Introduction to Telecommunications
EN1052

Chathuranga Weeraddana

December 2020

Lecture 2: Overview of Communication Process

Communication Process

- applications that uses communication is almost endless

Telecommunication Process

- in the most fundamental sense, it consists of
  - original information source $\rightarrow$ a message signal
  - transmitter
  - channel
  - receiver
  - a re-creation or an estimate of the original information $\rightarrow$ information sink



Telecommunication Process

- information by a source, e.g.,
  - audio information (e.g., speech, music)
  - visual information (e.g., pictures, video)
  - voltage across a resister
  - measurement information (e.g., temperature)



Telecommunication Process

- generation of a message signal
  - the original information is taken and converted it into an electrical waveform
  - result is referred to as **baseband signal** or message signal



Telecommunication Process

- transmitter
  - the message signal is transformed into a form that is suitable for transmission over a channel



Telecommunication Process

- channel
  - the physical medium for message delivery
  - e.g., wire, waveguide, coaxial cable, optical fiber, radio link
  - signal distortion due to channel imperfection
  - imperfections: noise, interference, fading, shadowing, etc



Telecommunication Process

- receiver
  - undoing the signal modifications at the transmitter and the channel
  - produce an estimate of the original message signal



Telecommunication Process

- re-creation of the original information
  - the estimate of the original message is taken and is converted it into desired information



Telecommunication Process

- information to a sink, e.g.,
  - audio information
  - visual information
  - voltage across a resister
  - measurement information (e.g., temperature)



Analog and Digital Systems

- analog communication systems
  - baseband signal is analog
  - continuous wave **modulation** is employed (e.g., AM, FM, PM)

Analog and Digital Systems

- digital communication systems
  - there is a finite set of continuous time waveforms, each with a duration T, a finite duration
  - baseband signal is a sequence of aforementioned waveforms
  - pulse modulation (e.g., PAM, PPM, PDM)
  - bandpass modulation (e.g., ASK, FSK, PSK)
  - spread spectrum modulation (e.g., DSSS)

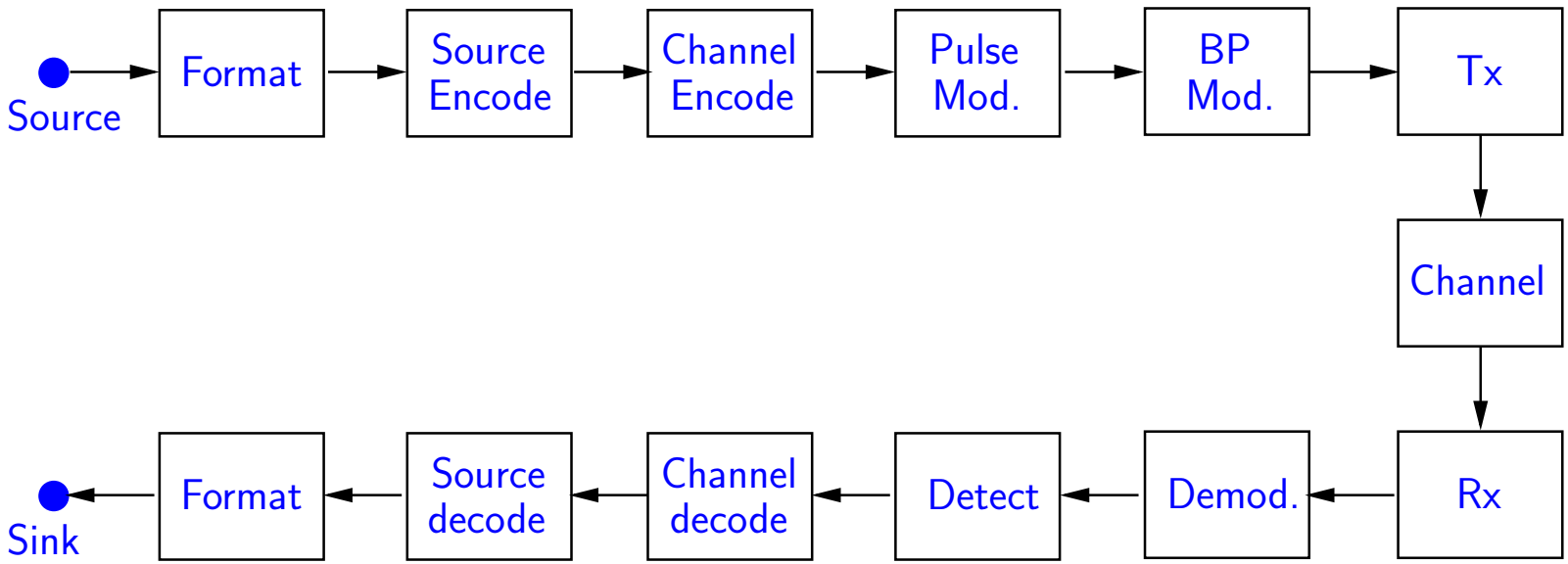
Modulation Process

- communication systems essentially deliver information from a source to a sink
- to do this, especially at different transmitter stages
  - information is modified into a form suitable for transmission over the channel
  - e.g., electrical signals, electromagneric waves
  - the above process is known as modulation

Analog or Digital

- digital communication systems are the most widely spread !

A Digital Communication System (DCS)



Why Digital ?

- regeneration is possible
  - transmission lines/circuites have non-ideal frequency transfer function
  - unwanted electrical noise or other interfering signals
  - regenerative repeaters $\rightarrow$ original pulse is reborn

Why Digital ?

- less subject to distortions and interfereonce
  - digital circuits $\rightarrow$ just two states
  - analog circuits $\rightarrow$ NOT two states, infinite possibilities
  - once analog signal distorted $\rightarrow$ distortion cannot be removed by amplification
  - regenerative repeaters $\rightarrow$ original pulse is reborn
- more reliable and at the same time less expensive circuits
- more flexible operation, e.g., microprocessors, digital switching, VLSI

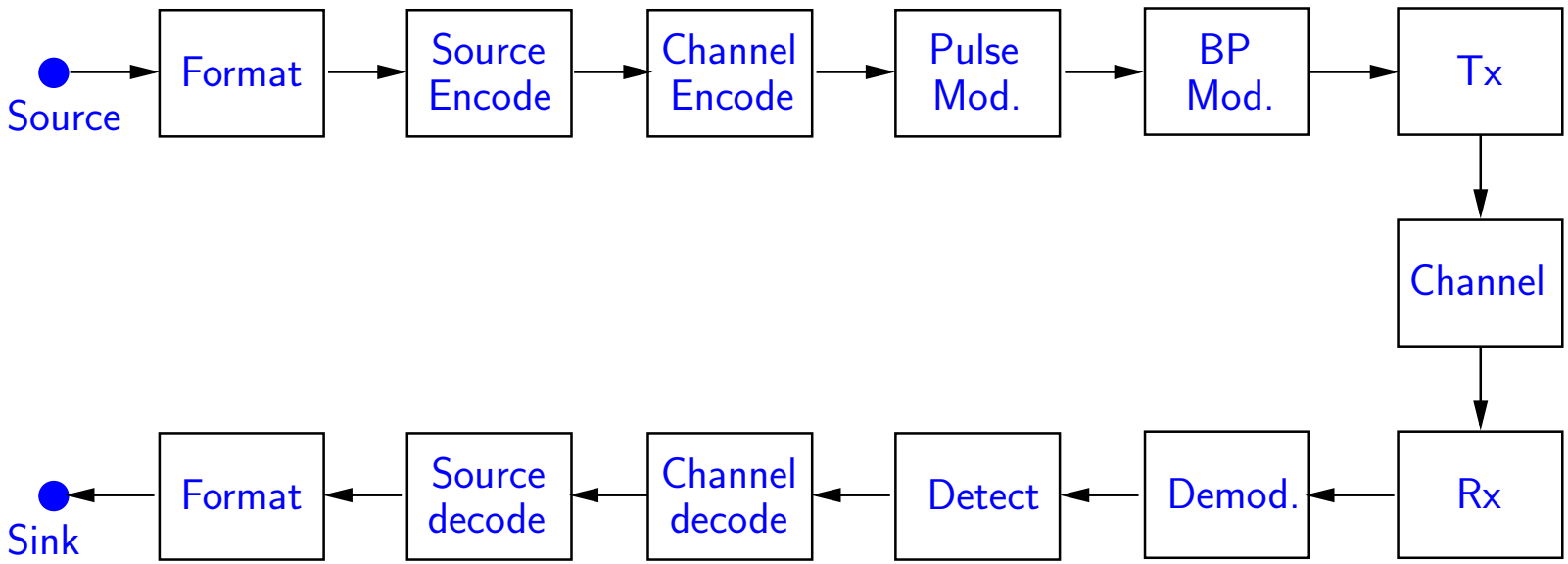
Why Digital ?

- combining digital signals using time-division multiplexing is simpler than combining analog signals using frequency-division multiplexing
- different types of traffic (e.g., data, telephone, television) can be treated identically, A Bit is a Bit
- techniques, for compete against interference, jamming, privacy, etc, can be integrated

Cost Associated with Digital ?

- very signal processing intensive
- significant share of resources to the task of Synchronization
- signal-to-noise ration below a threshold $\rightarrow$ quality drops abruptly

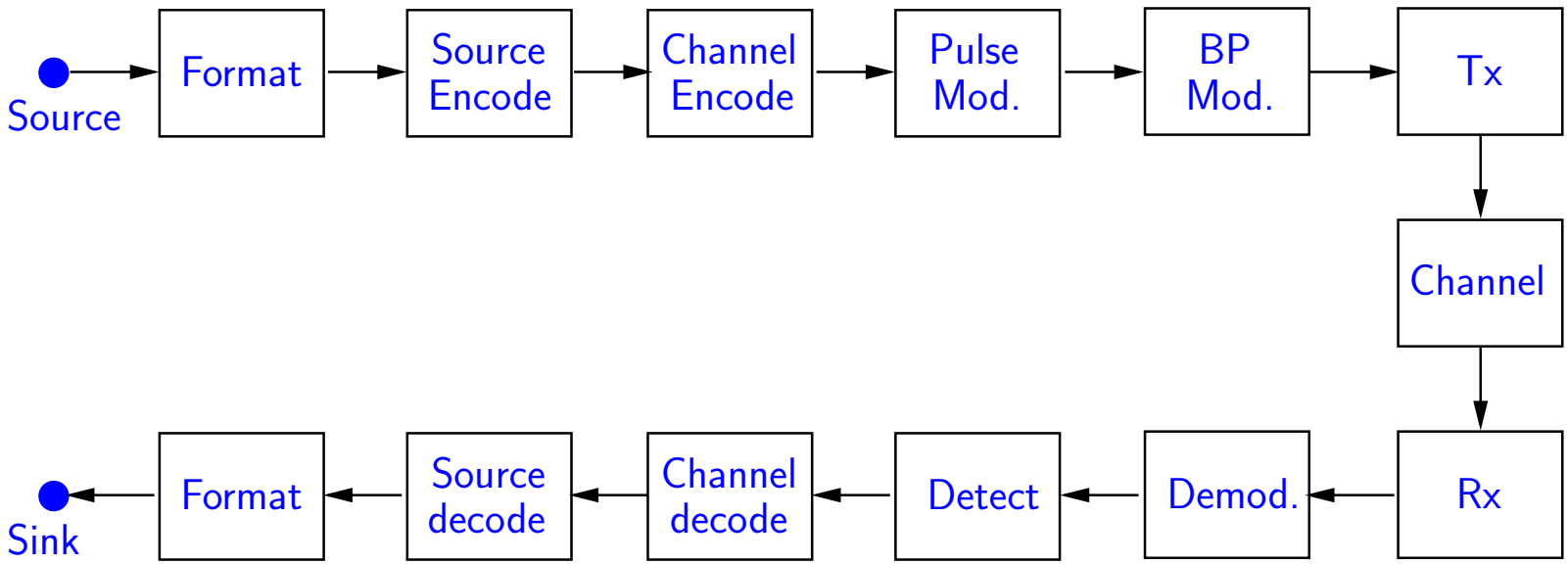
A Digital Communication System (DCS)



Digital Communication System

- information source
  - speech
  - music
  - moving pictures
  - computer data
  - not necessarily binary

A Digital Communication System (DCS)



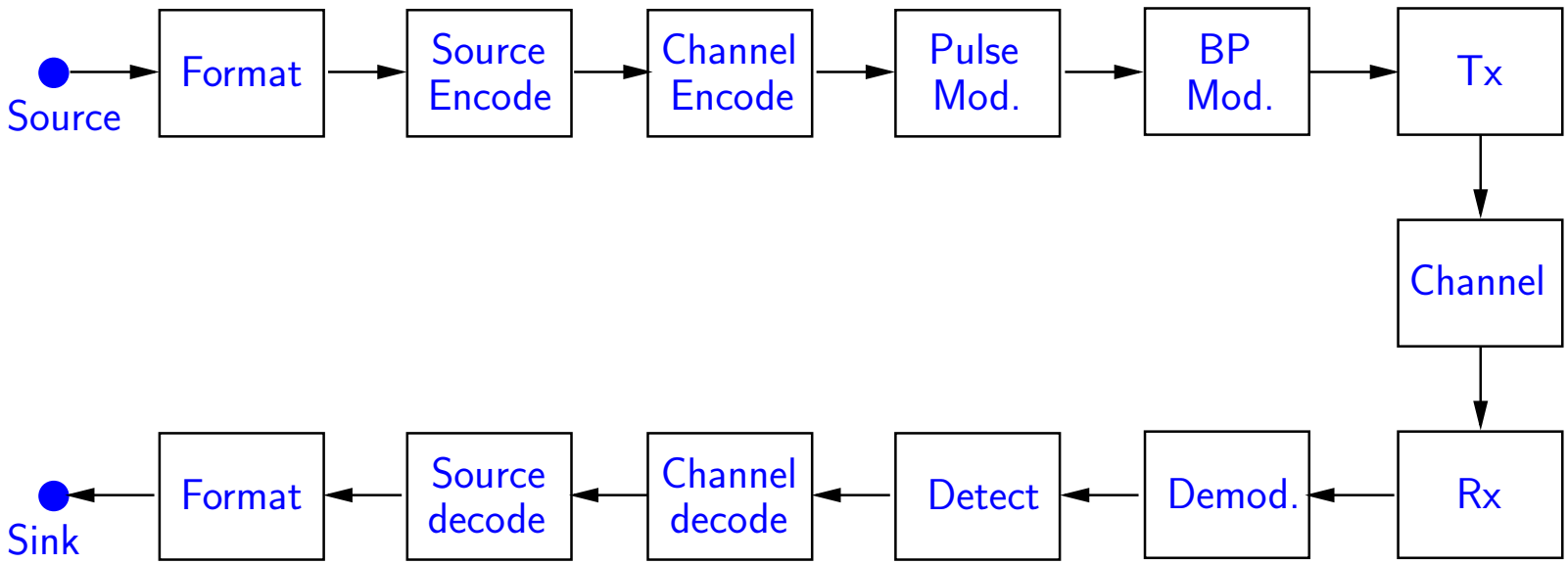
Digital Communication System

- formatting + source encoding
  - insure that message is compatible with digital processing
  - when data compression (source encoding), in addition to formatting is used $\rightarrow$ *source coding*
  - i.e., efficient use of the channel
  - e.g., Huffman codes, JPEG, MPEG
  - message symbols $(m_i, i = 1, 2, \ldots, M)$ constitute a finite alphabet
  - bit streams

Digital Communication System

- formatting
  - character coding
  - sampling
  - quantization
  - pulse code modulation (PCM)
- source encoding
  - predictive coding
  - block coding
  - variable length coding
  - synthesis/analysis coding
  - lossless compression
  - lossy compression

A Digital Communication System (DCS)



Digital Communication System

- channel encoder
  - errors due to noise, fading of signals, interference
  - add redundant bits to message symbols to compete with errors
  - i.e., message symbols are transformed to channel symbols;

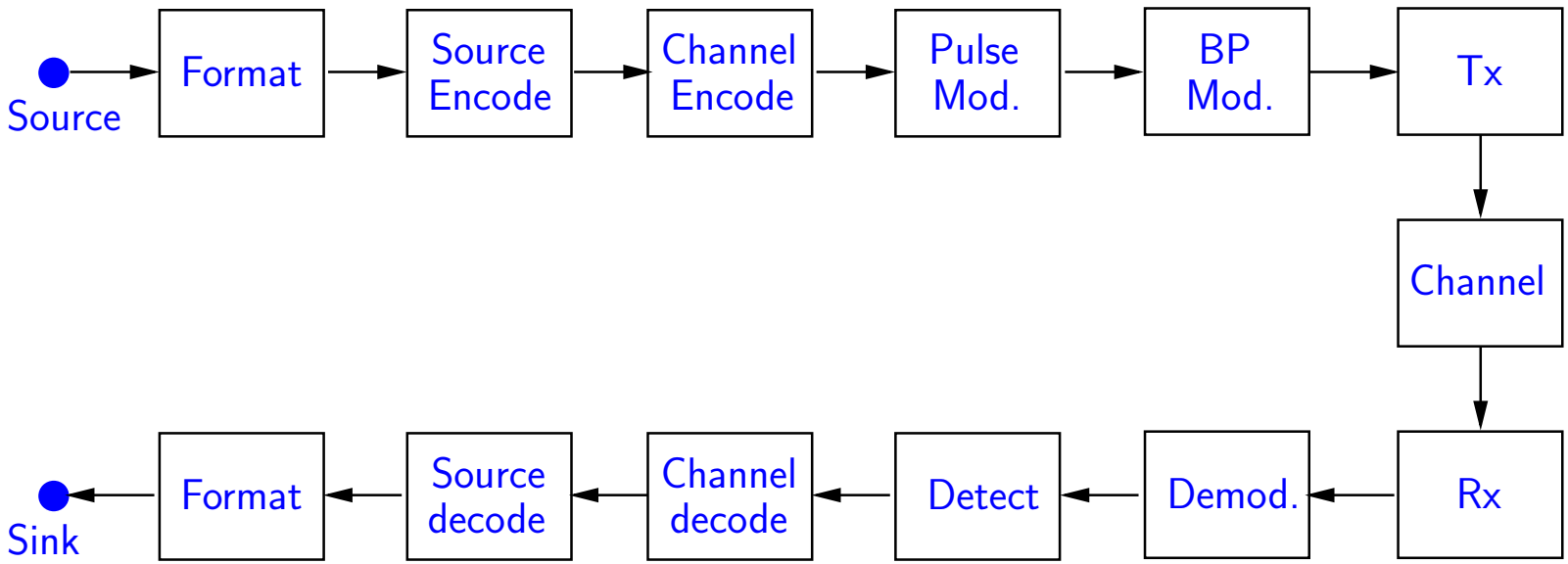
$$m_i \longrightarrow u_i, \quad i = 1, \ldots M$$

  - bit streams

Digital Communication System

- channel coding (waveform)
  - M-ary signalling
  - antipodal
  - orthogonal
  - Trellis-coded modulation
- channel coding (structured sequences)
  - block coding
  - convolutional coding
  - turbo coding

A Digital Communication System (DCS)



Digital Communication System

- pulse modulation (baseband signalling)
  - channel symbols are transformed to *baseband* waveforms, i.e.,

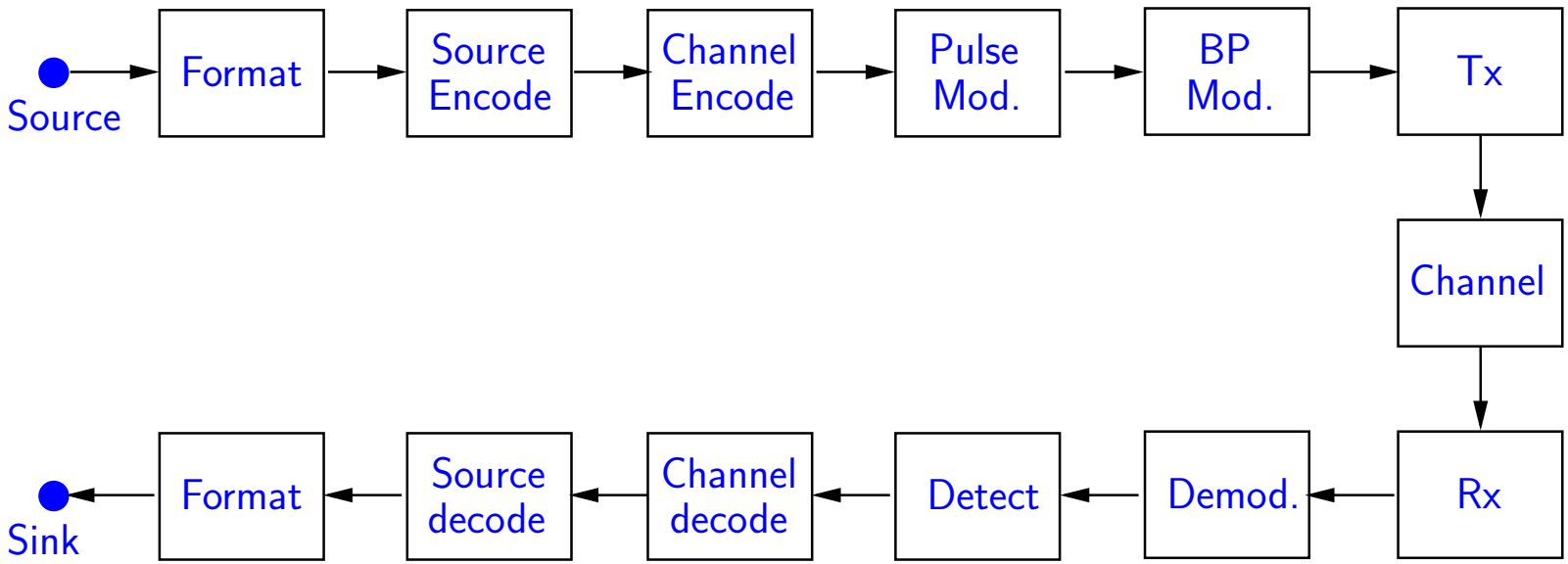
$$u_i \longrightarrow g_i(t), \quad i = 1, \ldots M$$

  - base band $\rightarrow$ spectrum $\approx 0-$few MHz
  - include filtering for minimizing transmission bandwidth
  - when applied to binary symbols, result is called pulse-code-modulation (PCM) waveform
  - when applied to non-binary symbols, result is called M-ary pulse-modulation waveform

Digital Communication System

- pulse modulation (applied to binary symbols), i.e., PCM waveforms
  - NRZ (non-return-to-zero)
  - RZ (return-to-zero)
  - phase encoded
  - multilevel binary
- pulse modulation (applied to non-binary symbols), i.e., M-ary pulse modulation waveforms
  - pulse-amplitude-modulation (PAM)
  - pulse-position-modulation (PPM)
  - pulse-duration-modulation (PDM)

A Digital Communication System (DCS)



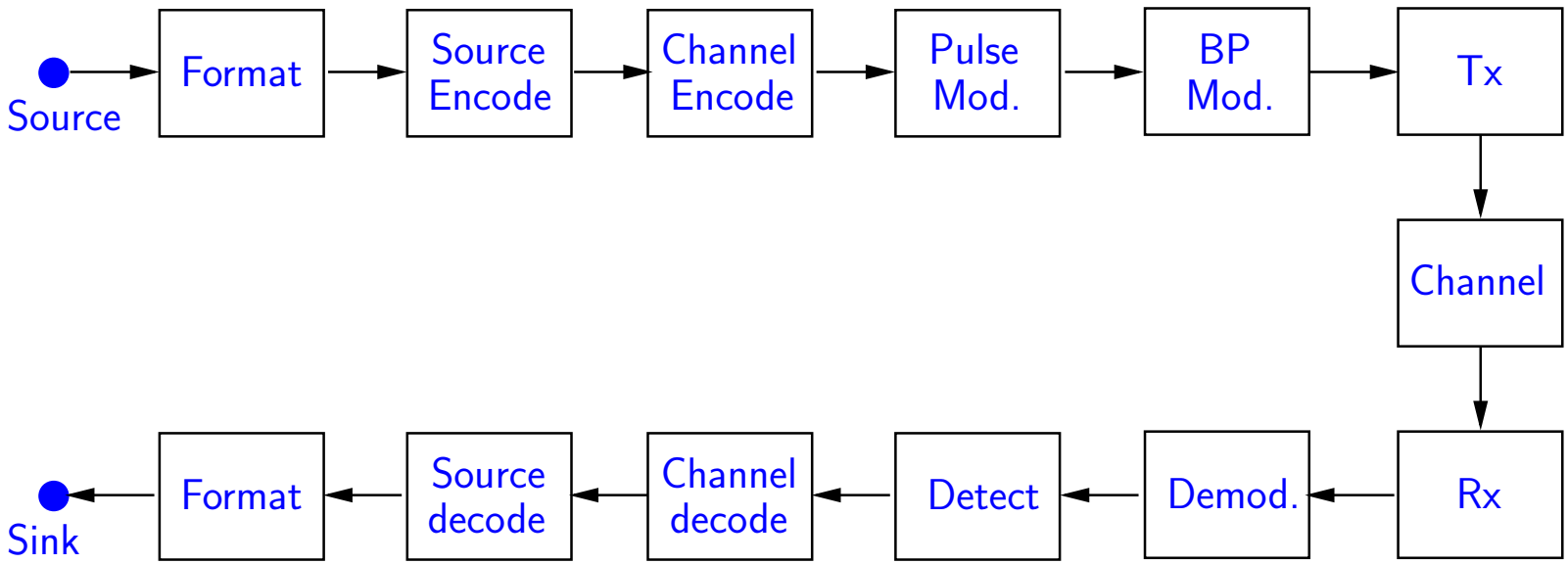
Digital Communication System

- bandpass modulation (bandpass signalling)
  - used whenever the transmission medium will not support prorogation of pulse-like waveform
  - *baseband* waveforms are transformed to *bandpass* waveforms, i.e.,
    $$g_i(t) \longrightarrow s_i(t), \quad i = 1, \ldots M$$
  - baseband wave $g_i(t)$ is **frequency translated** by a **carrier** wave, whose frequency is much larger than the spectral content of $g_i(t)$

Digital Communication System

- bandpass modulation
  - PSK (phase shift keying)
  - FSK (frequency shift keying)
  - ASK (amplitude shift keying)
  - continuous phase modulation
  - hybrid versions

A Digital Communication System (DCS)



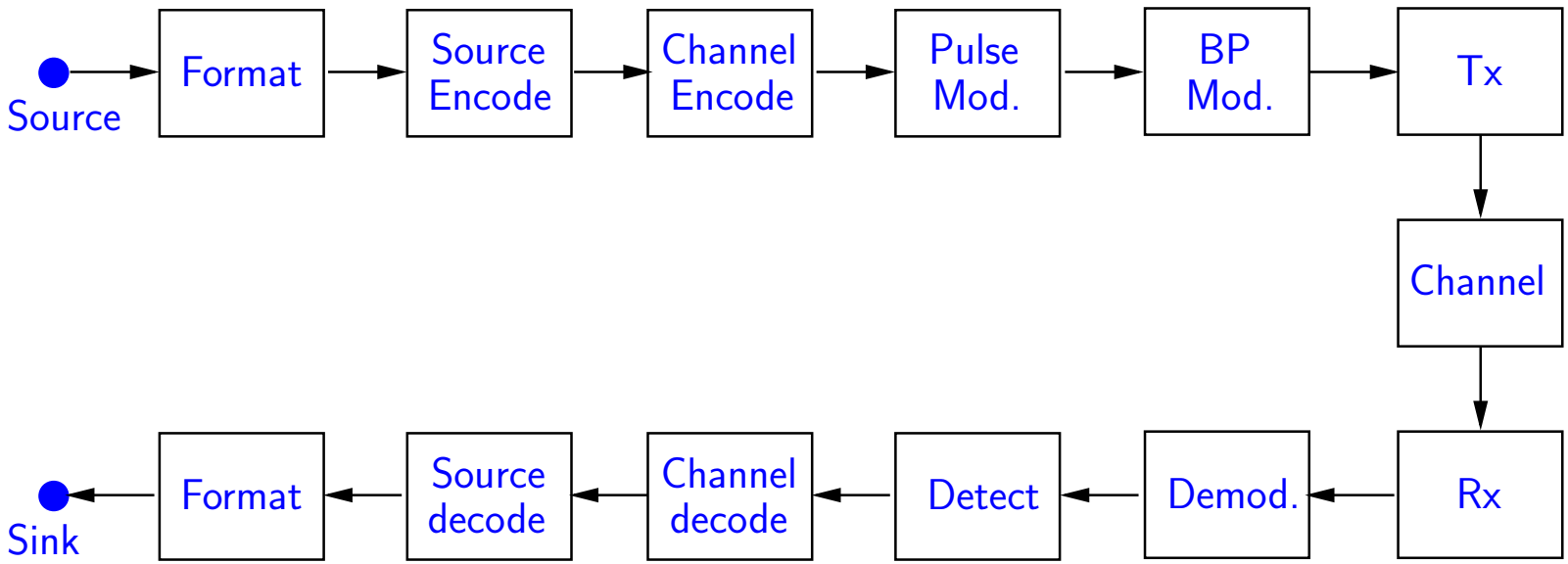
Digital Communication System

- channel
  - channel characteristics can be described by **channel impulse response** $h_c(t)$
  - at various points along the signal rout, **additive random noise** distort the signal
  - i.e., the received signal $r(t)$ is a corrupted version of $s_i(t)$, mathematically

$$r(t) = s_i(t) * h_c(t) + n(t), \quad i = 1, \ldots M$$

  - here $*$ denotes the convolution operation

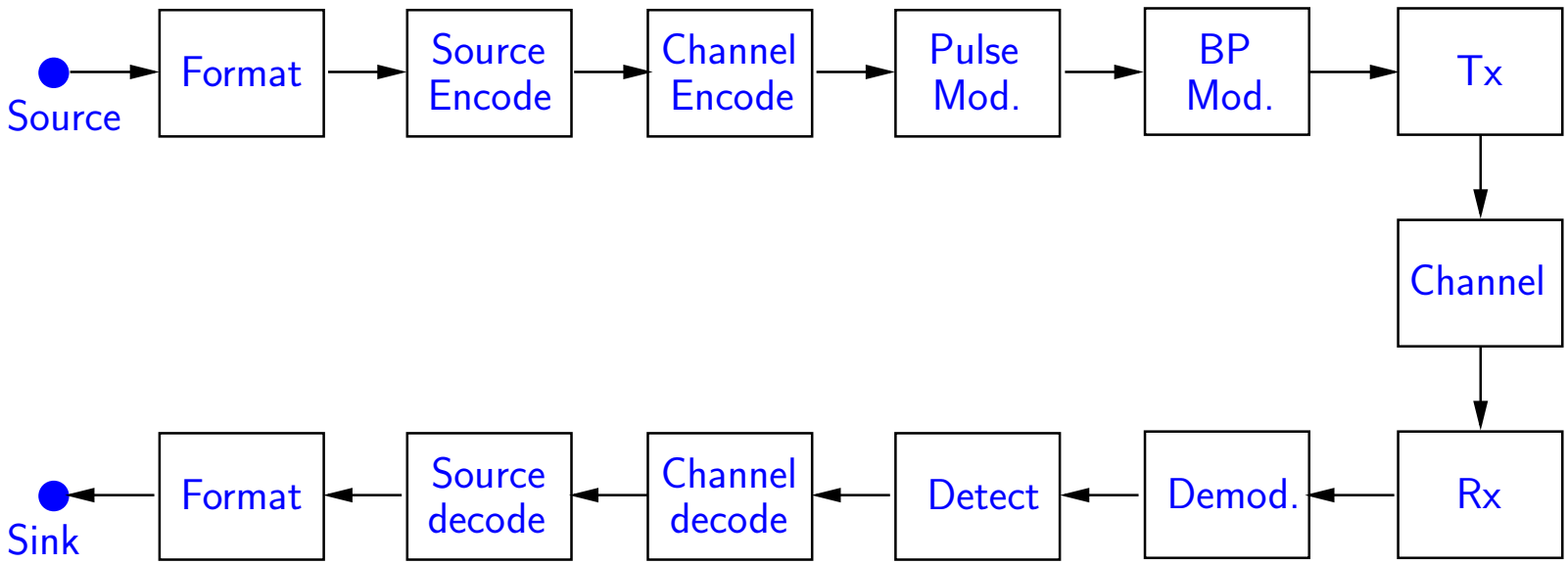
A Digital Communication System (DCS)



Digital Communication System

- demodulation and sampling
  - demodulator provides frequency down conversion for $r(t)$
  - there can be filters to eliminate unwanted high frequency components
  - there can be filters to shape the received wave forms for better performance gains
  - there can be equalizers to remove or diminish any signal distortions caused by non-ideal $h_c(t)$
  - after these, processes, $r(t)$ is restored to an baseband pulse $z(t)$ in preparation for sample
  - sampling process transforms $z(t)$ to a sample $z(T)$

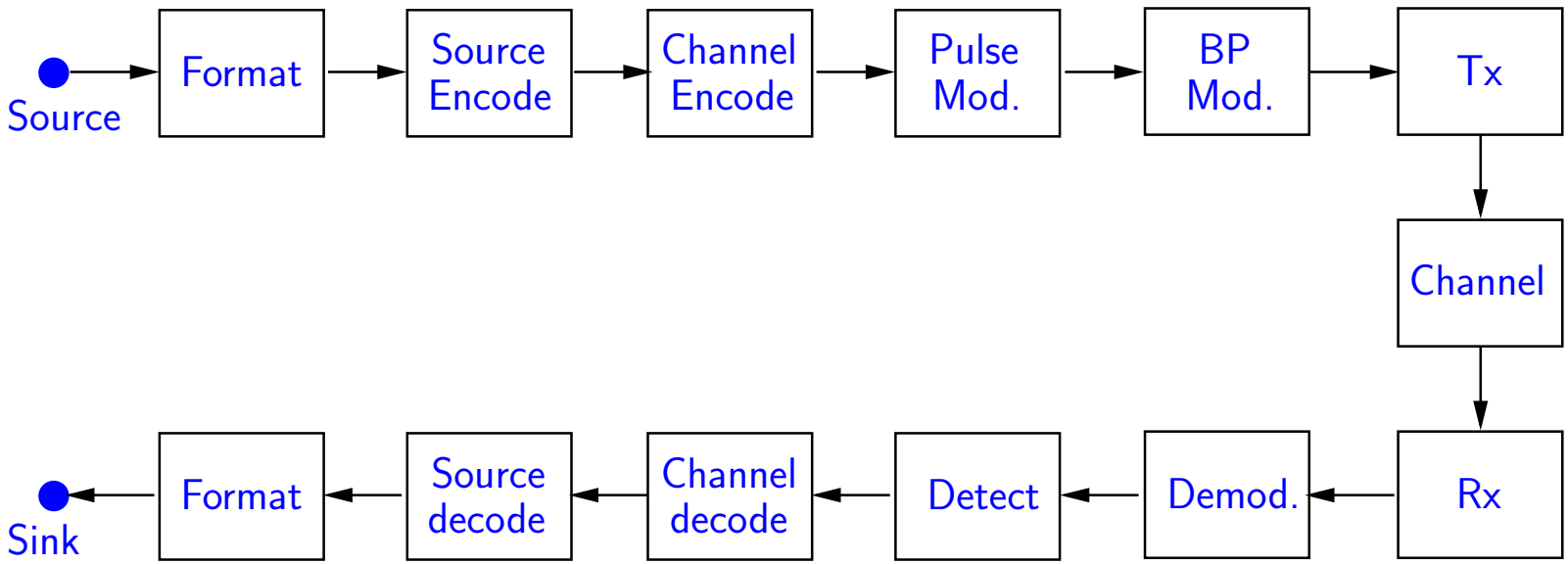
A Digital Communication System (DCS)



Digital Communication System

- detection
  - decides what could be the channel symbol transmitted
  - the sampled value $z(T)$ is used to make and estimate $\hat{u}_i$ of the channel symbol u_i

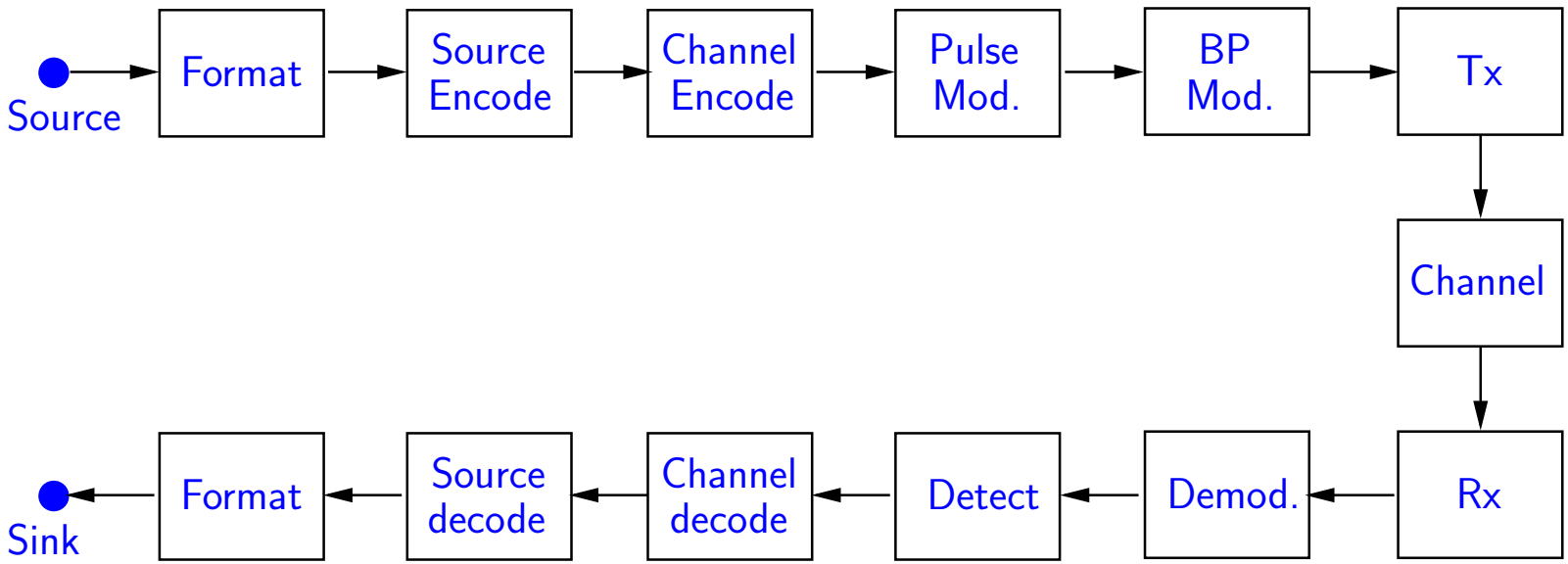
A Digital Communication System (DCS)



Digital Communication System

- channel decode
  - invoke error control coding mechanisms (together with its the redundant bits) to detect errors in $\hat{u}_i$
  - if error control coding mechanisms has means for correct the detected errors, correct those and remove redundant bits to yield the corresponding **message symbol** $\hat{m}_i$
  - if error control coding has No means for correct the detected errors, invoke an ARQ (automatic-repeat-on-request) mechanism so that the corrupted message symbol is retransmitted

A Digital Communication System (DCS)



Digital Communication System

- synchronization
  - involve estimation of both time and frequency
  - coherent systems $\rightarrow$ sync the frequency reference with the carrier in both frequency and phase
  - noncoherent systems $\rightarrow$ sync the frequency reference with the carrier in frequency
  - time synchronization mean symbol or bit synchronization
  - detector needs to know when to start and end the process of symbol or bit detection
  - frame synchronization to reconstruct the message symbols

A Digital Communication System (DCS)

