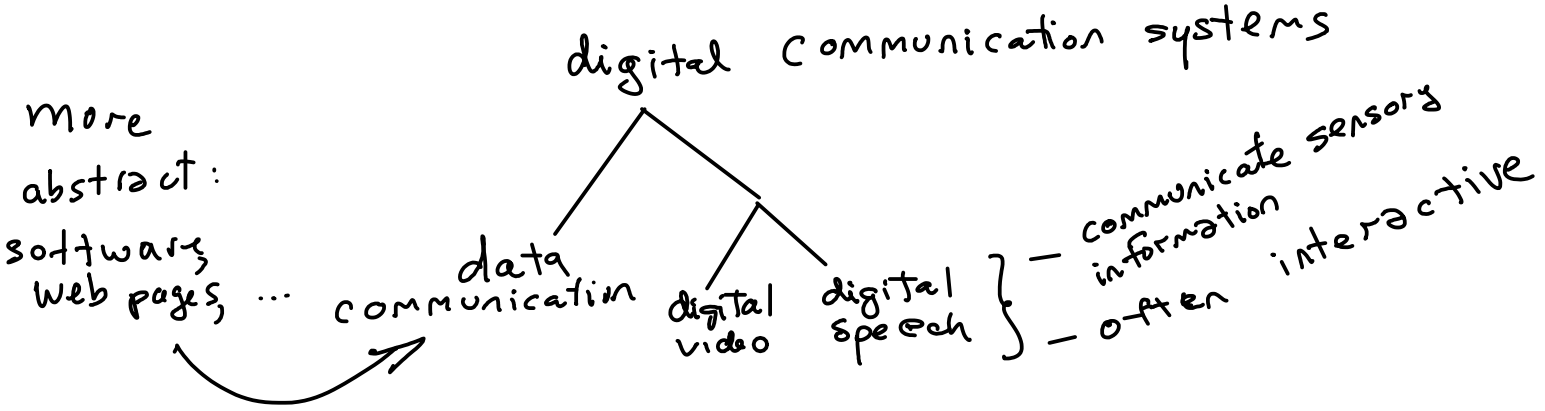
Lecture 1- Introduction to Data Communication

Exercise 1: For each of the following digital communication services identify the source, sink and the channel(s) involved: a cell phone call ; watching a YouTube video; downloading a file.

	source	sink	channels
cell phone	person	person	free space
Internet video	computer, server	viewer	Wifi, FO, co-ax, cable T.P.
downloading a file	computer	computer client	//



Exercise 2: A source generates four different messages with probabilities 0.125, 0.125, 0.25 and 0.5. How much information is transmitted by each message? What is the entropy of the source? What if there were four equally-likely messages?

	P_i	$I_i = -\log_2(P_i)$	
m_0	$\frac{1}{8}$	3	$\frac{3}{8}$
m_1	$\frac{1}{8}$	3	$\frac{3}{8}$
m_2	$\frac{1}{4}$	2	$\frac{2}{4}$
m_3	$\frac{1}{2}$	1	$\frac{1}{2}$
	sum = 1		1.75

P

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

$= -(-3) = 3$

$\log_2(4) = 2$

if equally likely

$P_i = \frac{1}{4} = 0.25$

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

$H = 4\left(\frac{1}{4} \cdot 2\right) = 2$ bits/message

e.g. 1 message $P = 1$ $I = 0$ $H = 0$

possible 3-bit sequences:

$$2 \times 2 \times 2 = 8$$

	y
0 0 0	+3 +5 +6
0 0 1	-1 3 2
0 1 0	
⋮	
1 1 1	

Review of Probability

: $0 \leq \text{prob} \leq 1$

probabilities sum to 1

100 %?
= 100 per 100
= 1 p.u. (per unit)

Message

bits: 2 messages (alarm, not alarm; 0, 1)

characters: 26 messages (A, B ... Z).

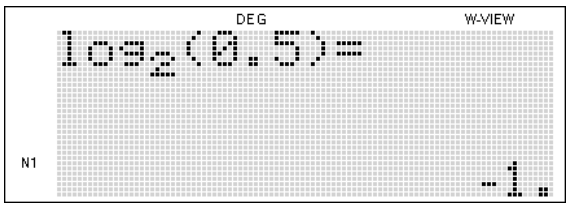
words: several thousand (... ,)

$$\log_2 8 = 3 \quad \text{because} \quad 2^3 = 8 \quad (\log_a a^b = b)$$

e.g. a message w/ prob. $\frac{1}{2}$

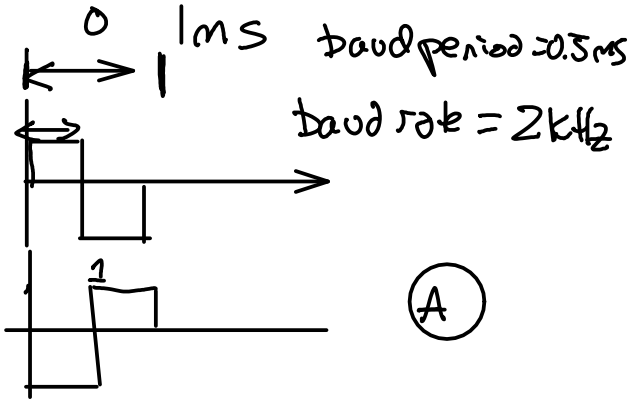
$$I = -\log_2 \left(\frac{1}{2}\right)$$

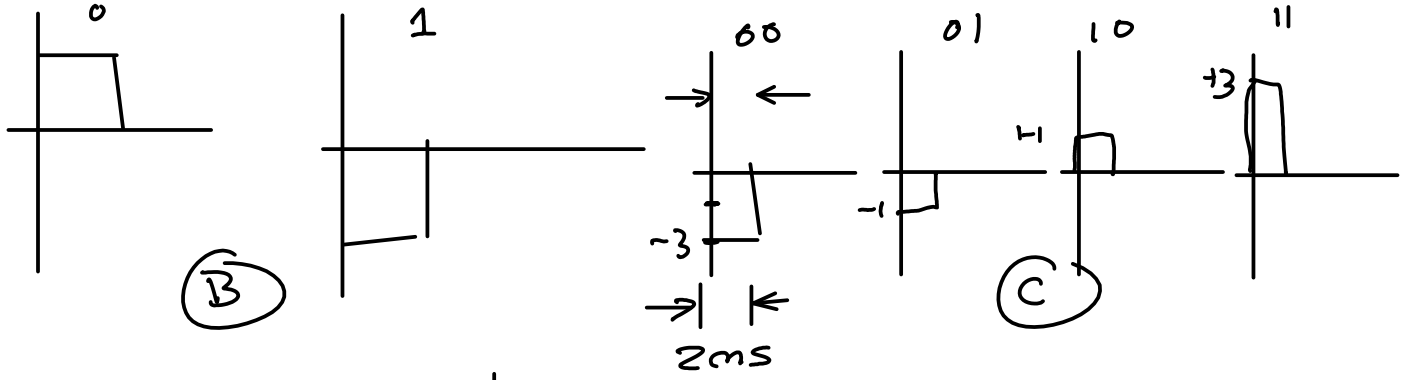
$$= -(-1) = 1$$



$$\log \frac{1}{a} = -\log a$$

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?





all transmit 1000 bps

	A	B	C
baud rate	2 kHz	1 kHz	500 Hz
# symbols	2	2	4
symbol rate	1 kHz	1 kHz	500

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?

10^6 frames total $= 10^8$ bits

40 frames have 1 bit error 40×1

15 2 bit errors $+ 15 \times 2$

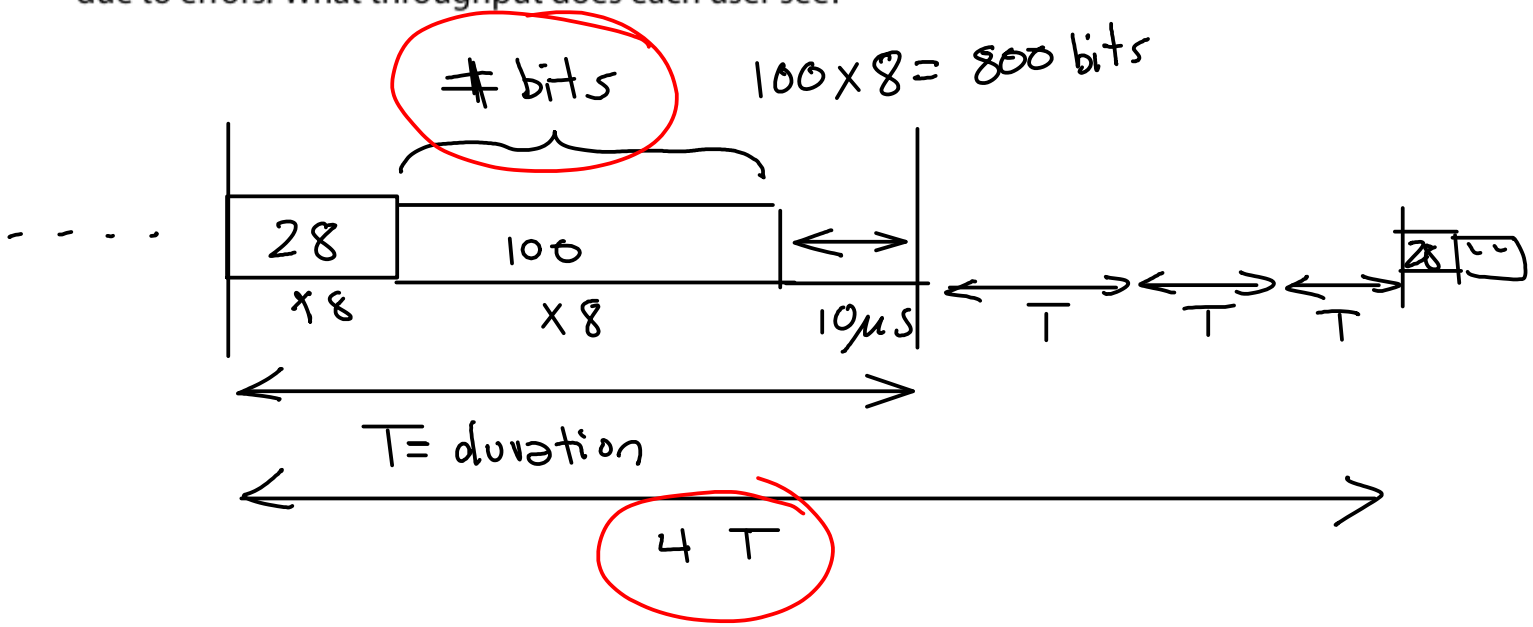
1 3 errors. $+ 1 \times 3$

73

$FER = 56 \times 10^{-6} \approx 6 \times 10^{-5}$

$BER = 73 \times 10^{-8} \approx 7 \times 10^{-7}$

Exercise 5: A system transmits data at a rate of 1 Mb/s in frames of 128 bytes. 100 of these bytes are data and the rest are overhead. The channel is shared between four users. There is a 10 μs gap between each packet. 10% of the frames are lost due to errors. What throughput does each user see?



128 bytes x 8 bits/byte = 1024 bits

$$T = \frac{1024 \text{ bits}}{1 \times 10^6} + 10 \times 10^{-6} = 1034\mu s = 1.034 ms$$

$4T \approx 4ms$

throughput = $\frac{800 \text{ bits}}{4ms} \times 90\%$ (1 − 10%)

= 180 Kb/s

Exercise 6: What features of a video source might result in a variable bit rate when it is compressed?

if the video is compressed by removing:

– similarities between successive frames:

motion will cause more diffences between frames & thus a higher data rate.

— similarities between adjacent pixels:
frames with more variability between pixels (higher spatial frequency content) will require a higher data rate.

Exercise 7: What units might be used to specify delay and delay variability? For each of the following data sources/sinks identify the relative data rate variability and the tolerance it is likely to have to errors, to the absolute delay and to the delay variability: a phone call between two people, downloading a computer program, streaming a video over a computer network. Try to guess typical values of tolerable delay.

delay is time & measured in seconds
delay variability is diffence in delays also measured in second, but often varies randomly & we speify the statistics (mean, median, minimum, standard deviation, etc.)

	phone call (2-way interactive)	downloading	streaming (1-way)
data rate variability	compressed: variable uncompressed: fixed	fixed (limited by slowest of network, source and sink)	same as phone call
tolerance to errors	higher (can ask to repeat)	zero	medium (due to inherent redundancy)
delay	low	high	high
delay variability	low unless buffered (gaps distort waveform)	high	as for phone but can tolerate larger buffer delay (not interactive)

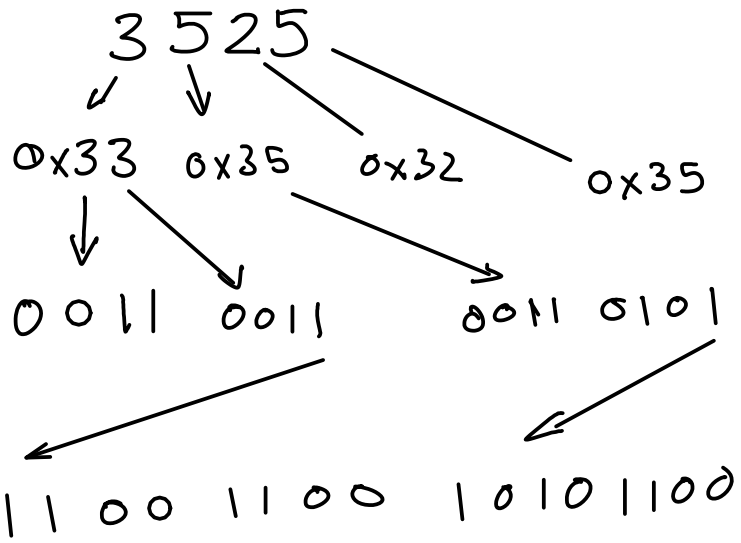
Exercise 8: How many bits would be required to uniquely identify 100,000 different characters? (Hint: $2^{16} = 65536$).

$2^{16} = 65536$

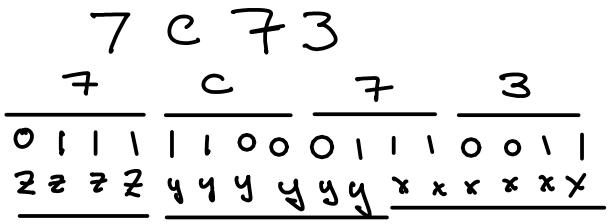
$2^{17} = 128K$ ∴ must use 17 bits/character

Exercise 9: Find the ASCII codes for the *characters* '3525'. 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.*

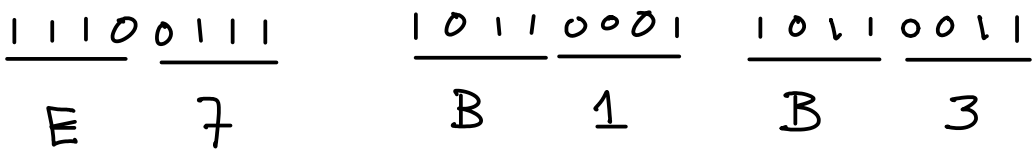
0x
0h
$



Exercise 10: 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?



zzzzyyyy yyxxxxxx	1110zzzz	10yyyyyy	10xxxxxx



Exercise 11: Convert the decimal number 3525 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".

by hand:

$3525 - 2048 = 1477 \quad 2^{11}$

$1477 - 1024 = 453 \quad 2^{10}$

$453 - 256 = 197 \quad 2^{8}$

$197 - 128 = 69 \quad 2^{7}$

$69 - 64 = 5 \quad 2^{6}$

$5 - 4 = 1 \quad 2^{2}$

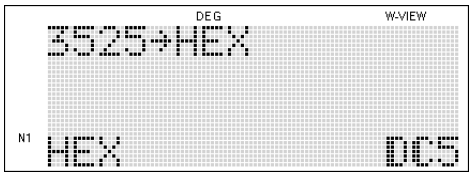
$1 - 1 = 0 \quad 2^{0}$

$\therefore 3525 = 2^{11} + 2^{10} + 2^{8} + 2^{7} + 2^{6} + 2^{2} + 2^{0}$

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	1	1	0	1	1	1	0	0	0	1	0	1

= 0000 1101 1100 0101

or, using calculator:



= 0000 1101 1100 0101

0 D C 5

in LSB-first order: 1011 0000 1101 1100

in network (MSB first): 0000 1101 1100 0101

Exercise 12: Write the 16-bit number above in hexadecimal notation.

0000 1101 1100 0101

0 D C 5

C syntax:

0xdc5

0x0dc5