Lecture 1 – **Introduction to Data Communication**

Exercise 1: How many bits would be required to uniquely identify 100,000 different characters? (Hint: $2^{16} = 65536$).

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

Exercise 2: 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?

7 C 7 3

z y x

0111 1100 0111 0011

zzzzyyyy yyxxxxxx	1110zzzz	10yyyyyy	10xxxxxx

zzzz = 0111

yyyyyy = 1100 01

xxxxxx = 110011

1110 0111 10 110001 10 110011

E 7 B 1 B 3

Exercise 3:

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.*

0x35, 0x32, 0x35

text

525
512 = 0x200 = 2^9
13
8 = 0x08 = 2^3
5
4 = 0x04 = 2^2
1
1 = 0x01 = 2^1
0

0x 020d → binary

Which of these two sequences of bits is the text format and which is the binary format? How many more bits would need to be stored or transmitted for the text format?

text : need 3 bytes x 8 bits/byte = 24 bits

binary : 2 byte " = 16 bits

Exercise 4: 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 = 0x20d

= 0000 0010 0000 1101

0 2 0d

1011 0000 0100 0000 LE, lsb first

0000 0010 0000 1101 BE, msb-first

Exercise 5: 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	channel	sink	uses network?
cell phone call	person cell phone	free space	person	y
YouTube video	server	F.O. cable wireless	person	y
uploading lab report	PC	many various	server	y

$2^3 = 2\times2\times2 = 8$

$\log_2 2^3 = 3$

$\log_{10} 100 = 2$

$2^{-3} = \frac{1}{2^3} = \frac{1}{8}$

$\log_2 2^{-3} = -3$

Exercise 6: 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?

$\sum P_i = 1$

$.125 = \frac{1}{8}$

$.25 = \frac{1}{4}$

$\frac{1}{8} + \frac{1}{8} + \frac{1}{4} + x = 1$

$x = 1 - \frac{1}{2} = \frac{1}{2}$

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

$\log_2\left(\frac{1}{4}\right) = -2$

$\log_2\left(\frac{1}{2}\right) = -1$

$-\log_2\left(\frac{1}{2}\right)$

$= \log_2(2) = \log_2(2^1) = 1$

$-\log_2\left(\frac{1}{4}\right)$

$\log_2(4) = \log_2(2^2) = 2$

$H = \sum\left(-\log_2 P_i\right)\cdot P_i$

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

$H = \frac{3}{8} + \frac{3}{8} + \frac{4}{8} + \frac{4}{8} = \frac{14}{8} = 1\frac{6}{8} = 1.75$ bits/message

" ln "

Information rate = $H \cdot R$ ← messages/second

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

$H = 4 \times \frac{1}{4} \cdot 2 = 2$ bits/message   200 bits/second.

(↑ $2 = -\log_2(\frac{1}{4})$)

1 kB $2^{10} = 1024$

1 MB $2^{20} = (1024)^2$

Exercise 7: How long will it take to transfer 1 MByte at a rate of 10 kb/s?

1 M Byte = 10^6 bytes (← telecom) or $(2^{10})^2 = 2^{20}$ bytes? (← computer memory)

10 kb/s.

$= \frac{8 \cdot 2^{20}}{10 \times 10^3}$

839 s if 2^{20} bytes

800 s if 10^6 bytes

note: $10 \times 10^3 = 1 \times 10^4 = 10^4$

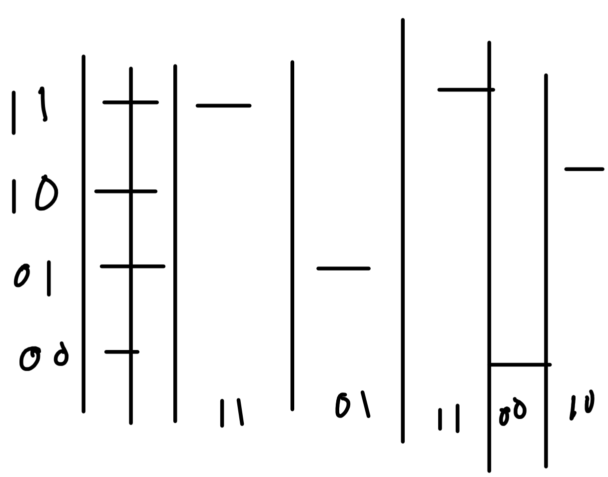
Exercise 8: In the example above each group of 3 bits is used to select a symbol. How many different symbols do we need? If the bit rate is 12 kbps, what is the symbol rate?

need $2^3 = 8$ symbols

(000, 001, 010, ⋮, 111)

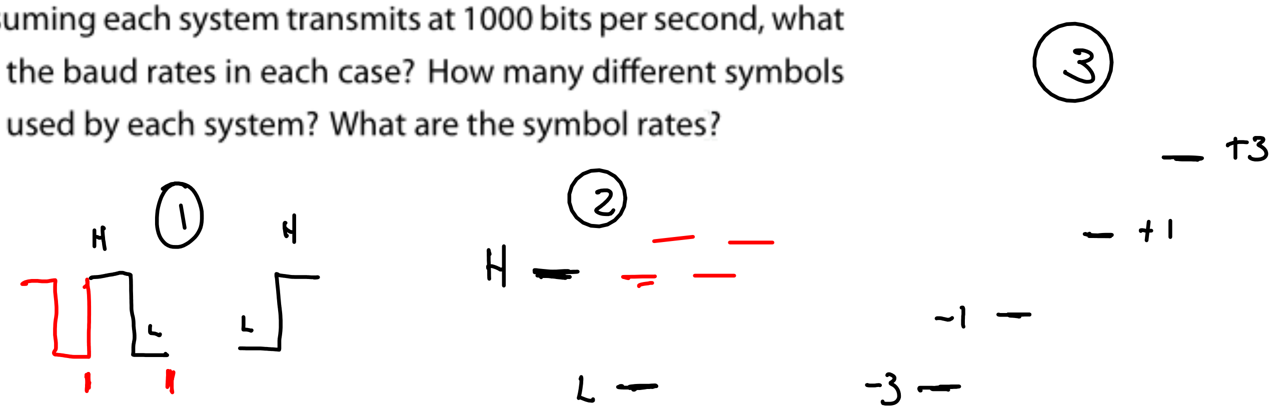
111 111 111

$12\,000 \frac{\text{bits}}{\text{second}} \cdot \frac{1}{3} \frac{\text{symbols}}{\text{bit}} = 4\,000 \frac{\text{symbols}}{\text{second}}$



← multiple levels (one way to encode multiple bits/symbol)

Exercise 9: 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?



all 1000 bps.

	(1)	(2)	(3)	units
# symbols	2	2	4	symbols
bits/symbol	1	1	$2 = \log_2(\#\text{symbols})$	
symbol rate?	1000/1	1000/1	$\frac{1000}{2} = 500$	symbols/second
baud rate	$2 \cdot 1000 = 2000$	1000	500	Hz

Exercise 10: 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?

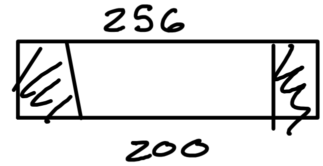
40 – 1 err
15 – 2 err
1 – 3 err

100×10^6 frames
100 bits / frame

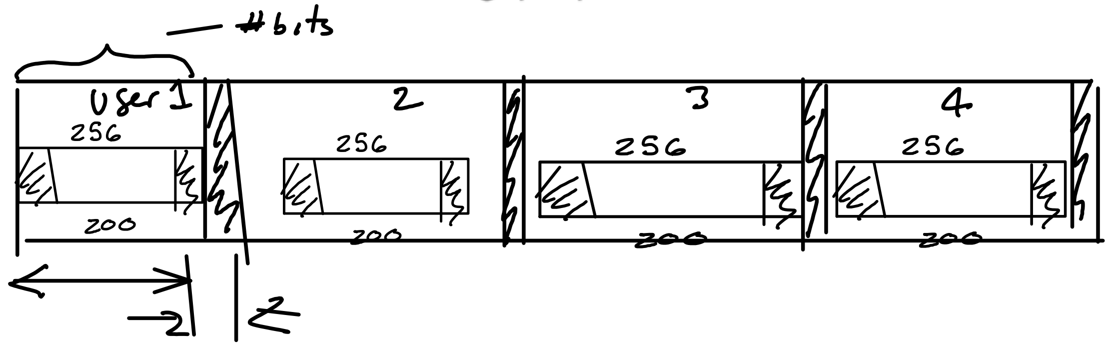
$$FER = \frac{56 \text{ frames in error}}{10^6 \text{ frames}} = 56 \times 10^{-6} = 56 \times 10^{-1} \times 10^{-6} \times 10^{1} = \underline{5.6 \times 10^{-5}}$$

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

Exercise 11: 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?



$$\text{throughput} = \frac{\text{bits}}{\text{time}} = \frac{1600}{?}$$



usable bits per user = 1600

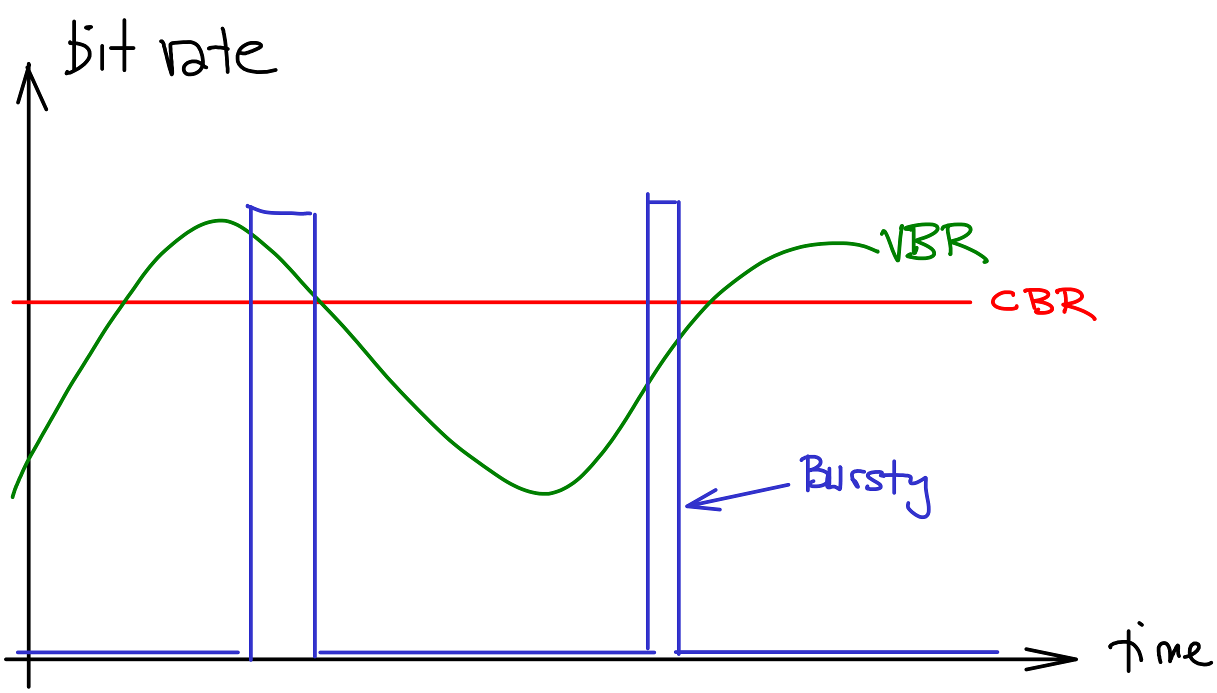
$$\text{time} = 4 \times \left(200\mu s + \frac{8 \times 256}{1\,\text{Mb/s}}\right)$$

superframe

$$= \frac{1600}{4 \times (200 \times 10^{-6} + 2048 \times 10^{-6})}$$

$$= 178 \text{ kb/s}$$

Exercise 12: 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 13: 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 of		tolerable
	errors	delay	max delay?
phone call (H–H interact)	Y	N	< 100ms (200ms)
"texting" (non-interactive)	somewhat	Y	minute?
downloading s/w	N	Y	hours?
streaming video	some types	Y	start-up: 10's of s.

Exercise 14: Highlight or underline each term where it is defined in these lecture notes.