Convolutional codes

- In convolutional coding, the channel encoder maps a continuous sequence of information bits into a continuous sequence of encoded output bits

- Convolutional coding differs from block coding in that information bits are not grouped into distinct blocks for encoding, rather the entire data stream can be encoded into a single code word

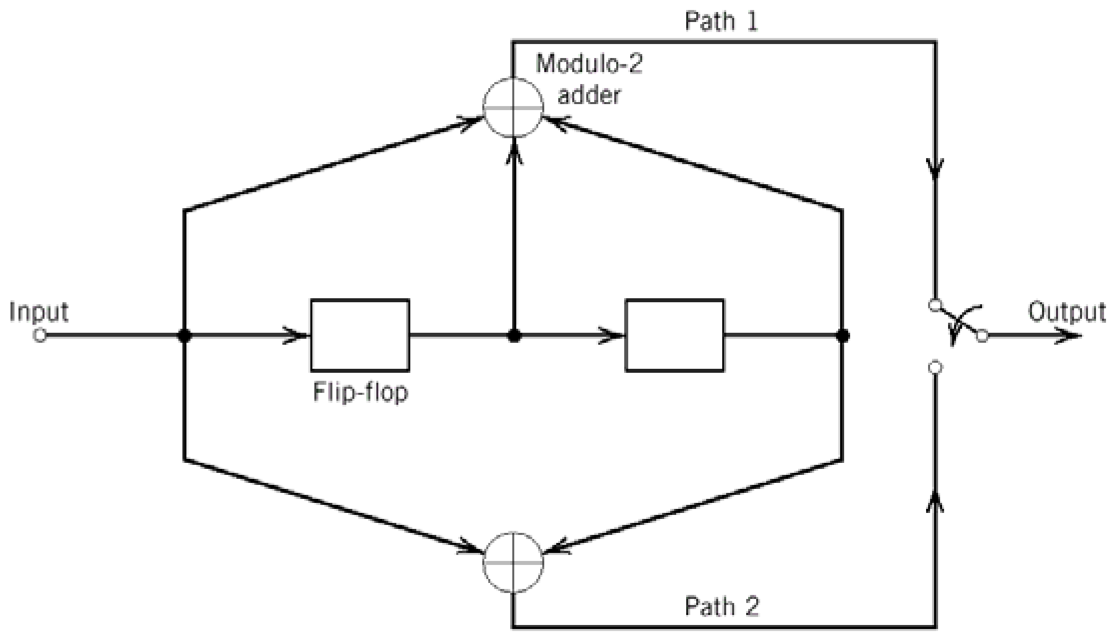
- Convolutional codes can achieve a larger coding gain as compared to block codes with the same complexity

- The convolutional encoder requires memory elements, a code is generated by passing the information bit sequence through a finite state shift register

Convolutional codes

- K number of stages in shift register
- 1 stage of shift register = 1 bit storage
- At each unit of time, k information bits are shifted into the left-most k stages of the register, and the previous contents of the register are shifted k stages to the right
- At any given time, rightmost (K-1) stages store the previous (K-1) data bits
- The input data is shifted into and along the register, k bits at a time The number of output bits for each k bit input data sequence is n bits (which is the number of summers)
- The code rate = k/n
- The parameter K is the Constraint Length which represents the number of stages in the encoding shift register The constraint length determines how powerful and complex the code is
- Decoding of convolutional codes: Viterbi algorithm is the most important method which performs maximum likelihood decoding

Convolutional codes



Convolutional codes

- Effective code rate of a convolutional code
- In practice, *km zeros are often appended at the end to* clear the shift register contents.
- Hence, *kL message bits will produce n(L+m) output* bits.
- The *effective code rate is therefore given by*

$$\tilde{R} = \frac{kL}{n(L+m)}$$

- Since *L is often much larger than m,* $\tilde{R} \approx k/n$.
- This is named the *code rate of a convolutional* code.

Convolutional codes

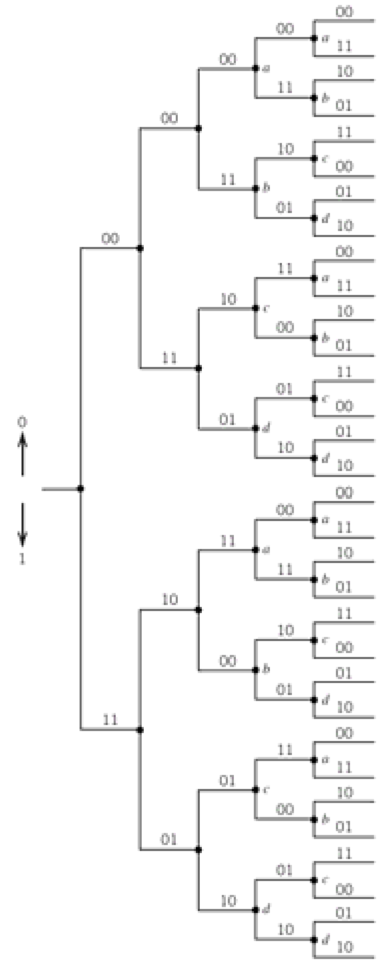
Code tree

$$\boldsymbol{m} = (10011)$$
$$\to \boldsymbol{c} = (11, 10, 11, 11, 01, 01, 11)$$

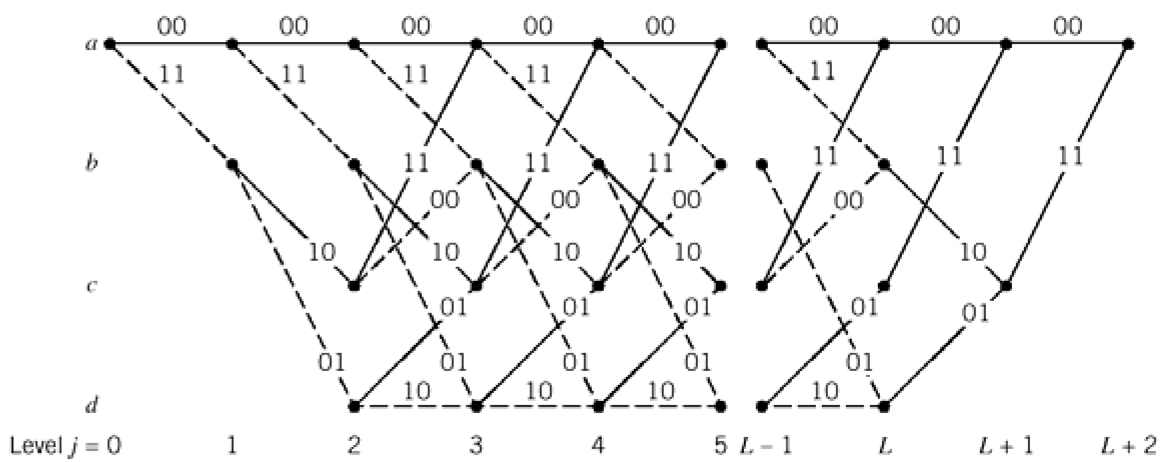
Code trellis

$$\begin{cases} (100m_3m_4\ldots) \\ (000m_3m_4\ldots) \end{cases}$$

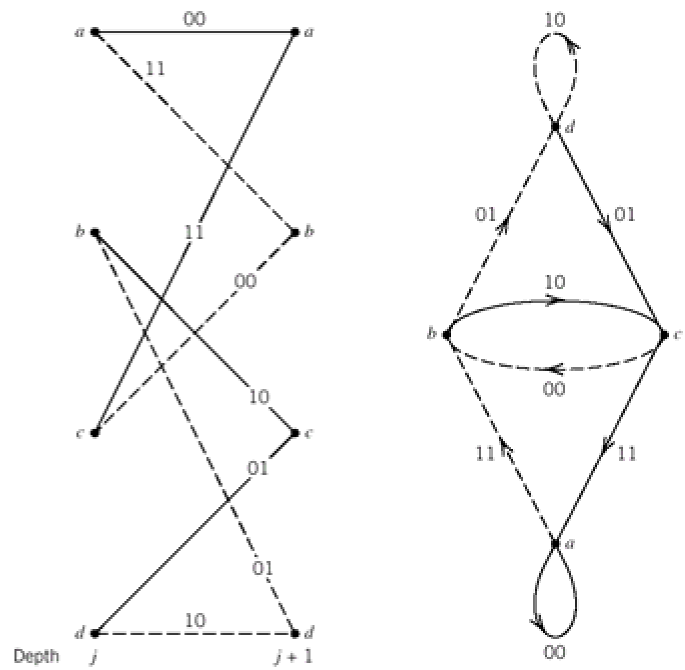
generate the same “next code symbol”



Code trellis (continue)



State diagram



(a) (b)

Turbo codes

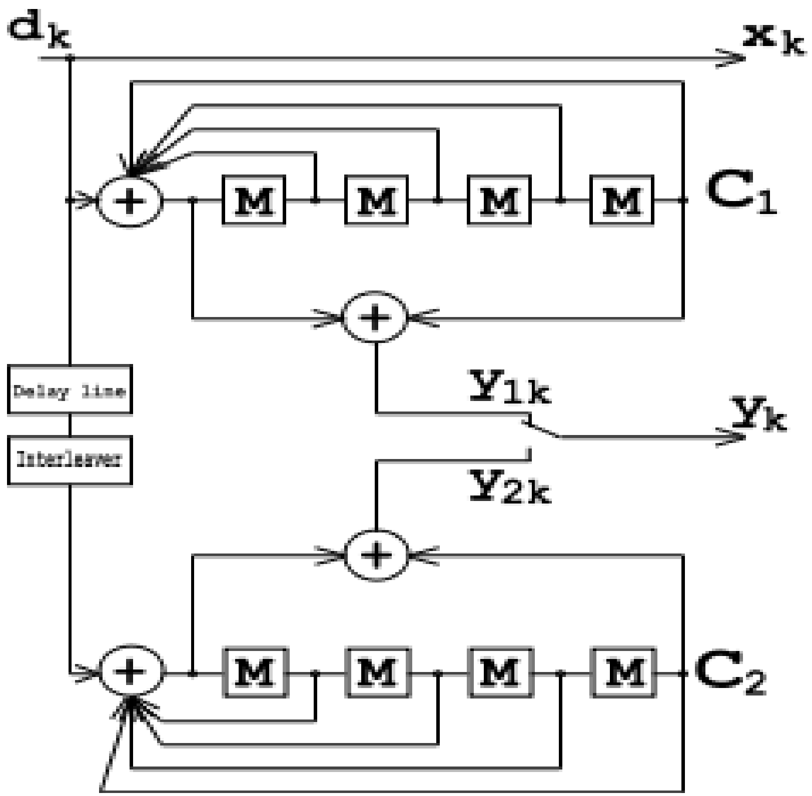
Practical applications using turbo codes

Telecommunications:

- Turbo codes are used extensively in 3G and 4G mobile telephony standards e.g. in HSPA, EV-DO and LTE.
- MediaFLO, terrestrial mobile television system from Qualcomm.
- The interaction channel of satellite communication systems, such as DVB-RCS.
- New NASA missions such as Mars Reconnaissance Orbiter now use turbo codes, as an alternative to RS-Viterbi codes.
- Turbo coding such as block turbo coding and convolutional turbo coding are used in IEEE 802.16 (WiMAX), a wireless metropolitan network standard.

Turbo encoder

This turbo-code encoder consists of two identical RSC coders, C_1 and C_2, as depicted in the figure, which are connected to each other using a concatenation scheme, called *parallel concatenation.*



Decoder

The decoder is built in a similar way to the above encoder – two elementary decoders are interconnected to each other, but in serial way, not in parallel.