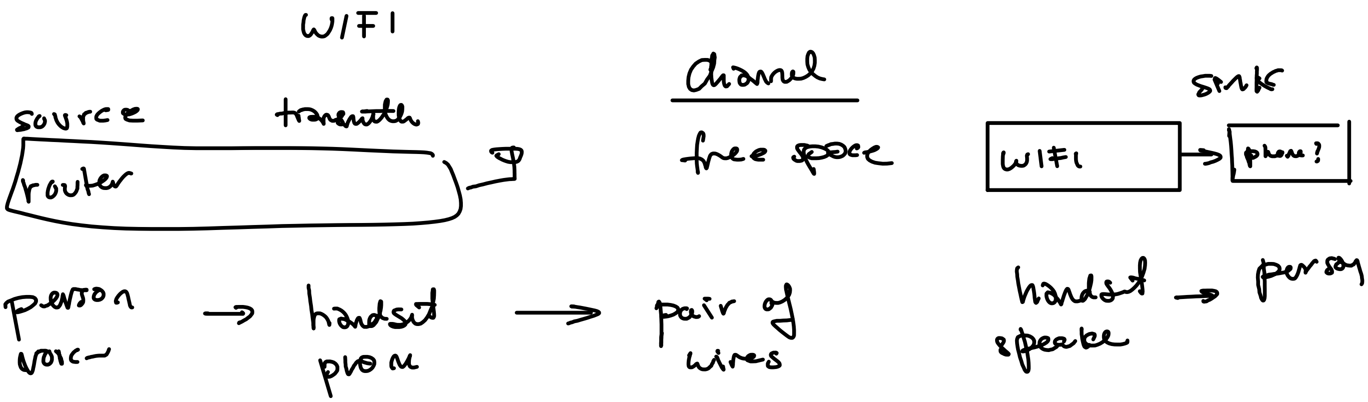
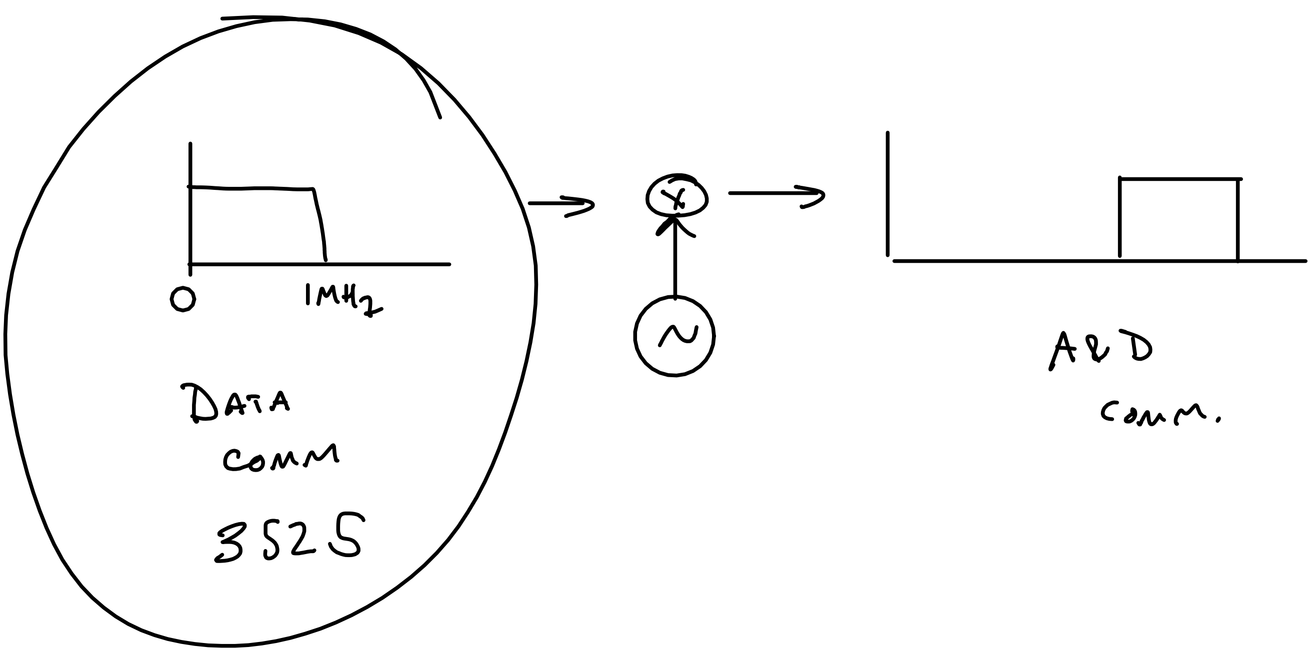
Exercise 1: Give some examples of communication systems and identify the channel, source, transmitter, receiver and sink for each one. Give some examples of networks and identify different channels and their associated transmitters and receivers.





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

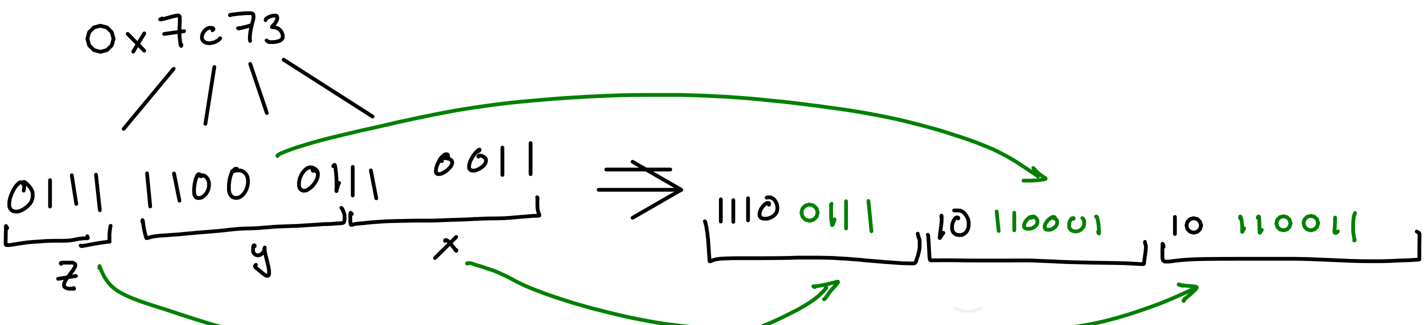
0 0 0 0 0

$2^{16} = 65535$ 2 bytes.

$2^{16} \cdot 2^{1} = 2^{17} = 128K$

"米"

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?



Scalar Value	First Byte	Second Byte	Third Byte	Fourth Byte
00000000 0xxxxxxx	0xxxxxxx			
00000yyy yyxxxxxx	110yyyyy	10xxxxxx		
zzzzyyyy yyxxxxxx	1110zzzz	10yyyyyy	10xxxxxx	
000uuuuu zzzzyyyy yyxxxxxx	11110uuu	10uuzzzz	10yyyyyy	10xxxxxx

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.*

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?

525
512 2^9
13
8 2^3
5
4 2^2
1
1 2^0

$525 = 2^9 + 2^3 + 2^2 + 2^0$

10 0000 1101

525 = 0x 0 2 0 D ← 'C' language prefix

"525" = 0x35, 0x32, 0x35

0x 20D how many bits?

0011 0101 , 0011 0010 , 0011 0101
'5' '2' '5'

assume bits transmitted L.S. bit first:

"525"

1,0,1,0, 1,1,0,0, 0100 1100 1,0,1,0, 1,1,0,0,

525

10 0000 1101 ← 525

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.

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'?

1200 = E

$$\frac{1200}{10{,}000} = 0.12 = 12\%$$

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?

$$P_0 = 0.125 = \frac{1}{8}$$

$$P_1 = \text{"} \quad \text{"}$$

$$P_2 = 0.25 = \frac{1}{4}$$

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

	$-\log_2(P_i)$	P_i
$I_0 = -\log_2(P_0) =$	3	$\frac{1}{8}$
$I_1 =$	3	$\frac{1}{8}$
$I_2 =$	2	$\frac{1}{4}$
$I_3 =$	1	$\frac{1}{2}$

$$\sum_i -\log_2(P_i) \cdot P_i = 3 \cdot \frac{1}{8} + 3 \cdot \frac{1}{8} + 2 \cdot \frac{1}{4} + 1 \cdot \frac{1}{2}$$

$$= \frac{3}{4} + \frac{1}{2} + \frac{1}{2} = 1.75 \text{ bits/message.}$$

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

Exercise 9: A communication system transmits one of the symbols above each microsecond. The probability of each symbol being transmitted is given above each symbol. What are the bit rate, the symbol rate, the information rate and the baud rate?

Exercise 10: Another system, as shown above, 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? Assuming each symbol is equally likely, what are the information rates?

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?

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 ”s 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?

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?

Exercise 15: Highlight or underline each term where it is defined in these lecture notes.