

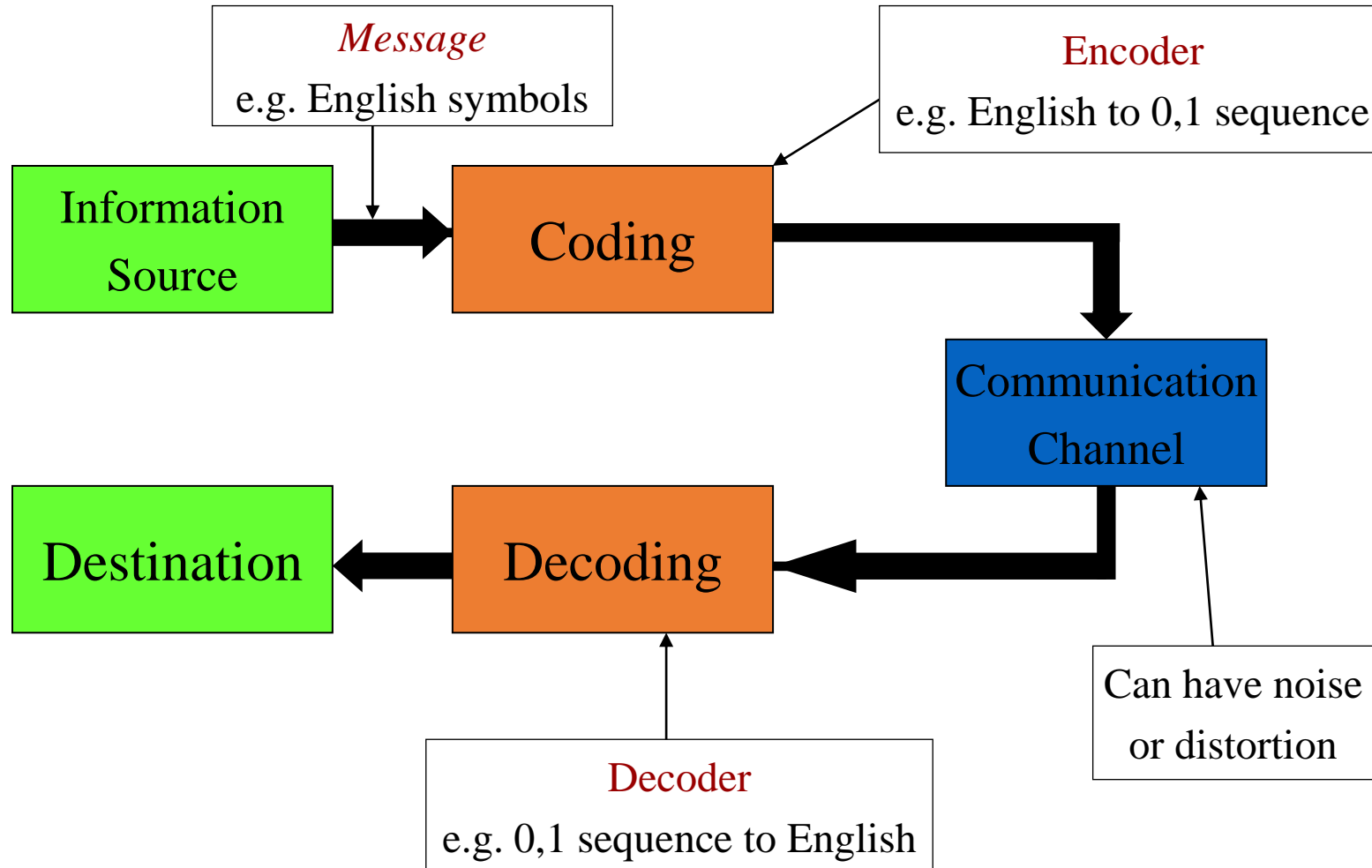
How can we represent information

# Father of Digital Communication



The roots of modern digital communication stem from the ground-breaking paper “A Mathematical Theory of Communication” by **Claude Elwood Shannon** in 1948.

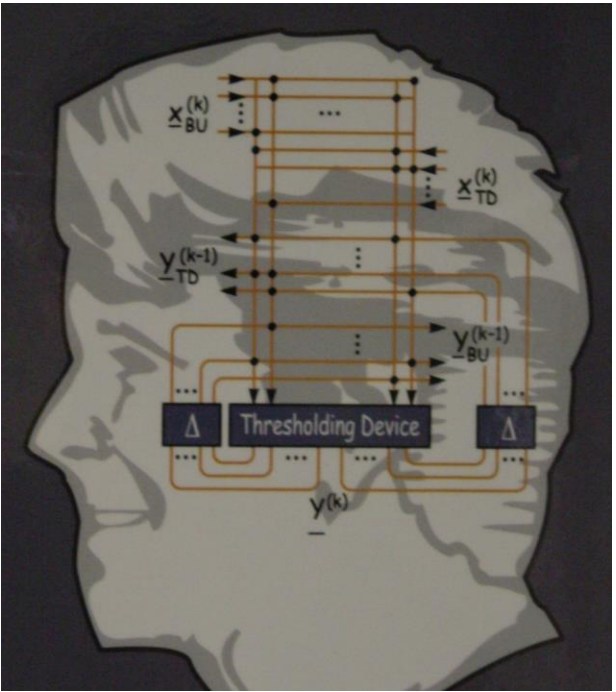
# Model of a Digital Communication System



# Communication Channel Includes



And even this...



# Shannon's Definition of Communication



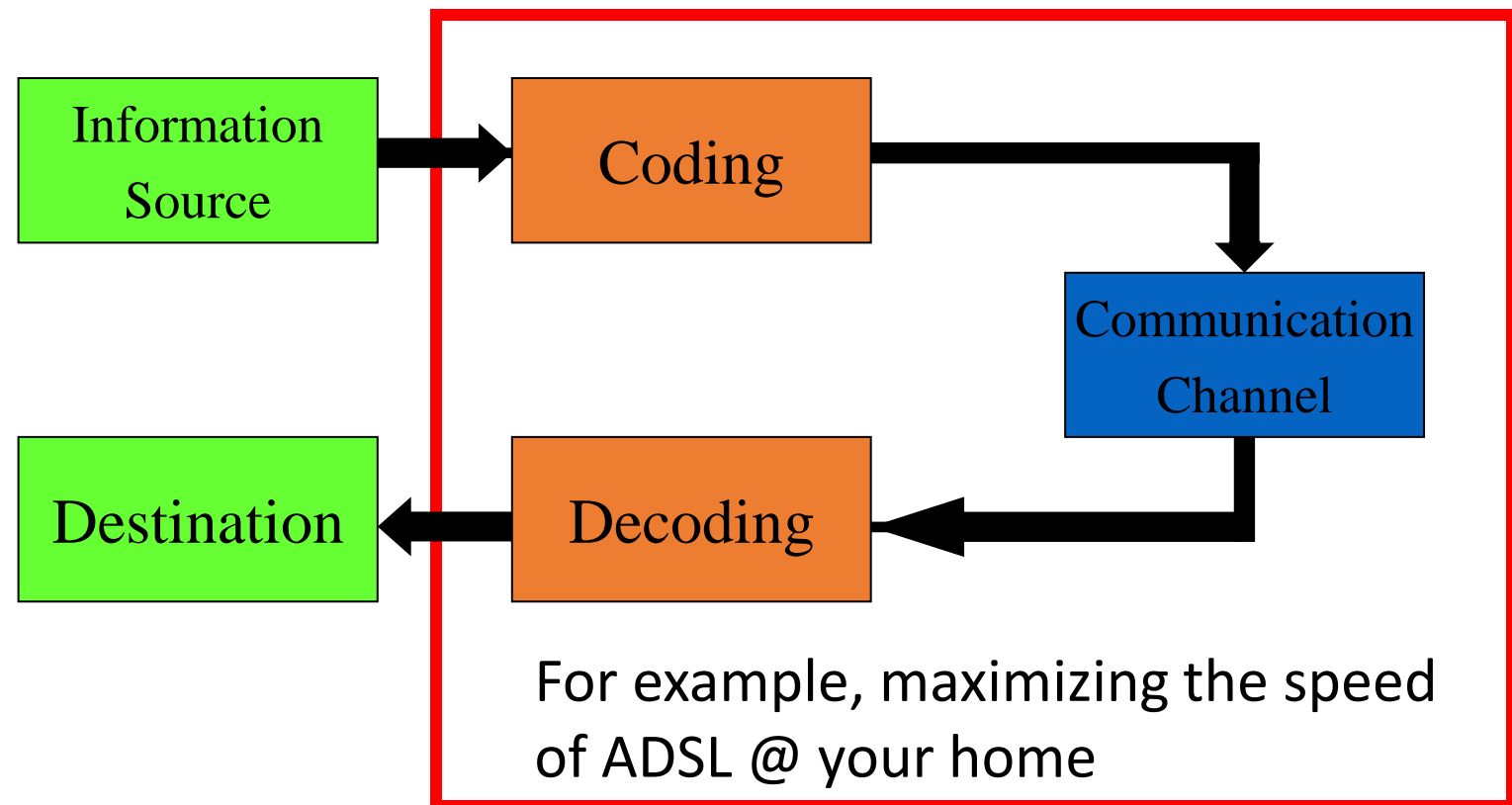
**“The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point.”**

**“Frequently the messages have *meaning*”**

**“... [which is] irrelevant to the engineering problem.”**

# Shannon Wants to...

- Shannon wants to find a way for “**reliably**” transmitting data throughout the channel at “**maximal**” possible rate.



And he thought about this problem for a while...



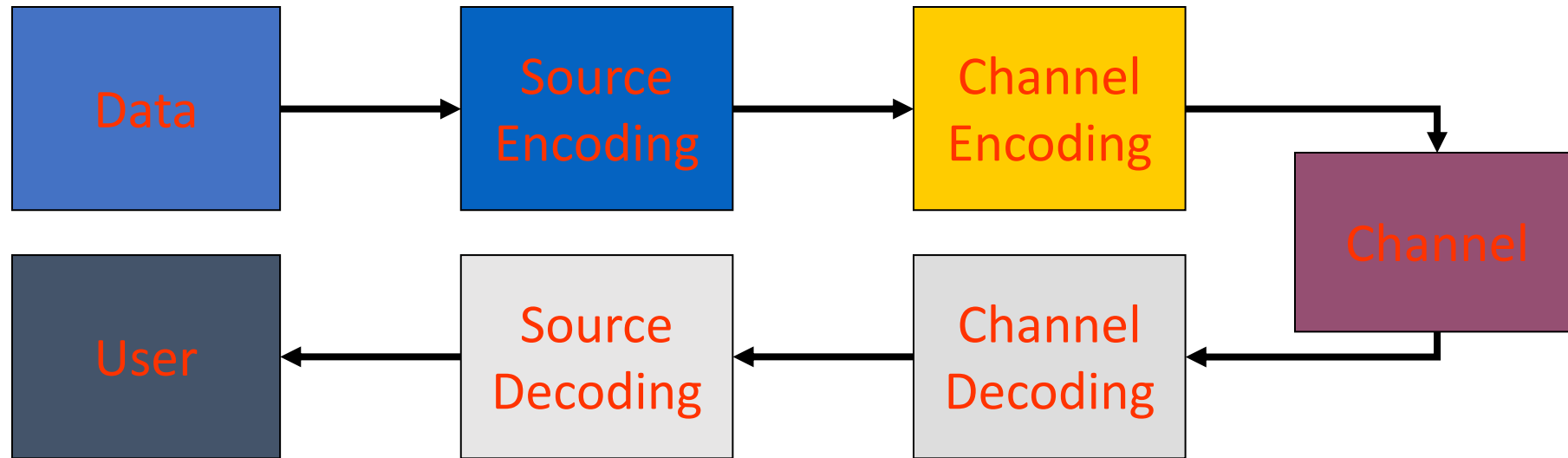
**He later on found a solution and published in this 1948 paper.**



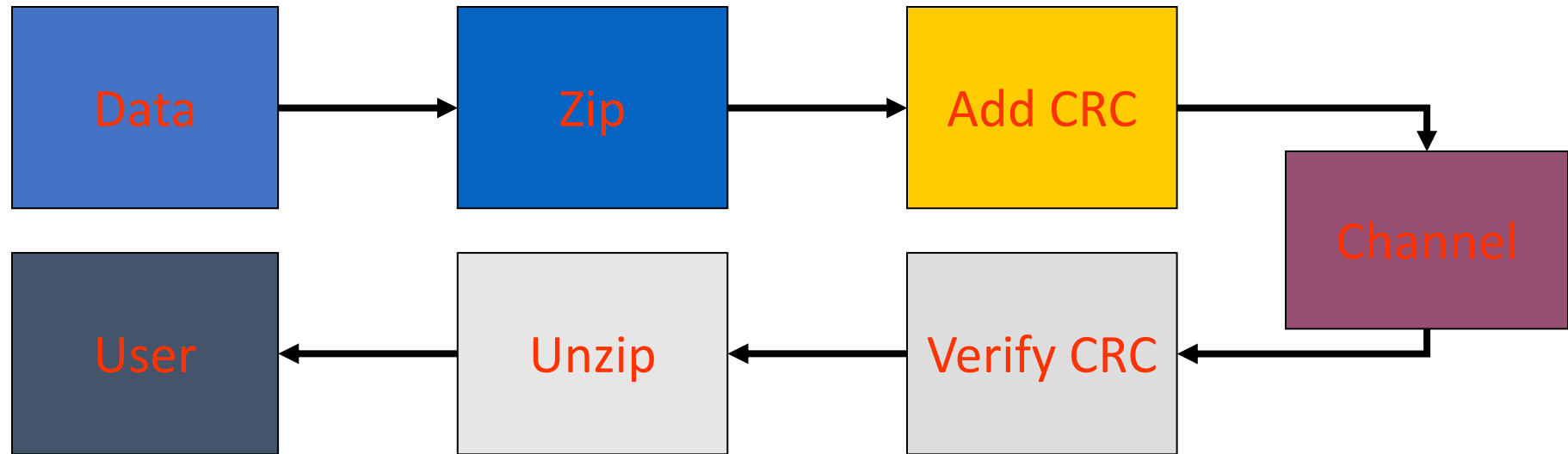


In his 1948 paper he build a rich theory to the problem of reliable communication, now called “**Information Theory**” or “**The Shannon Theory**” in honor of him.

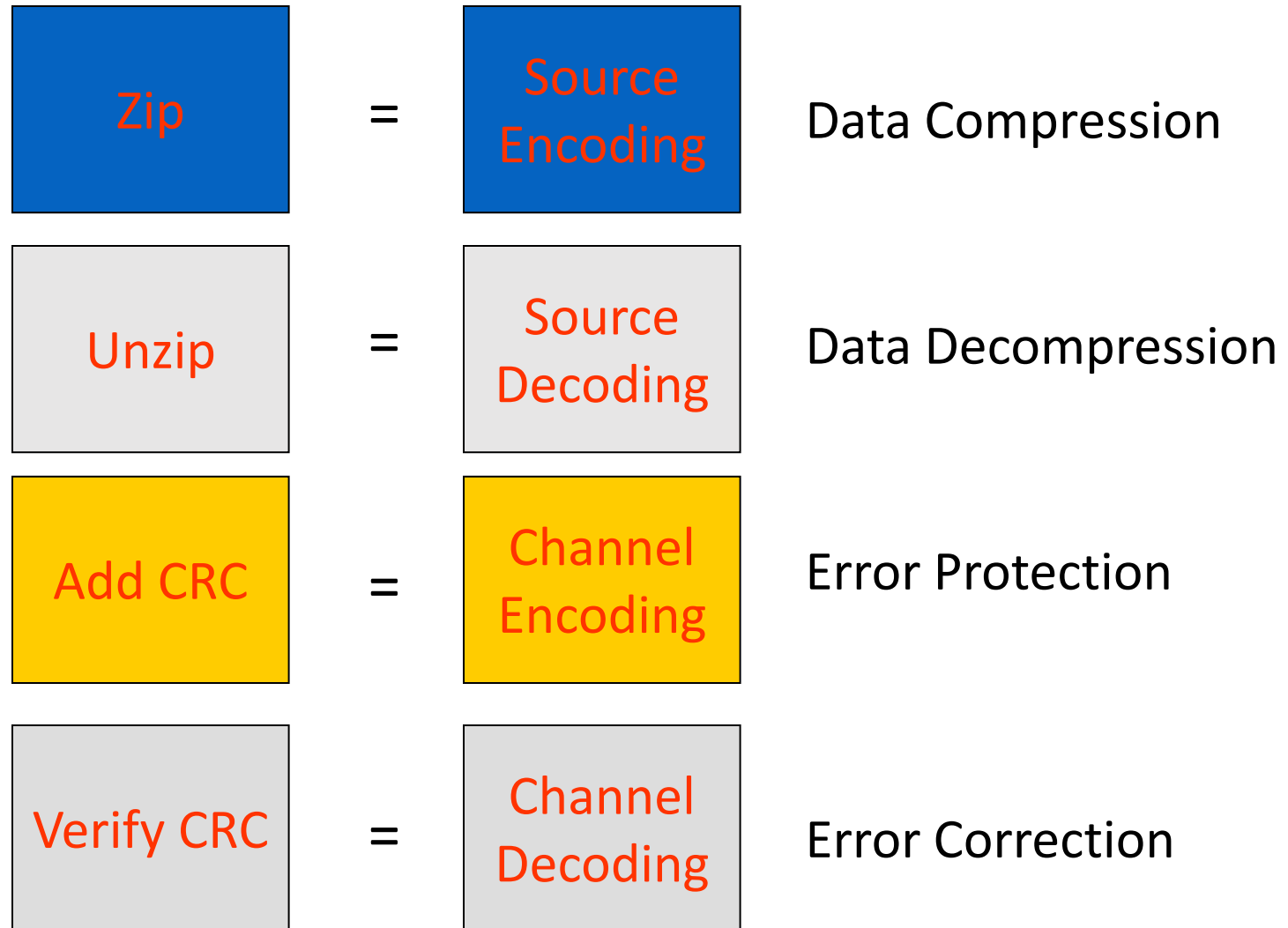
# Shannon's Vision



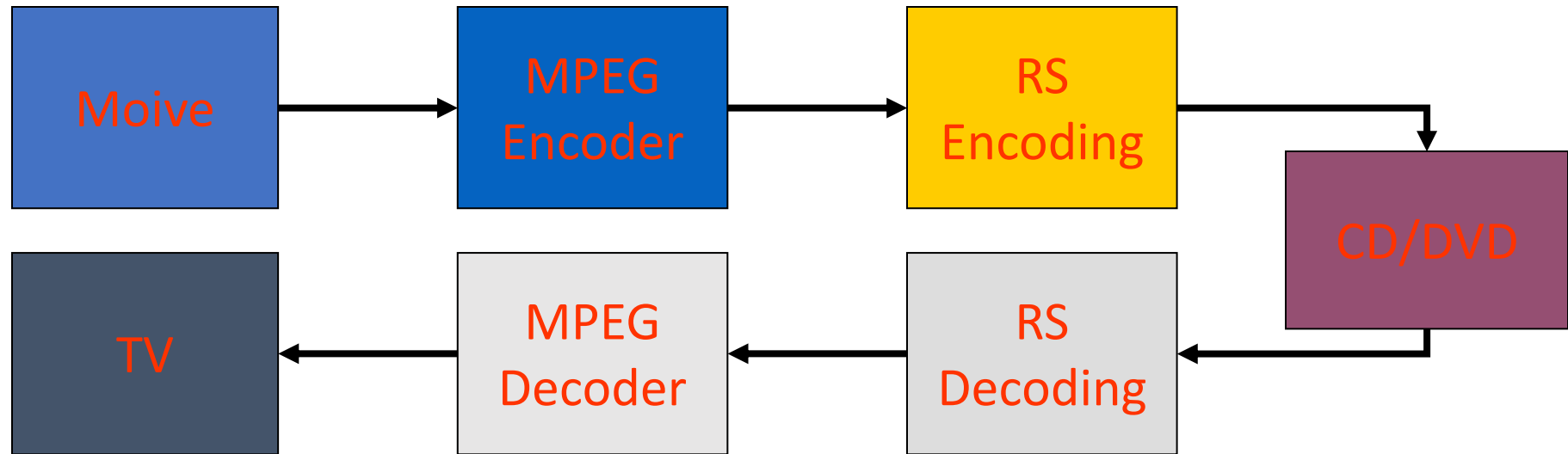
# Example: Disk Storage~



# In terms of Information Theory Terminology

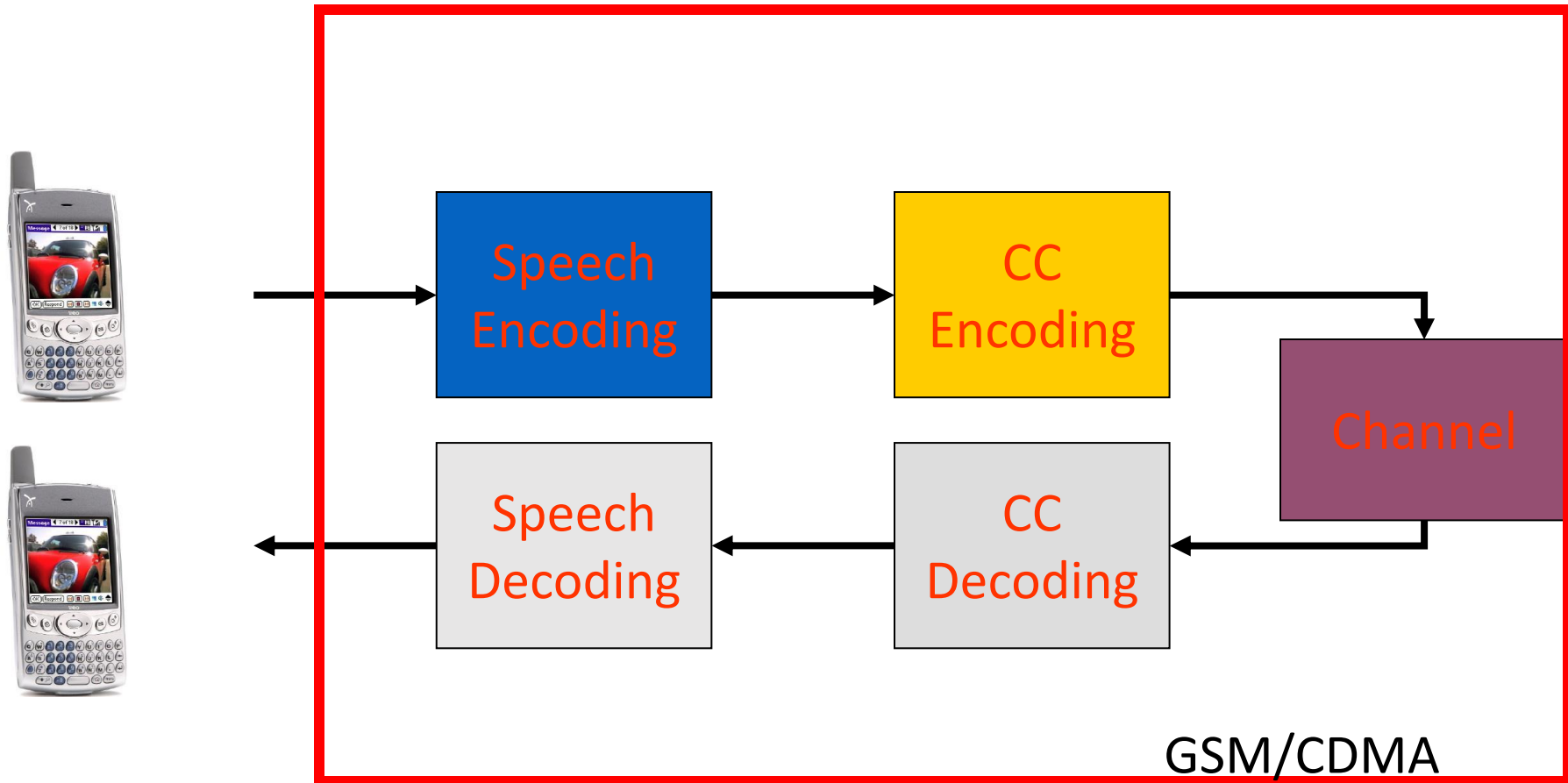


# Example: VCD and DVD



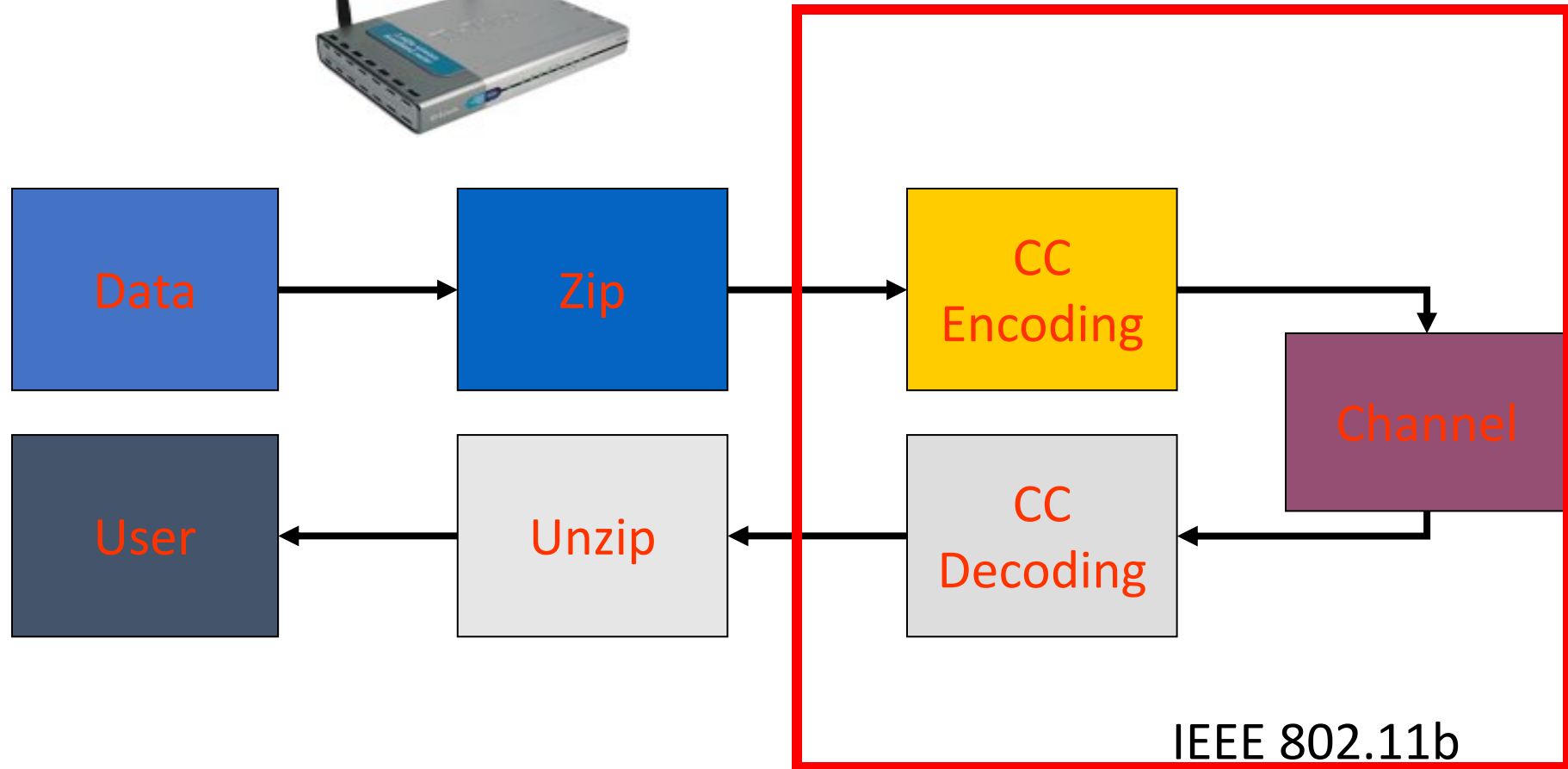
RS stands for Reed-Solomon Code.

# Example: Cellular Phone



CC stands for Convolutional Code.

# Example: WLAN IEEE 802.11b



CC stands for Convolutional Code.

# Shannon Theory

- The original 1948 Shannon Theory contains:
  1. Measurement of Information
  2. Source Coding Theory
  3. Channel Coding Theory



# Measurement of Information

- Shannon's first question is

“How to measure information  
in terms of bits?”



= ? bits



= ? bits

# Or Lottery!?



= ? bits



Or this...

Mars



= ? bits



= ? bits

# All events are probabilistic!

- Using Probability Theory, Shannon showed that there is **only one way** to measure information in terms of number of bits:

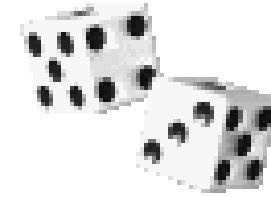
$$H(X) = -\sum_x p(x) \log_2 p(x)$$

called the **entropy function**

# For example

- Tossing a dice:

- Outcomes are 1,2,3,4,5,6
- Each occurs at probability 1/6
- Information provided by tossing a dice is



$$\begin{aligned} H &= -\sum_{i=1}^6 p(i) \log_2 p(i) = -\sum_{i=1}^6 p(i) \log_2 p(i) \\ &= -\sum_{i=1}^6 \frac{1}{6} \log_2 \frac{1}{6} = \log_2 6 = 2.585 \text{ bits} \end{aligned}$$

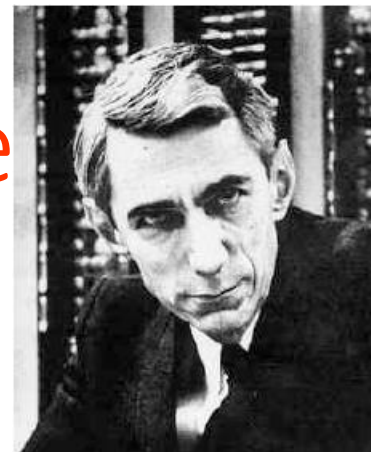


Wait!  
It is nonsense!

The number 2.585-bits is not an integer!!

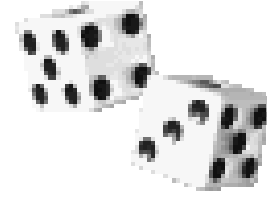
What does you mean?

# Shannon's First Source Coding Theorem



- Shannon showed:  
“To reliably store the information generated by some random source  $X$ , you need no more/less than, on the average,  $H(X)$  bits for each outcome.”

# Meaning:



- If I toss a dice 1,000,000 times and record values from each trial  
1,3,4,6,2,5,2,4,5,2,4,5,6,1,....
- In principle, I need 3 bits for storing each outcome as 3 bits covers 1-8.  
So I need **3,000,000** bits for storing the information.
- Using ASCII representation, computer needs **8 bits=1 byte** for storing each outcome
- The resulting file has size **8,000,000** bits



# But Shannon said:




- You only need 2.585 bits for storing each outcome.
- So, the file can be compressed to yield size

$$2.585 \times 1,000,000 = 2,585,000 \text{ bits}$$

- Optimal Compression Ratio is:

$$\frac{2,585,000}{8,000,000} = 0.3231 = 32.31\%$$

# Let's Do Some Test!

	File Size	Compression Ratio
No Compression	8,000,000 bits	100%
Shannon 	2,585,000 bits	32.31%
Winzip 	2,930,736 bits	36.63%
WinRAR 	2,859,336 bits	35.74%