Introduction to Networks

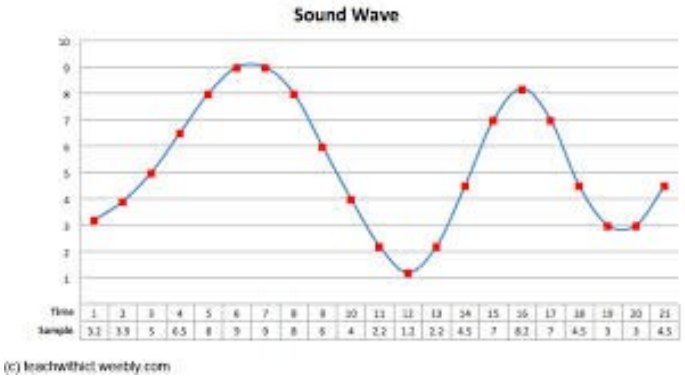
CS487/587 Lecture
Department of Computer Science
Iowa State University

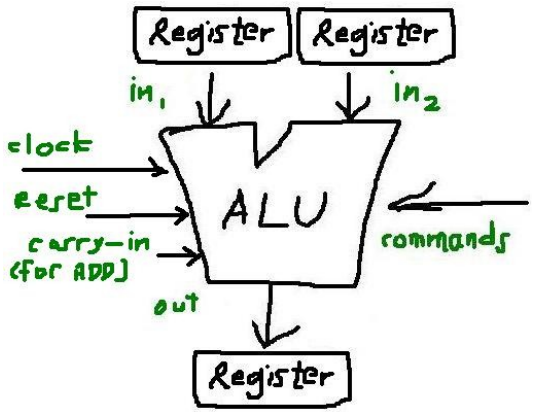
In the beginning, everything is 0 and 1

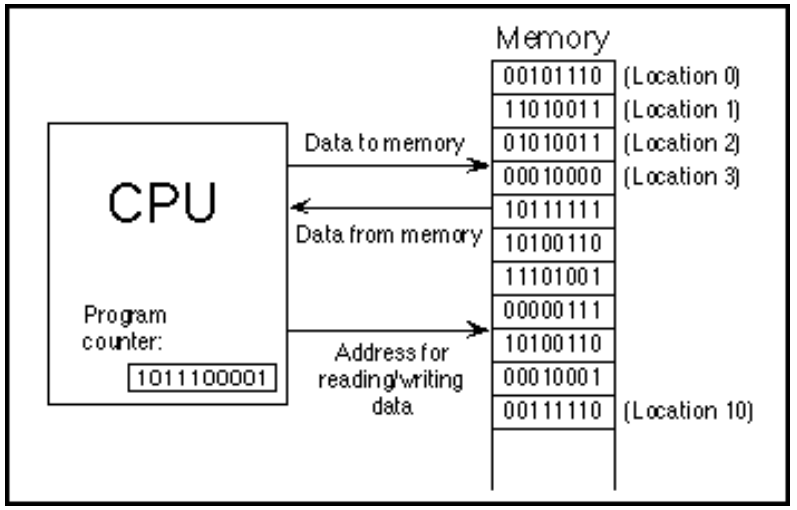
Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

ASCII Code Chart

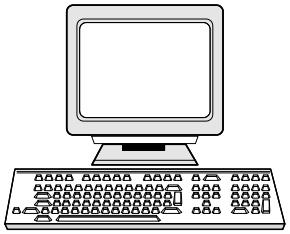
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT	LF	VT	FF	CR	SO	SI
1	DLE	DC1	DC2	DC3	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS	RS	US
2		!	"	#	$	%	&	'	(	)	*	+	,	-	.	/
3	0	1	2	3	4	5	6	7	8	9	:	;	<	=	>	?
4	@	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
5	P	Q	R	S	T	U	V	W	X	Y	Z	[	\	]	^	_
6	`	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o
7	p	q	r	s	t	u	v	w	x	y	z	{	|	}	~	DEL





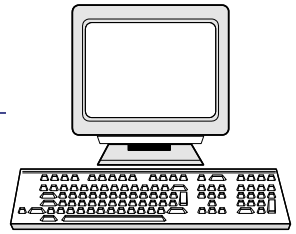


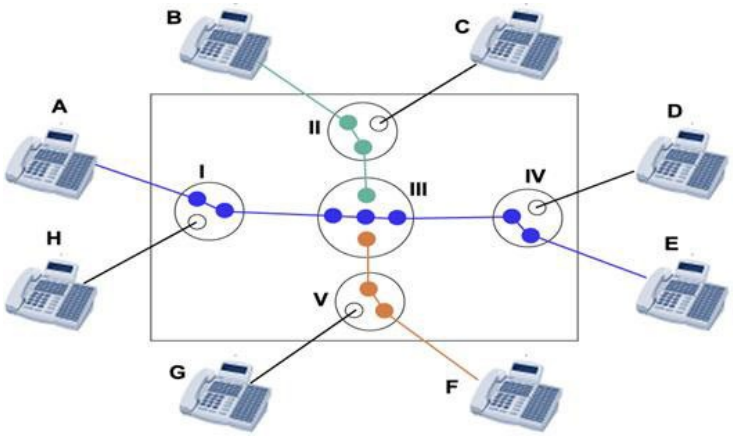
Network Basics

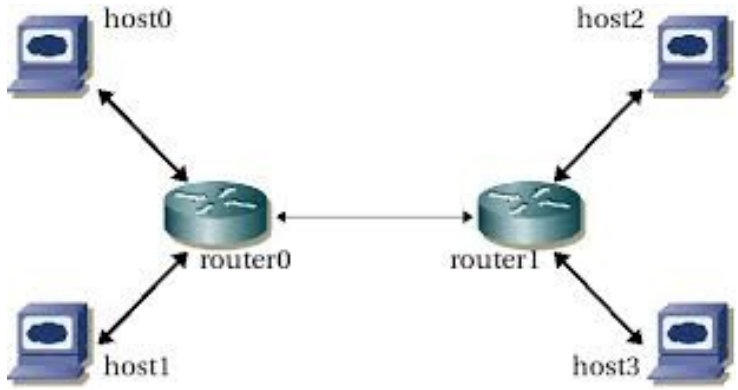


Communication Media

1/0







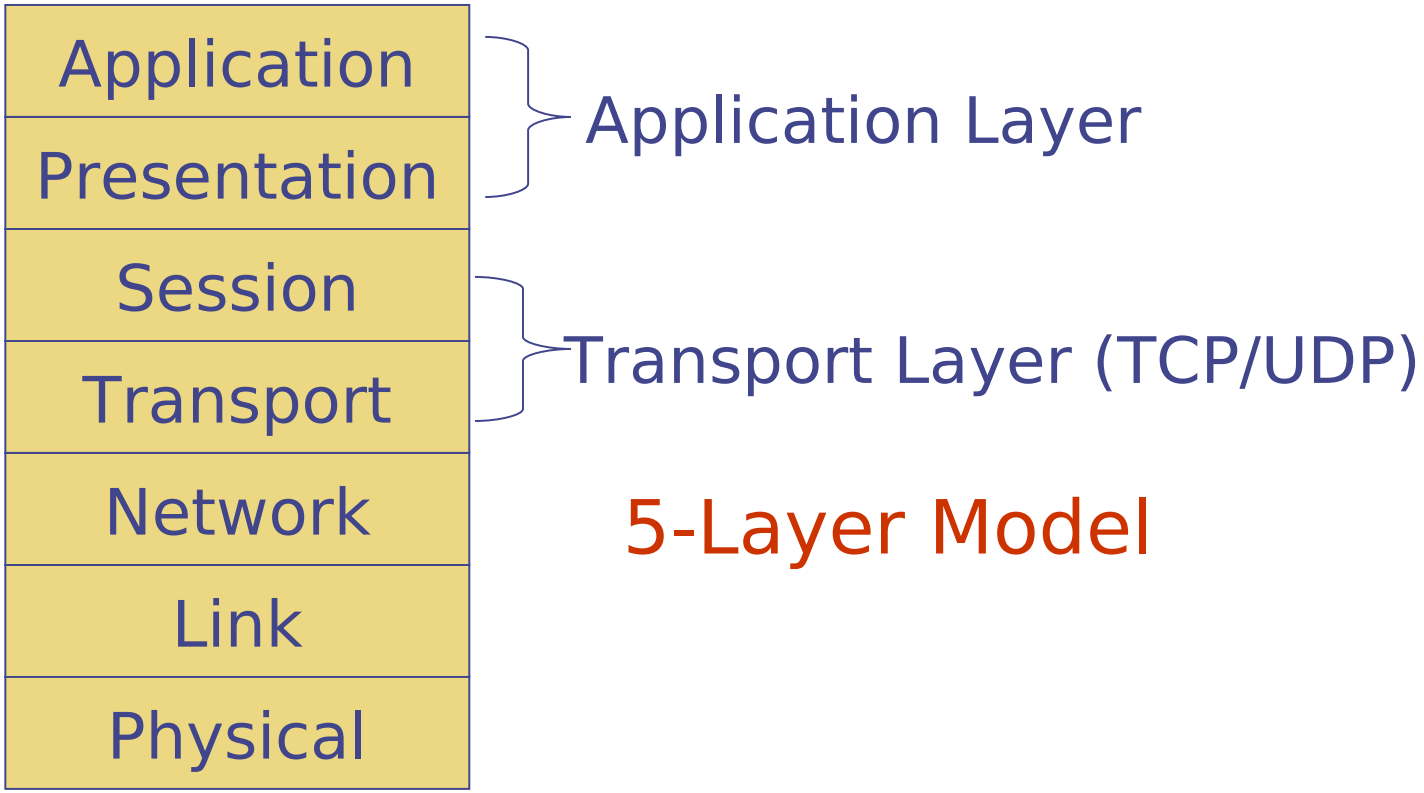
Circuit switching
manual or automatic
Dedicated end-to-end connection
Speed of light

Packet switching
Buffered, store and forward
Shared connection
delayed? Latency?

Protocol: Predefined formats (preexisting agreement) as to how to represent information, how to structure, how to send and receive, and how to interpret

•Two machines must agree on a protocol before they can communicate

Open Systems Interconnection (OSI) 7-Layer Model

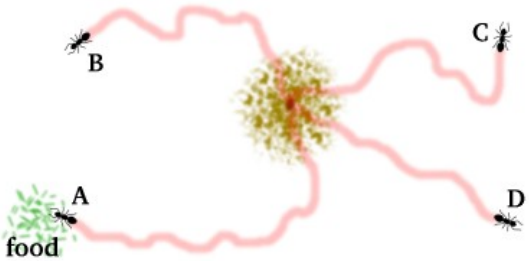


5-Layer Model

OSI 7-Layer Model

Application
Presentation
Session
Transport
Network
Link
Physical

- Bit
  - Communication media (copper, fiber, air, etc.)
  - Signal processing (0/1 representation, speed, etc.)
- Applications
  - Beacon tower (fire)
  - Other (sound, pheromone)
- Transmission mode
  - Simplex, half duplex, full duplex



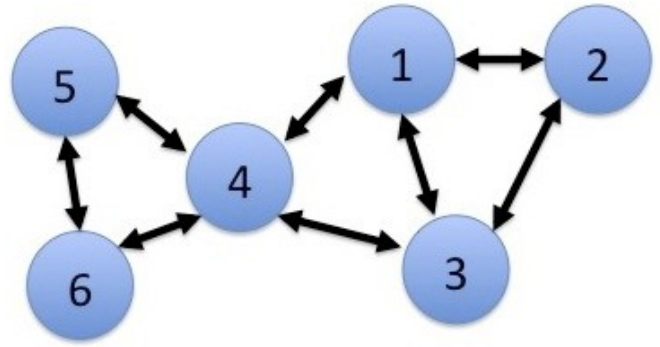
OSI 7-Layer Model

Application
Presentation
Session
Transport
Network
Link
Physical

- Frame
  - Typically contains a few hundreds of bytes
  - Special mark for start and end of each frame
  - Checksum error detections (or even correction)
  - Erroneous frames can be discarded or retransmitted
  - Medium access control (MAC): controlling how devices gain access to medium and permission to transmit data

OSI 7-Layer Model

Application
Presentation
Session
Transport
Network
Link
Physical



- Packets, also known as datagram
  - Packet routing and congestion control
- Challenges of path finding
  - Network heterogeneity
    - e.g., from Ethernet to Token Ring to FDDI
  - Multi-hop
    - A data packet may have to go several hops before reaching its destination
  - Multi-path
    - The shortest route is not always the best route
    - What really matters is the amount of delay on a given route

OSI 7-Layer Model

- Data stream
  - Provide a virtual tunnel for end-to-end connection
- Flow control
  - Partition data into packets and assign each one a sequence number
  - Provide service to assemble the received packets back into their original order
  - Error detection and correction
- Lowest layer to which application programs are typically written

OSI 7-Layer Model

- Application-to-application data exchange
  - Establishment
  - Synchronization
  - Re-establishment

OSI 7-Layer Model

- Data representation and conversion
  - Character representation
    - ASCII, UTF-8, or Unicode
  - Integer representation
    - Little/Big-endian, 32/64-bit
  - Floating point representation
    - IEEE 754, VAX
- Data compression/decompression

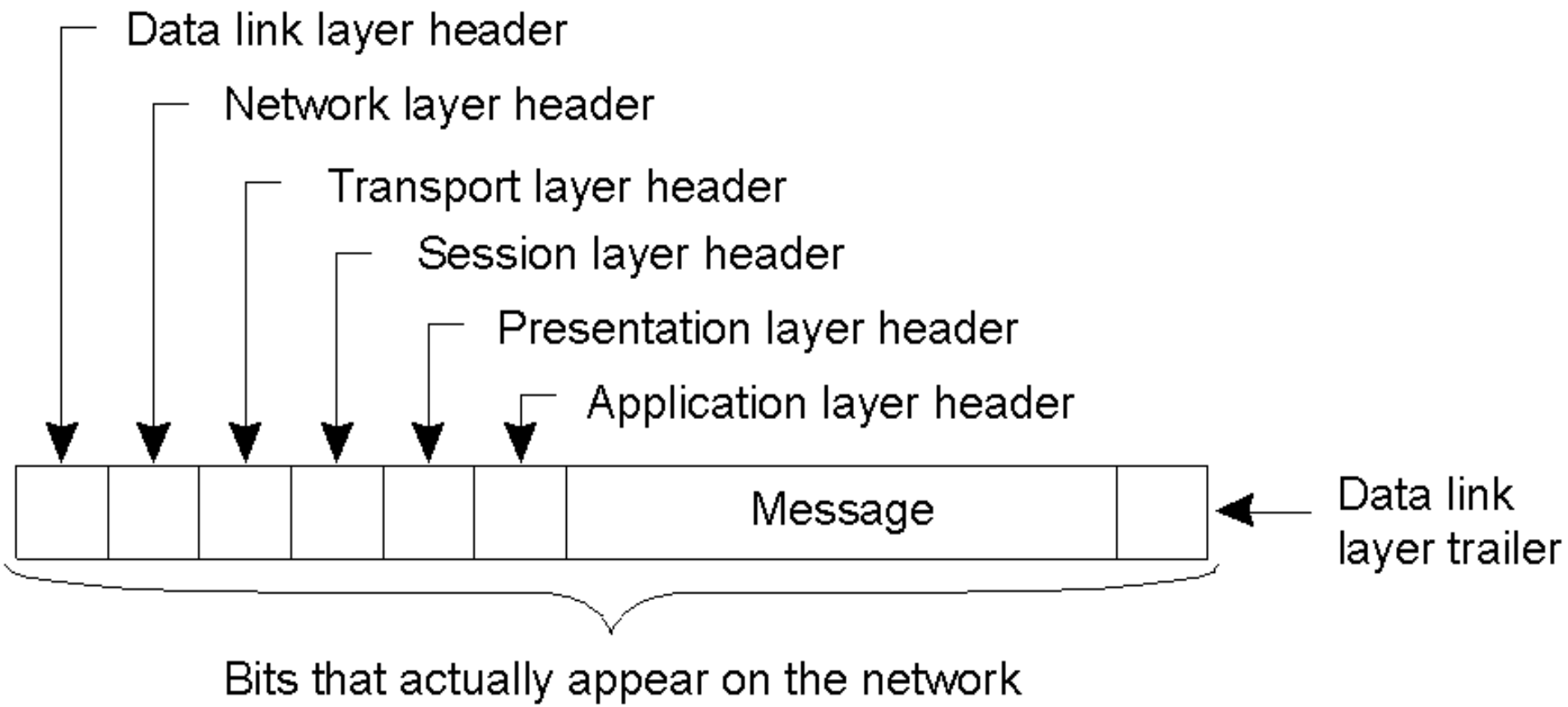
OSI 7-Layer Model

- Dictate the semantics of how requests for services are made, such as requesting a file or checking for email.
- The container for all applications and protocols
  - Telnet, HTTP, POP, SMTP, Finger, FTP, etc.
- Virtually all distributed systems are applications
- In Java, almost all network software written will be for applications.

Quick Review

	Application to application
stream	Machine to machine
packet	Direct/indirect
frame	direct connection
bit	direct connection

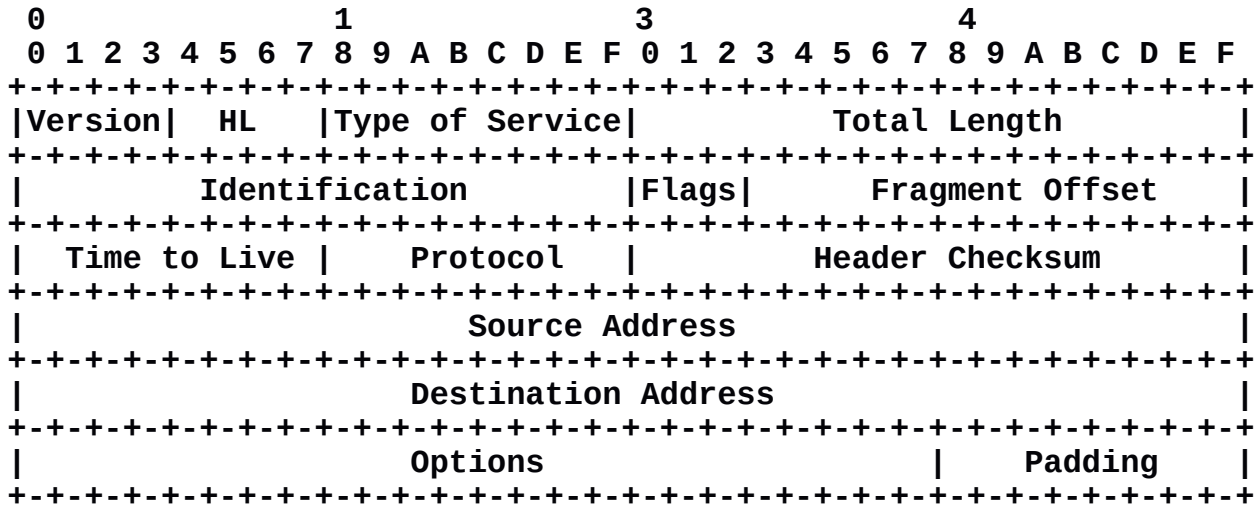
OSI 7-Layer Model



Internet Protocol (IP)

- An implementation of network layer
  - Designed for packet-switched network
    - Each packet contains no more than 64K bytes
  - Connectionless
    - Each packet is routed independently with sender and receiver address (what is the advantage?)
  - Best-effort
    - Packets could be discarded during transmission because of the exhaustion of resources or a failure at the data link or physical layer
  - Unreliable
    - Reliability is ensured at higher layer, such as TCP

IP Header

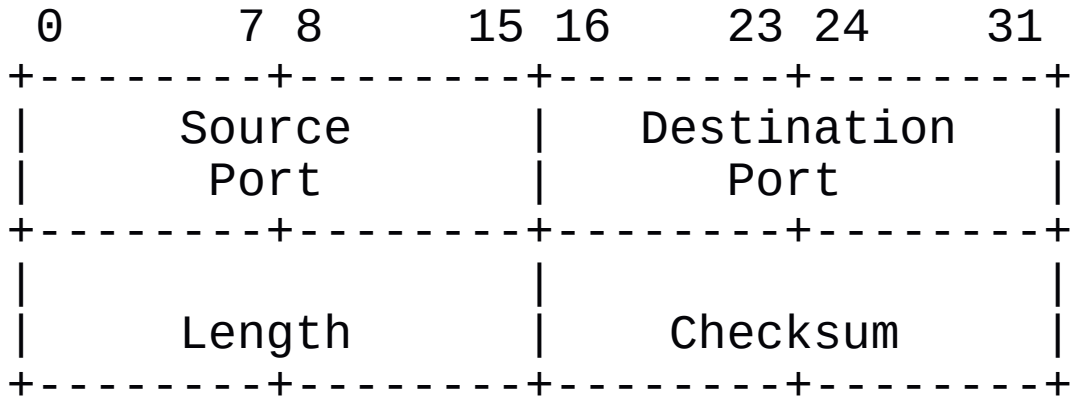


- Version: 4 bits
  - helps smooth the transition to future version of IP
- Header length: 4 bits
  - specifies the length of the header, in multiples of 32 bits
  - limits the header to 15 * 32bits = 60 bytes
- Type of Service: 4 bits
  - Specify a tradeoff between fast service and reliable service, not commonly used
- Total length: 16 bits
  - Length of packet, which is limited to 64K bytes
- Time-To-Live (TTL): 8 bits
  - limit the life of the packet on the network
    - Initialized to thirty
    - Decremented each time the packet arrives at a routing step
    - Discarded when it is equal to 0
- Identification (16 bits), Flags (3 bits), and Fragment Offset (13 bits)
  - Partition a datagram into packet if it is too large
    - Each packet must be no larger than 2^16 = 64K
    - The maximum number of fragments per datagram is 2^13 = 8192
  - Flags field controls whether these datagrams may be fragments
    - If a gateway can support only smaller packets, fields marked “do not fragment” are discarded

User Datagram Protocol (UDP)

- An implementation of transport layer on top of IP
- Unreliable data transmission
  - No guaranteed on delivery
  - Packets could be received out of order
- Add port identification numbers and payload checksum to IP
  - Ports allow multiplexing of data streams
- Highly efficient because of low overhead
  - Suitable for delivering data that is small amount and needs to be sent frequently
  - Typically used for latency-sensitive or low-overhead applications (video, time, DNS, etc.)

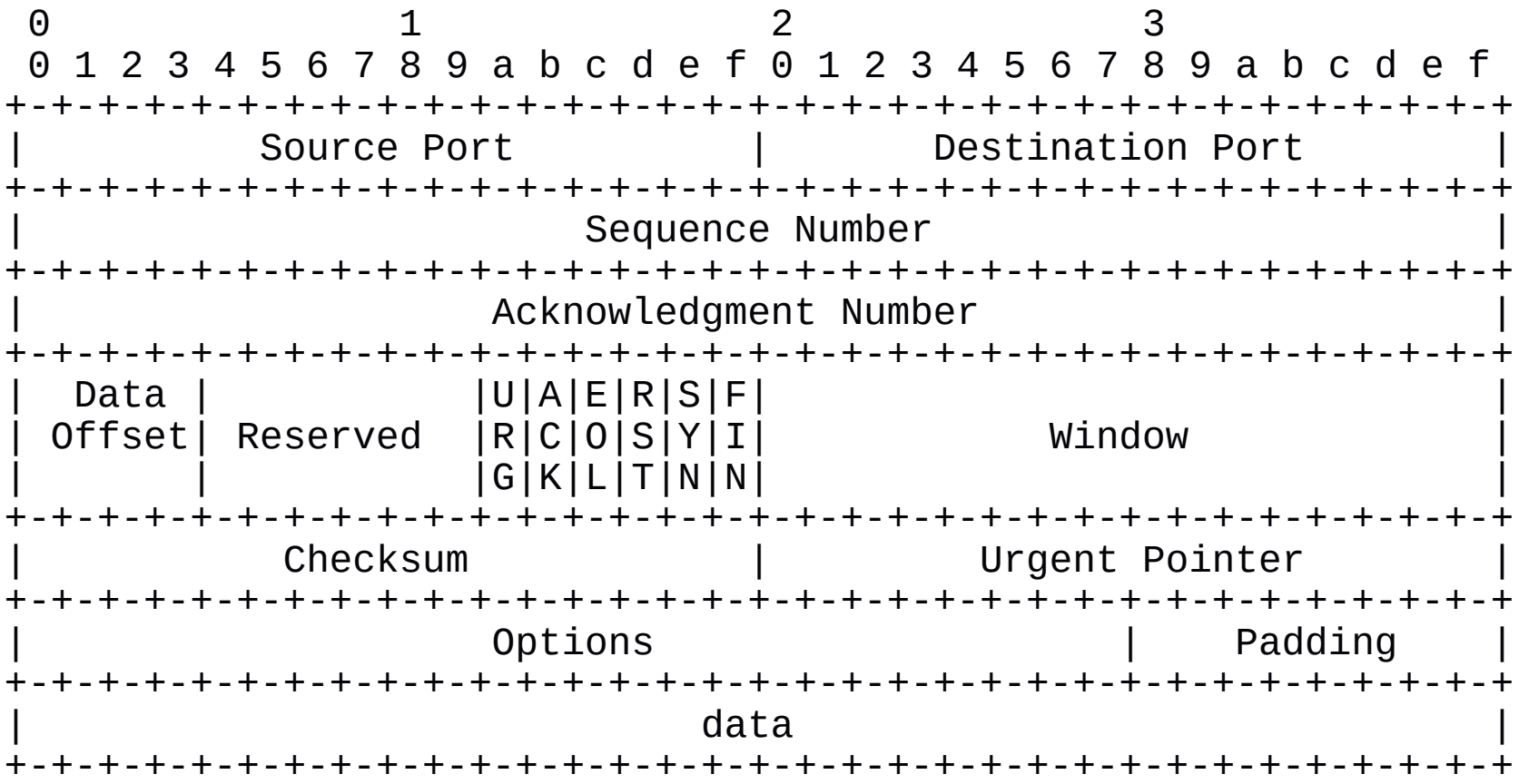
UDP Header


0 7 8 15 16 23 24 31
Source Port
Destination Port
Length
Checksum

Transmission Control Protocol (TCP)

- An implementation of transport layer on top of IP
- Reliable data transmission that can be used to send a sequence of bytes
  - Provide guaranteed delivery and ordering of bytes, i.e., data are always received in their original order
- Port numbers, like UDP
- Checksums payload
- Flow control
  - Sensitive to packet loss and round-trip time
- Error recovery: retransmit lost/corrupted packets

TCP Header


0 1 2 3
0 1 2 3 4 5 6 7 8 9 a b c d e f 0 1 2 3 4 5 6 7 8 9 a b c d e f
Source Port
Destination Port
Sequence Number
Acknowledgment Number
Data Offset
Reserved
U R G
A C K
E O L
R S T
S Y N
F I N
Window
Checksum
Urgent Pointer
Options
Padding
data

IP + TCP/UDP = INTERNET

- Resource sharing between networks
  - Information sharing
  - Computing resource sharing
- Hardware and software independence
  - Interoperable with any CPU architecture, operating system, and network interface card
- Reliability and robustness
  - Data can be rerouted if necessary in order to reach its destination, regardless of the state of intermediary networks
- Distributed management and control

Reading Material

- https://en.wikipedia.org/wiki/OSI_model
- https://en.wikipedia.org/wiki/Port_(computer_networking)

Review Questions

1. What pros and cons are for circuit switching and packet switching?
2. What are names of the 5/7 layers and their corresponding functionalities?
3. Which layer(s) deal with machine to machine communication?
4. Which layer(s) deal with application to application communication?
5. An IP packet can hold up to 64k bytes. Why?
6. Why the concept of port is significant? How many ports can a machine have? Why?
7. In your view, which layer is most challenging to implement? Why?