Lecture 1

Exercise 1: For each of the following communication systems identify the source, sink and the channel(s) involved: a cell phone call; watching a YouTube video, uploading your lab report to D2L. Which of these involve networks? Come up with your own examples of communication systems and identify these components.

	source	destination	channel(s)
cell phone call	person	person	free space, twisted pair
youtube video	server	person video display.	optical fiber wireless.
uploading PDF	scanner.	server	11

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

$2^{16} = 65536 < 100{,}000 < 2^{17} = 128K.$

64K.

need 17 bits

Exercise 3: The Chinese character for "Rice" (the grain) is "米" with Unicode value (code point) U+7C73. What is the UTF-8 encoding for this character?

U+7C73 = 0111 1100 0111 0011

0173

z =

y =

x =

UTF8 = 1110 0111 | 10 111001 | 10 110011

E 7 B 1 B 3

Exercise 4:

Convert the decimal number 525 to a 16-bit (two-byte) binary number. How would you write this in hexadecimal notation?

Find the ASCII codes for the *characters* '525'. Write out the bits of the sequence that would be transmitted assuming each character is encoded in UTF-8. *Hint: the UTF-8 character code for a digit is 0x30 plus the value of the digit.*

$525_{10} = 0x20D$

"525" U+0035, U+0032, U+0035

0x35 0x32 0x35

Exercise 5: Write the sequence of bits that would be transmitted if the 16-bit value 525 was transmitted with the bytes in little-endian order and the bits lsb-first. Write the sequence of bits that would be transmitted in "network order" and the bits msb-first.

525 = 20D

msbit → 0000 0010 0000 1101 ← lsbit

first → second. first

"network" order

first → 1011 0000 0100 0000 ← last

$2^x = y \quad \log_2 y = x$

Exercise 6: We observe a source that outputs letters. Out of 10,000 letters 1200 were 'E'. What would be a reasonable estimate of the probability of the letter 'E'?

$$\frac{1200}{10000} \qquad 12\%$$

Exercise 7: 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?

$\frac{1}{8}$ $\frac{1}{8}$ $\frac{1}{4}$

$\frac{1}{8} + \frac{1}{8} + \frac{1}{4} = \frac{1}{2}$ $\quad P(4^{th}\ msg) = 1 - \frac{1}{2} = \frac{1}{2}$

for $P = \frac{1}{8}$ $\quad I = -\log_2\left(\frac{1}{8}\right) = 3$

$P = \frac{1}{4}$ $\quad I = 2$

$P = \frac{1}{2}$ $\quad I = 1$

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

$$= \frac{7}{4} = 1\frac{3}{4}$$

Exercise 8: How long will it take to transfer 1 MByte at a rate of 10 kb/s?

$$1\ MByte = \frac{10^6 \cdot 8\ \text{bits}}{10 \times 10^3\ \frac{\text{bits}}{s}} = 8 \times 10^2$$

$= 800$ seconds

10×10^3

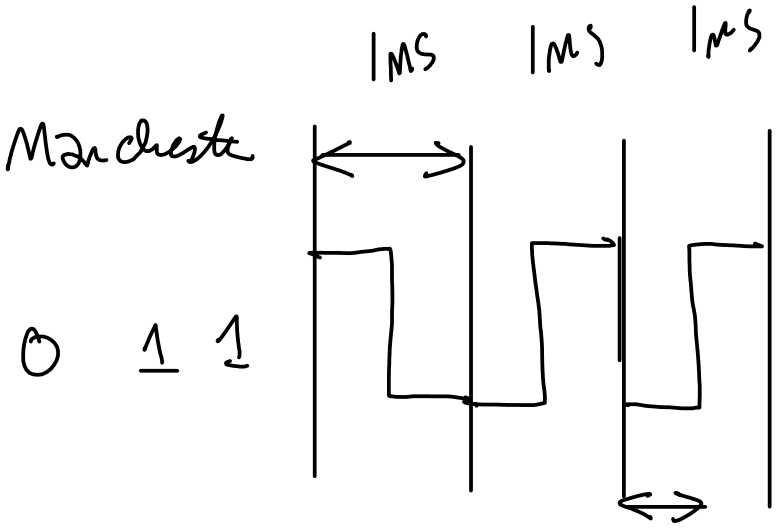
1×10^3

10^4

Exercise 9: In the example above each group of 3 bits is used to select a symbol. How many different symbols do we need? If the bit rate is 12 kbps, what is the symbol rate?

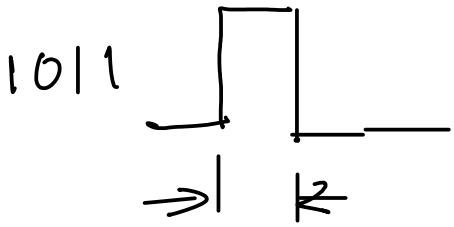
need $2^3 = 8$ symbols

4 kHz = symbol rate



baud period = $\frac{1}{2}$ MS.

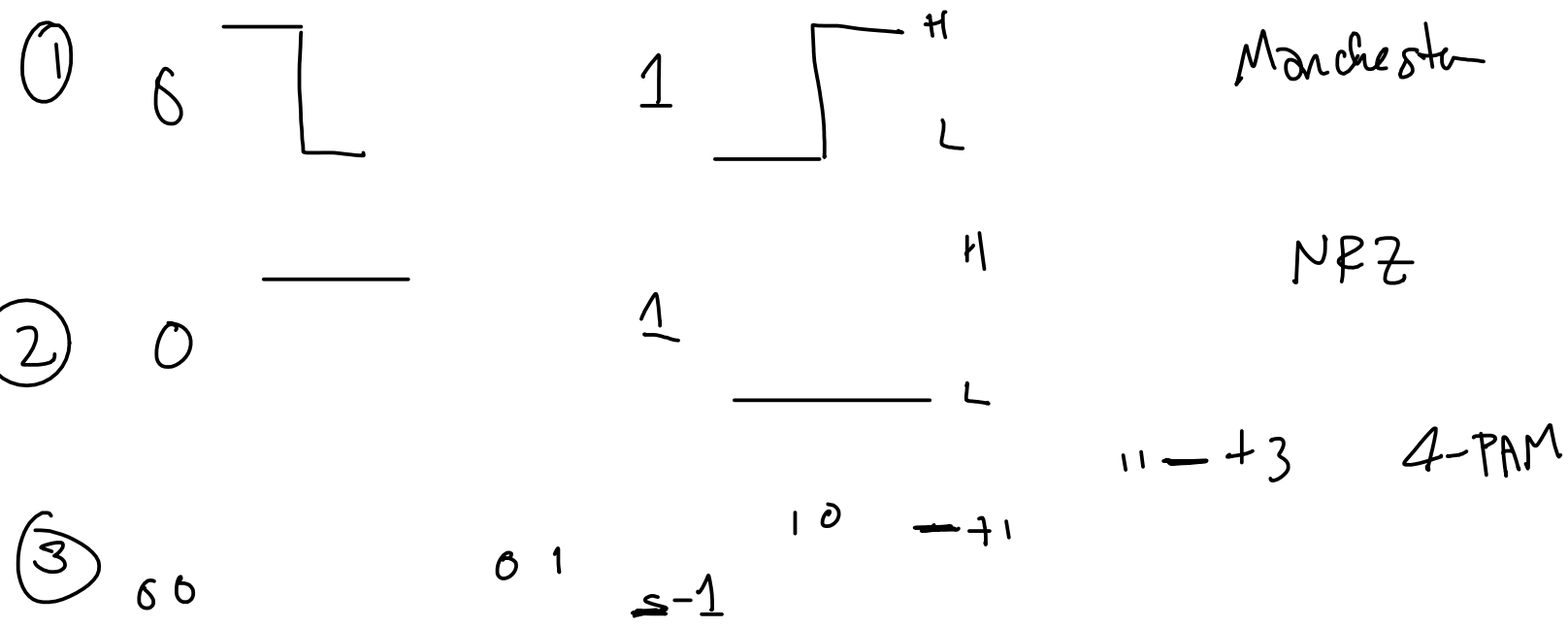
baud rate = $\frac{1}{0.5 \times 10^{-3}} = 2$ kHz



baud period = 1MS

baud rate = 1kHz

Exercise 10: 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?



	bit rate	baud rate	# symbols	symbol rate.
1	1000	2000	2	1000
2	1000	1000	2	1000
3	1000	500	4	500 Hz

Exercise 11: 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?

10^6 total frames $\times$ (x) 100 bits $= 10^8$

40 frames had 1 bit error

15 2 bit errors

1 3 bits errors.

$40 \times 1 = 40$

$+ 15 \times 2 = 30$

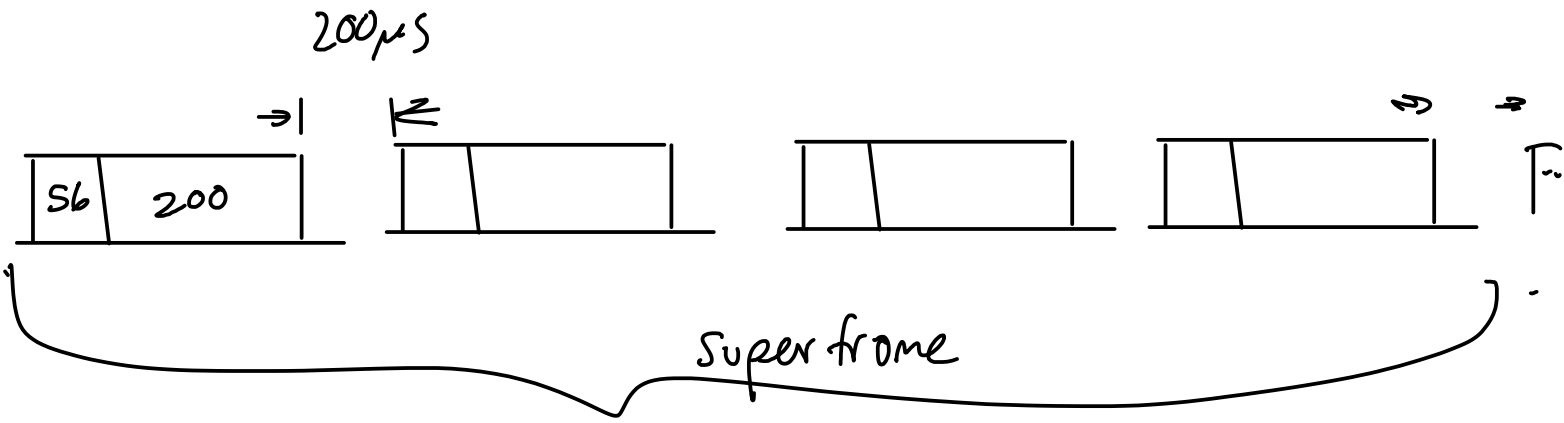
$+ 1 \times 3 = 3$

73 total bit error

$$FER = \frac{\#\text{frames with errors}}{\#\text{frames}} = \frac{56}{10^6} = 5.6 \times 10^{-5}$$

$$BER = \frac{\#\text{bits in error}}{\#\text{bits}} = \frac{73}{10^8} = 7.3 \times 10^{-7}$$

Exercise 12: 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?



$$\frac{\#\text{ useful bits received}}{\text{Superframe duration.}} = \frac{200 \text{ bytes} \times 8 \text{ bits/byte.}}{}$$

bits/byte

$$\text{frame duration} = \frac{\#\text{bits}}{1\text{ Mb/s.}} = \frac{(56+200)\times 8}{10^6} = 2048 \times 10^{-6}$$

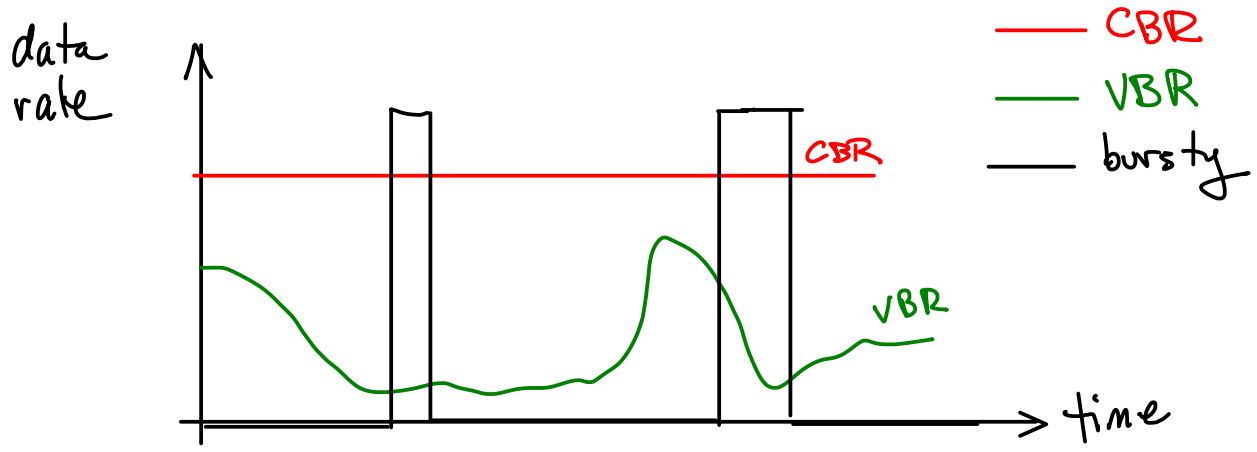
$$\text{superframe} = 4 \times (\text{frame duration} + \text{gap duration})$$

$$= 4 \times (2048 \times 10^{-6} + 200 \times 10^{-6}) = 8992\,\mu s$$

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

if 10% are "lost" throughput = $178 \cdot (1-10\%) \simeq 160$ kb/s.

Exercise 13: 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?*).



Exercise 14: 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 errors	tolerance to delay
phone call	yes	$\ll$ 100's of ms.
texting	yes	yes
downloading program	no	$\approx$ seconds, minutes?
video streaming	yes? no?	yes? no?