Basic Concepts of Computer Networks and Services

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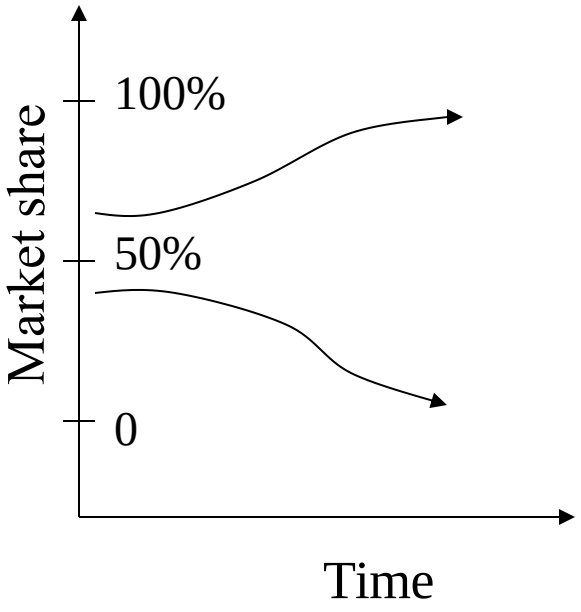
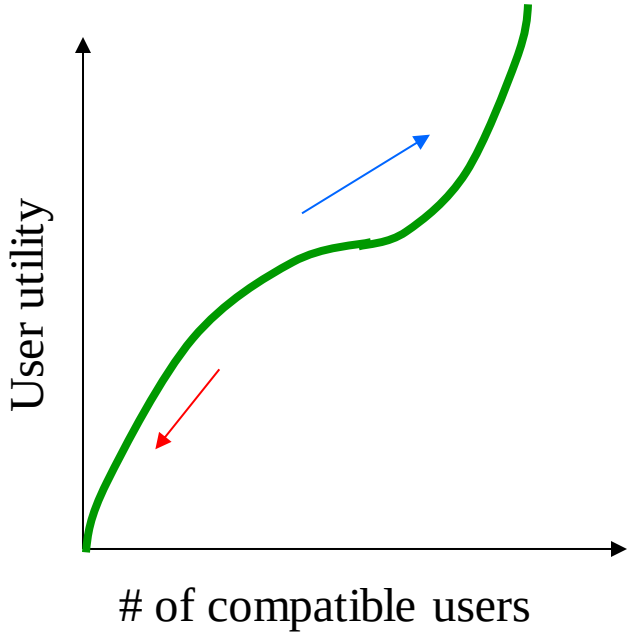
What are Computer Networks?

- Consist of software and hardware
- Allow exchange of information and access to services and applications
- Factors that contribute to the broad adoption of computer networks
  - Economies of scale in production
  - Economies of scale in demand (network externalities)

Network Economies



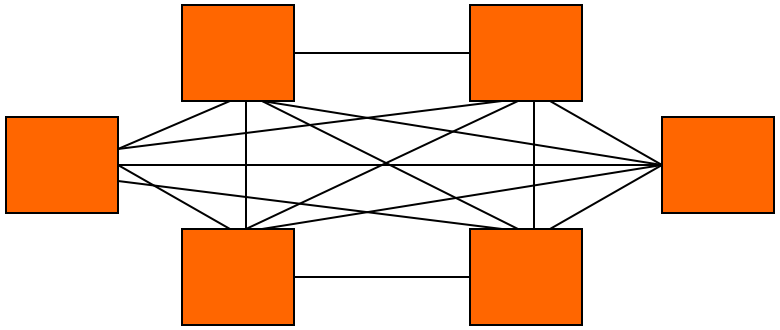


Economies of scale in production and demand :
positive externalities and feedback

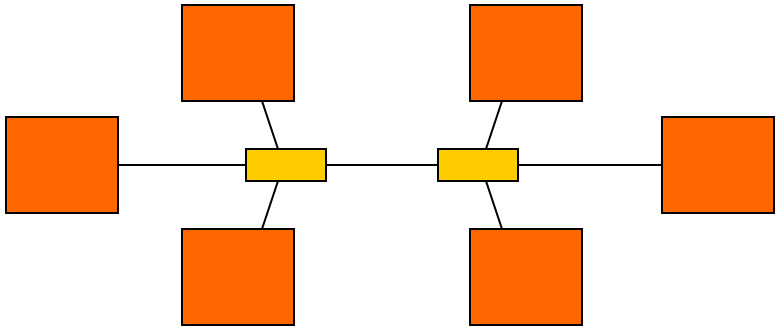
Computer Networks → Variety in

- Information encoding: digital or analog
- Physical medium: copper, optical fiber, air, cable
- Geographic distribution:
  - Wide Area Networks: Internet core, X.25, ...
  - Metropolitan Area Networks: Optical Rings, WiMax, FDDI
  - Local Area Networks: WLANs, Ethernet, Token Ring, ...
- Services and applications:
  - voice, data, video, multimedia, online social networks
  - all application are served by the same network

Basic Idea



Point to point links
→ non-viable approach



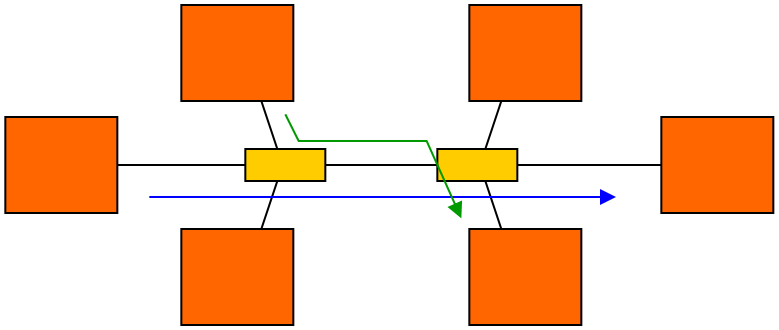
Shared links

Required:

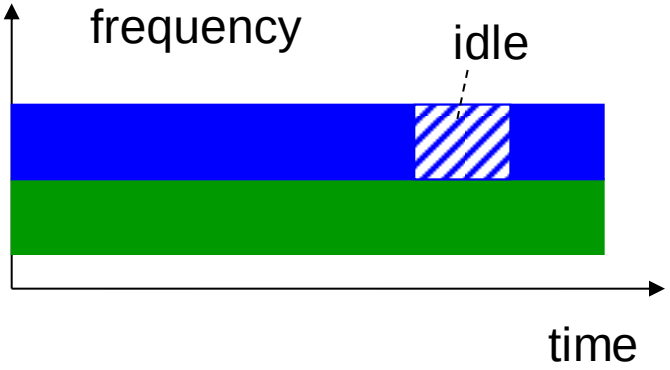
- Switching, and
- Multiplexing: FDM, TDM, Statistical

➔ Economies of scale

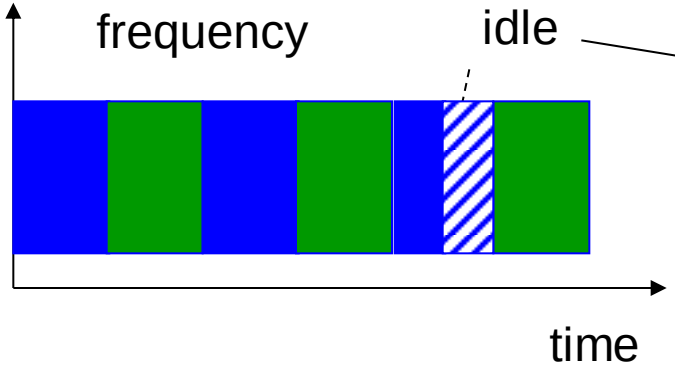
Types of Multiplexing



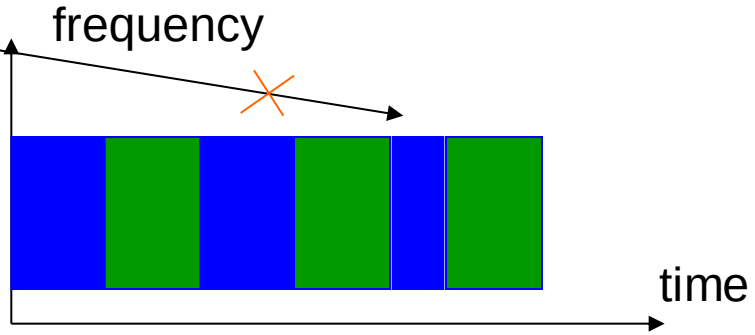
Frequency Division Multiplexing (FDM)



Time Division Multiplexing (TDM)

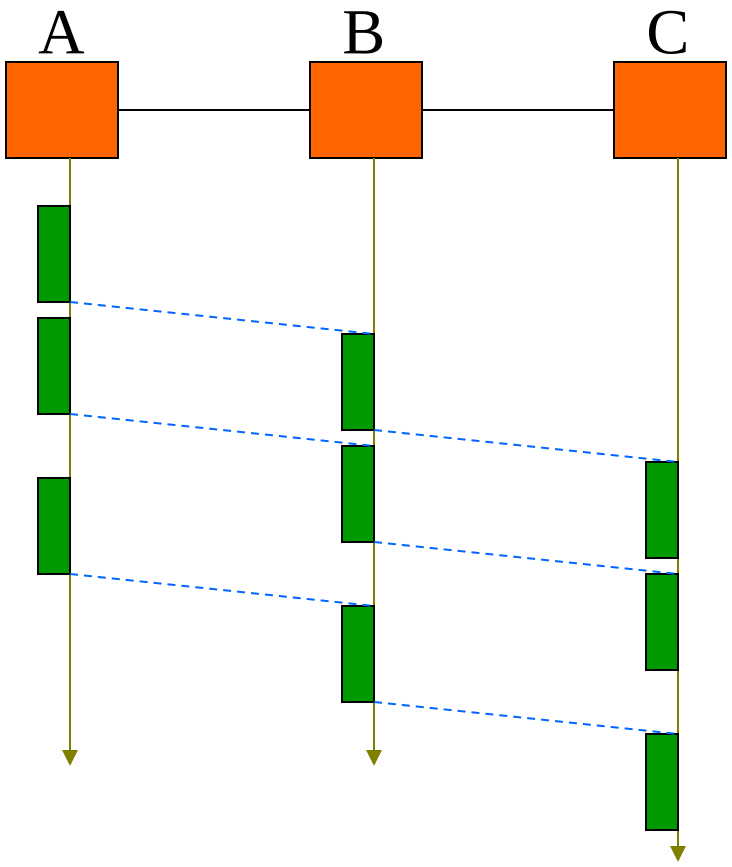


Statistical Multiplexing



Statistical Multiplexing

- Packet switching and transmission "Store-and-forward"



History of Networks (I)

- 1830: Telegraph (digital!!)
- 1876: Telephony (analog ??)
  - 1887: 150000 tel. USA, 26000 UK, 9000 Fr, 7000 Rus.
  - 1903s: non-Bell = 50-60%, long-distance call= 3%
    - Need for interconnection
  - 1934: Regulatory issues, creation of FCC
  - …
- 1960+: RS-232-C for asynchronous transmission of symbols at 38.4 kbps
  - Modems
  - Data link layer protocols
- 1960+: First ideas for the Internet by Baran, J.C.R. Liklider, Bob Taylor and Larry Roberts

History of Networks (II)

- 1967-69: Design and Implementation of Arpanet, mainly in UCLA and BBN
  - 2 Sept. 1969: Transmission of first bits within UCLA network
- 1970+: Rapid evolution of Arpanet, X.25, LANs, CATV
  - 1970: Protocol and network ALOHA in Hawaii
  - 1976: Ethernet (Xerox PARC), proprietary networks - SNA etc.
  - 1972: 15 nodes in ARPANET → 200 nodes in 1979
  - 1974: Introduction of TCP/IP (V.Cerf, R.Kahn)

History of Networks(III)

- 1980+: Spread of TCP/IP, protocols on the Internet: ftp, smtp. - FAX, ISDN, Mobile Communications, competition in telephony.
- 1990+: Multimedia, Wide spread and evolution of mobile communications, Broadband ISDN and:
  - User-friendly applications → Commercial applications
  - WWW by Tim Burnes Lee → brings together all human knowledge transparently with respect to position
  - Led to the wide-spreading and the final(??) prevalence of the Internet over other networking technologies
  - Netscape, Search Engines (Yahoo! , altavista etc.) – Commercial ISPs

History of Networks (IV)

- 2000-10: Wide-spreading of broadband, in wired and wireless networks, in both core and access networks - dramatic increase of applications and content, in both volume and diversity
  - Peer-to-peer provisioning of information and services
  - Google, Skype, You-tube, Facebook, Web2.0.
  - Security and privacy are very important issues
  - Analysis of networks in light of the stakeholders' incentives → tussles

Networks History (IV)

- 2010+:
  - Virtualization, SDN (Software Defined Networks), emphasis on network control plane
  - Need for energy saving
  - Interaction with the cloud – cross-layer management
  - Fundamental business issues: who benefits economically from the wide-spreading of Internet?
    network neutrality, and how this is affected by technologies, software architectures etc.
  - Big Data and their exploitation – new privacy issues

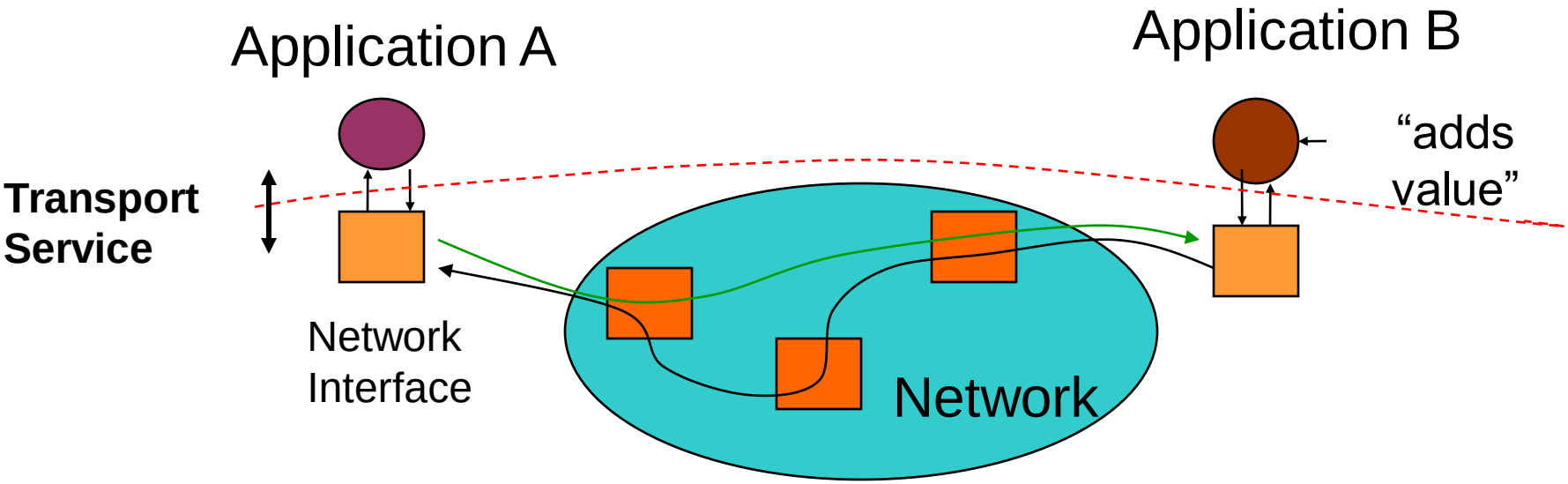
Network Architectures

- Physically: consists of
  - computers, links, routers, switches, ...
  - Basic requirement: interoperability
- Logically: consists of services
  - simple services → complex services
  - layered architecture
  - transport service: best-effort or with assured quality
- end-to-end services
  - End-user is interested in those services
  - The quality delivered is determined by Service Level Agreements (SLAs)

Assured-quality and Elastic Services

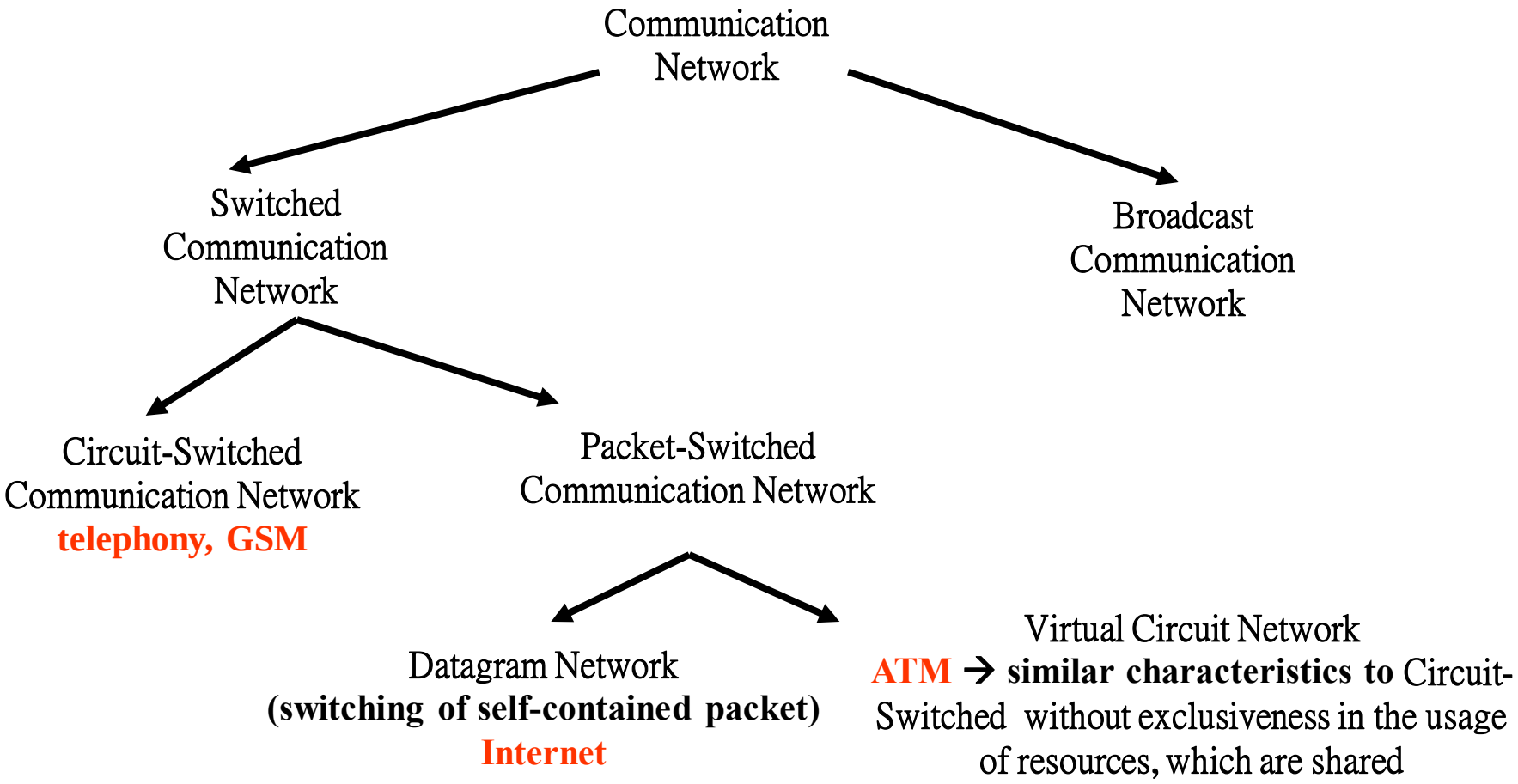
- **Assured-quality Services (based on SLAs):**
  - the network provides performance guarantees , with respect to packet loss rate, average delay and variability of delay (jitter)
  - users apply for resources in order to be served.
  - need for admission control
- **Elastic Services:**
  - the network does not provide performance guarantees (best effort), the performance is degraded in case of congestion
  - users do not apply for reserving bandwidth, the use of which may be unlimited
  - they better serve applications with adaptive rate

Transport and Value-added Services

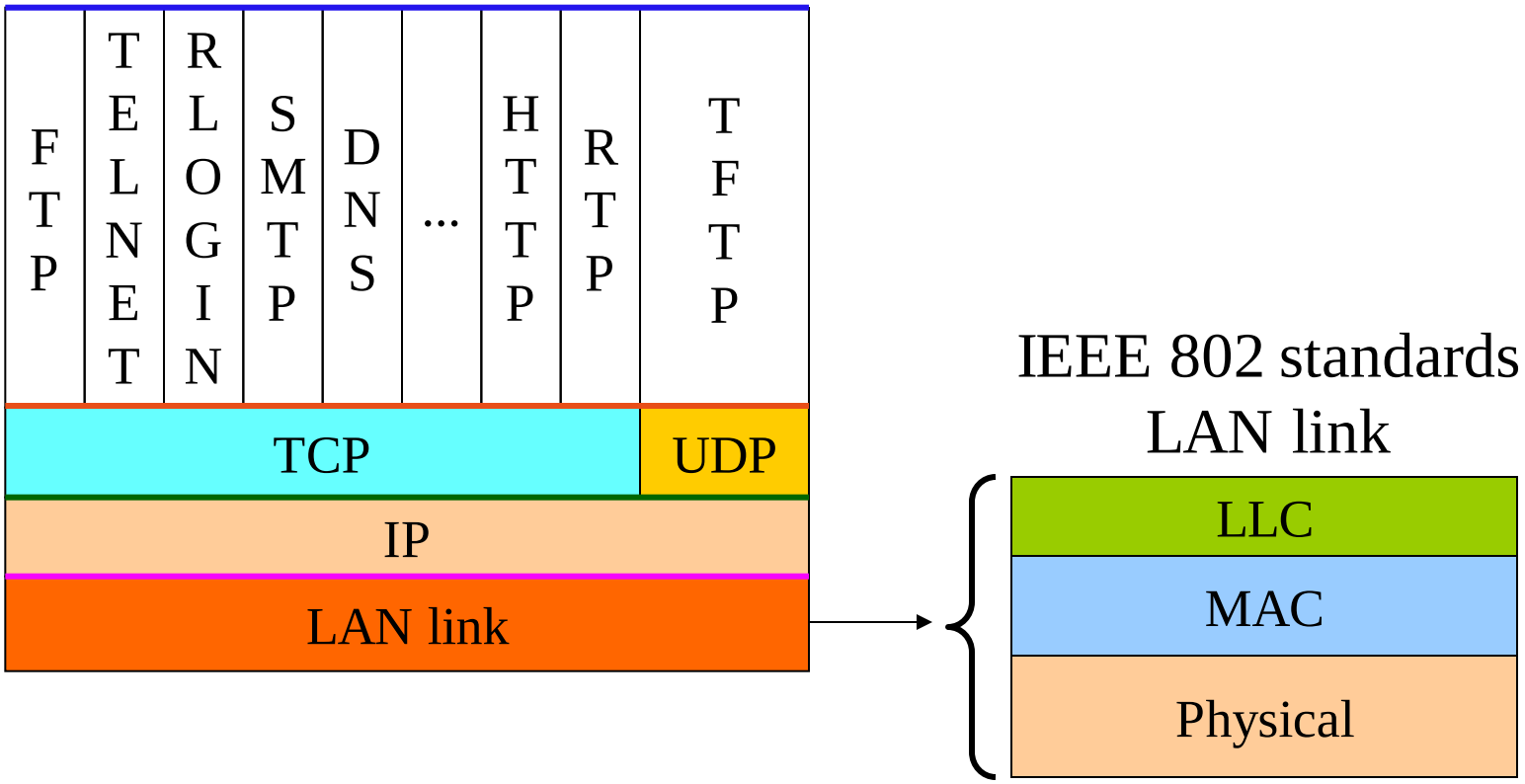


Service = Transport + Added value

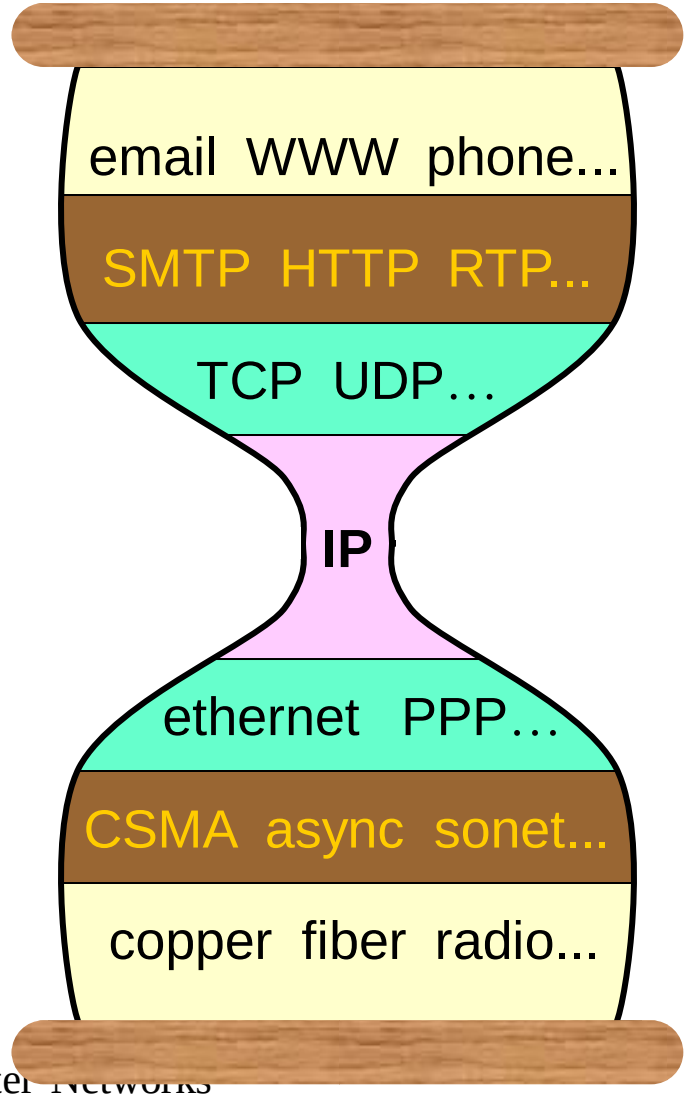
Networks Classification



Internet


FTP
TELNET
RLOGIN
SMTP
DNS
...
HTTP
RTP
TFTP
TCP
UDP
IP
LAN link
IEEE 802 standards
LAN link
LLC
MAC
Physical

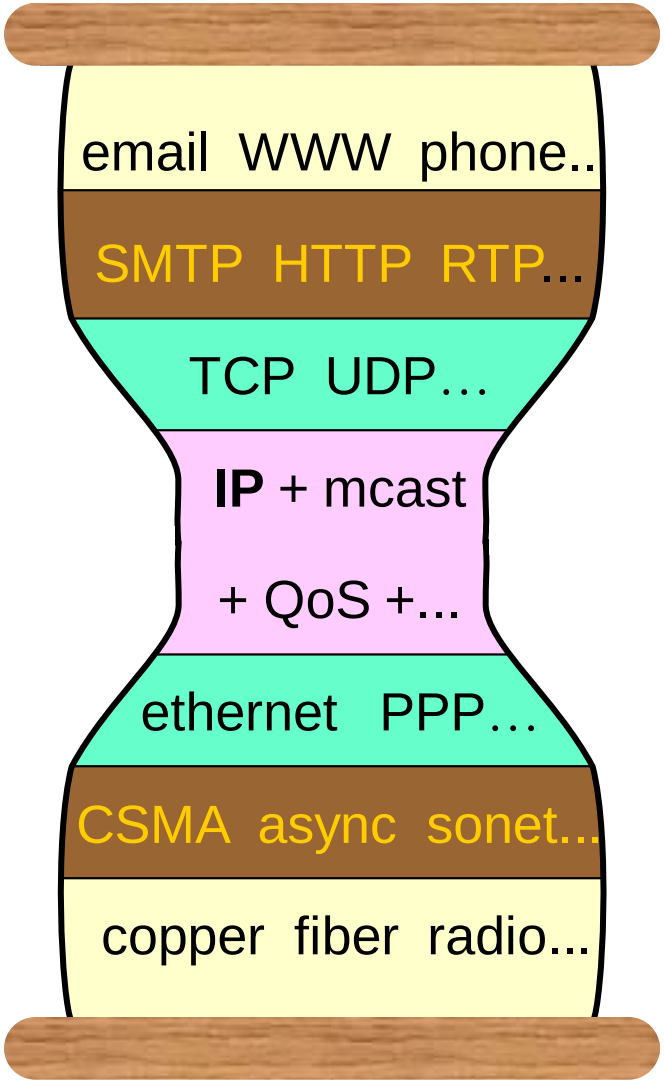
Internet: hourglass model (Deering, 1998)



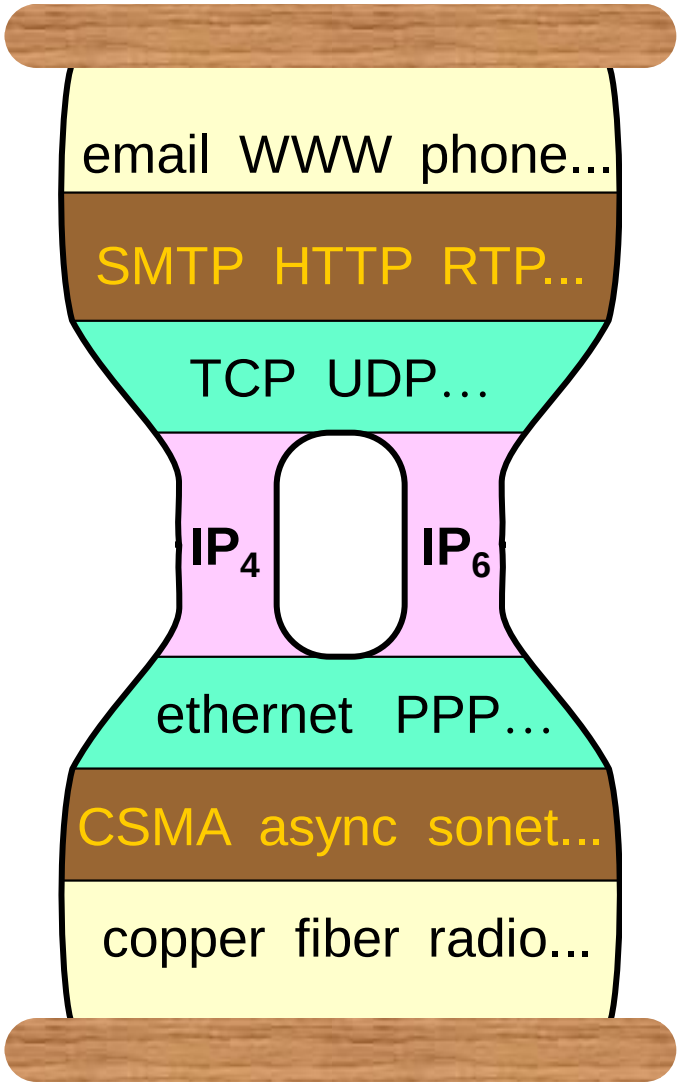
- Network layer protocol:
  - one and only
  - simple

➔ Leads to:
  - Easy network expansion
  - interconnectivity

Internet: “heavier” version (Schultzrinne)

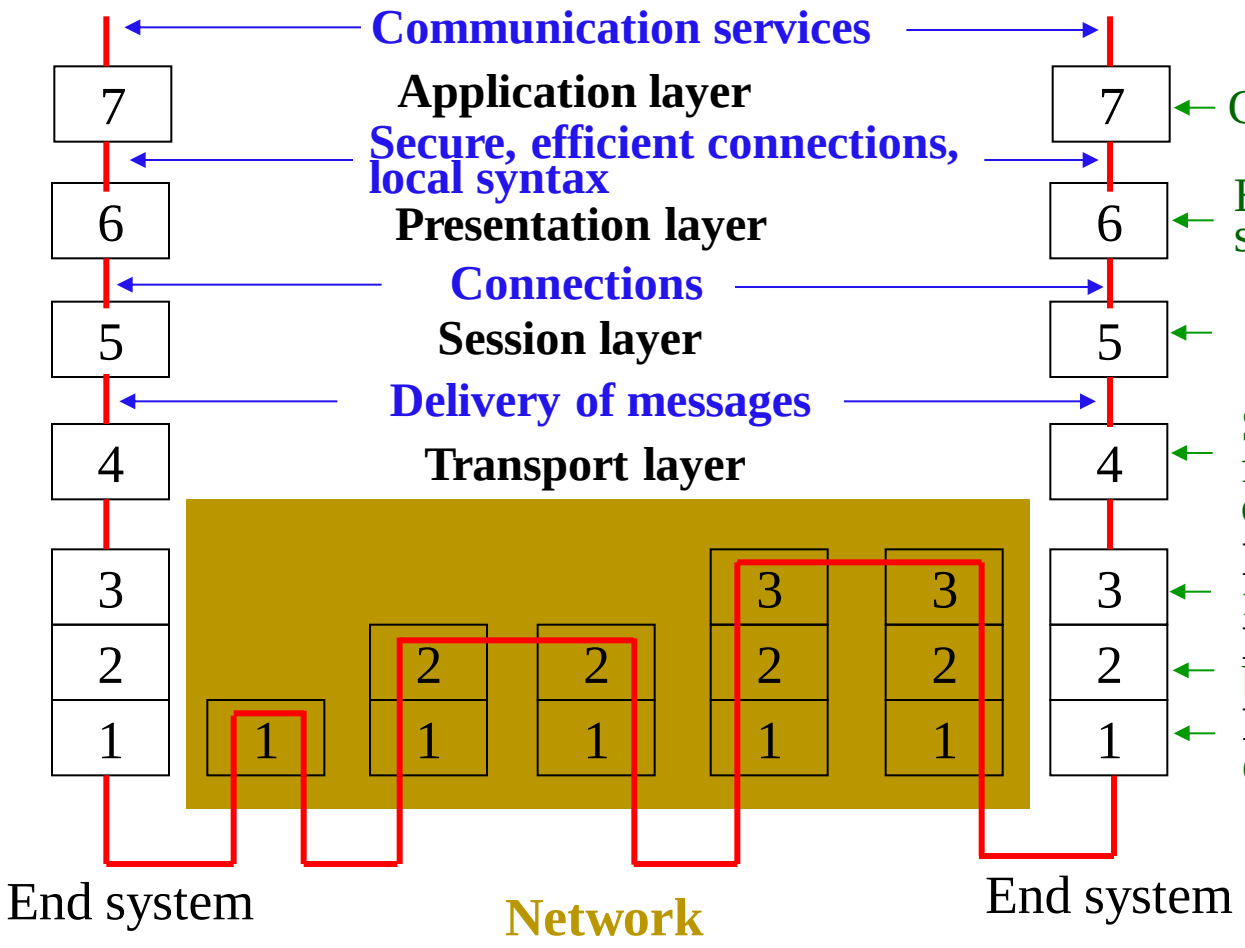


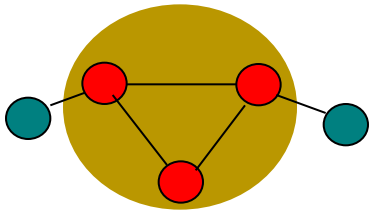
Internet: “double” version (Schultzrinne)



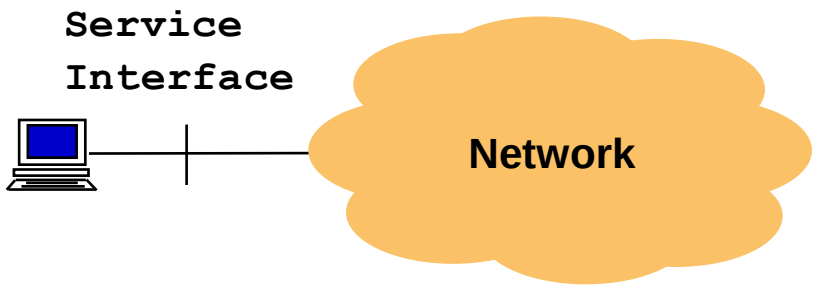
- Double interfaces
- Basic interoperability issues

OSI Model


Communication services
7
Application layer
Secure, efficient connections, local syntax
6
Presentation layer
Connections
5
Session layer
Delivery of messages
4
Transport layer
3
2
1
End system
Network
End system
7
6
5
4
3
2
1
Commonly used applications
Encryption, compression, syntax conversion
Supervision of connections
Segmentation/reassembly, flow control, end-to-end error control
Network layer: guides packet from source to destination
Data link layer: packet delivery between two adjacent nodes
Physical layer: digital comm., delivers bits



Networks Control



- A set of internal mechanisms that are used by the network in order to comply with its obligations towards customers' SLAs
- Typically involve other protocols from those used for information transfer
- More control options → wider set of services
- Levels of control
  - policing and shaping
  - switching and scheduling
  - routing
  - admission control
  - multicasting
  - flow and congestion control
  - resource management
  - pricing policy
- The services' architecture includes the control software units for the service provisioning.

Time Scales for Network Control