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 connection	laptop	cable	hard drive	N
cell phone call	person	free space twisted pair	person	Y
YouTube video	server	many	viewer	Y

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?

$P_0 = \frac{1}{8}$ $\quad I_0 = -\log_2\left(\frac{1}{8}\right) = -\log_2(2^{-3})$ $= 3b$

$P_1 = \frac{1}{8}$ $\quad I_1 = 3b$

$P_2 = \frac{1}{4}$ $\quad I_2 = 2b$

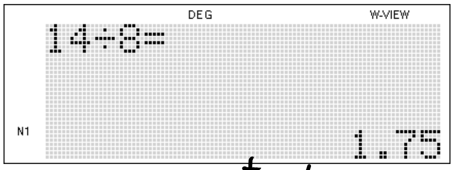
$P_3 = ?$ $\quad 1 - \left(\frac{1}{8} + \frac{1}{8} + \frac{1}{4}\right) = \frac{1}{2}$

$I_3 = -\log_2(2^{-1}) = --1 = 1$

$$H = \sum_i (I_i \cdot P_i)$$

$$= I_0 P_0 + I_1 P_1 + I_2 P_2 + I_3 P_3$$

$$= 3 \cdot \frac{1}{8} + 3 \cdot \frac{1}{8} + 2 \cdot \frac{1}{4} + 1 \cdot \frac{1}{2} = \frac{3}{8} + \frac{3}{8} + \frac{4}{8} + \frac{4}{8} = \frac{14}{8} = 1.75$$



bits / message

100 ~~msgs~~/ second × 1.75 bits /~~msg~~

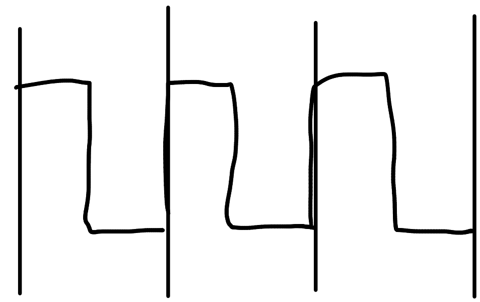
175 bits/second

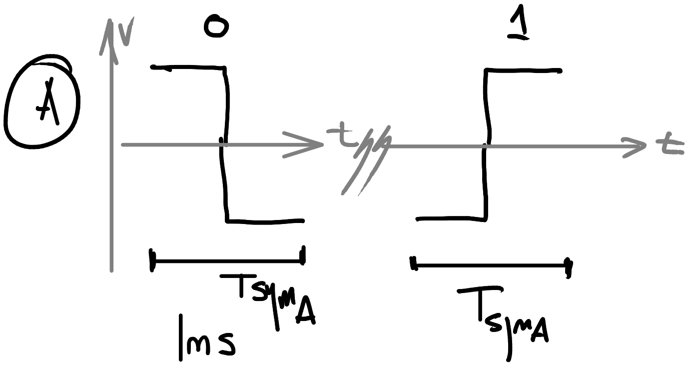
4 equally likely messages: $P_i = \frac{1}{4}$

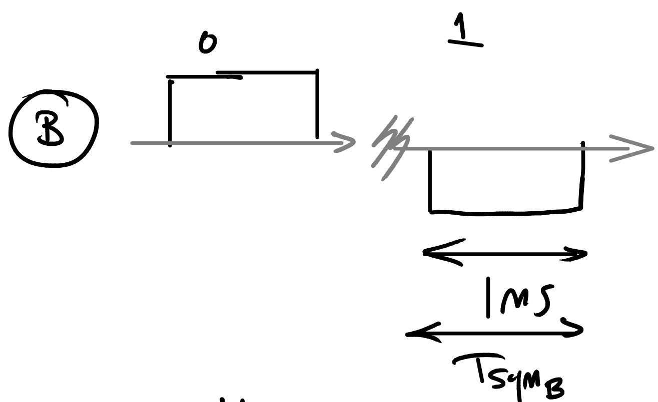
$$H = \sum_{i=0}^{3} 2\text{ bits} \cdot \frac{1}{4} = 4 \times \left(2 \cdot \frac{1}{4}\right) = 2 \text{ bits/msg.}$$

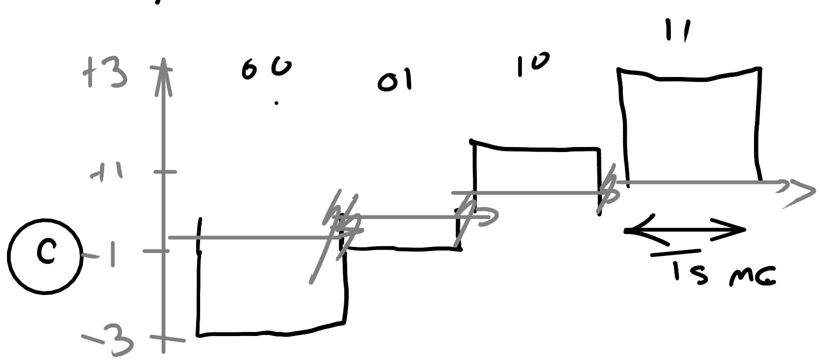
100 msgs/second · 2 bits/msg ⇒ 200 bits/second.

Exercise 3: One system (A) encodes each bit using two pulses of opposite polarity (H-L for 0 and L-H for 1). A second system (B) encodes bits using one pulse per bit (H for 0 and L for 1). A third system (C) 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?









data rate is 1000 bps for each

	number of symbols	number of bits per symbol	symbol rate	maximum transitions per symbol	baud rate
A	2	1	1000	2	2000
B	2	1	1000	1	1000
C	4	2	$\frac{1000}{2}$ = 500	1	500

$$\frac{\text{symbols}}{\text{second}} \cdot \frac{\text{transitions}}{\text{symbol}} = \frac{\text{transitions}}{\text{second}} \equiv \text{baud rate}$$

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?

40 1 errors
15 2 errors
1 3 errors

$40+15+1 = 56$ frames

$$FER = ? \quad \frac{56}{10^6} = 56\times10^{-6} = 5.6\times10^{-5}$$

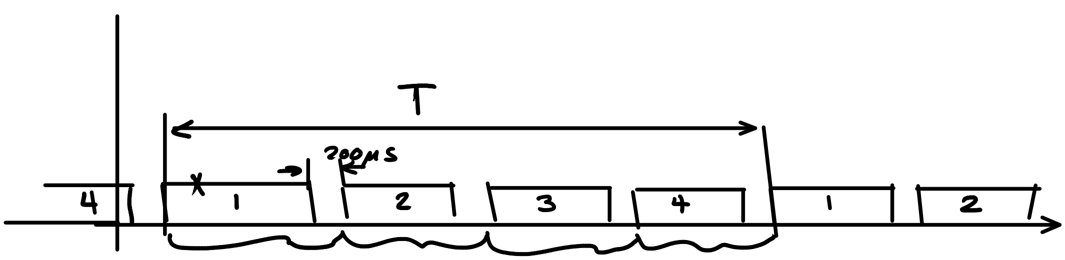
$$BER = ? \quad \frac{40\times1 + 15\times2 + 1\times3}{100\times10^6} = \frac{73}{10^8} = 73\times10^{-8}$$

7.3×10^{-7}

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?

1 Mb/s
256 byte frames
200 bytes useful data
4 users.
200μs gap / packet.

bps

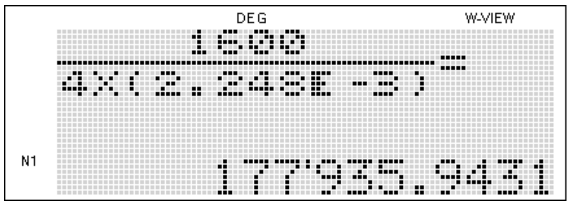


1 packet is $256 \cdot 8 = 2048$ bits
$200 \cdot 8 = 1600$ bits of usable data

$$\frac{\text{useful bits per user}}{\text{time}} = \frac{1600 \text{ bits}}{4 \times (2.048 \times 10^{-3} + 200 \times 10^{-6})} \approx$$

$$T_{packet} = \# \text{bits} \cdot \text{seconds/bit} = 2048 \div 10^{6}$$
$$= 2.048 \times 10^{-3}$$

$$\text{throughput} \approx \frac{1606}{\times 10^{-3}} \approx 200 \times 10^{3} \approx 200 \text{ kb/s}$$



≈ 180 kb/s.

ignoring retransmissions (for now):

$$\text{throughput} = (1 - \text{FER}) \cdot (\text{error-free throughput})$$
$$= (1 - 0.1) \cdot 180 \text{ kb/s} = 0.9 \cdot 180$$
$$\hat{=} 160 \text{ kb/s}$$

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?*).

CBR ———
VBR ——— (red)
bursty ——— (green)

- motion between frames
- intra-frame compression
  - within 1 line
  - between lines

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?

	tolerant to delay	tolerance to loss/errors.
phone call	≃< 100ms	a few %
texting	< minutes	no
download software	yes (hours?)	no
streaming video	initial delay Y interruptions N	typically no

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 = 0x020D

00000010 0000 1101

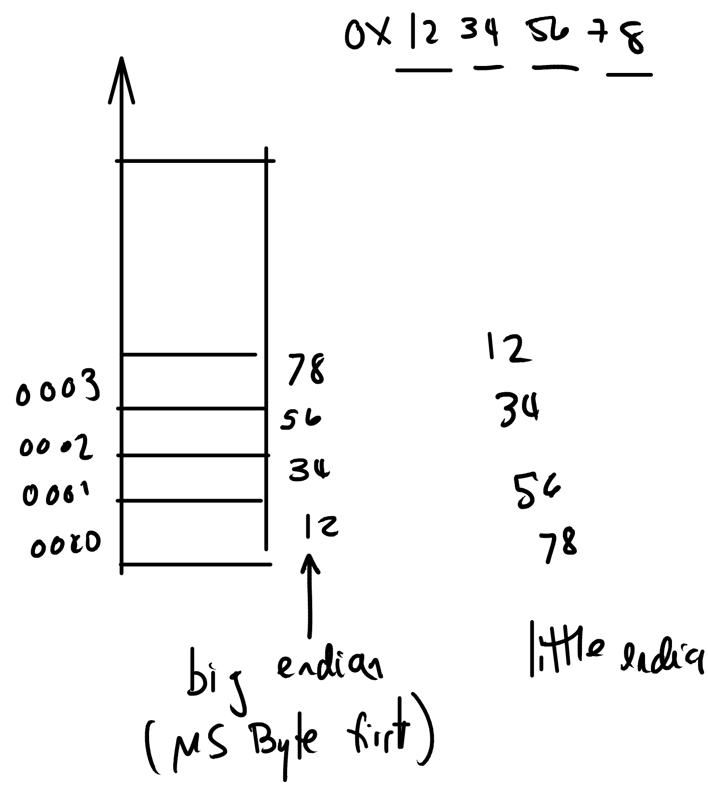
little endian: 1011 0000 0100 0000

big endian "network order": 00000010 0000 1101

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

00000010 0000 1101

0X020D



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

17 bits $\Rightarrow 2^{17} = 2 \times 65536$

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.*

'3' $\xrightarrow{\text{ascii}}$ = 0x33

5 2 5

0x35 0x32 0x35

MSbit first

→ 0011 0101 00110010

little endian order: 10101100 01001100

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?

0x 7 C 7 3

0111 1100 0111 0011

z = 0111

y = 110001

x = 110011

1110 0111 10 110001 10 110011

0xE7 0xB1 0xB3