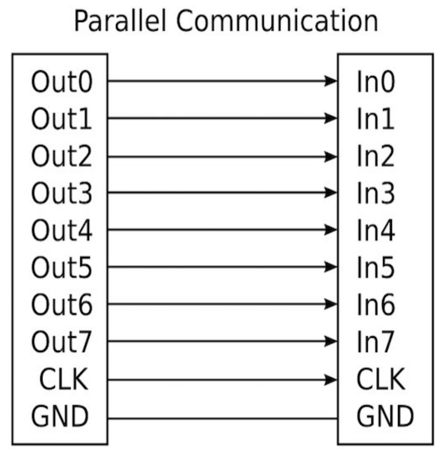
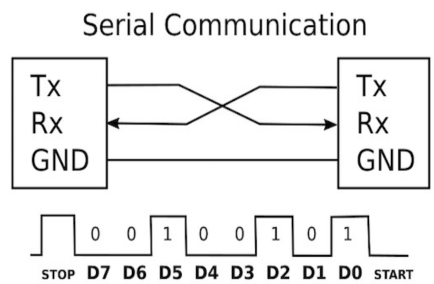
Introduction to Data Communications

Lecture Notes – Ying Sun

Data Communi-cations	Parallel	1 m	
	Serial	Synchronous	USB 5 m
		Asynchronous	Ethernet 100 m, Wifi 32 m, Bluetooth 100m





Communication Protocol for Packet Switching: ISO's OSI

(Open System Interconnection network protocol structure from the International Organization for Standardization)

The OSI model defines a networking framework for implementing protocols in seven layers. Control is passed from one layer to the next, starting at the application layer in one station, proceeding to the bottom layer, over the channel to the next station and back up the hierarchy. Easy Way to Remember the OSI 7 Layer Model: All People Seem To Need Data Processing.

Application (Layer 7) This layer supports application and end-user processes. Communication partners are identified, quality of service is identified, user authentication and privacy are considered, and any constraints on data syntax are identified. Everything at this layer is application-specific. This layer provides application services for file transfers, e-mail, and other network software services.

Presentation (Layer 6) This layer provides independence from differences in data representation (e.g., encryption) by translating from application to network format, and vice versa. This layer formats and encrypts data to be sent across a network, providing freedom from compatibility problems. It is sometimes called the syntax layer.

Session (Layer 5) This layer establishes, manages and terminates connections between applications. The session layer sets up, coordinates, and terminates conversations, exchanges, and dialogues between the applications at each end. It deals with session and connection coordination.

Transport (Layer 4) This layer provides transparent transfer of data between end systems, or hosts, and is responsible for end-to-end error recovery and flow control. It ensures complete data transfer.

Network (Layer 3) This layer provides switching and routing technologies, creating logical paths, known as virtual circuits, for transmitting data from node to node. Routing and forwarding are functions of this layer, as well as addressing, internetworking, error handling, congestion control and packet sequencing.

Data Link (Layer 2) At this layer, data packets are encoded and decoded into bits. It furnishes transmission protocol knowledge and management and handles errors in the physical layer, flow control and frame synchronization. The data link layer is divided into two sublayers: The Media Access

Control (MAC) layer and the Logical Link Control (LLC) layer. The MAC sublayer controls how a computer on the network gains access to the data and permission to transmit it. The LLC layer controls frame synchronization, flow control and error checking.

Physical (Layer 1) This layer conveys the bit stream - electrical impulse, light or radio signal -- through the network at the electrical and mechanical level. It provides the hardware means of sending and receiving data on a carrier, including defining cables, cards and physical aspects.

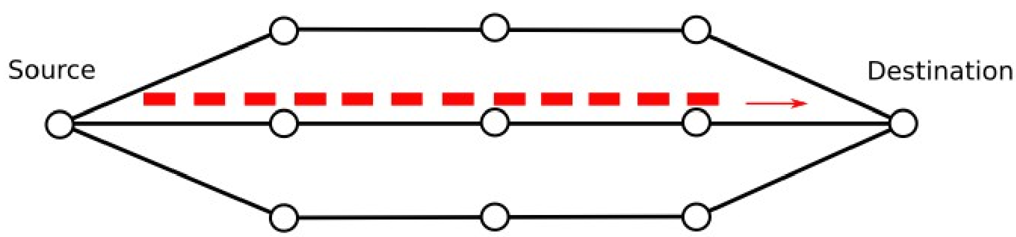
OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example		Central Device/ Protocols			DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management		**User Applications** SMTP		GATEWAY Can be used on all layers	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**		JPEG/ASCII EBDIC/TIFF/GIF PICT			
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.		**Logical Ports** RPC/SQL/NFS NetBIOS names			
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	PACKET FILTERING	TCP/SPX/UDP			Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		**Routers** IP/IPX/ICMP			Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control		**Switch** **Bridge** **WAP** PPP/SLIP	Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts		**Hub**			

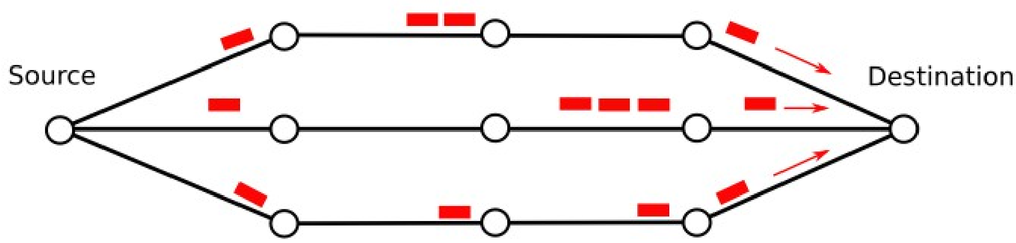
Packet Switching vs. Circuit Switching

Item	Circuit-switching	Packet-switching
Dedicated "copper" path	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

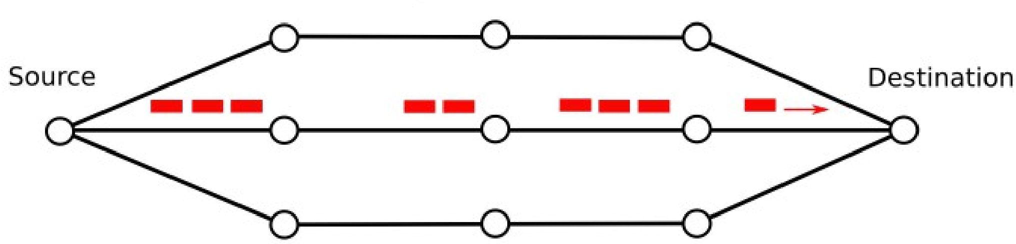
Circuit Switching



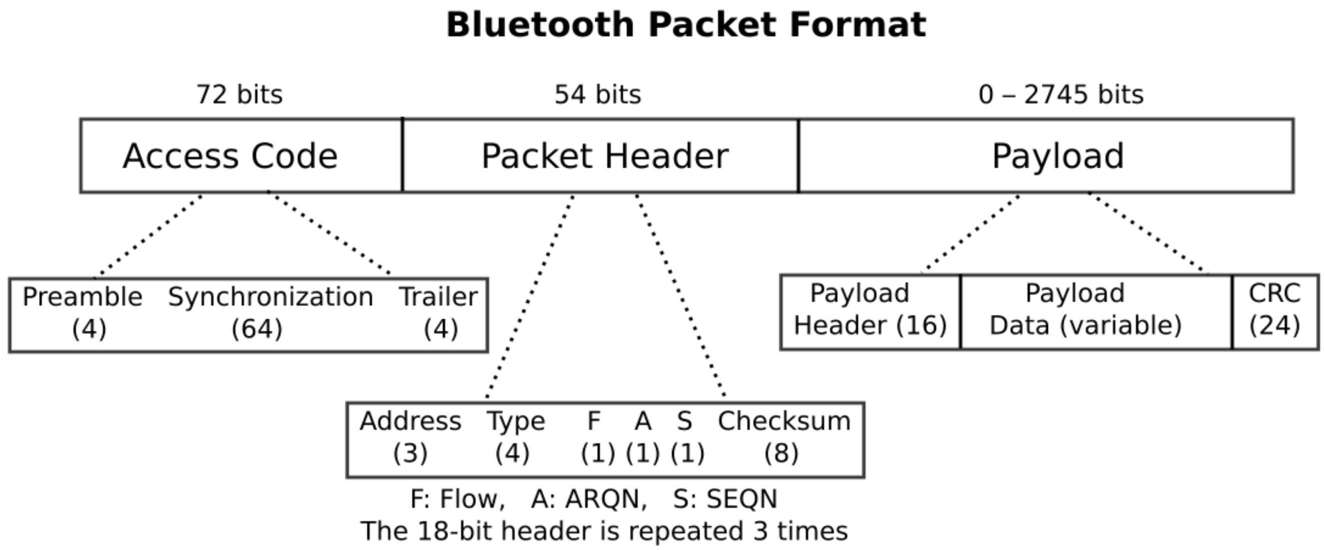
Packet Switching



Virtual Circuit Switching

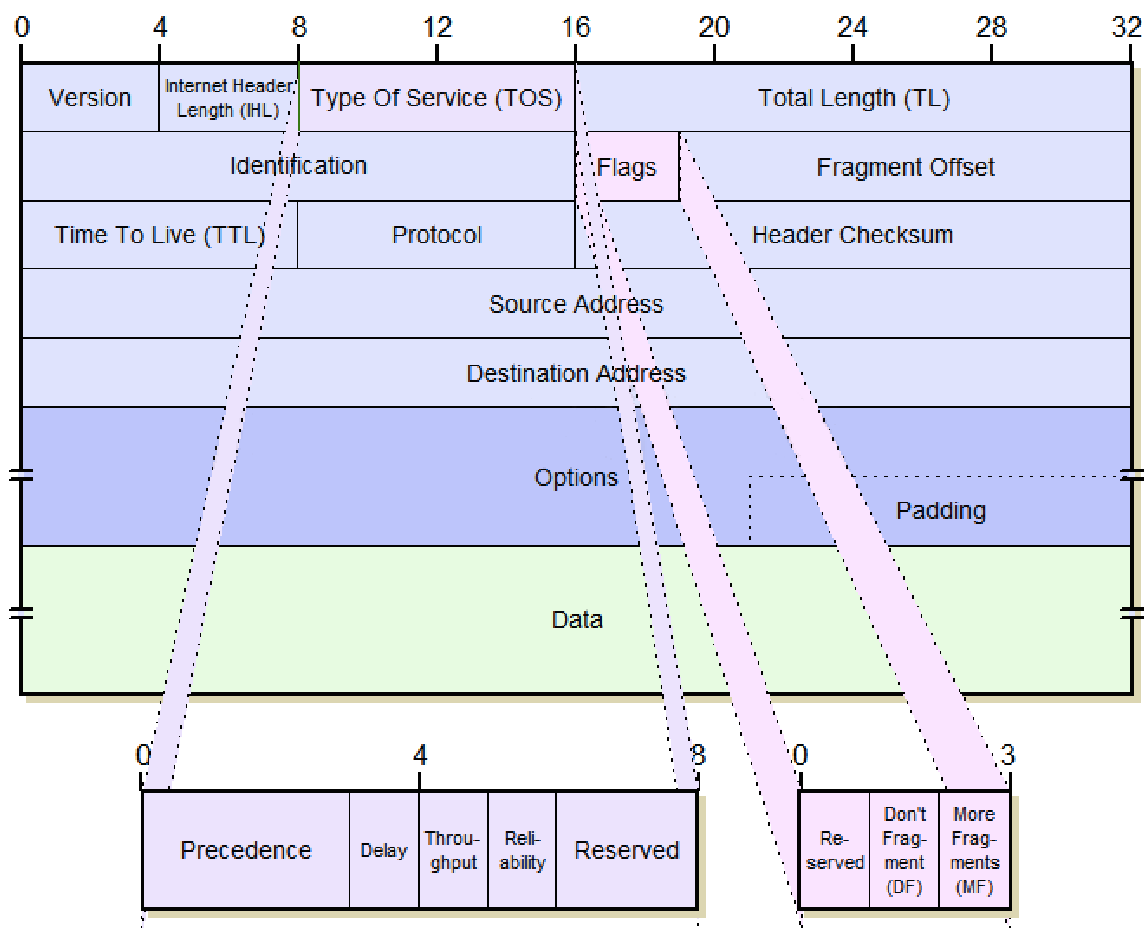


Bluetooth

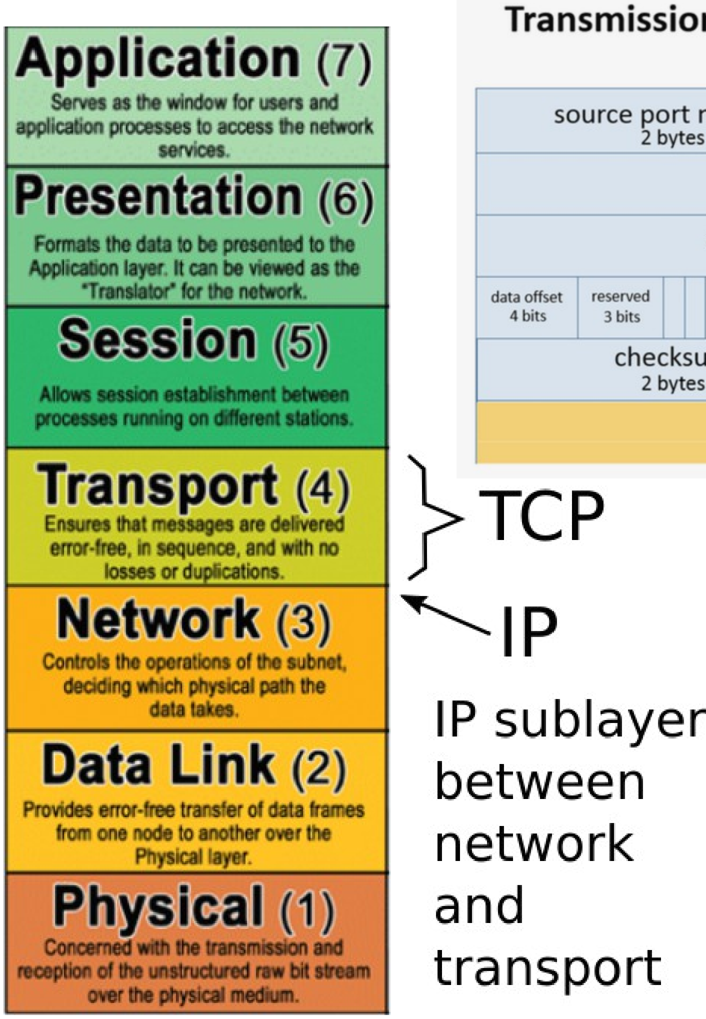


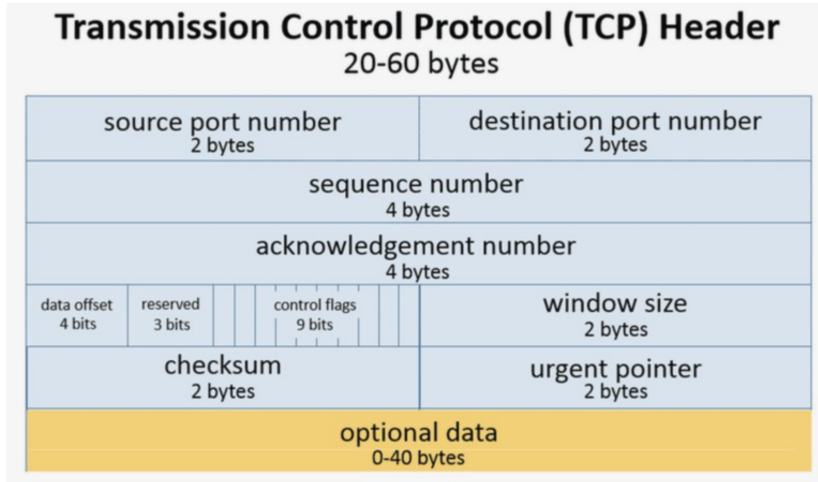
Internet TCP/IP

IPv4 Datagram Format (20-Byte Header)



<u>Example:</u> The 32-bit IPv4 address for Domain Name Servers (DNS) ele.uri.edu is 131.128.51.64.





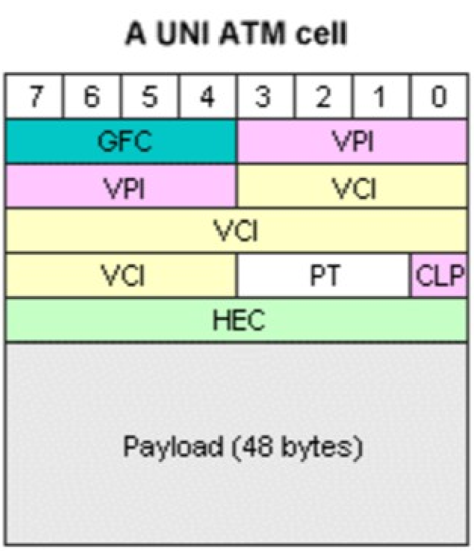
IPv6 address: 128 bits ⇒ $2^{128} = 3.4 \times 10^{38}$

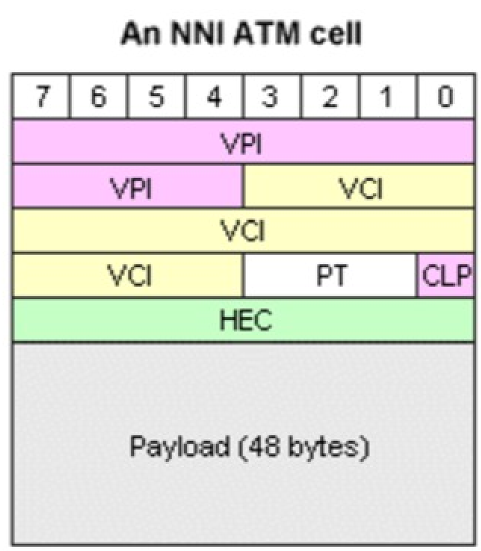
Earth's surface area = $5.1 \times 10^{18}\ \text{cm}^2$

IP address density = $6.7 \times 10^{19}\ \text{addresses/cm}^2$

Internet of Things (IoT)

Asynchronous Transfer Mode (ATM) – Fixed 53-byte cell (5-byte header and 48-byte payload)
ATM uses virtual path and virtual channel to provide better quality of service (QoS), especially for voice of IP (VoIP) and video streaming.

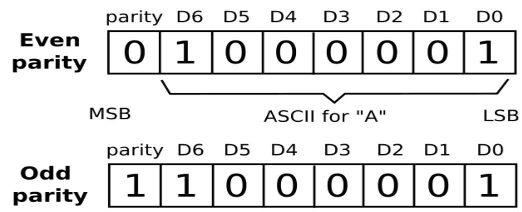




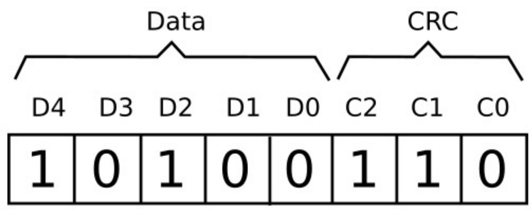
Error Detection and Error Correction

The addition of redundancy bits to the data results in a code work (data + redundancy). The minimum distance of the code ($d_{\min}$) is the minimum number of bit changes between any two adjacent codes. The coding system has the ability to detect an error up to ($d_{\min}$–1) bit-changes and correct an error up to $\lfloor (d_{min}-1)/2 \rfloor$ bit-changes, where $\lfloor \; \rfloor$ the floor operator.

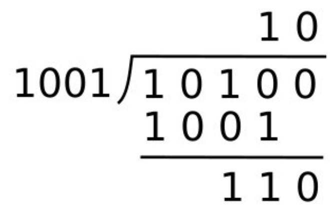
<u>Parity:</u> For even parity, add an extra bit to make the total number of 1's an even number. For odd parity, add an extra bit to make the total number of 1's an odd number. The 1-bit parity check can detect 1-bit error.



<u>Cyclic redundancy check (CRC):</u> CRC is that standard for the TCP/IP and the ATM protocols.



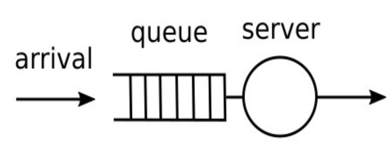
CRC generator polynomial g(x) = x^3 + 1
Divid the data by 1001 using modulo-2 subtraction and the remainder is the CRC



Queueing Theory

Queueing theory is the mathematical study of waiting lines, or queues. In queueing theory, a model is constructed so that queue lengths and waiting time can be predicted. Queueing theory is generally considered a branch of operations research because the results are often used when making business decisions about the resources needed to provide a service. Queueing theory has its origins in research by Agner Krarup Erlang when he created models to describe the Copenhagen telephone exchange. The ideas have since seen applications including telecommunication, traffic engineering, computing and the design of factories, shops, offices and hospitals as well as in project management. [Wikipedia]

Example: An M/M/1 queue has one server; the arrival interval and the service interval are both Poisson distributed. “M” stands for memoryless or Markov.



Little's Theorem

The long-term average number of customers in a stable system N is equal to the long-term average effective arrival rate, λ, multiplied by the average time a customer spends in the system, T:

$$N = \lambda T$$

<u>Example 1:</u> On average there are 2 customers going into a postoffice every minute and the average service time for each customer is 5 minutes. On average, how many customers are in the postoffice?

$$N = \lambda T = 2 \text{ min}^{-1} \times 5 \text{ min} = 10$$

<u>Example 2:</u> We send the PPG signal from the PIC to the Android tablet at a rate of 50 bytes per second. If the average length of the queue for receiving the data is 10 bytes, what is the average service time?

$$T = N / \lambda = 10 \text{ bytes} / 50 \text{ bytes/s} = 0.2 \text{ s}$$