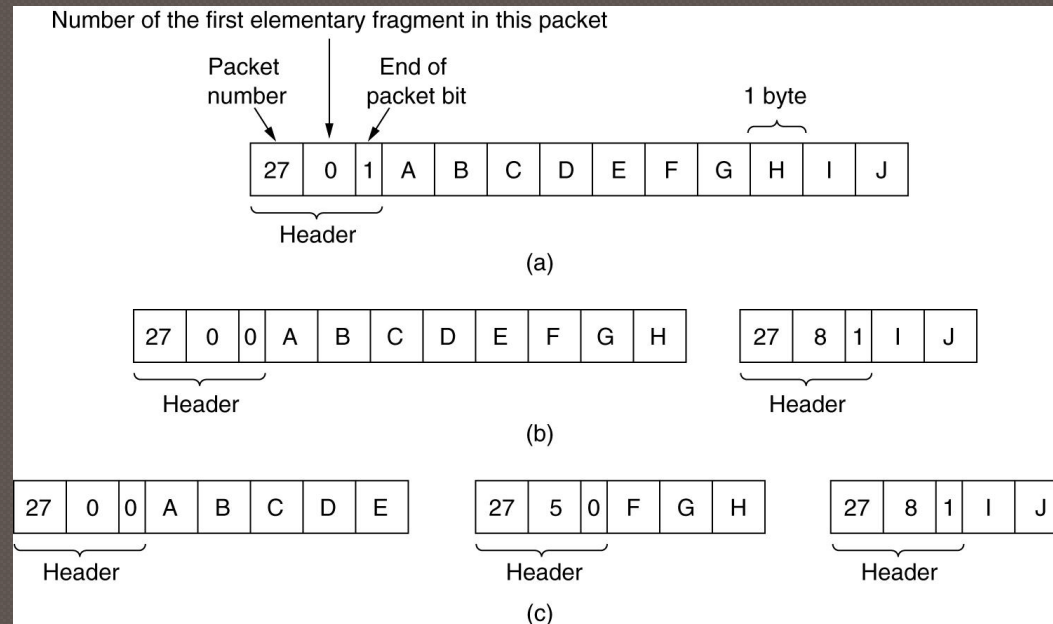
(a) Transparent fragmentation

- Overhead – each fragment has a header

(b) Nontransparent fragmentation.

- Every host must be able to reassembly

Fragmentation (2)



Fragmentation when the elementary data size is 1 byte.

- (a) Original packet, containing 10 data bytes.
- (b) Fragments after passing through a network with maximum packet size of 8 payload bytes plus header.
- (c) Fragments after passing through a size 5 gateway.

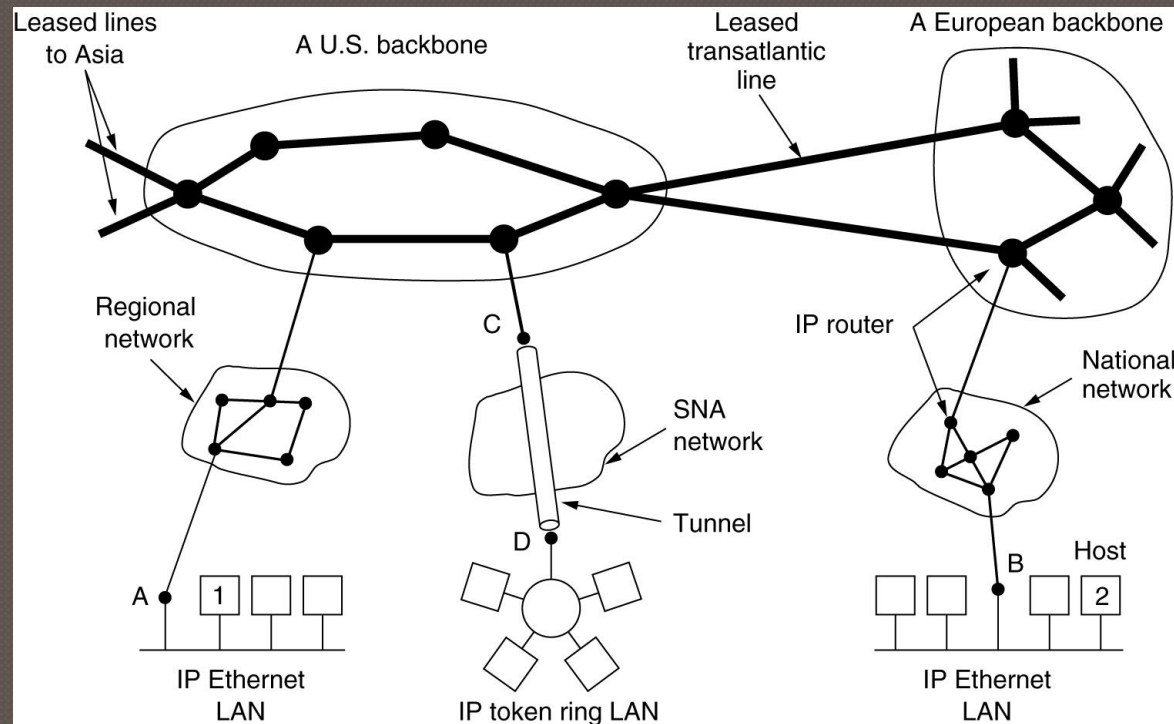
The Network Layer in the Internet

- Today:
 - The IP Protocol
 - IP Addresses
- Next time:
 - Internet Control Protocols
 - OSPF – The Interior Gateway Routing Protocol
 - BGP – The Exterior Gateway Routing Protocol
 - Internet Multicasting
 - Mobile IP
 - IPv6

Design Principles for Internet

1. Make sure it works.
2. Keep it simple.
3. Make clear choices.
4. Exploit modularity.
5. Expect heterogeneity.
6. Avoid static options and parameters.
7. Look for a good design; it need not be perfect.
8. Be strict when sending and tolerant when receiving.
9. Think about scalability.
10. Consider performance and cost.

Collection of Subnetworks

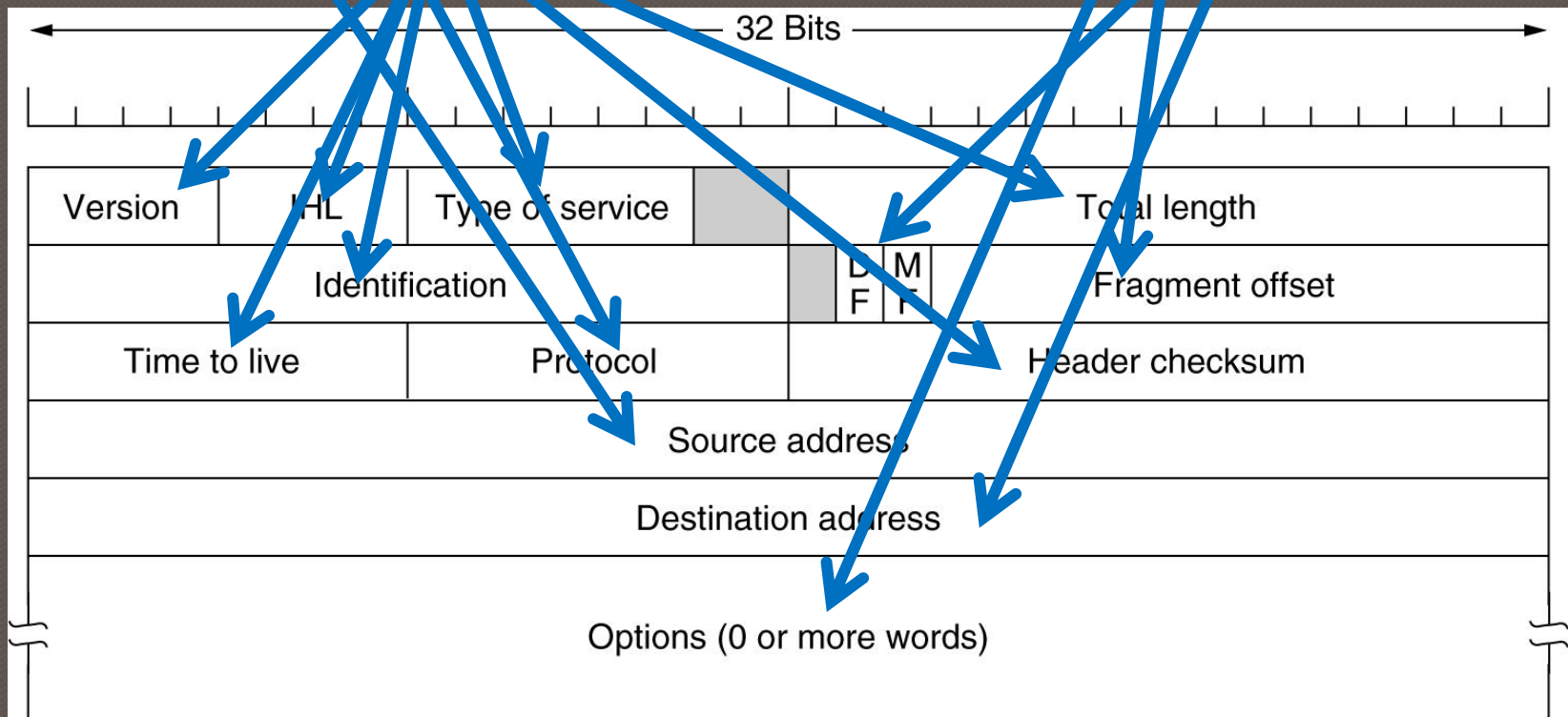


- The Internet is an interconnected collection of many networks.
- Each network is an Autonomous System (AS)

DEF63bits(1 byte)used)
(DEF63bits(1 byte)used=1 byte)

[illegible]

- All fragments have it except the last



The IP Protocol (2)

Some of the IP options.

Option	Description
Security	Specifies how secret the datagram is
Strict source routing	Gives the complete path to be followed
Loose source routing	Gives a list of routers not to be missed
Record route	Makes each router append its IP address
Timestamp	Makes each router append its address and timestamp

Next Time

- ◉ Internet Routing protocol