## Reasons for using bin. ary interface

1. Shannon has proven that it is a good way to do so
2. Hardware is a) very cheap and b) small
3. Standardization
4. Simplifies implementation and understanding

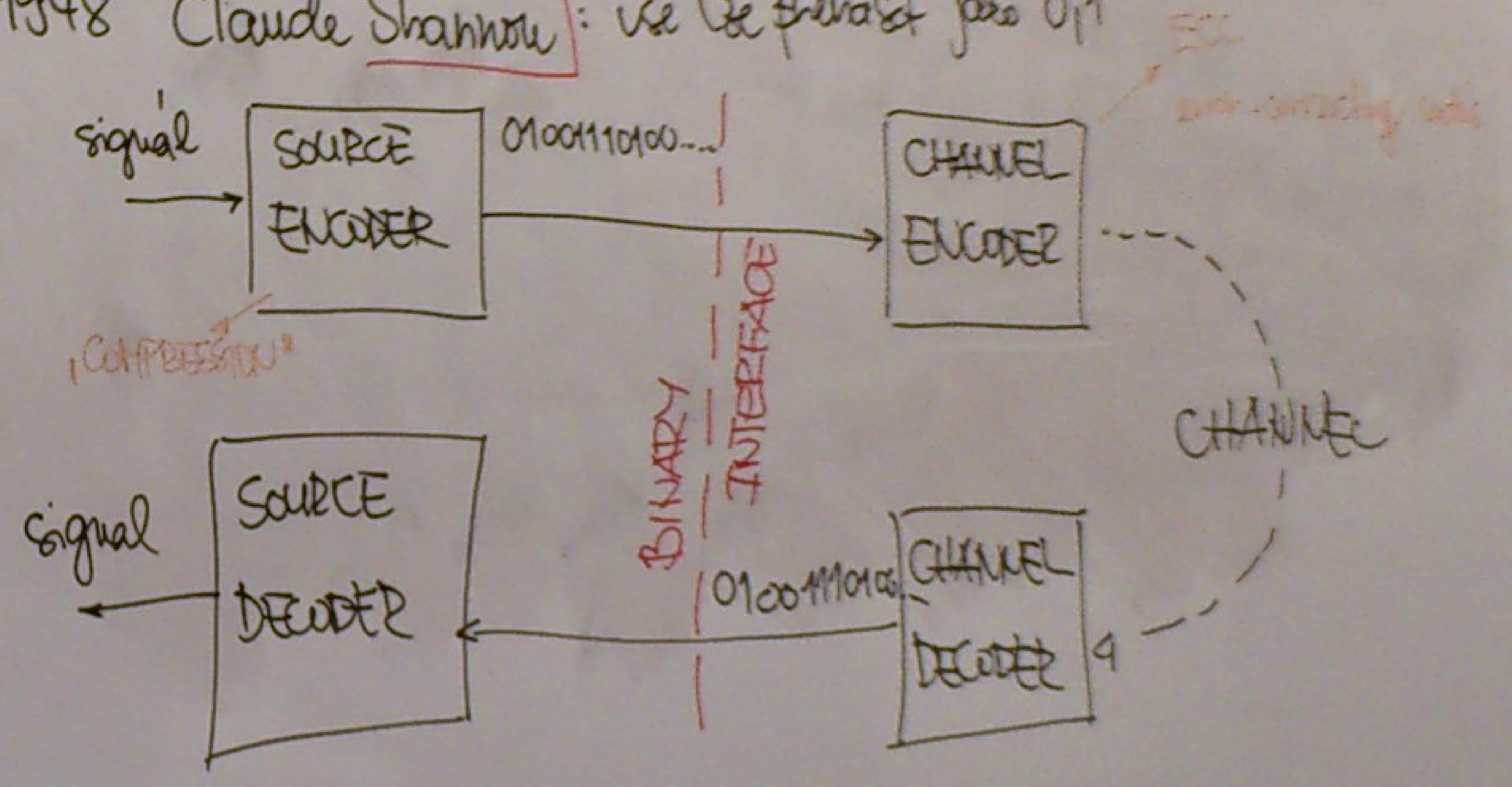
for single-source & single-reciever

Web postupně migruje:

http://zolotarev.fd.cvut.cz/ske/

**Digitální komunikace**

1948 Claude Shannon: vše lze převést jako 0,1



# SOURCE ENCODING

Communication source

- Nyquist: superimposed sine wave ⇒ Fourier analysis
- Shannon: random process ⇒ $\boxed{\text{information theory}}$

Example: $f(t) = a \cdot \sin(\omega t + \varphi)$ .....

↳ Shannon: $(a, \omega, \varphi)$

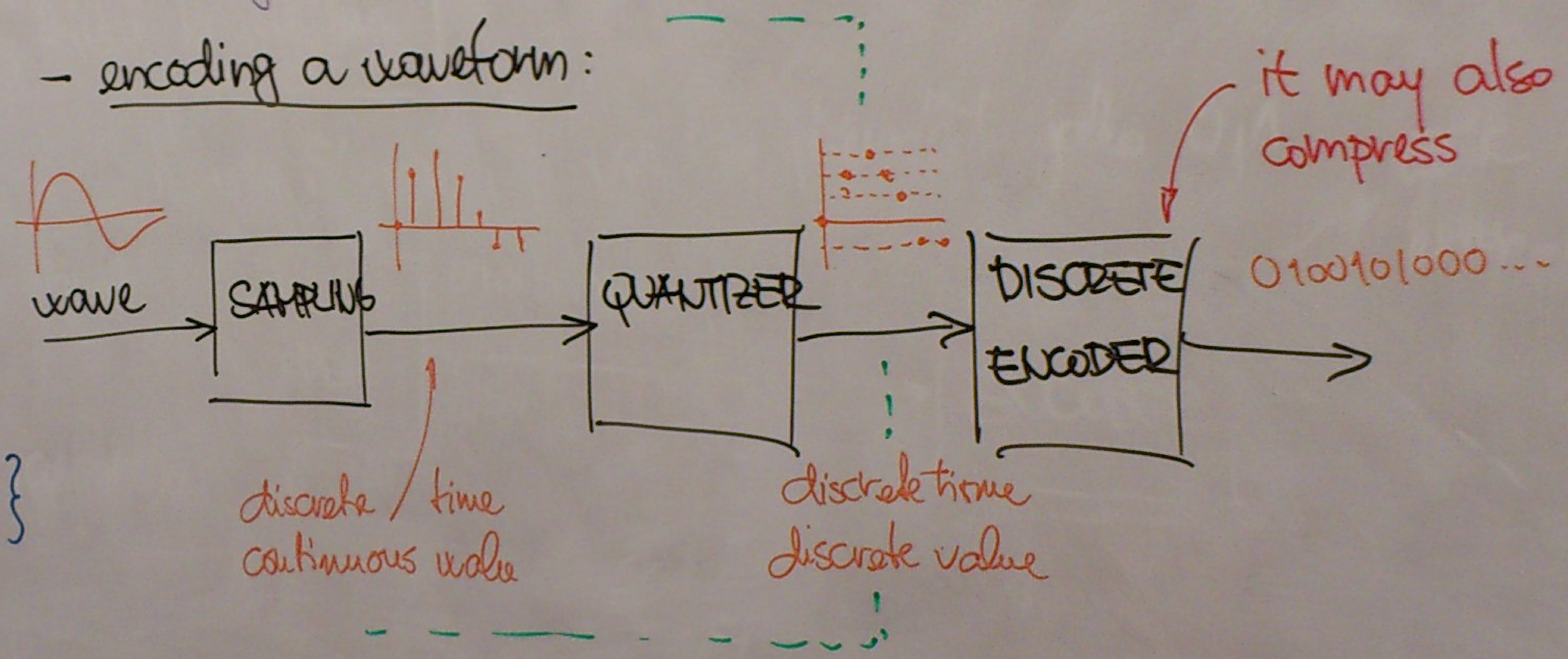
$\boxed{\text{ENTROPY}}$ in bits

Random process generated by a source $X = \{x_1, x_2, x_3, x_4, \ldots, x_n\}$ with probabilities $p(x_1), p(x_2), p(x_3) \ldots$

possible "symbol" generated by the source

$$H(X) = -\sum_{i=1}^{n} p(x_i) \cdot \log_2(p(x_i))$$ → number of bits necessary to represent the source

- OSI network model
  - ↳ layers & interfaces
- encoding a waveform:



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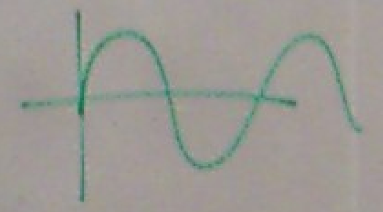
Example: $f(t) = a \cdot \underline{\sin}(\omega t + \varphi)$  .....

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→ number of bits necessary to represent the source

Example: Fair dice $p(x_i) = 1/6$ $X = \{1, 2, 3, 4, 5, 6\}$

$$H(X) = -\sum_{i=1}^{6} \frac{1}{6} \log_2 \frac{1}{6} = -\log_2 \frac{1}{6} = -(-2.585)$$

↳ i need 3 bits to represent numbers 1 ... 6.

$\boxed{\text{Shannon's coding theorem}}$

Source with entropy $H(X)$ producing $\underline{r}$ symbols / sec

→ source speed: $\boxed{V(X) = H(X) \cdot r}$ [bps]

Communication channel with capacity $C$ [bps]

a) $V(X) > C$ $\Rightarrow$ i can not transmit anything

b) $V(X) < C$ $\Rightarrow$ $V(X)$ can be transmitted with an arbitrary low error

c) $V(X) = C$ i cannot make guarantees about the error

# CHANNEL CODING

The channel is given; we have no influence over it

converting 0's and 1's $\longrightarrow$ modulation

main problem: $\boxed{\text{noise}}$

$$Y(t) = X(t) + Z(t)$$

$Z(t)$ noise

$$\underset{\text{source}}{X(t)} \longrightarrow \oplus \longrightarrow \underset{\text{receiver}}{Y(t)}$$

AWGN channel (Additive white Gaussian noise)

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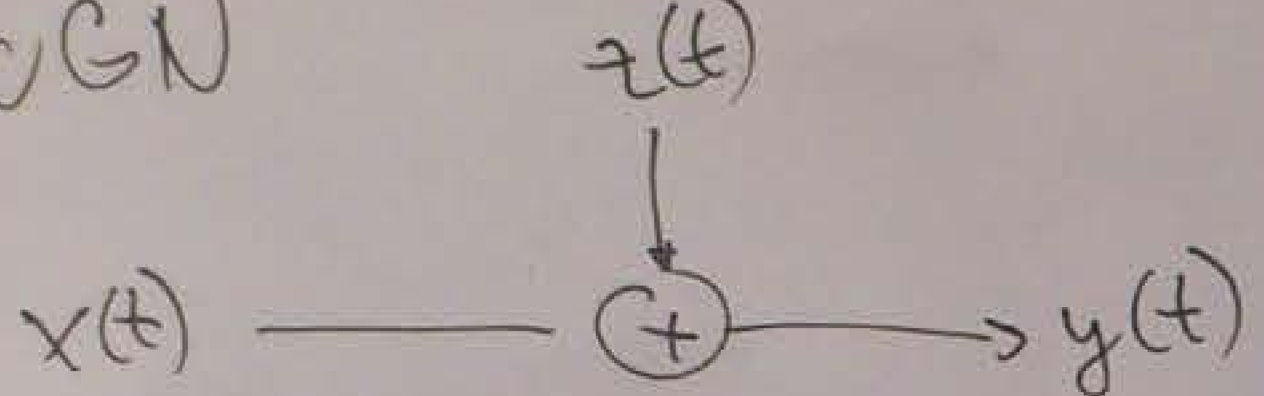
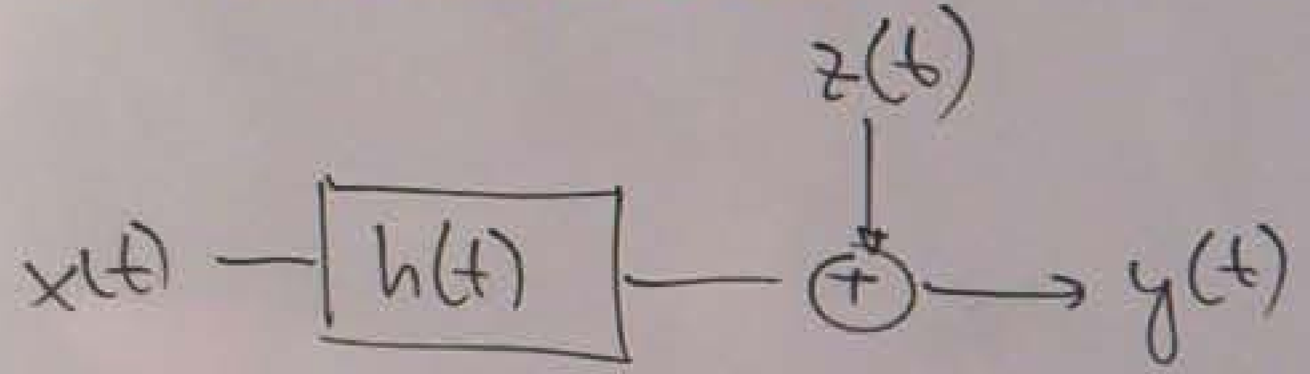
## AWGN




$$y(t) = x(t) + z(t)$$

→ linear Gaussian channel



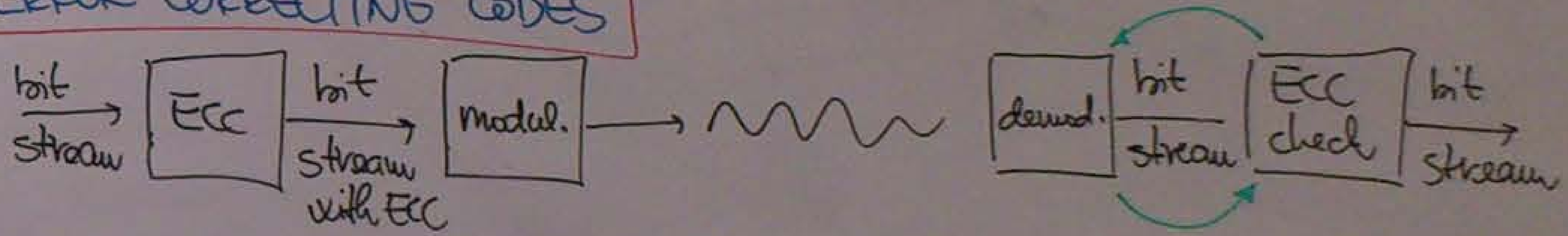

$$\boxed{y(t) = x(t) * h(t) + z(t)}$$

- wired
- wireless (only for direct line-of-sight transmitter & receiver static)

## CHANNEL ENCODING

- encoded signal is stream of 0s and 1s
  - → modulation (PAM, PSK, QPSK, QAM, ...)
  - → convert signal to complex number → waveform ⊕ noise
  - → different waveform at the receiver
  - → demodulation main task: detect the correct transmitted waveform
    - ↳ ERRORS!!

⇒ ERROR CORRECTING CODES



Shannon: A more sophisticated encoding scheme can achieve arbitrarily low error rates at any data rate below channel capacity

$$\boxed{C = W \cdot \log_2\left(1 + \frac{P}{N_0 W}\right) \ [\text{bps}]}$$

$W$ [Hz] ... bandwidth of the channel

only for AGWN proven

$P$ [W] ... input power

$N_0$ [W/Hz] ... noise per unit bandwidth

## Digital interfaces – complicating factors

- unequal data rates: rate of the source encoder $\neq$ input rate of channel encoder
- errors: source decoder needs an exact replica of the encoded data, but not always the channel decoder is able to provide it
- networks: different paths to destination
  shared medium