Contents

- Introduction
- Physical and Link Layers Protocols (IoT Access Technologies)

Mostly adopted from Chapters 4, 5, and 6 of IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing, Cisco press, 2017

Contents

- Introduction
  - Connecting Smart Objects
  - IoT Protocol Stack (Standards, Protocols and Technologies)
- Physical and Link Layers Protocols (IoT Access Technologies)

Mostly adopted from Chapters 4, 5, and 6 of **IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing**, Cisco press, 2017

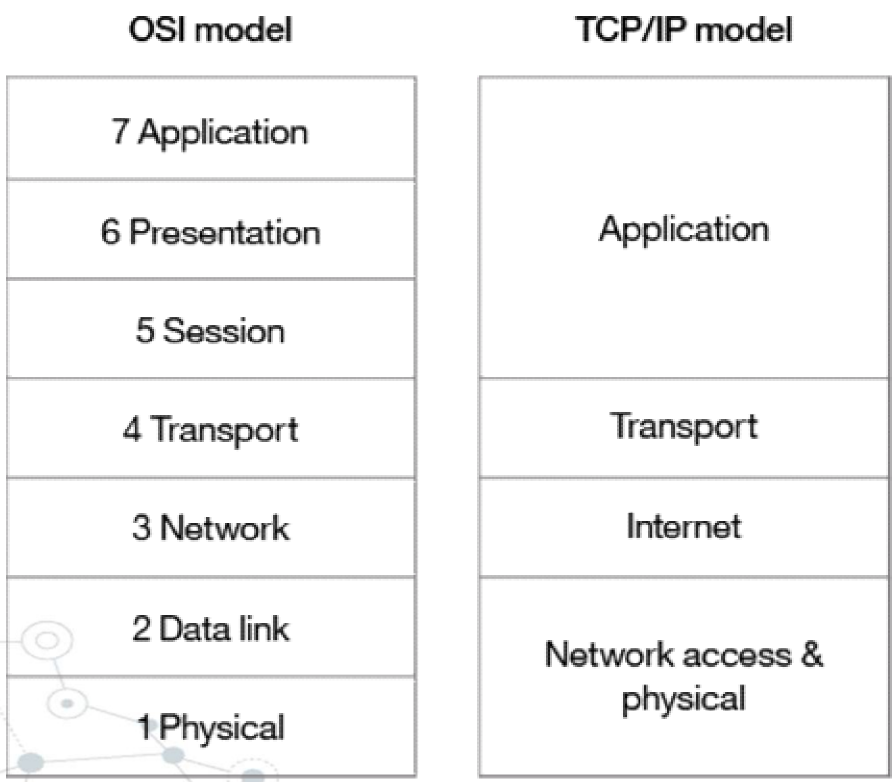
IoT Protocol Stack: Why layering

Dealing with *complex systems*:

- *explicit structure* allows *identification* relationship of complex system's pieces
  - layered ***reference model*** for discussion
- *modularization* eases maintenance, updating of system
  - change of implementation of layer's service ***transparent*** to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

IoT Protocol Stack

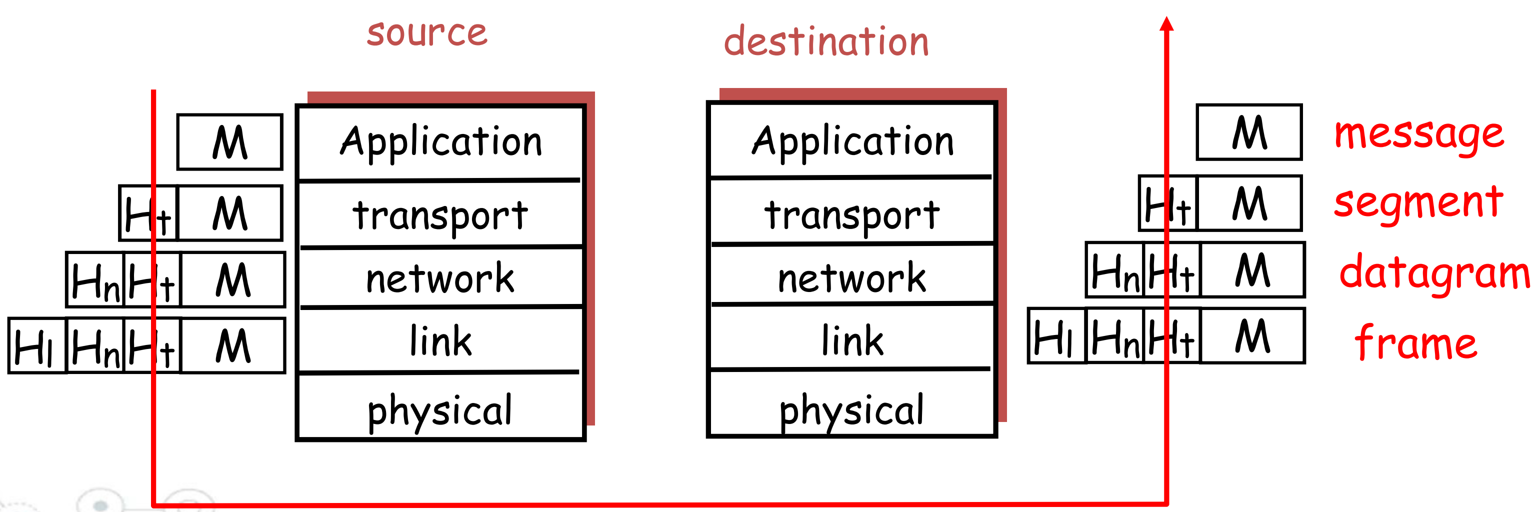
- OSI and TCP/IP Networking Models



Protocol layering and data

Each layer takes data from above

- adds header information to create new data unit
- passes new data unit to layer below



Physical and Link Layers Protocols- IEEE 802.15.4

- "Networking Technologies"
  - Enable IoT devices to communicate with other devices, applications, and services running in the cloud
    - **Network Access & Physical Layer**," Presented in Lecture 3 (*Chapter 4) .
    - **Internet Layer:** IP as the IoT Network Layer, Presented in Lecture 4 (*Chapter 5)
    - **Transport & Application Layers,** Presented in Lecture 5 (*Chapter 6)

  - As you look further down the stack toward physical transmission technologies, you face more challenges that are specific to IoT devices and IoT contexts.

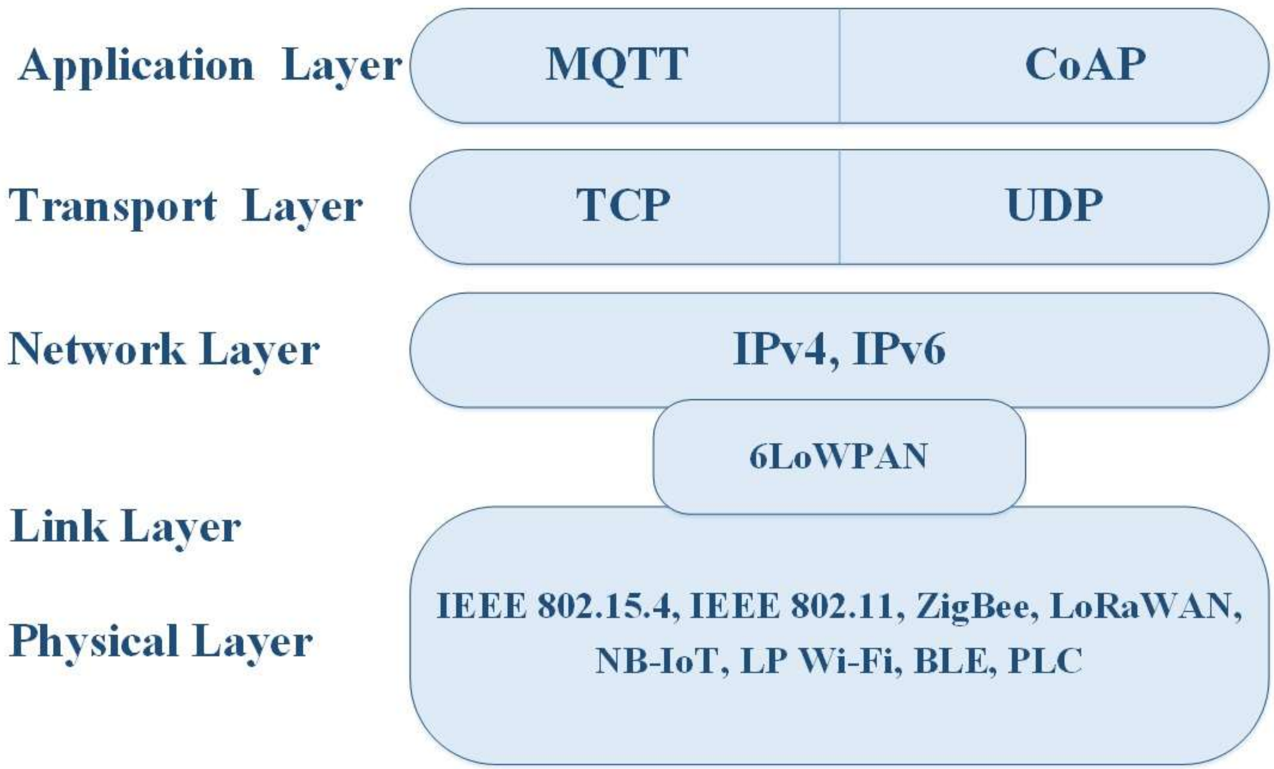
* IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Thing, Cisco press, 2017

IoT Protocol Stack

- IoT network protocols mapped to the TCP/IP model

TCP/IP model	IoT protocols
Application	HTTPS, XMPP, CoAP, MQTT, AMQP
Transport	UDP, TCP
Internet	IPv6, 6LoWPAN, RPL
Network access & physical	IEEE 802.15.4 Wifi (802.11 a/b/g/n) Ethernet (802.3) GSM, CDMA, LTE

IoT Protocol Stack



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  - Physical Layer Issues
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Physical Layer issues

- Media (Electrical Channel)
- Frequency Ranges
- Signal
  - Signal Power
  - Signal Frequency Spectrum
  - Signal Propagation
- Transceivers Structure
  - Modulation and Demodulation
  - Coding

Physical Media

- Transmission Medium
  - Physical path between transmitter and receiver

- Categories of physical medium
  - Guided Media
    - Waves are guided along a solid medium
    - E.g., copper twisted pair, copper coaxial cable, optical fiber
  - Unguided Media
    - Provides means of transmission but does not guide electromagnetic signals
    - Usually referred to as wireless transmission
    - E.g., atmosphere, outer space

Difference Between Wireless and Wired Networks

- Layers Affected by the Wireless Transmission
  - Wireless and Wired Networks are not so different at application and transport layers!
  - They are mostly different at following layers:

- Physical Layer
  - Media (Electrical Channel)
  - Frequency range
  - Signal
  - Modulation and Demodulation
  - Multiplexing

- Data Link Layer
  - Logical link control (LLC)
  - Media Access Control (MAC)

- Network Layer
  - Packet Forwarding
  - Routing

Frequency Range

- Radio
  - Signal carried in electromagnetic spectrum
  - Propagation environment effects:
    - Reflection
    - Obstruction by objects
    - Interference

Frequency Range

Frequency	Wavelength	Designation	Abbreviation
3 - 30 Hz	10^5km-10^4km	Extremely low frequency	ELF
30 - 300 Hz	10^4km-10^3km	Super low frequency	SLF
300 - 3000 Hz	10^3km-100km	Ultra low frequency	ULF
3 - 30 kHz	100km-10km	Very low frequency	VLF
30 - 300 kHz	10km-1km	Low frequency	LF
300 kHz - 3 MHz	1km-100m	Medium frequency	MF
3 - 30 MHz	100m-10m	High frequency	HF
30 - 300 MHz	10m-1m	Very high frequency	VHF
300 MHz - 3 GHz	1m-10cm	Ultra high frequency	UHF
3 - 30 GHz	10cm-1cm	Super high frequency	SHF
30 - 300 GHz	1cm-1mm	Extremely high frequency	EHF
300 GHz – 3 THz	1 mm – 0.1 mm	Tremendously high frequency	THF

Radio Frequency

- **Required antenna size for good reception is inversely proportional to the signal frequency**
  - so moving to a higher frequency allows for more compact antennas

- **Received signal power with nondirectional antennas is proportional to the inverse of frequency squared.**
  - So it's hard to cover large distances with higher frequency signals (with nondirectional antennas)

*Adopted from Wireless Communication by Goldsmith (Chapter2)

Frequency Range

- **Radio frequency range**
  - 30 MHz to 30 GHz
  - Suitable for omnidirectional applications
  - Frequencies of 1 GHz and above are conventionally called microwave
- **Millimeter Wave**
  - Frequencies of 30 GHz and above are designated .
- **Infrared frequency range**
  - Roughly, 3x10^11 (300 GHz) to 2x10^14 (200 THz)
  - Useful in local point-to-point multipoint applications within confined areas

Frequency Range

- **Most wireless applications reside in radio frequency between 30MHz to 30 GHz (VHF, UHF and SHF)**

- **Why these frequencies?**
  - They are not affected by earth curvature
  - Require only moderated size antennas

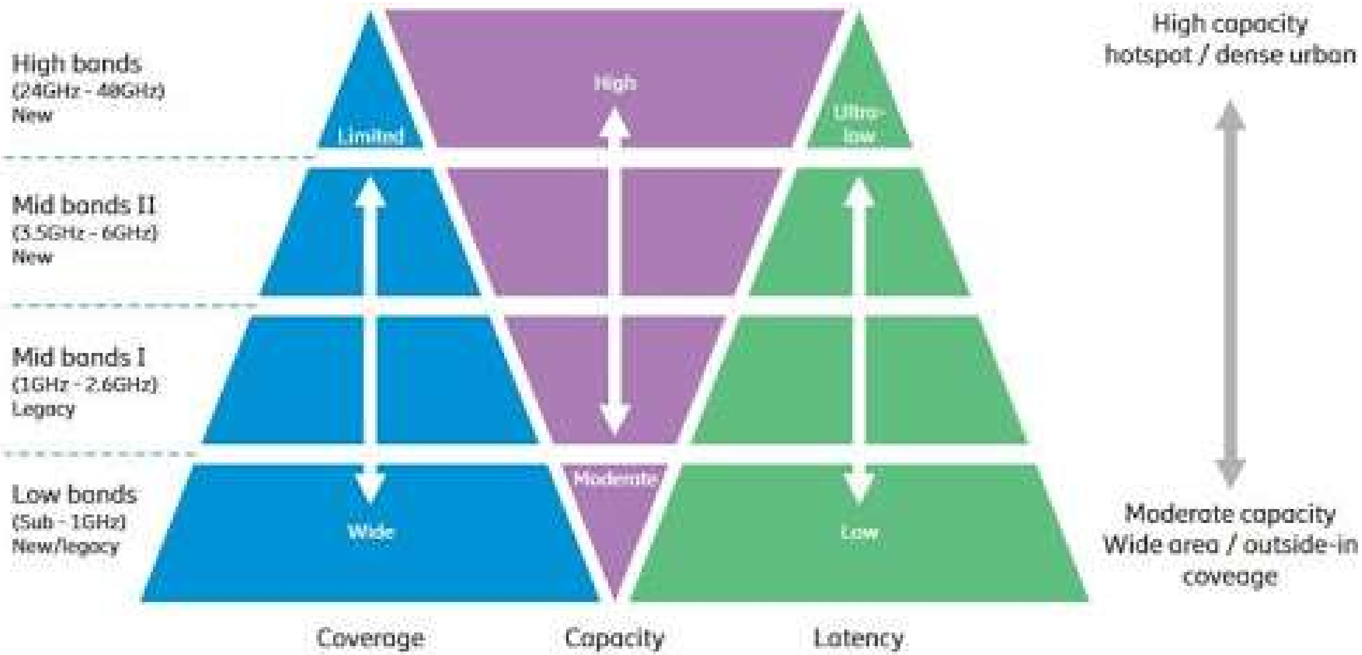
*Adopted from Wireless Communication by Goldsmith (Chapter2)

Example of ISM frequency allocation

Frequency range		Center frequency	Bandwidth	Type	Availability	Licensed users
6.765 MHz	6.795 MHz	6.78 MHz	30 kHz	A	Subject to local acceptance	FIXED SERVICE & Mobile service
13.553 MHz	13.567 MHz	13.56 MHz	14 kHz	B	Worldwide	FIXED & Mobile services except Aeronautical mobile (R) service
26.957 MHz	27.283 MHz	27.12 MHz	326 kHz	B	Worldwide	FIXED & MOBILE SERVICE except Aeronautical mobile service, CB Radio
40.66 MHz	40.7 MHz	40.68 MHz	40 kHz	B	Worldwide	Fixed, Mobile services & Earth exploration-satellite service
433.05 MHz	434.79 MHz	433.92 MHz	1.74 MHz	A	only in Region 1, subject to local acceptance	AMATEUR SERVICE & RADIOLOCATION SERVICE, additional apply the provisions of footnote 5.280. For Australia see footnote AU.
902 MHz	928 MHz	915 MHz	26 MHz	B	Region 2 only (with some exceptions)	FIXED, Mobile except aeronautical mobile & Radiolocation service; in Region 2 additional Amateur service
2.4 GHz	2.5 GHz	2.45 GHz	100 MHz	B	Worldwide	FIXED, MOBILE, RADIOLOCATION, Amateur & Amateur-satellite service
5.725 GHz	5.875 GHz	5.8 GHz	150 MHz	B	Worldwide	FIXED-SATELLITE, RADIOLOCATION, MOBILE, Amateur & Amateur-satellite service
24 GHz	24.25 GHz	24.125 GHz	250 MHz	B	Worldwide	AMATEUR, AMATEUR-SATELLITE, RADIOLOCATION & Earth exploration-satellite service (active)
61 GHz	61.5 GHz	61.25 GHz	500 MHz	A	Subject to local acceptance	FIXED, INTER-SATELLITE, MOBILE & RADIOLOCATION SERVICE
122 GHz	123 GHz	122.5 GHz	1 GHz	A	Subject to local acceptance	EARTH EXPLORATION-SATELLITE (passive), FIXED, INTER-SATELLITE, MOBILE, SPACE RESEARCH (passive) & Amateur service
244 GHz	246 GHz	245 GHz	2 GHz	A	Subject to local acceptance	RADIOLOCATION, RADIO ASTRONOMY, Amateur & Amateur-satellite service

Frequency Range

- Frequency Bands



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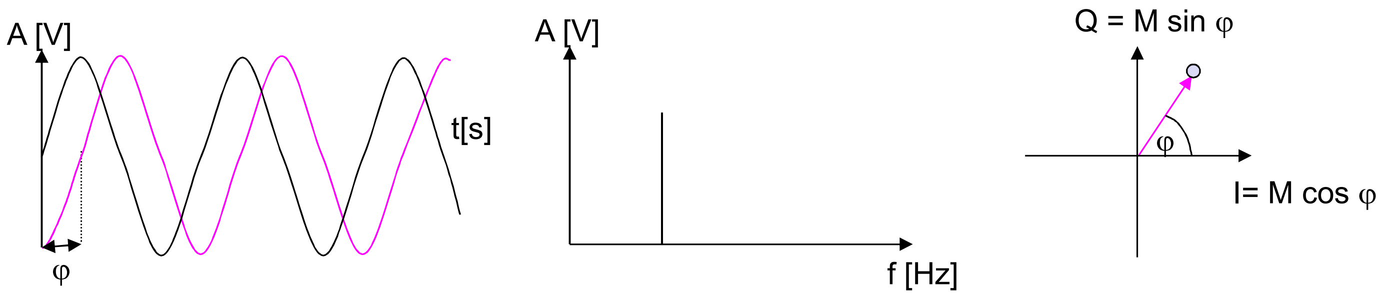
Signal

- **Signal:**
  - **physical representation of data**
  - **function of time and location**
  - **signal parameters: parameters representing the value of data**
  - **classification**
    - **continuous time/discrete time**
    - **continuous values/discrete values**
    - **analog signal = continuous time and continuous values**
    - **digital signal = discrete time and discrete values**
  - **signal parameters of periodic signals: period T, frequency f=1/T, amplitude A, phase shift ϕ sine wave as special periodic signal for a carrier:**

$$s(t) = A_t \sin(2 \pi f_t t + \varphi_t)$$

Signal

- **Different representations of signals**
  - amplitude (amplitude domain)
  - frequency spectrum (frequency domain)
  - phase state diagram (amplitude M and phase ϕ in polar coordinates)



- **Composed signals transferred into frequency domain using Fourier transformation**
- **Digital signals need**
  - infinite frequencies for perfect transmission
  - modulation with a carrier frequency for transmission (analog signal!)

Signal Propagation Ranges

- **Propagation in free space always like light (straight line, line of sight)**
- **Receiving power proportional to**

  $1 / (d \times f)^2$ (ideal)

  $1/(d \times f)\alpha$ (α=3...4 realistically)

  d = distance between sender and receiver
- **Receiving power additionally influenced by**

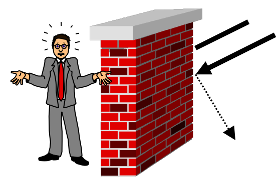
  fading (frequency dependent)

  shadowing

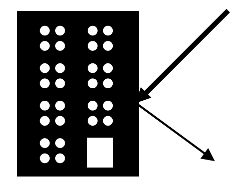
  reflection at large obstacles

  scattering at small obstacles

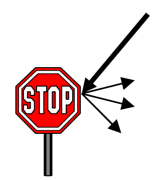
  diffraction at edges



shadowing



reflection



scattering

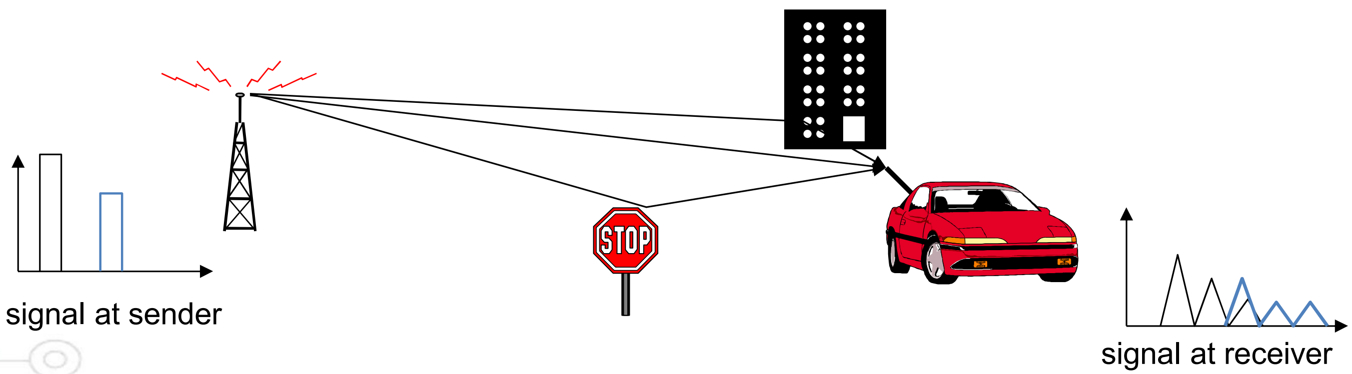
diffraction

Multipath propagation

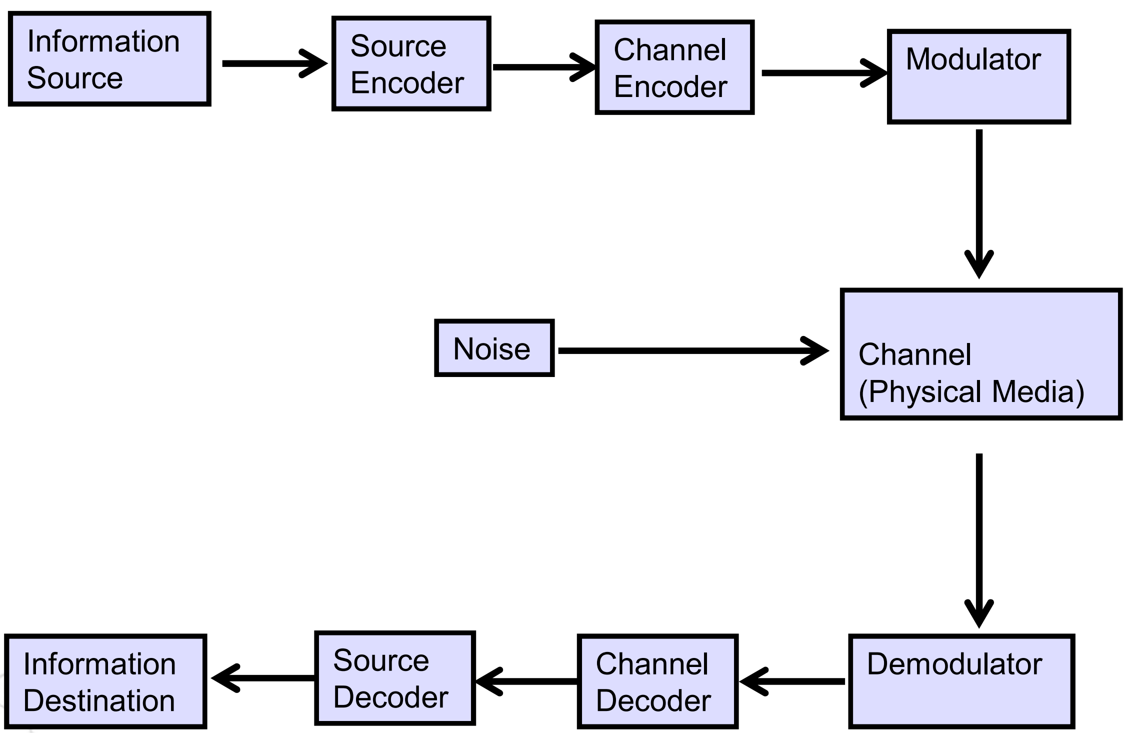
- **Time dispersion: signal is dispersed over time**

  interference with “neighbor” symbols, Inter Symbol Interference (ISI)
- **The signal reaches a receiver directly and phase shifted**

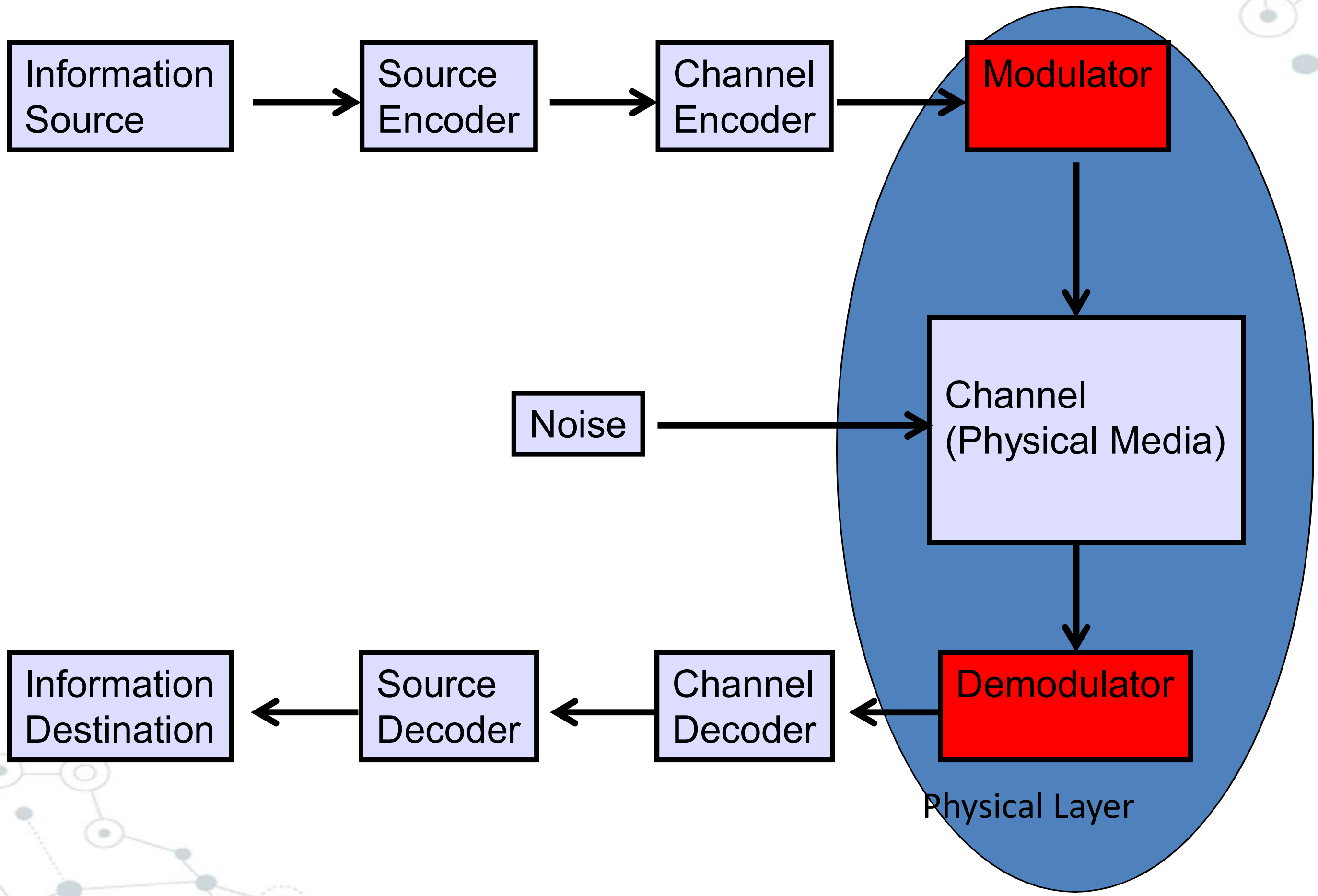
  distorted signal depending on the phases of the different parts



Transceiver Structure: Communications Block Diagram

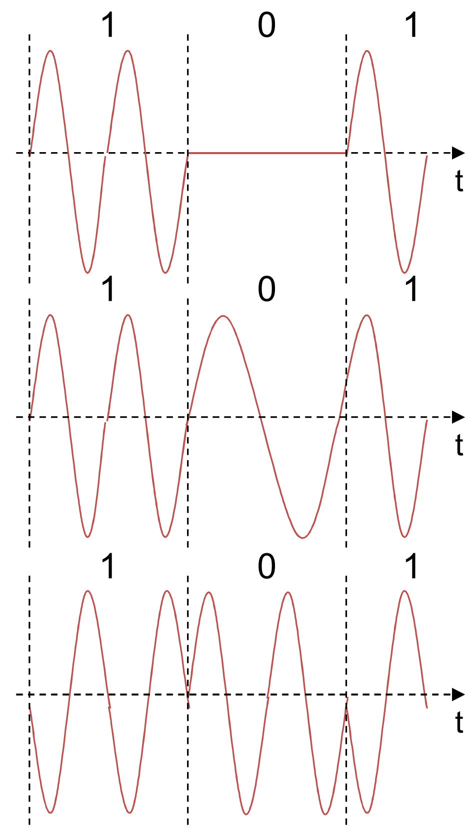


Physical Layer Issues



Modulation

- Transceiver Structure
  - **Digital modulation**
    - Digital data is translated into an analog signal (baseband) ASK, FSK, PSK
    - Differences in spectral efficiency, power efficiency, robustness
  - **Analog modulation**
    - Shifts center frequency of baseband signal up to the radio carrier
  - **Motivation**
    - Smaller antennas (e.g., λ/4)
    - Frequency Division Multiplexing
    - Medium characteristics



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