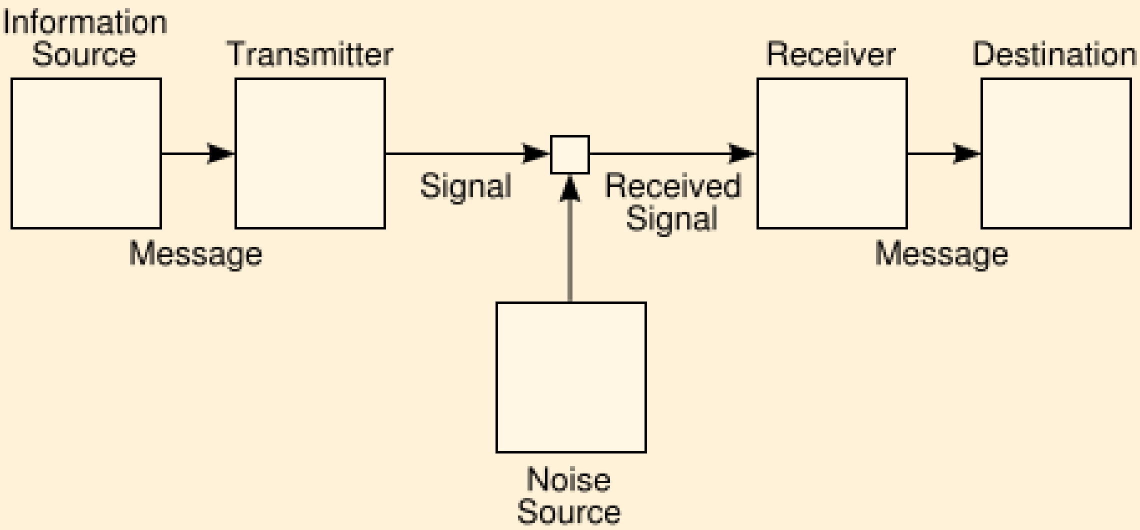
9.1 General Communication Systems

- Draw the "Shannon-Weaver Communication System" diagram and label the components.

Solution:



- For each component, describe what it does and how it is affecting the information through the process of communication.

Solution:

Information Source: Decides on which intelligence is to be transmitted. This information can be generated by some source (sensor) or human who want to communicate something.

Transmitter: Encodes the information into something that can be physically transmitted (signal). For instance turning voice into currents sent over radio antennas or more digital solutions.

Noise Source: Every physical process is prone to noise. The environment deteriorates the signal and modifies it thereby. It could well be possible that the signal vanishes completely, in which case there is no communication possible. Usually there are models for this, e.g. Gaussian Noise, Packet Erasure, Gilbert-Elliot, ...

Receiver: Reconstructs the original message from the received signal. Hence it decodes the signal, tries to compensate for the noise and detects possible errors that happened on the connection.

Destination: The displaying subject (monitor, loudspeaker) or human being to receive the message.

9.2 Weird Communication System

You are transmitting data using quantum coupled 24-side dices. The system works quite easy: If you roll a dice, your friend's dice will show the same side (which is the "symbol"). Rolling a die and detecting which side is on top takes 2 seconds.

- How many bits do you need to map each symbol to a different bitstring?

Solution:

$$24 options \rightarrow 2^5 = 32 > 24 \rightarrow 5 bit$$

- How many bits of information does one symbol carry?

Solution:

$$24options \rightarrow ld(24) = 4,584bit$$

- For now assume that you can encode 4 bit in one symbol. What is your data rate?

Solution:

$$\frac{4bit}{2s} = 2.0bps$$

- How many sides should the die have to achieve 64kbps?

Solution:

$$64kbps \cdot 2s = 128kb = 131072bit \rightarrow \ 4 \cdot 10^{39456}$$

- What would be a better way to increase the data rate?

Solution: Shorten the time required to transmit a symbol. Transmit many symbols in parallel.

9.3 Marathon Telecommunications

Remember the Marathon runner from the first lecture. Our goal is to use his running activity to achieve a similar data rate to your home DSL connection (16Mbit/s). He is still running moderate pace of 5min/km for the complete distance of 42km.

- Which size should the hard disk he carries have to achieve the aforementioned data rate?

Solution:

$$16Mbps \cdot (210 \cdot 60s) = 16Mbps \cdot 12600s = 2MBps \cdot 12600s = 25200MB = 24GB$$

- Now assume he carries a 16 GB USB stick. Would it be possible for him to achieve the data rate, e.g. by using a bicycle?

Solution:

$$\begin{aligned} 16GB &= 8 \cdot 16Gbit = 128Gbit \\ &= 128 \cdot 1024MBit = 131072Mbit \\ \frac{131072Mbit}{16Mbps} &= 8192s \\ \frac{42,000m}{8192s} &= 5m/s = 3.6 \cdot 5km/h = 18km/h \end{aligned}$$

9.4 Delays

You are sending packets with maximum size 1500 byte over 1Gbit cables (rate: 1Gbps) with length 1km. The optical fibre operates with speed of light as $(2 \cdot 10^8 \frac{m}{s})$ The responding server takes 1ms to process your order and sends packets with the same size back.

- How large is your transmission delay?

Solution:

$$1500byte = 12000bit \rightarrow \frac{12000bit}{1 \cdot 1024^3 bps} = 11.175us = D_t$$

- What is the propagation delay using the optical fibre?

Solution:

$$\frac{1000m}{2 \cdot 10^8} = 5us$$

- How long is the RTT measured by your application?

Solution:

$$2 \cdot D_p + 2 \cdot D_t + D_s = 2 \cdot 5us + 2 \cdot 11.175us + 1ms = 1.03235ms$$

9.5 Web Performance

You download a website with one HTML file (size: 12kB) which contains links to 5 JPG images (size: 100kB each). You have a 16Mbps Internet connection and the one-way-trip time is 10ms. Processing is done instantly ($D_s = 0s$). Teardown is not considered (while closing, you already open the next connection).

- How long does it take until the complete page is loaded using non-persistent connections?

Solution: 6 Requests:

$$6 \cdot 2 \cdot RTT = 12 \cdot 2 \cdot 10ms = 240ms$$

Files:

$$12kB + 5 \cdot 100kB = 512kB \rightarrow \frac{512kB}{16Mbps} = \frac{4096 \cdot 1024bit}{16 \cdot 1024^2 bps} = \frac{4096bit}{16 \cdot 1024bps} = 250ms$$

Result:

$$240ms + 250ms = 490ms$$

- How long using persistent connections?

Solution: 6 Requests:

$$6 \cdot RTT + 1 \cdot RTT = 7 \cdot 2 \cdot 10ms = 140ms$$

Files: Unchanged.

Result:

$$140ms + 250ms = 390ms$$

9.6 Pipelining Utilization

You are running a pipelining protocol over a channel with RTT 100ms and your goal is to achieve a utilization of 100%. Packets have a size of 1500 Byte, the data rate is 1 Mbps.

- How many packets do you have to send in sequence (before awaiting an ACK) to achieve this goal?

Solution:

$$U = \frac{n \cdot L/R}{RTT + L/R} \Leftrightarrow n = U \cdot \frac{RTT + L/R}{L/R} \Leftrightarrow n = \frac{R}{L} \cdot RTT + 1$$

$$n = \frac{1Mbps}{1500Byte} \cdot 100ms + 1 = 87.38 \cdot 0.1 + 1 = 9.738 \approx 10$$