1.264 Lecture 22

Local area networks (LANs)

Wide area networks (WANs)

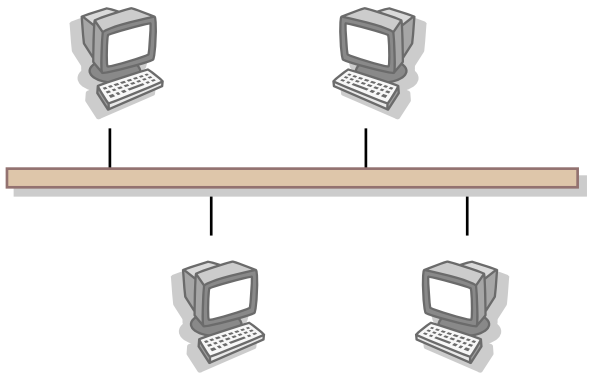
Metro area networks (MANs)

Course summary

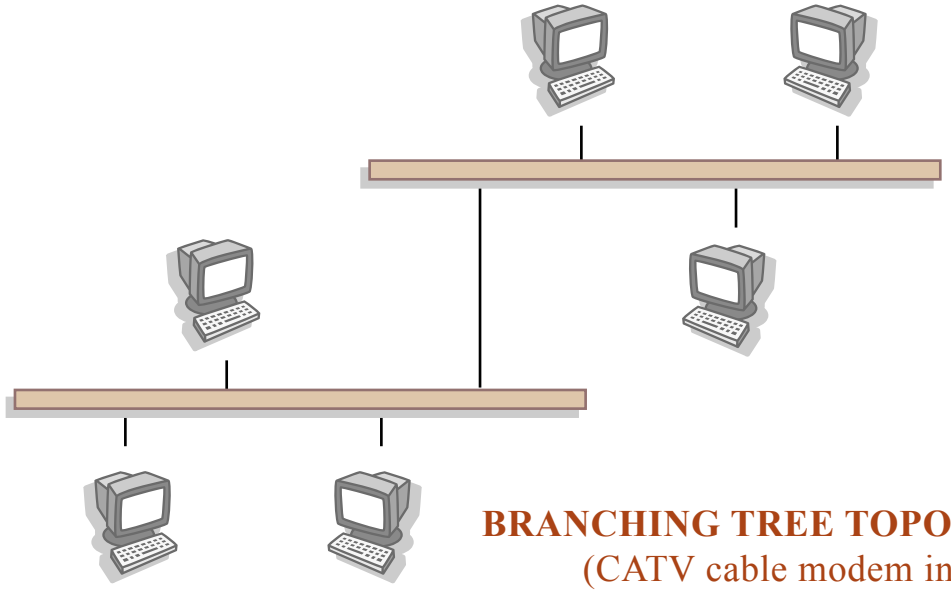
Local area networks (LANs)

- High speed (10Mb/s, 100Mb/s, 1Gb/s)
- Restricted range (2000 meters or less)
- Common access protocol for connected devices
  - Clients, servers, printers, other network devices
- Ethernet is dominant medium
- Carried over coax, copper (cat 5 UTP), fiber
- Wide area nets increasingly are collections of LANs
- The Internet is just a collection of LANs, connected by WANs
  - Unstructured, unplanned but it wouldn't have happened if planned
  - Problems with quality of service, capacity, security due to lack of management and planning

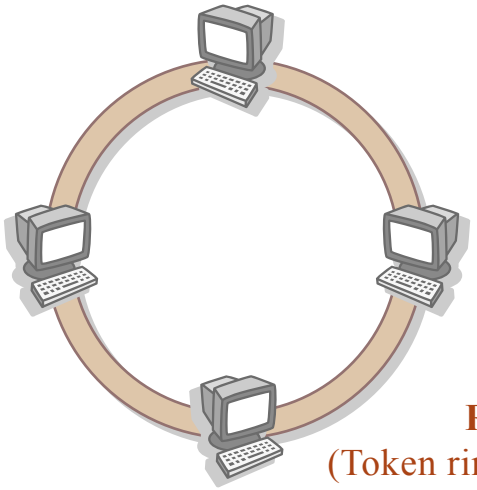
Local area network topologies



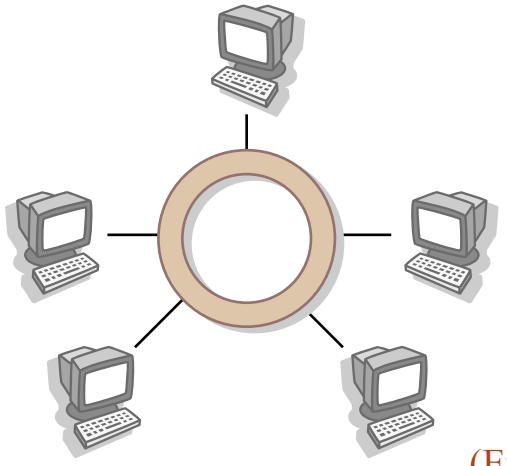
BUS TOPOLOGY
(Ethernet over coax cable)



BRANCHING TREE TOPOLOGY
(CATV cable modem in neighborhood)



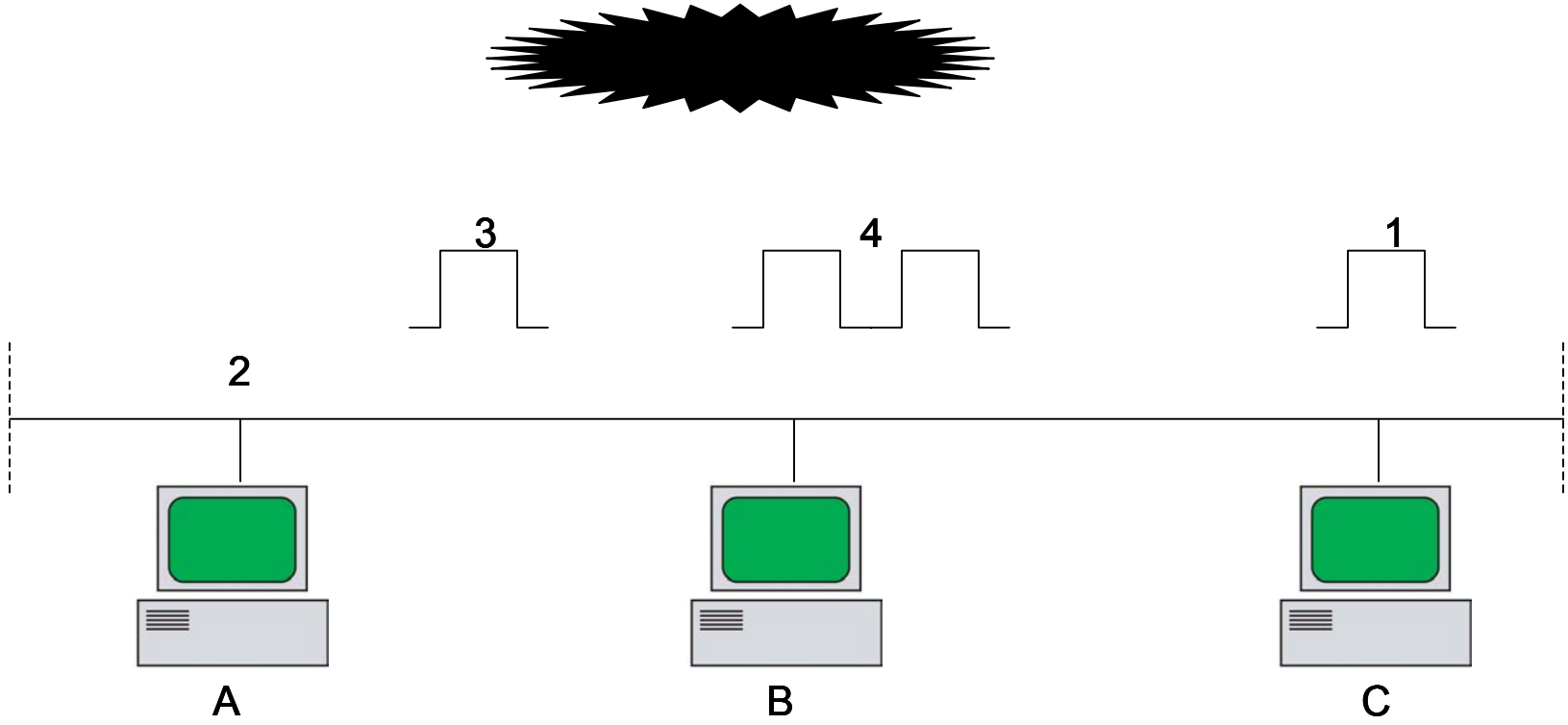
RING TOPOLOGY
(Token ring — too expensive for LAN but dominant in WAN)



STAR TOPOLOGY
(Ethernet over twisted pair)

Figure by MIT OCW.

Ethernet: shared network contention



1. Station C begins to transmit.
2. Station A listens to network, but signal from C has not arrived.
3. Station A transmits.
4. Signals from A and C collide.
5. Station B detects the collision and transmits a jamming signal.
6. Stations A and C back-off and wait a random time before retransmitting.

Figure by MIT OCW.

Ethernet operation

- Carrier sense multiple access (CSMA) with collision detection (CD)
  - Collision window is 5 microseconds per km of cable
  - Frames are padded to >= 64 bytes to ensure collisions detected
  - Restricts LAN length: longer LAN has bigger collision window
  - With > 10 microsecond collision window, can't get 10Mb/sec
  - Generally adequate performance, but not real time or heavy load
- This is exactly the same as optimistic locking in databases
  - Token ring used pessimistic locking, which didn't work well
- Layered protocol (layer 2) to work with multiple physical media: twisted pair, coax, fiber, wireless
- Wireless LANs still problematic: security, interference, …
- Ethernet on factory floor is finally possible:
  - Bogs down under load, doesn't provide real-time performance
  - With 1Gb Ethernet, the load (%) is low enough it's no problem
- Ethernet now runs at 10Mb, 100Mb, 1Gb.
  - Long haul "Ethernet" being developed and likely to succeed

Token rings and buses

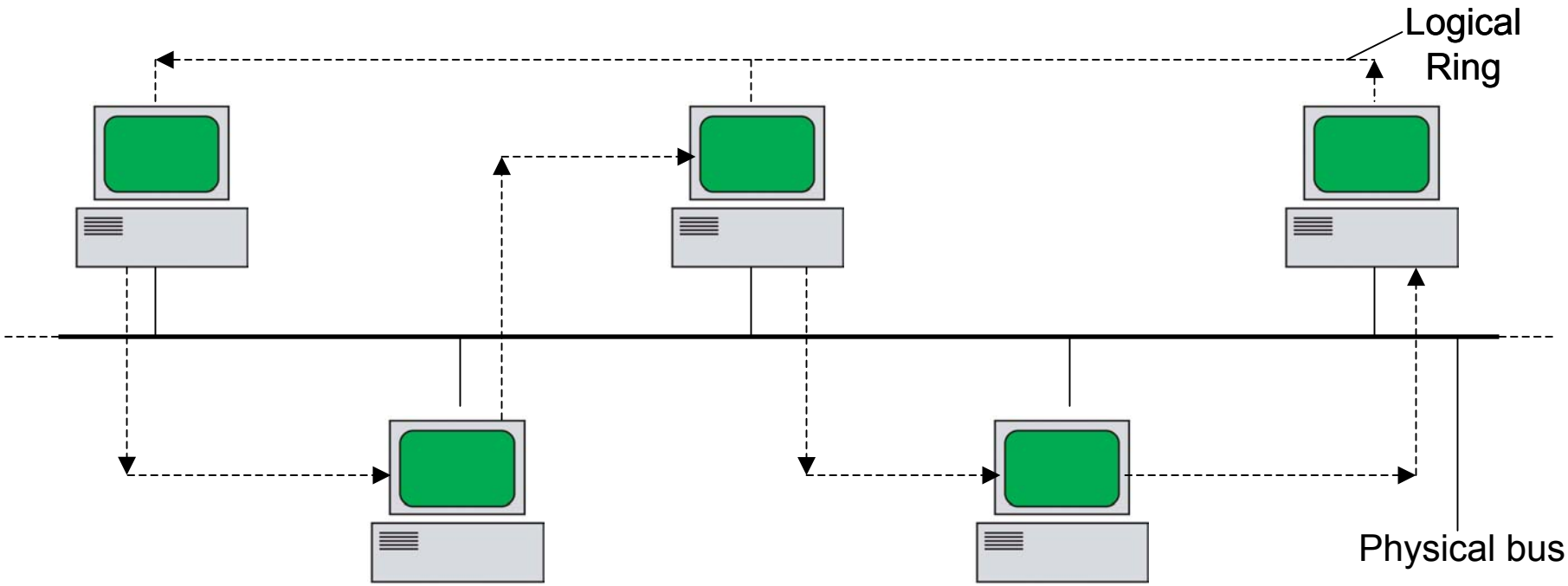
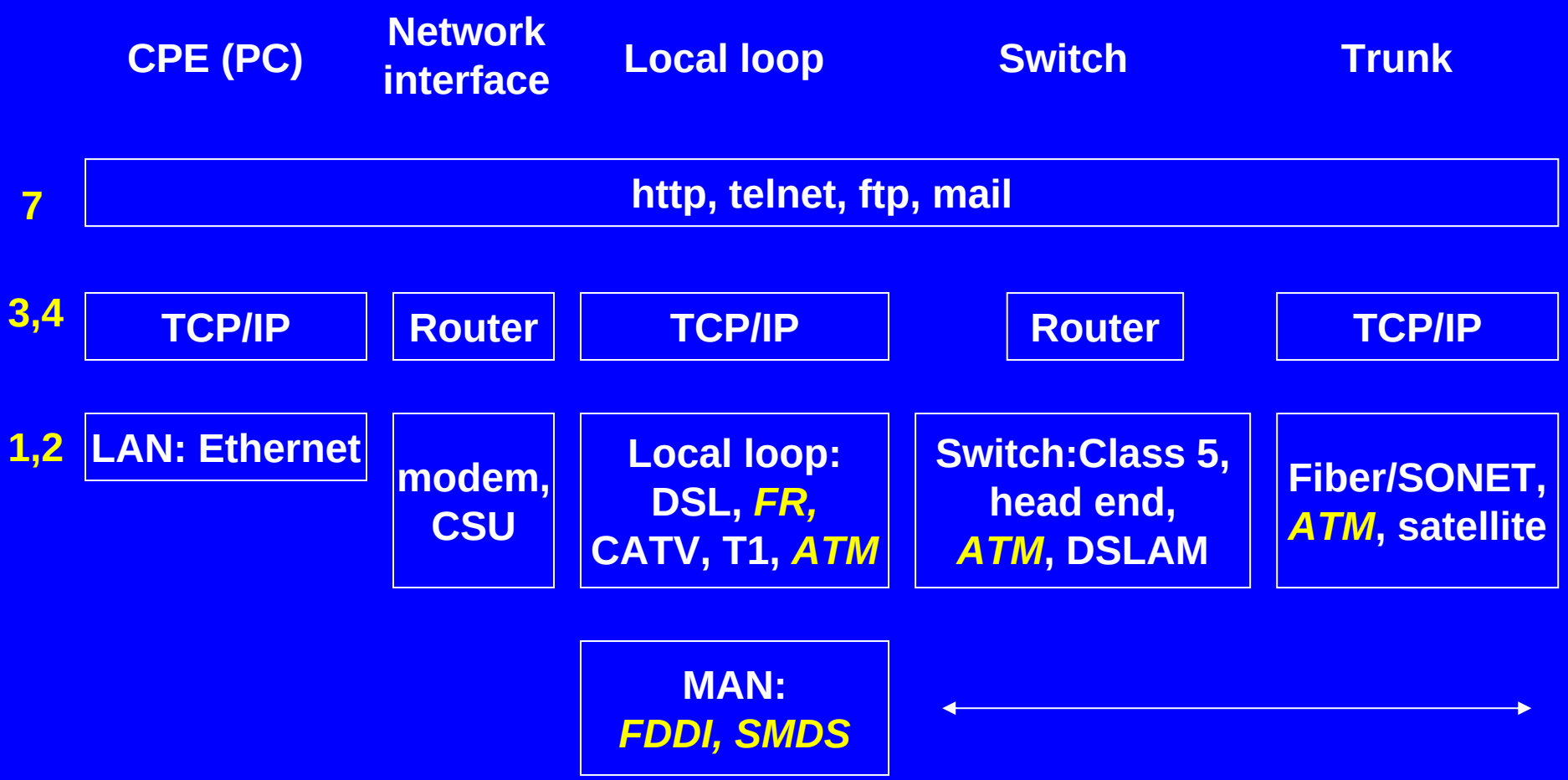


Figure by MIT OCW.

IBM token ring too expensive. Adapters more complex, improvement over Ethernet is small
Tokens are more stable under load and can be tuned for real time performance
Token rings used in WANs (next lecture)

Network summary



Repeaters, Bridges, Routers, Gateways

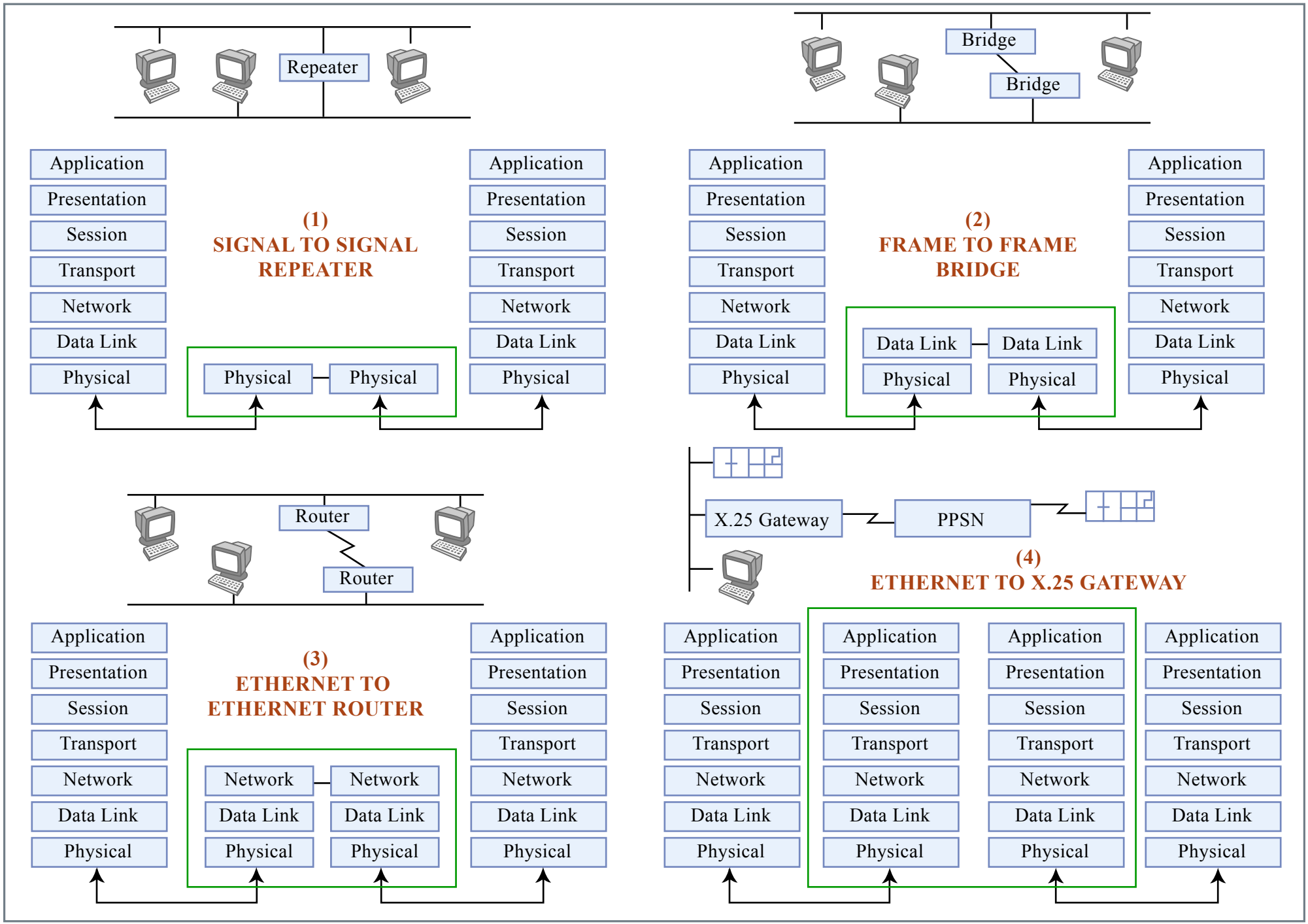


Figure by MIT OCW.

Repeaters, Bridges, Routers, Gateways

- Repeaters just extend physical layer
- Bridges segment by MAC (Ethernet) addresses, send just to correct segment
  - Only know location of local devices
- Routers segment by IP address
  - Know locations of destination addresses, all paths, congestion, cost of routes, …
  - Policy routing: settlements, preferred routings over given networks, firewalls, ...
- Gateways are really servers with application software to convert protocols
- Unstructured LANs with wide area interconnects make up the Internet
  - Packet may go through dozens of routers
  - Only problem is delay for voice and video; data is generally fine
  - Recall the contrast with the highly structured telecom network
- This really is the Internet…
  - Gigabit routers, policy routers, gatekeepers/gateways, ...

Example network

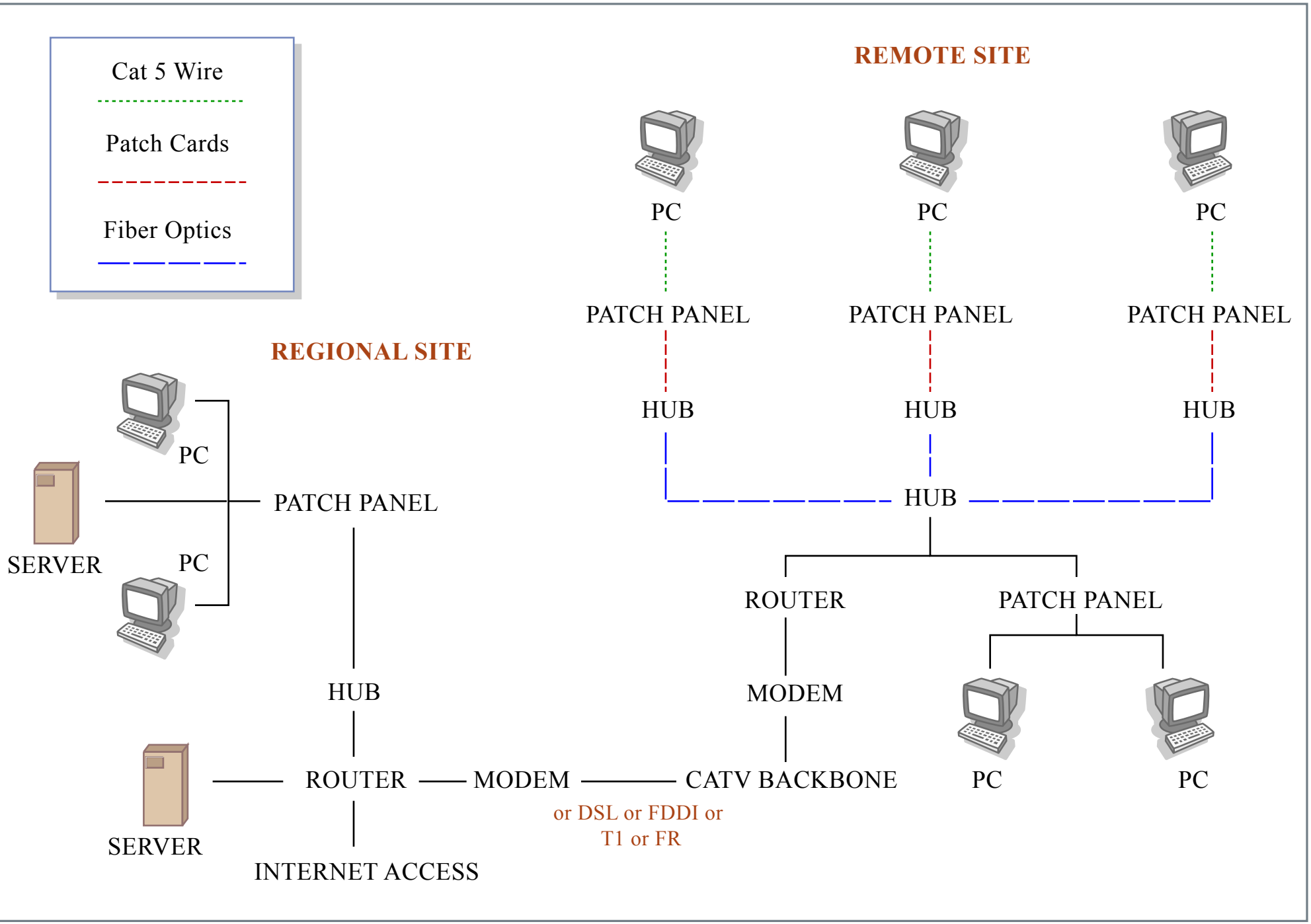


Figure by MIT OCW.

Wide area network: frame relay

- Similar architecturally to TCP/IP though with larger packets, different headers. Frame relay predates TCP/IP
  - Frame relay is reliable, easy to install and use
  - Used in lower data rates (56 kbps up to T-1)
- Frame relay supports virtual circuits that are permanently set up
  - Remote site always homes on the same company facility
- Frame relay also supports switched virtual circuits
- IECs and LECs offer frame relay widely and cheaply (distance-insensitive)
- Generally carried over copper to class 5 switch, then fiber trunks
- FR does no error correction and assumes virtually error-free links (fiber)
- Essentially a layer 1, 2 protocol

Frame relay network

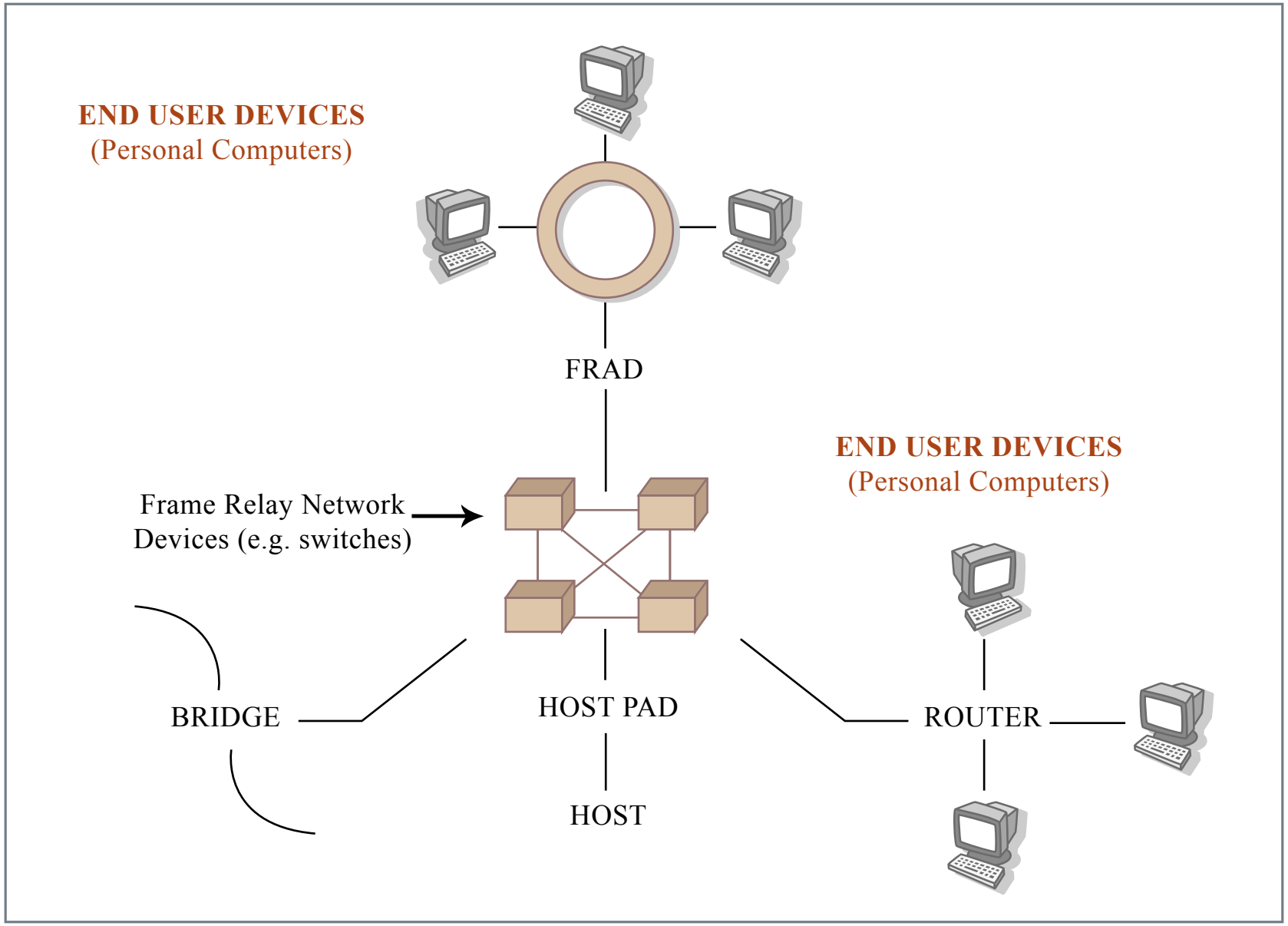


Figure by MIT OCW.

Frame relay vs X.25

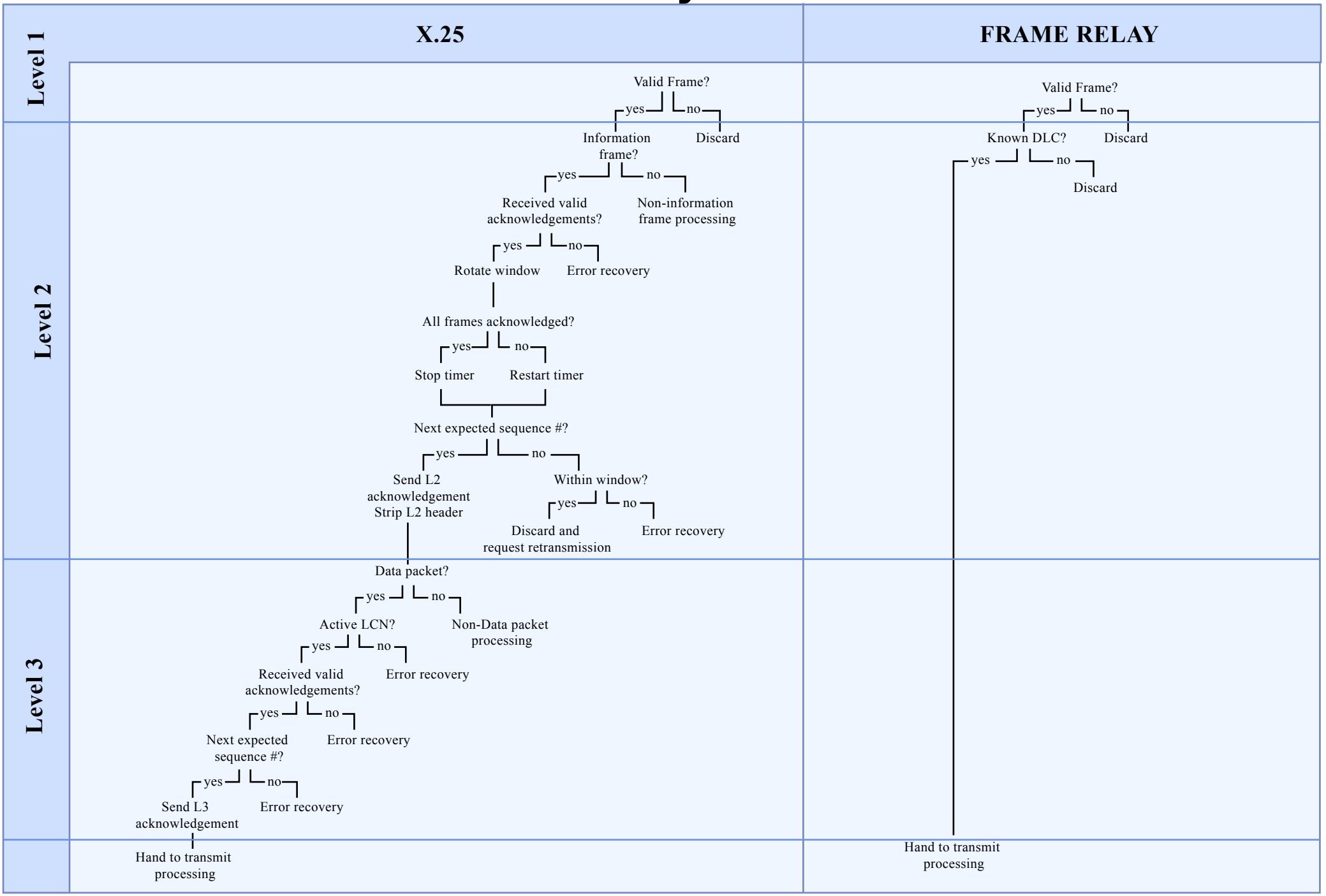


Figure by MIT OCW.

Frame relay vs. X.25

- Difference between reliable and unreliable networks
  - Fiber has error rate of 1 bit in 10^{14}; can correct end-to-end
  - Copper has error rate of 1 bit in 10^{6}; must correct link-by-link
- Difference between smart and dumb terminals
  - Formerly, terminals had no CPU and just displayed what the communications line sent to them
    - Could not detect or correct errors
  - PCs as terminals can correct and detect errors
- "Hollowing out of the network"
  - Network used to have all the intelligence
  - Not network is just a set of 'bit pipes'
  - Edge devices have the intelligence

Fiber data distributed interface (FDDI)

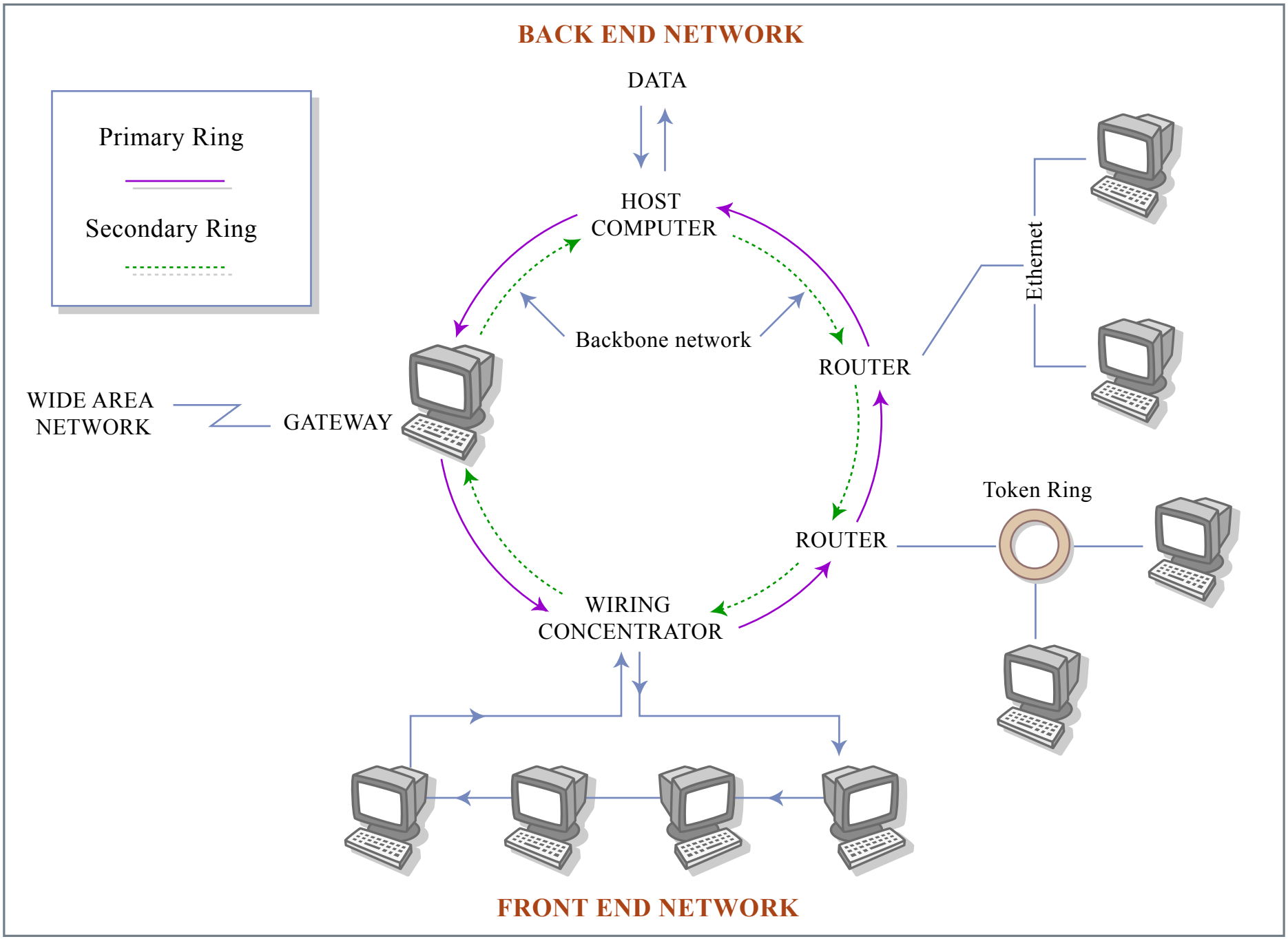


Figure by MIT OCW.

Fiber data distributed interface (FDDI)

- 2 km or less between attachments
- Total diameter less than 200 kilometers
- Two token rings
  - Servers dual attached, can survive single ring failure
- Used in campus settings and within buildings to connect servers
- Better performance than 100BaseT Ethernet
- Not offered publicly by IECs or LECs; always a private network
- IECs and LECs won't offer dark fiber to allow users to run FDDI
  - SMDS is similar architecturally, and is what LECs offer
- FDDI not likely to be major player

ATM network

- Was to be silver bullet, solving all problems
- Voice, data, video
- Need 48 byte packet to keep voice, video latency ok
- Too expensive!
- Raw IP over fiber (SONET) is being pushed as alternative
- Similar philosophy to frame relay
  - No error correction, very lightweight
  - Network really hollowed out, just a bit pipe
- AAL offers 4 classes of service (pricing is distance-insensitive except for access)
  - Constant bit rate, connection, timing: video
  - Variable bit rate, connection, timing: voice
  - Variable bit rate, connection, no timing: bursty data
  - Variable bit rate, connectionless: data broadcast

ATM architecture

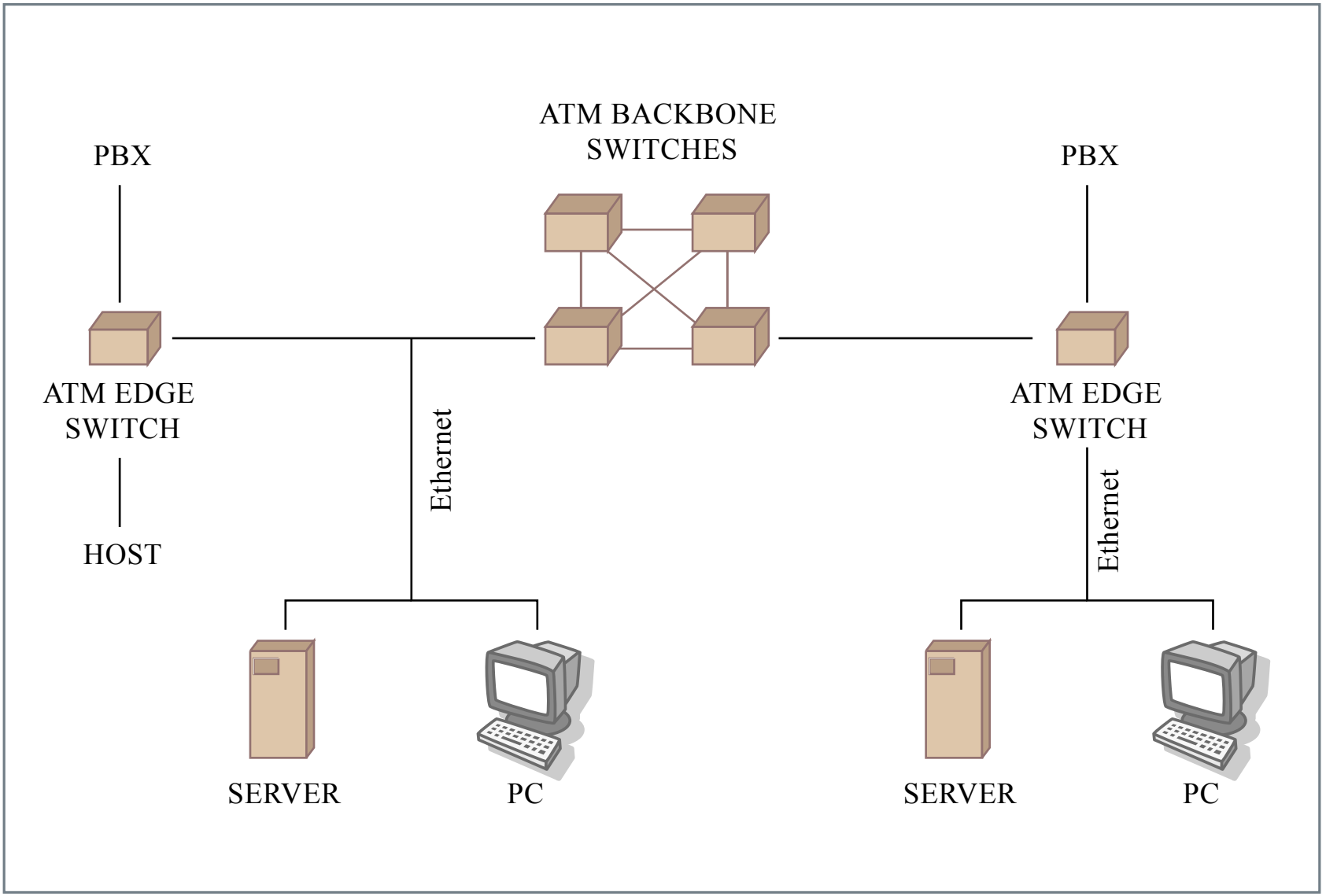


Figure by MIT OCW.

ATM Network

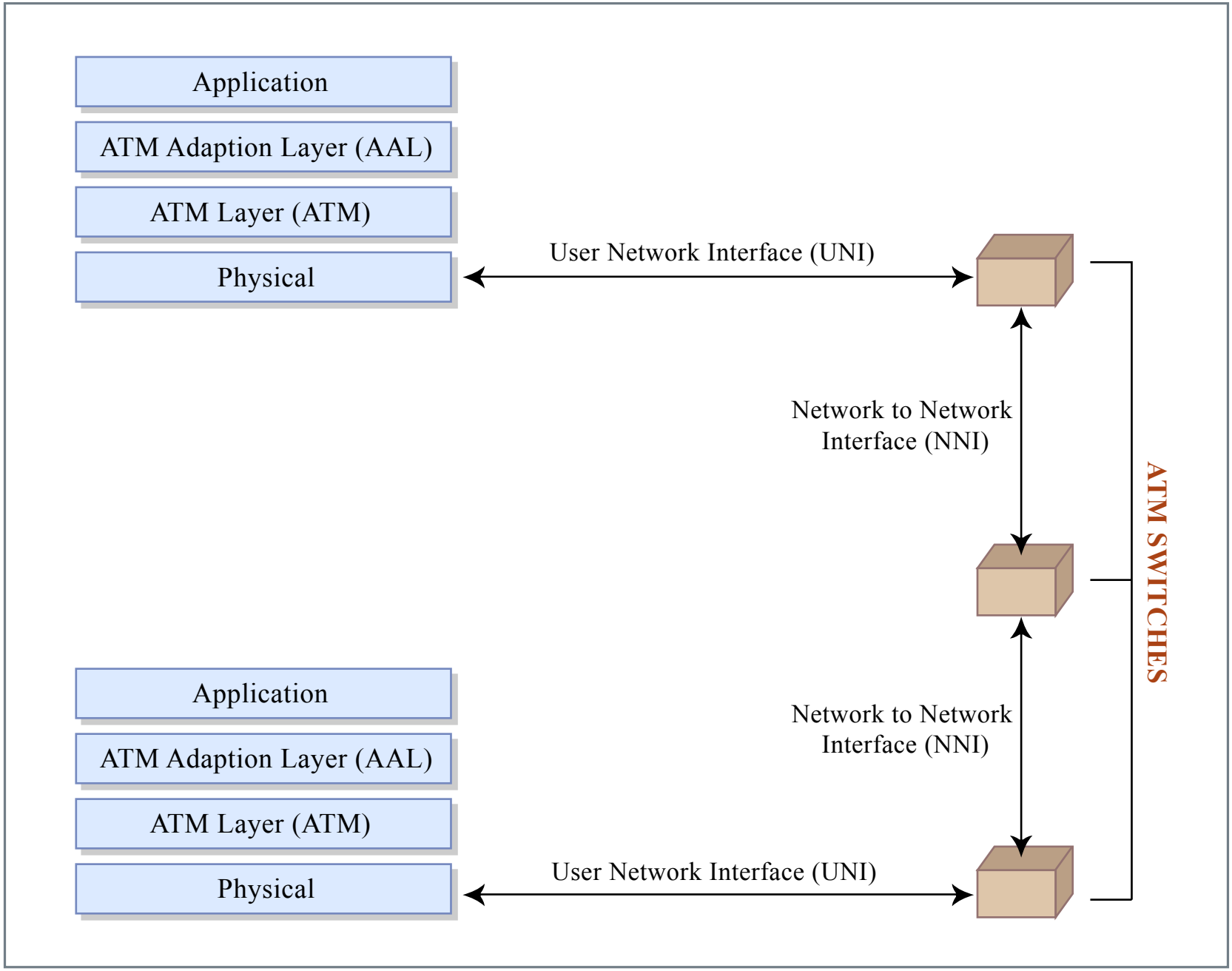


Figure by MIT OCW.

Virtual Private Network (VPN)

- Uses Internet to replace leased private circuits over T-1, frame relay, ISDN
- Used for small or branch offices, telecommuters
- Uses regular Internet service provider (ISP) but encrypts all traffic between company/organization endpoints
- VPNs require client software and reduce capacity substantially (50%?)
- VPNs don’t interoperate across vendors well
- But…standard practice, well-justified, is to replace many low-capacity leased circuits with VPN today

Supply chain and collaborative engineering issues

- Reduce error rates in paper documents
  - Error rate in paper documents is 5%
  - Key entry error rate is also about 5%
  - Cost of handling error condition is 5-10 times as much as handling correct information
  - Average cost of handling a paper order is $50-70
- Use data that is too expensive to collect manually
  - Vendor management of retail inventory
  - Tailored shipments, products based on actual demand
  - Advance notice for warehouse, store space planning
  - Reduce cycle time by shorter information transmission delays
  - Process financial transactions efficiently
- Standard processes based on XML emerging

Retail information flows

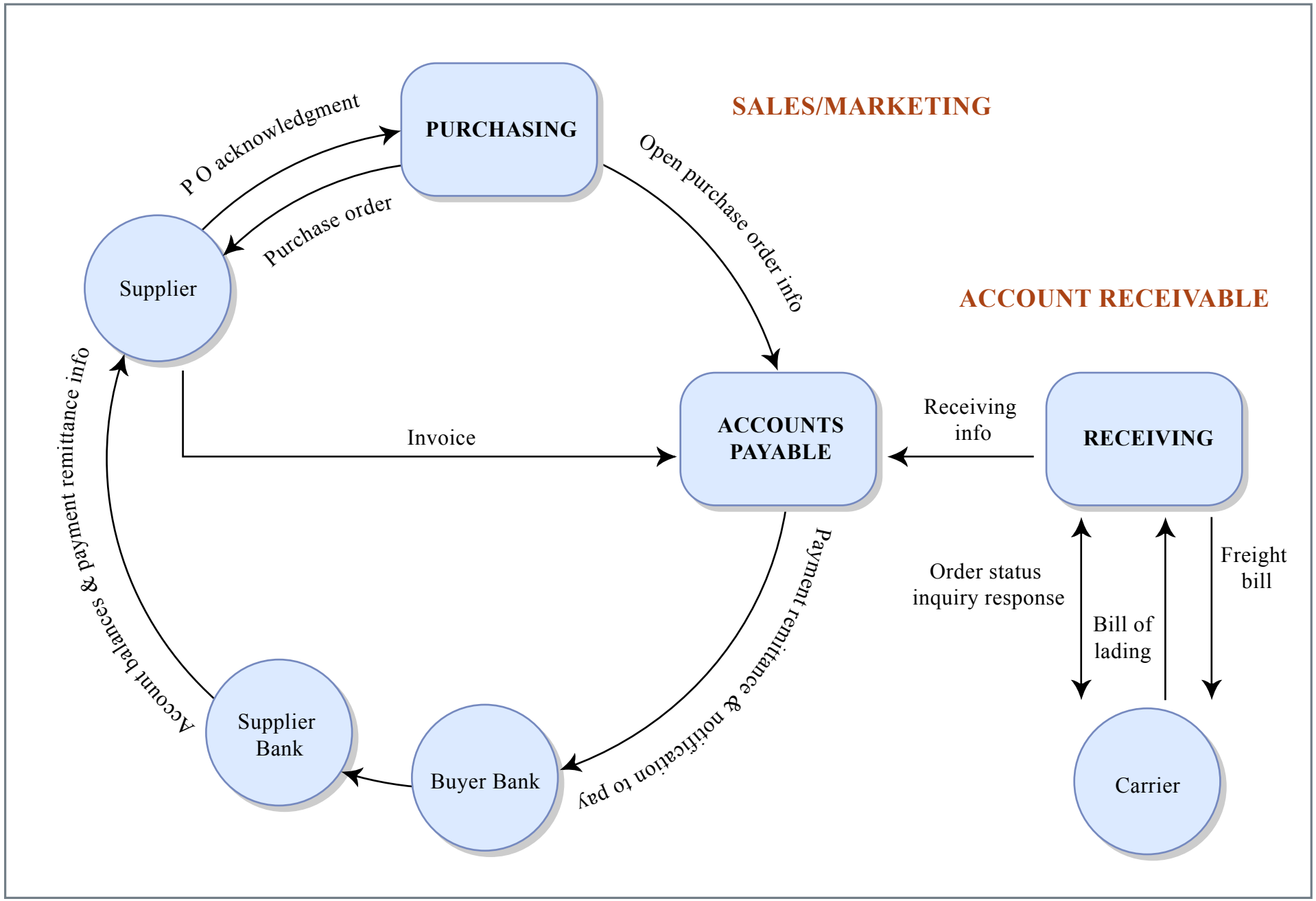


Figure by MIT OCW.

Distributor information flow

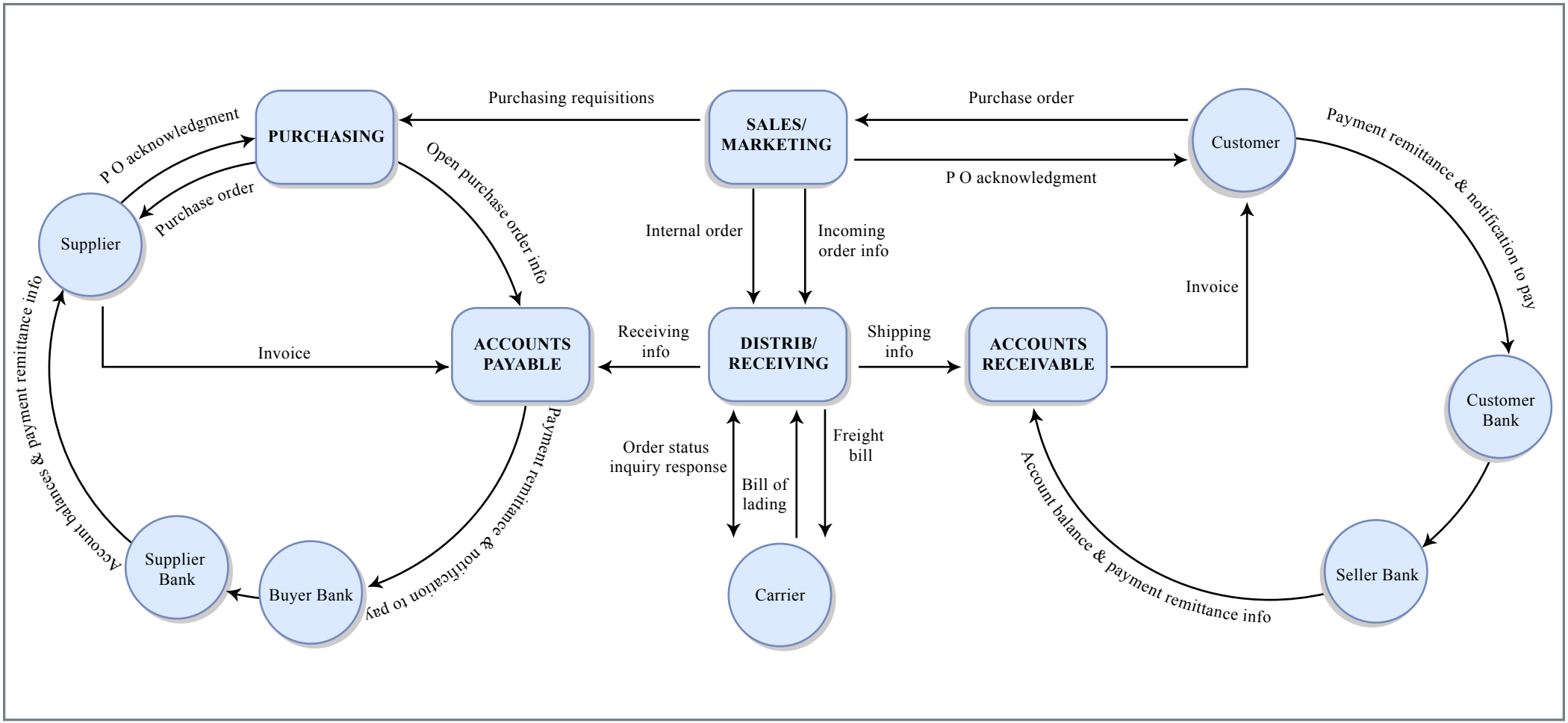


Figure by MIT OCW.

Financial information flow

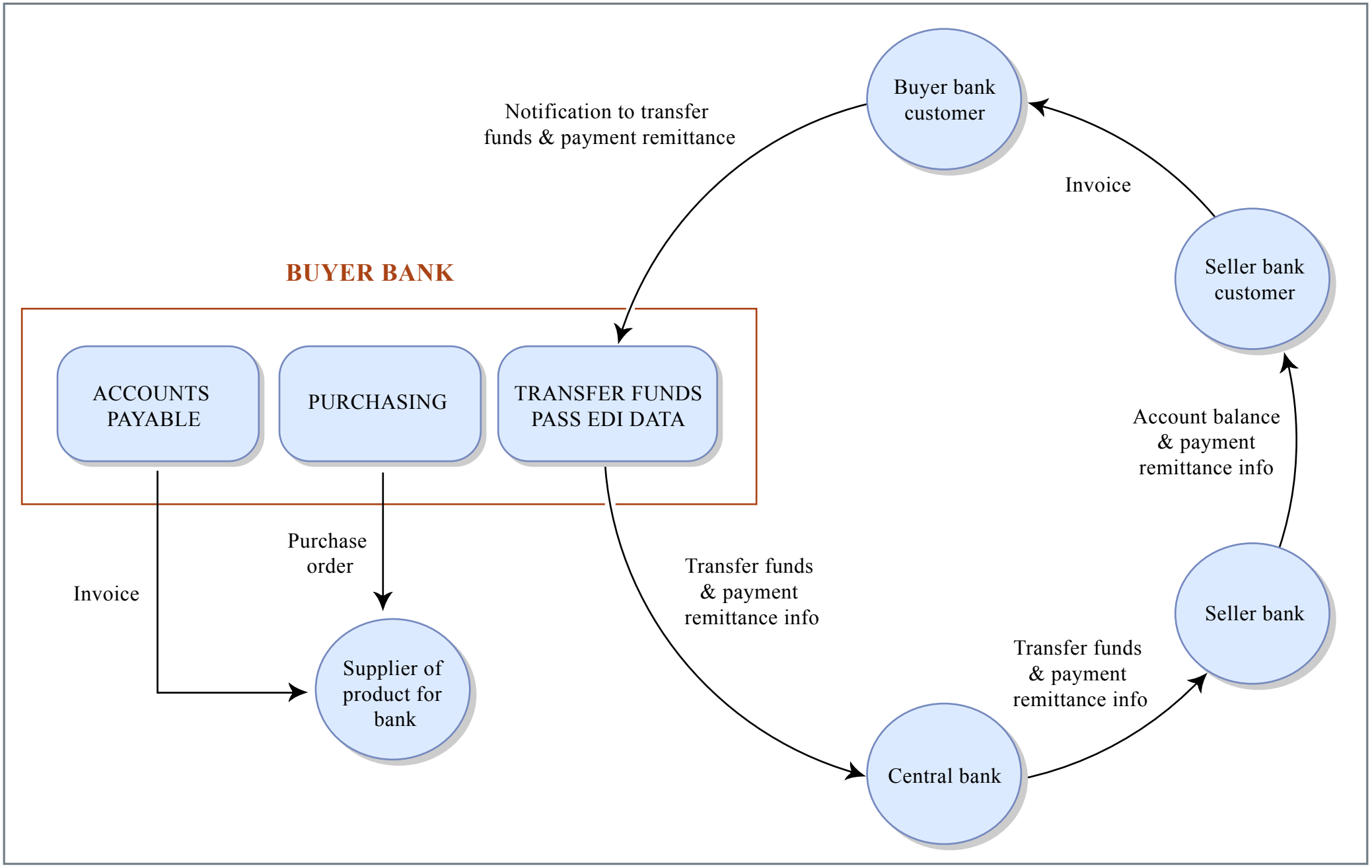


Figure by MIT OCW.

Manufacturing/engineering information flow

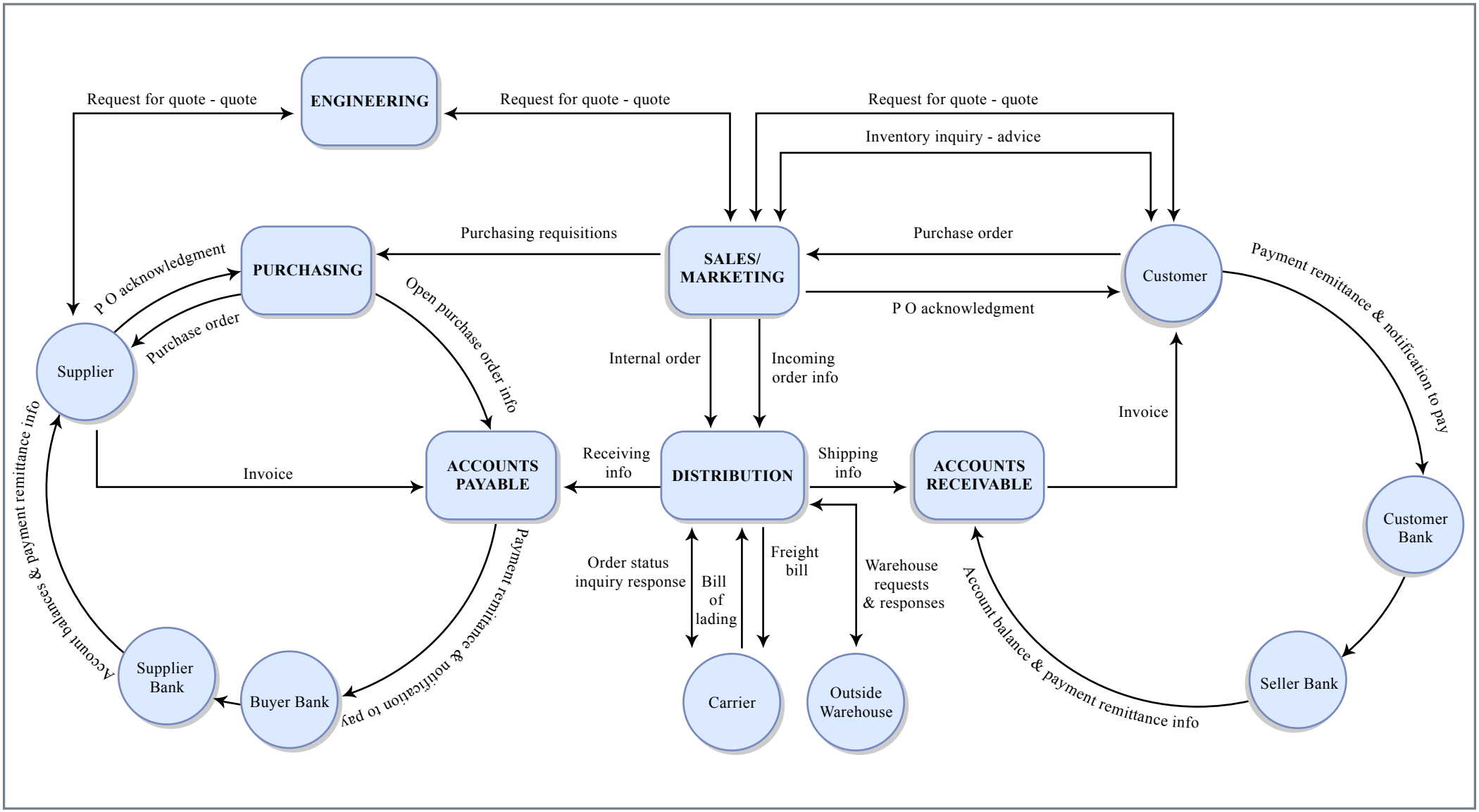


Figure by MIT OCW.

Manufacturer information flow: detail

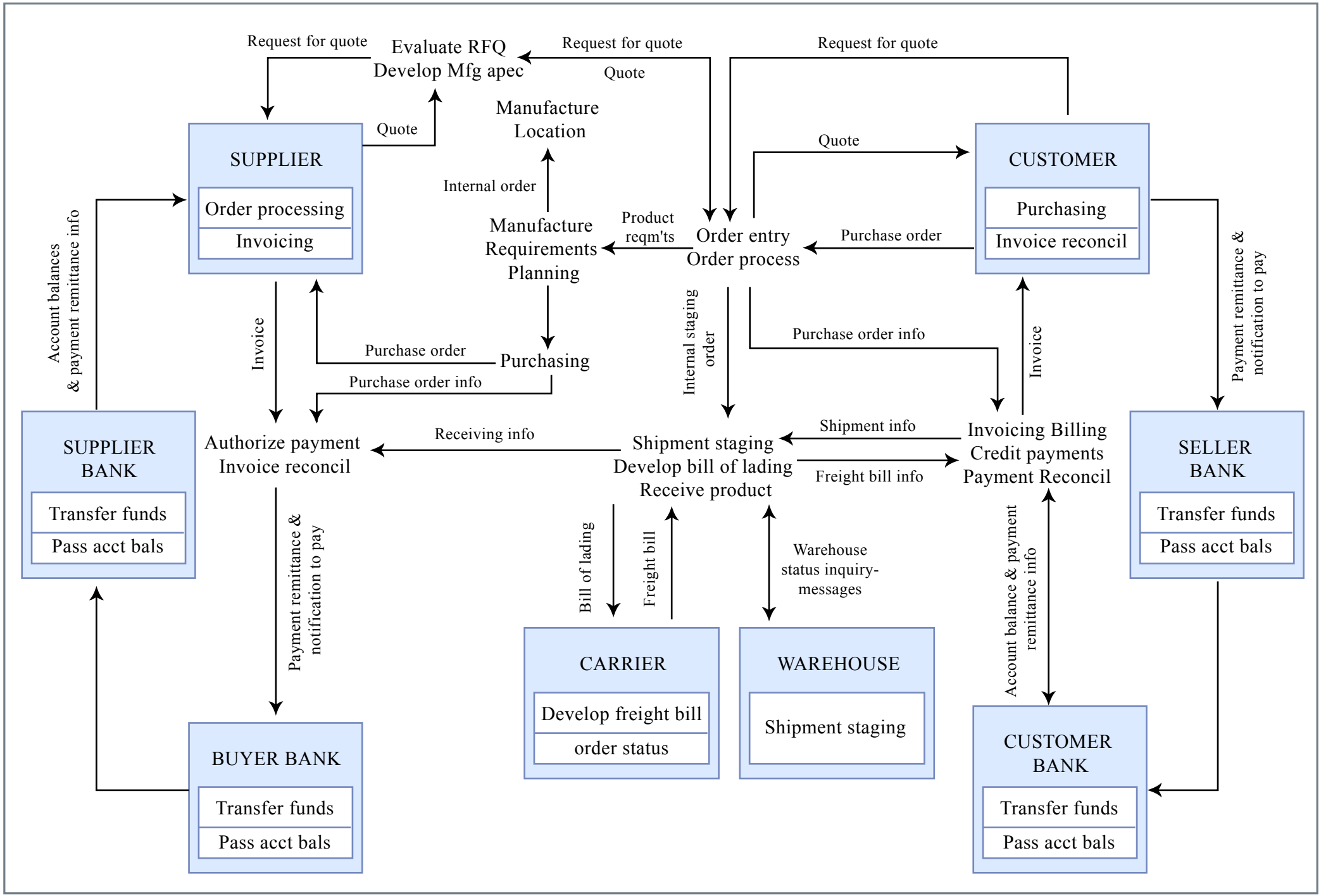


Figure by MIT OCW.

Steps and skills for building these systems are same as we've covered in class this semester

- Software engineering
  - Select development method (often spiral model)
  - Requirements, design, resource estimation, development, QA
- Data modeling
  - Data is persistent: model, normalize, referential integrity
  - Model business rules, verify with users (engineers, customers, …)
- Database
  - Relational databases, SQL at core of applications, Web
- World Wide Web:
  - Connect clients and servers: SOAP/HTTP, XML, UDDI, WSDL
  - Use HTTP, XML as 'data dial tone': universal data access
  - XML to allow human, machine and document interpretation
  - XML documents include business rules, database schema

Steps, continued

- Security
  - Network uses SSL, encryption, certificates, digital signatures
  - Nodes (client, server) are people and process issues
    - Patches, passwords, audits/monitoring, culture, …
- System architecture
  - Multi tier architecture: Web server, application server, database
  - Many small boxes, leading to grid computing
  - Virtual storage hierarchy, configuration
  - Disk configuration: RAID, database
- Networks
  - 7 layer model, with TCP/IP at layers 3 and 4
  - Many layer 1, 2 technologies carry TCP/IP, fiber dominant
  - Hollowed out network, intelligence at edge devices
  - Machine-machine traffic to be dominant, distributed

Course summary: process

- If you spent 12 hours per week for 14 weeks, that's 168 hours, or 4 40 hour weeks
- Ready for second spiral in software model after 12 person weeks of work (4 person weeks times 3 people)
  - This can be done in the wasted “up-front” time to prepare for an anticipated project
  - It will always take this long because you'll always be learning new technology
- You’ll never know all of information technology, because there's too much, but you need to know enough to understand it
  - To work with software staff collaboratively in configuration, development or implementation projects
  - To manage development, if you have an engineering or logistics project
  - To be a developer

Future steps

- There are full courses in every one of the topics we covered in class
  - Software process: 16.355
  - Data models, database:
    - Harvard courses; MIT doesn't have one now
    - Or take a SQL course after MIT
  - Web as channel between databases:
    - Few courses available; industry short courses on XML, SOAP, WSDL, EJBs, .NET, etc.
  - Hardware classes: 6.xxx: theoretical, hard, good
  - Network classes: 6.xxx: theoretical, hard, good
  - Security classes: 6.xxx: theoretical, hard, good
  - Software development: 1.001

What you know

- You have all have built the most important components beyond straight programming:
  - A data model and database,
  - A dynamic, database-enabled Web site with server technology (ASP)
- You have 4 books that introduce you to deeper knowledge of key areas. Reread them in the future, use them as references
  - Rapid Application Development
  - SQL: Practical Handbook
  - UML Distilled
  - Telecommunications Handbook
- Other books:
  - Practical Cryptography
  - Murach SQL Server
- Read the online literature: Subscribe to daily email summaries:
  - Internet Week, Information Week, Network Computing, …
  - Other sites listed in lecture notes this term (www.w3c.org, www.tpc.org, www.sei.org, …)

Future trends

- You have references, pointers, introduction to the key areas of IT for future follow-up. It will all change:
  - Object database capabilities
  - SOAP, UDDI, XML, machine-machine communication
  - Internet and Web evolution: reliability, bandwidth, video, …
  - Ecommerce: electronic bonding, replacement of paper/fax/phone
  - Security (IPsec, broad encryption)
  - Architecture (hardware evolution, IP devices)
  - Networks (convergence, ATM, wireless)