Lecture 2
Protocol Stacks

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Today's Lecture

- **Some history.**
- **What is a protocol.**
- **Protocol stacks.**
- **Standards organizations.**
- **Application layer.**

Some History: The Early Days

- Early packet switching networks (61-72).
  - » Definition of packet switching
  - » Early DARPA net: up to tens of nodes
    - – single network
    - – discovery of “interesting” applications
  - » Less than 100 years after telephone (Alexander Bell, 1876)
- Internetworking (72-80).
  - » Multiple networks with inter-networking: networks are independent, but need some rules for interoperability
  - » Key concepts: best effort service, “stateless” routers, decentralized control (very different from telephones!)
  - » Basis for Internet: TCP, IP, congestion control, DNS, …
  - » Rapid growth: 10 to 100000 hosts in 10 years
    - – Driven by NSF net, research community

Next Step: Commercialization

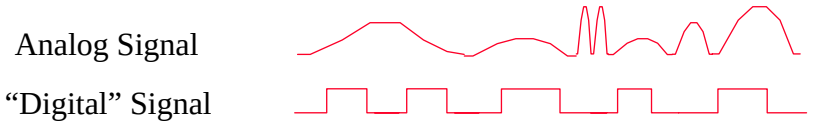
- Industry interest in networking encourages first commercial network deployment.
  - » In part also encouraged by NSFNET policies
- Introduction of the Web makes networks more accessible.
  - » Killer application
  - » Good user interface that is accessible to anybody
  - » Network access on every desktop and in every home
- Today: e-commerce.
  - » Integral part of the economy
  - » Part of every day life: entertainment, news, ..

Current Trends

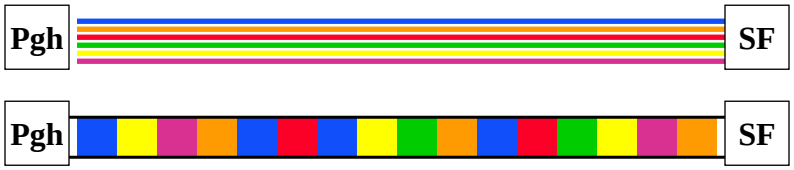
- **Access for mobile users:**
  - » **802.11 is becoming ubiquitous**
  - » **PDA/cellphone access**
- **Networked sensors:**
  - » **Have always existed in "embedded" networks, e.g. X10**
  - » **Integration into broader network infrastructure next**
- **What else?**

Alexander Bell versus the Internet

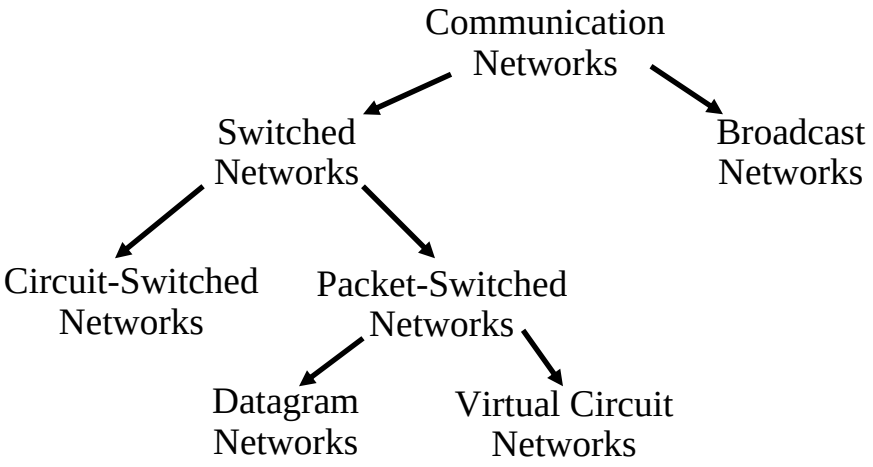
- **Analog voice versus digital information.**



- **Permanent circuit versus packet switched.**



Taxonomy of Communication Networks

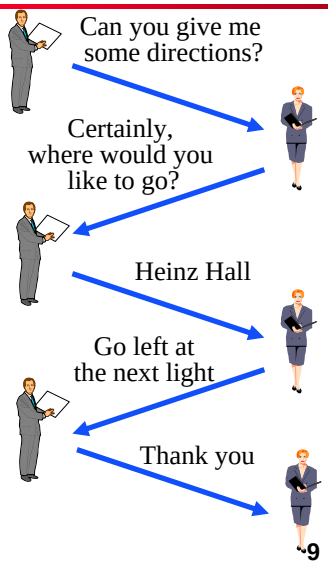


Different Network Views

- **A network is a shared infrastructure that supports communication for many users.**
  - » **Sharing view: how do users share the network?**
- **Many network technologies exist.**
  - » **Technology view: how do the technologies coexist?**
- **Networks are owned and managed by multiple organizations.**
  - » **Management view: how does global communication take place?**
- **Networks cover different geographic areas.**
  - » **Geographic view: network diameter?**
- **Networks run many protocols that are responsible for different functions.**
  - » **Protocol view: how are the many protocols coordinated?**

Protocols

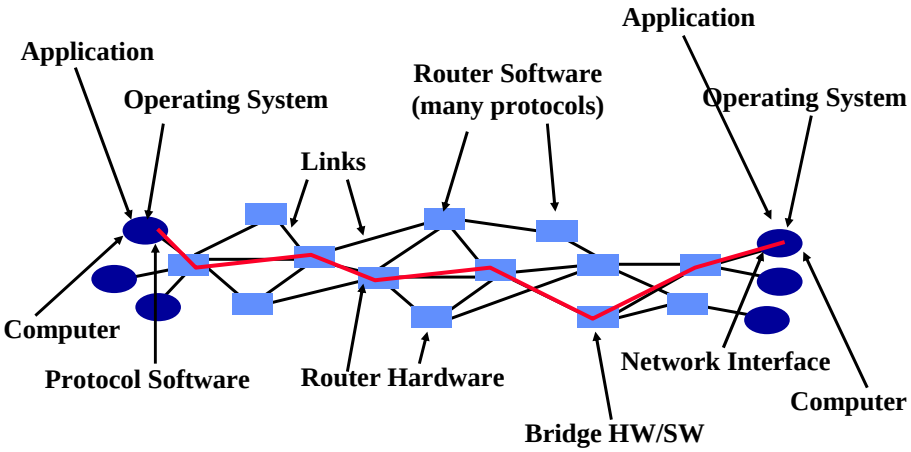
- An agreement between parties on who communication should take place.
- Protocols may have to define many aspects of the communication.
  - » Data encoding, language, error recovery, termination conditions, ..
- Network protocols can exist between computer programs or hardware components.



More on Protocols

- Protocols are the key to interoperability.
  - » The hardware/software of communicating parties are often not built by the same vendor
    - – Sun workstation with PC, 3COM with Cisco bridge, ..
  - » Yet they can communicate because they use the same protocol
- Protocols exist at many levels.
  - » Application level protocols, e.g. access to mail, distribution of bboards, web access, ..
  - » Protocols at the hardware level allow two boxes to communicate over a link, e.g. the Ethernet protocol
  - » Intermediate protocols can “add value” to a lower-level protocol, e.g. provide a reliable communication service over an unreliable link

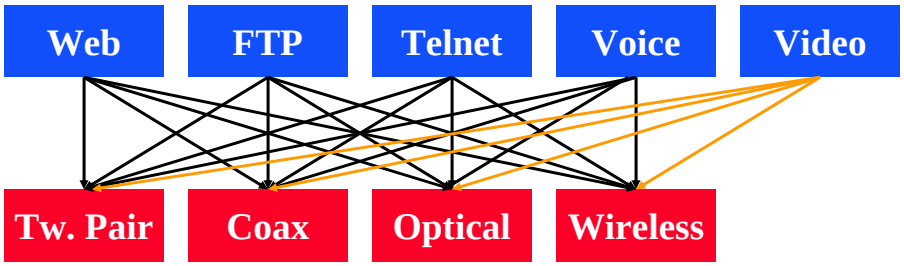
Too Many Network Components



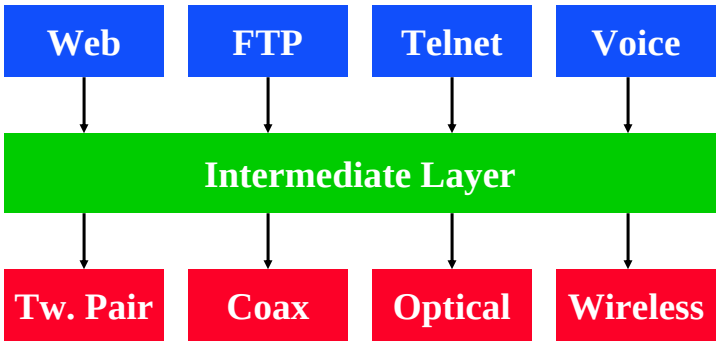
What is a Communication Network

- Electrons and photons as communication medium.
- Links: fiber, copper, wireless, ..
- Switches: electronic, optical, crossbar, Banyan, ..
- Protocols: Ethernet, X.25, SONET, Framerelay, IP, TCP, HTTP, …
- Functionality: routing, error control, flow control, congestion control, QoS, security, ..
- Applications: FTP, web, games, telephone, video streaming, ..

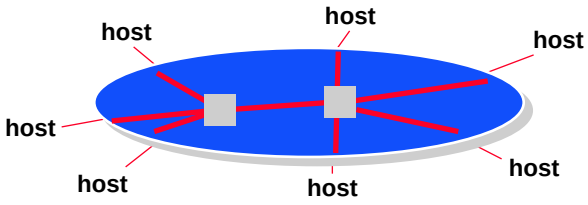
How to Organize the Network?



Try Again: How to Organize the Network?

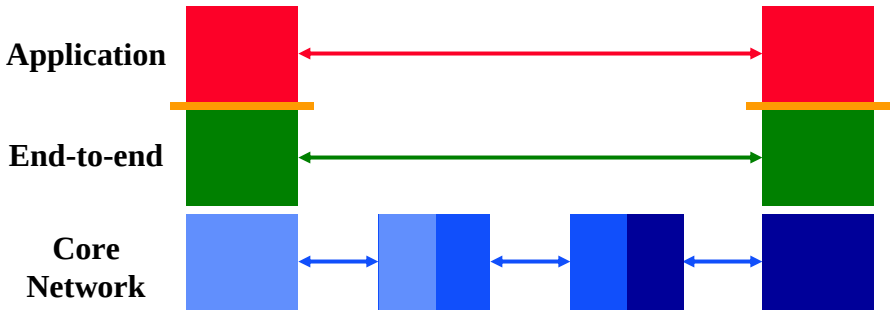


Types of Protocols



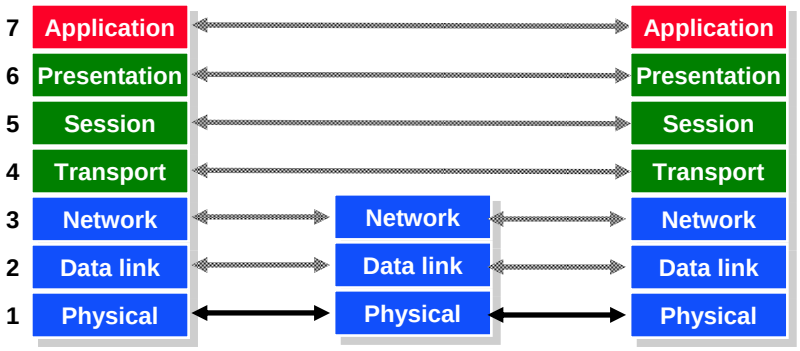
- Core network: responsible for transferring data between a sending and receiving host.
- End-to-end protocols: present a network service to applications and users.
  - » May add value to the core network protocols

Protocol and Service Levels



A Layer Network Model

The Open Systems Interconnection (OSI) Model.



OSI Motivation

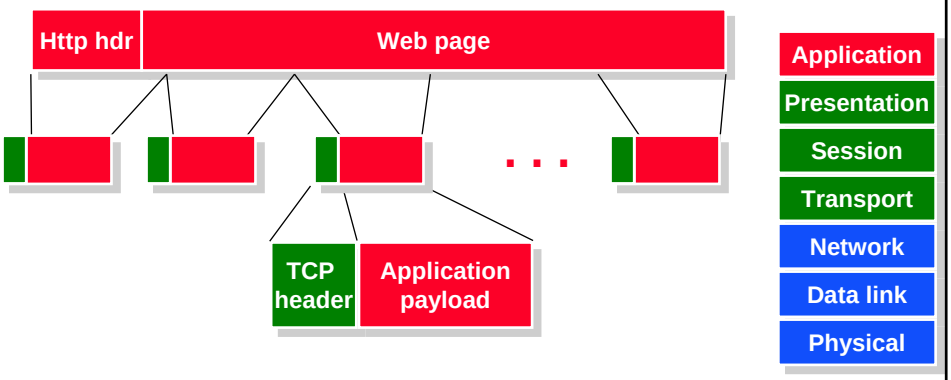
- **Standard way of breaking up a system in a set of components, but the components are organized as a set of layers.**
  - **Only horizontal and vertical communication**
  - **Components/layers can be implemented and modified in isolation**
- **Each layer offers a service to the higher layer, using the services of the lower layer.**
- **"Peer" layers on different systems communicate via a protocol.**
  - **higher level protocols (e.g. TCP/IP, Appletalk) can run on multiple lower layers**
  - **multiple higher level protocols can share a single physical network**

OSI Functions

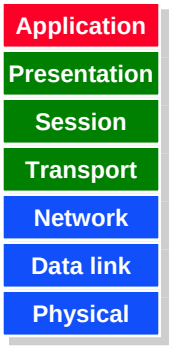
- (1) Physical: transmission of a bit stream.
- (2) Data link: flow control, framing, error detection.
- (3) Network: switching and routing.
- (4) Transport: reliable end to end delivery.
- (5) Session: managing logical connections.
- (6) Presentation: data transformations.
- (7) Application: specific uses, e.g. mail, file transfer, telnet, network management.

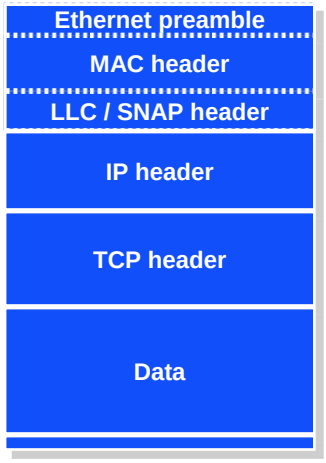
Multiplexing takes place in multiple layers

Example: Sending a Web Page



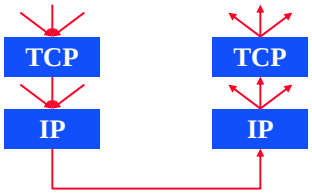
A TCP / IP / 802.3 Packet

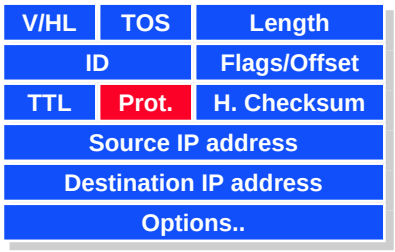




Multiplexing and Demultiplexing

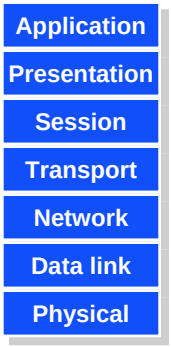
- There may be multiple implementations of each layer.
  - » How does the receiver know what version of a layer to use?
- Each header includes a demultiplexing field that is used to identify the next layer.
  - » Filled in by the sender
  - » Used by the receiver





Different Sources of Components

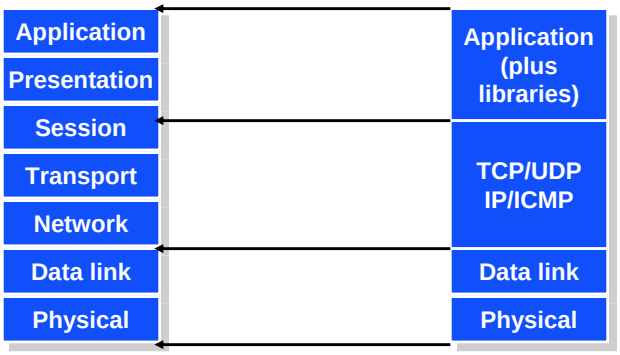
- Application: web server/browser, mail, distributed game,..
- Presentation/session.
  - » Often part of application
  - » Sometimes a library
- Transport/network.
  - » Typically part of the operating system
- Datalink.
  - » Often written by vendor of the network interface hardware
- Physical.
  - » Hardware: card and link



Limitations of the Layered Model

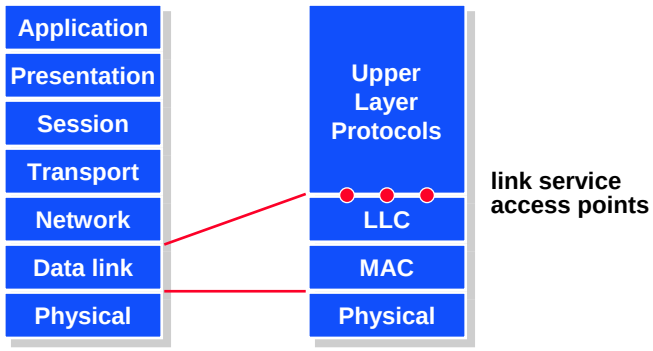
- Some layers are not always cleanly separated.
  - » Inter-layer dependencies in implementations for performance reasons
  - » Some dependencies in the standards (header checksums)
- Higher layers not always well defined.
  - » Session, presentation, application layers
- Lower layers have “sublayers”.
  - » Sublayers well defined in the standards
- Interfaces are not really standardized.
  - » It would be hard to mix and match layers from independent implementations
  - » Many cross-layer assumptions, e.g. buffer management

The TCP/IP Model

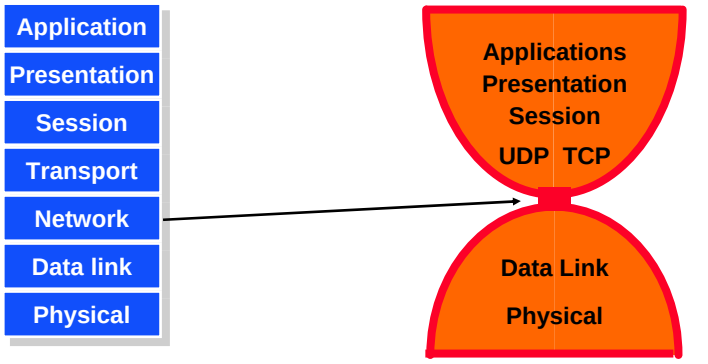


Local Area Network Protocols

IEEE 802 standards "refine" the OSI data link layer.



The Internet Protocol Suite



The Hourglass Model

Standardization

- Key to network interoperability.
- A priori standards.
  - » Standards are defined first by a standards committee
  - » Risk of defining standards that are untested or unnecessary
  - » Standard may be available before there is serious use of the technology
- De facto standards.
  - » Standards is based on an existing systems
  - » Gives the company that developed the base system a big advantage
  - » Often results in competing “standards” before the official standard is established

Relevant Standardization Bodies

- ITU-TS - Telecommunications Sector of the International Telecommunications Union.
  - » government representatives (PTTs/State Department)
  - » responsible for international "recommendations"
- T1 - telecom committee reporting to American National Standards Institute.
  - » T1/ANSI formulate US positions
  - » interpret/adapt ITU standards for US use, represents US in ISO
- IEEE - Institute of Electrical and Electronics Engineers.
  - » responsible for many physical layer and datalink layer standards
- ISO - International Standards Organization.
  - » covers a broad area

The Internet Engineering Task Force

- The Internet society.
  - » Oversees the operations of the Internet
- Internet Engineering Task Force.
  - » decides what technology will be used in the Internet
  - » based on working groups that focus on specific issues
  - » encourages wide participation
- Request for Comments.
  - » document that provides information or defines standard
  - » requests feedback from the community
  - » can be "promoted" to standard under certain conditions
    - – consensus in the committee
    - – interoperating implementations

Higher Level Standards

- **Many session/application level operations are relevant to networks.**
  - » **encoding: MPEG, encryption, ...**
  - » **services: electronic mail, newsgroups, HTTP, ...**
  - » **electronic commerce, ...**
- **Standards are as important as for "lower-level" networks: interoperability.**
  - » **defined by some of the same bodies as the low-level standards, e.g. IETF**
- **Interactions between layers are important.**
  - » **persistent HTTP**
  - » **encryption and compression**
  - » **MPEG frame types**