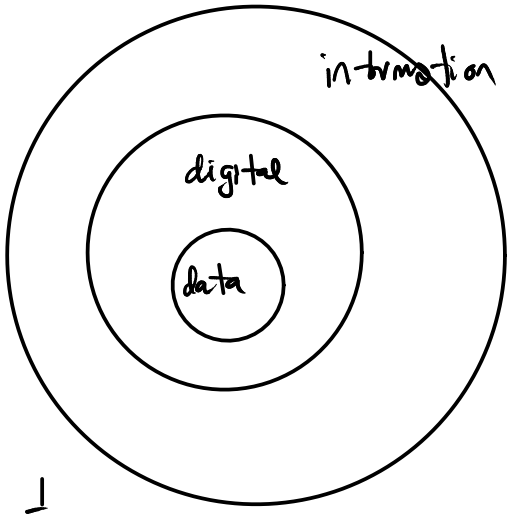
Lecture 1 - Introduction

Exercise 1: For each of the following communication systems identify the source, sink and the channel(s) involved: a laptop's connection to an external hard drive; a cell phone call; watching a YouTube video. Which of these involve networks? Come up with your own examples of communication systems and identify these components.

	source	channel	sink	network?
USB drive	laptop	USB cable	HD	N
cell phone call	person	free space	person	y
Internet video	server	various	person	y
your own: (telegraph)	operator	cable	operator	N

Exercise 2: A source generates four different messages. The first three have probabilities 0.125, 0.125, 0.25. What is the probability of the fourth message? How much information is transmitted by each message? What is the entropy of the source? What is the average information rate if 100 messages are generated every second? What if there were four equally-likely messages?



$P_0 = \frac{1}{8}$ $P_1 = \frac{1}{8}$ $P_2 = \frac{1}{4}$ $P_3 = \frac{1}{2}$

$\sum_i P_i = 1$ $P_3 = 1 - \left(\frac{1}{4} + \frac{1}{8} + \frac{1}{8}\right) = \frac{1}{2}$

$I_0 = -\log_2\left(\frac{1}{8}\right) = -(-3) = 3$

$I_1 = 3$ $I_2 = 2$ $I_3 = 1$

$H = -\sum_{i=0} \log_2(P_i) \cdot P_i = \frac{3 \cdot \frac{1}{8}}{} + \frac{3 \cdot \frac{1}{8}}{} + \frac{2 \cdot \frac{1}{4}}{} + \frac{1 \cdot \frac{1}{2}}{} =$

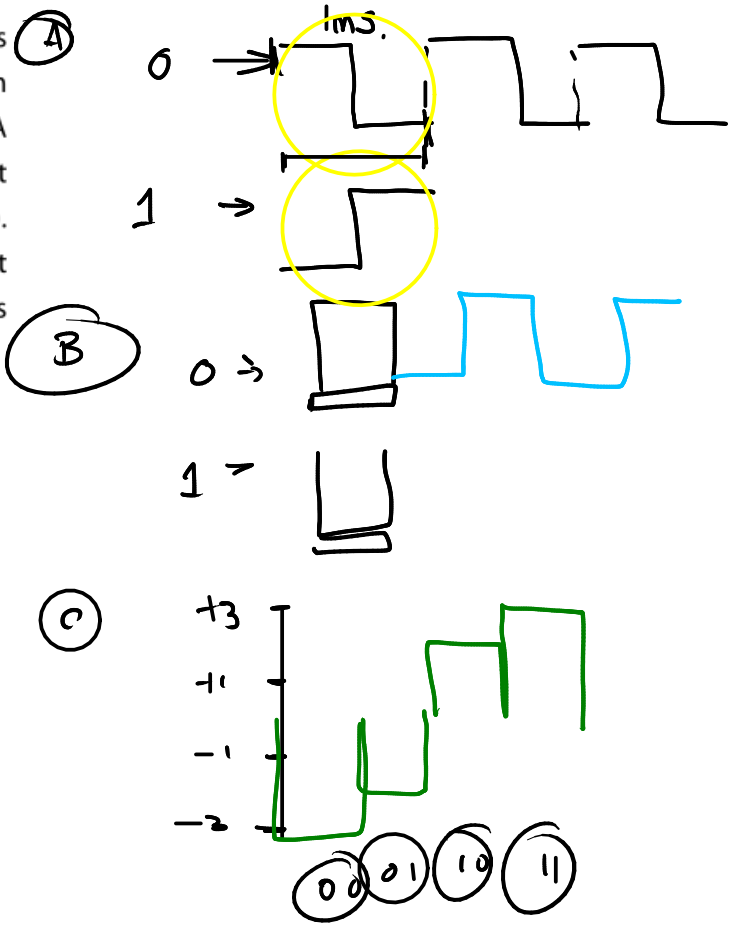
$\frac{3+3+4+4}{8} = \frac{14}{8} = 1\frac{3}{4} = 1.75$ bits/message

Information rate = $1.75 \cdot 100 = 175$ bits/second

(for 4 $P_i = \frac{1}{4}$ $4 \times 2 \times \frac{1}{4} = 2$ bit/message

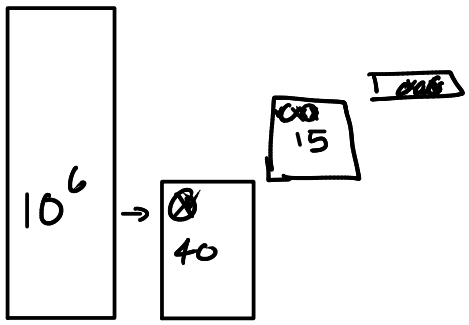
200 b/s.

Exercise 3: One system encodes each bit using two pulses of opposite polarity (H-L for 0 and L-H for 1). A second system encodes bits using one pulse per bit (H for 0 and L for 1). A third system encodes two bits per pulse by using four different pulse levels (-3V for 00, -1V for 01, +1V for 10 and +3V for 11). Assuming each system transmits at 1000 bits per second, what are the baud rates in each case? How many different symbols are used by each system? What are the symbol rates?



1000 bps	baud rate	# symbols	symbol rate (symbols/s)	bits/symbol = $\log_2$(#bits/symbol)	bit rate (bps)
A	2000	2	1000	1	1000
B	1000	2	1000	1	1000
C	500	4	500	2	1000

Exercise 4: You receive 1 million frames, each of which contains 100 bits. By comparing the received frames to the transmitted ones you find that 56 frames had errors. Of these, 40 frames had one bit in error, 15 had two bit errors and one had three errors. What was the FER? The BER?



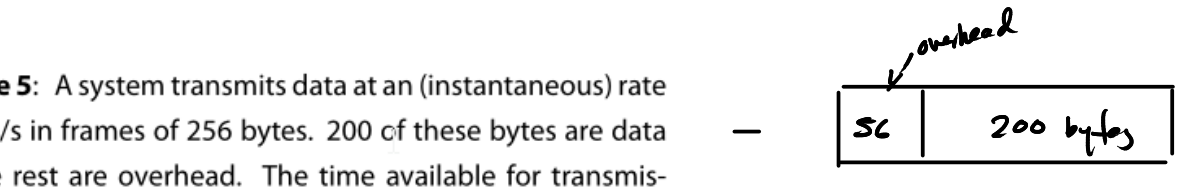
$$FER = \frac{40 + 15 + 1}{10^6} = 56 \times 10^{-6} = 5.6 \times 10^{-5}$$

$$BER = \frac{40 \times 1 + 15 \times 2 + 1 \times 3}{10^6 \cdot 100} = \frac{40 + 30 + 3}{10^8} = 73 \times 10^{-8} = 7.3 \times 10^{-7}$$

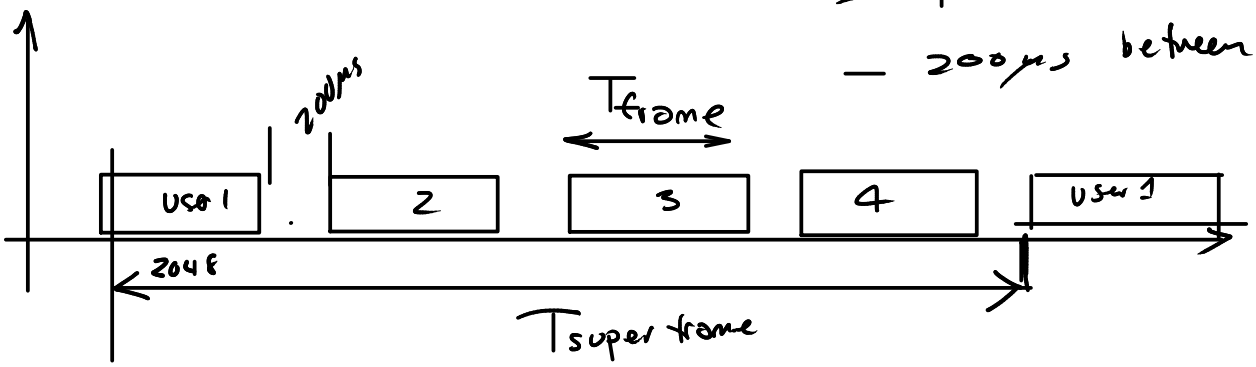
56 MHz 56x

5.6×10^7 Hz

Exercise 5: A system transmits data at an (instantaneous) rate of 1 Mb/s in frames of 256 bytes. 200 of these bytes are data and the rest are overhead. The time available for transmission over the channel is shared equally between four users. A 200 μs gap must be left between each packet. What throughput does each user see? Now assume 10% of the frames are lost due to errors. What is the new throughput per user?



- X8 for bits
- 1 Mb/s
- 4 users
- 200 μs between packets.



$$256 \frac{\text{bytes}}{\text{frame}} \times 8 \text{ bits/byte} = 2048 \text{ bits/frame}$$

$$T_{frame} = 2048 \text{ bits/frame} \cdot 1 \mu\text{s/bit} = 2.048 \text{ ms/frame}$$

$$T_{superframe} = 4(2048 + 200) = 8992 \mu\text{s/frame}.$$

$$\text{throughput} = \frac{200 \times 8}{8992 \times 10^{-6}} = 178 \text{ kb/s}$$

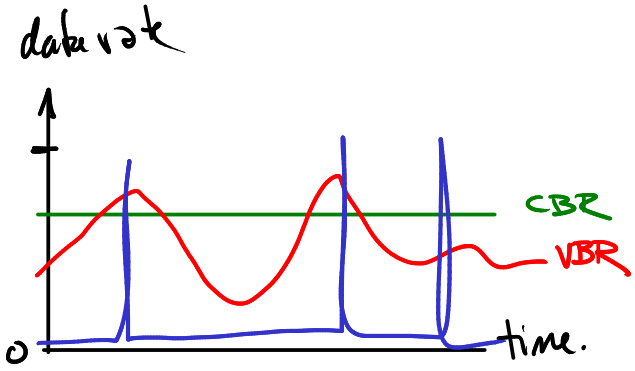
$$\approx \frac{2000}{10^{-2}} \quad 2 \times 10^3 \cdot 10^2 \approx 2 \times 10^5$$

FER = 10% useful fraction of frames = 1 − FER

= 1 − 0.1 = 90% = 0.9

assuming NO retransmissions

Exercise 6: Plot some sample data rate versus time curves for these three types of sources. What characteristics of a video source might result in a variable bit rate when it is compressed? (*Hint: what types of redundancy are there in video?*).



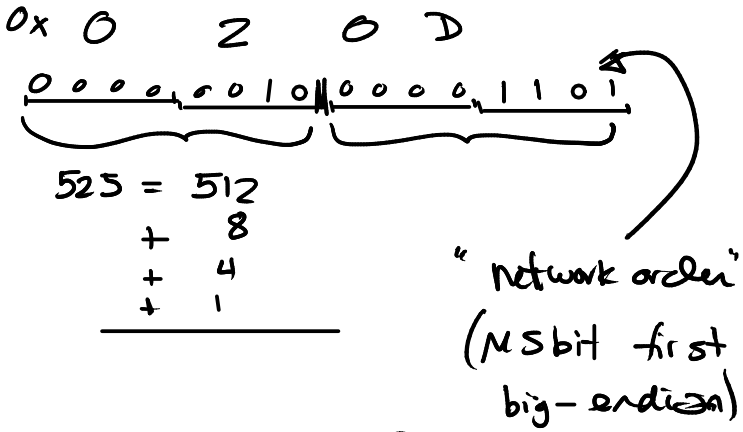
video
- motion (inter-frame)
- intra-frame (white areas vs. lots of detail).

audio
silence

Exercise 7: For each of the following communication systems identify the tolerance it is likely to have to errors and delay: a phone call between two people, "texting", downloading a computer program, streaming a video over a computer network. What do you think might be the maximum tolerable delay for each?

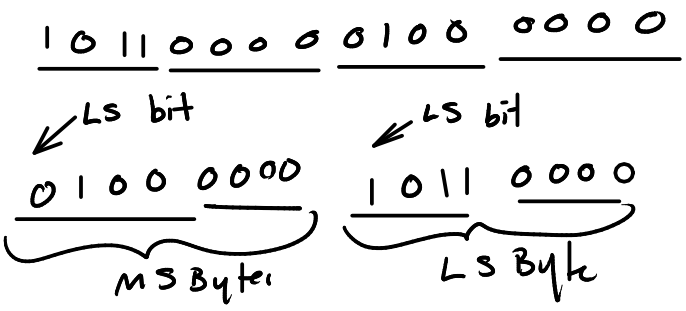
	tolerance to delay	tolerance to loss/errors.
phone call	not if > ≈ 100ms	yes ≈ 10%
texting	yes (not interactive)	maybe / ?
download a program	yes.	No
streaming video	yes (not interactive)	No (due to compression)

Exercise 8: Convert the decimal number 525 to a 16-bit (two-byte) binary number. Write the sequence of bits that would be transmitted if both the bytes and bits were transmitted in little-endian order. Write the sequence of bits that would be transmitted in "network order".



$525_{10} = 0x020d$

in LSB-first order:



if bytes MSB
bits as LSB

Exercise 9: Write the 16-bit number above in hexadecimal notation.

0x020D

Exercise 10: How many bits would be required to uniquely identify 100,000 different characters? (Hint: $2^{16} = 65536$).

17 bits $(2^{17} = 128k)$

Exercise 11: Find the ASCII codes for the *characters* '525'. Write out the first 16 bits of the sequence that would be transmitted assuming each character is encoded using 8 bits per character and little-endian bit order. *Hint: the character code for a digit is 0x30 plus the value of the digit.*

5 2 5

0x35 0x32 0x35

0011 0101 0011 0010 0011 0101

1010 1100 0100 1100

Exercise 12: The Chinese character for "Rice" (the grain) is "⊠" with Unicode value (code point) U+7C73. What is the UTF-8 encoding for this character?