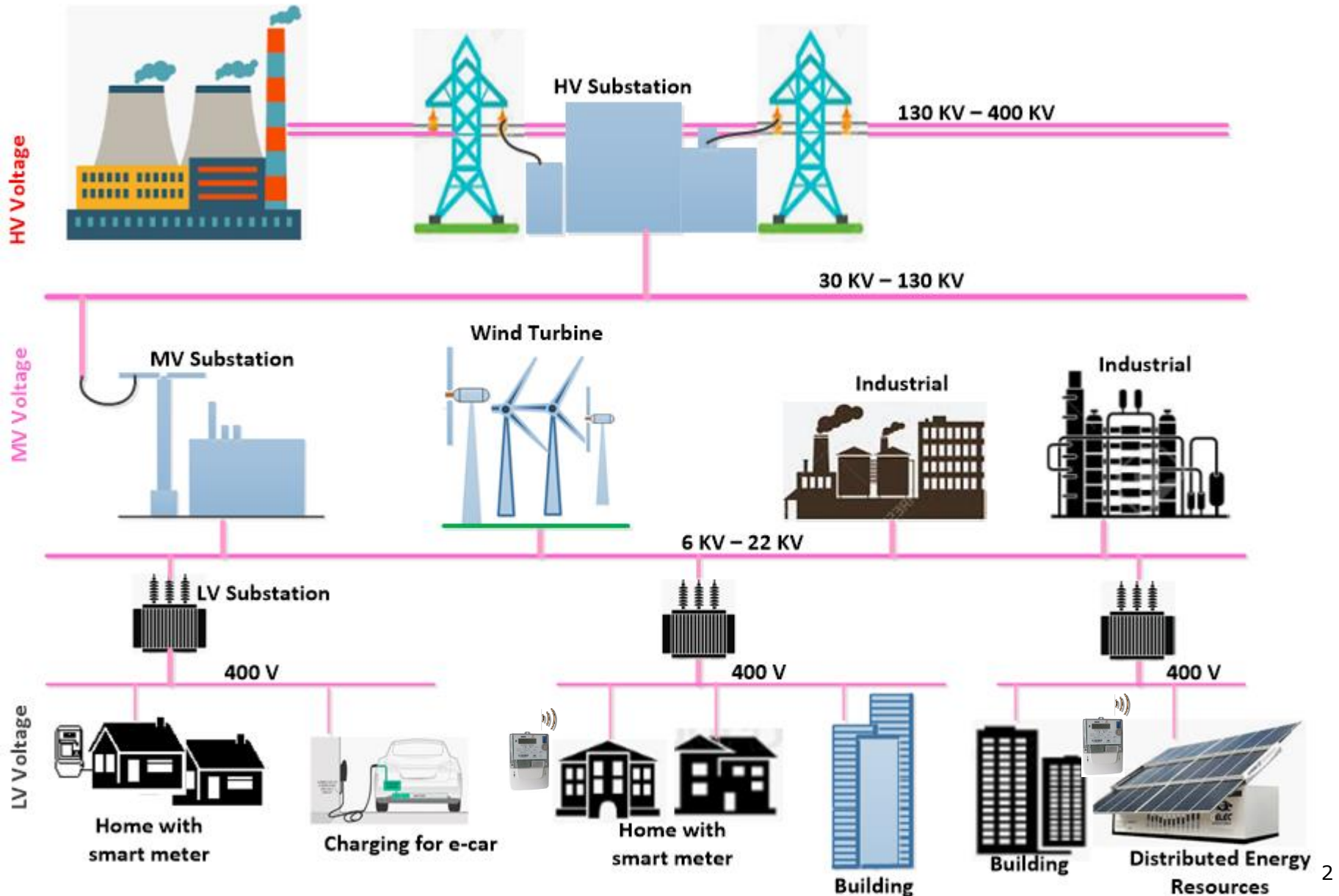


The image is a composite background. The top half shows a city skyline with several skyscrapers under a cloudy sky. The bottom half shows a close-up of a green printed circuit board (PCB) with various electronic components like capacitors and integrated circuits. A white, glowing network of lines and nodes is overlaid on the entire image, connecting various points across the city and the circuit board.

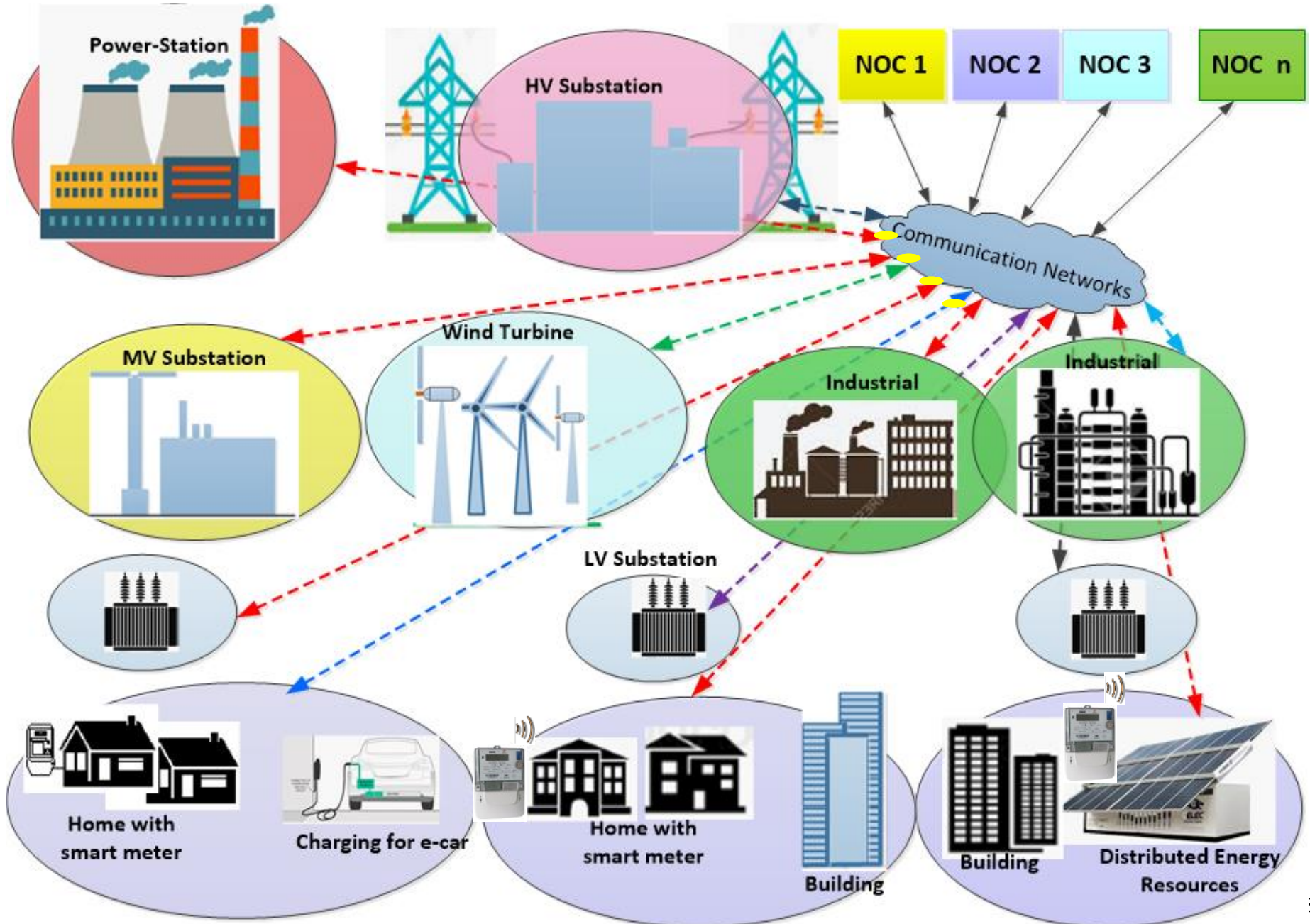
# Communication Technologies for Smart-Grid

# Grid End-to-End

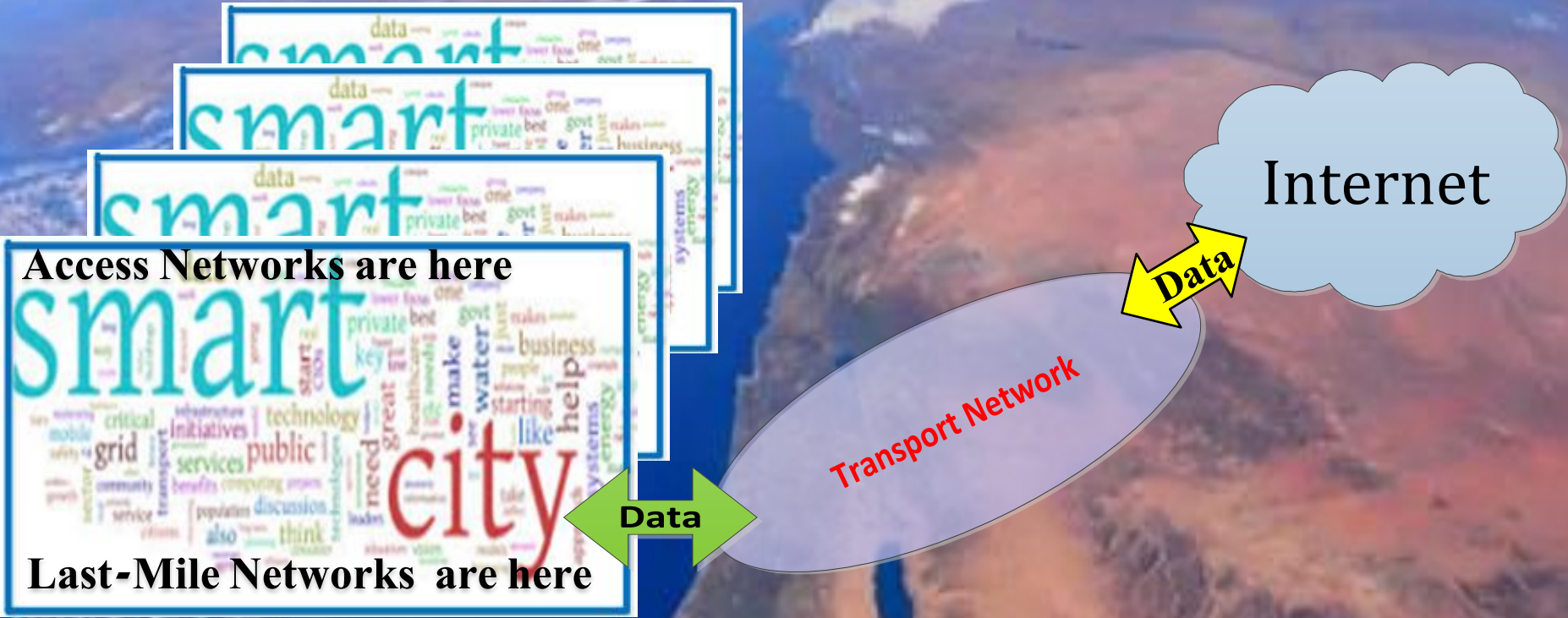




# Smart Grid relies on a Communication networks



# End-to-End Communication Network



What are the communications Technologies and what are the Rates of communication in each network part?

192.168.0.0 – 192.168.255.255



# The Transmission Medium

**Air**



**Twisted-Pair**



**COAX**



**Fiber Optic**



**Electric Lines**



**Working frequency**  
Defined

**Working frequency**  
Defined

**Working frequency**  
Defined

**Working frequency**  
Defined

**Working frequency**  
Not Defined

**Impedance**  
Defined (379  $\Omega$ )

**Impedance**  
Defined (100,600,900  $\Omega$ )

**Impedance**  
Defined (50, 75,95  $\Omega$ )

**Impedance**  
Not Defined

**Attenuation**  
Defined

**Attenuation**  
Defined

**Attenuation**  
Defined

**Attenuation**  
Defined

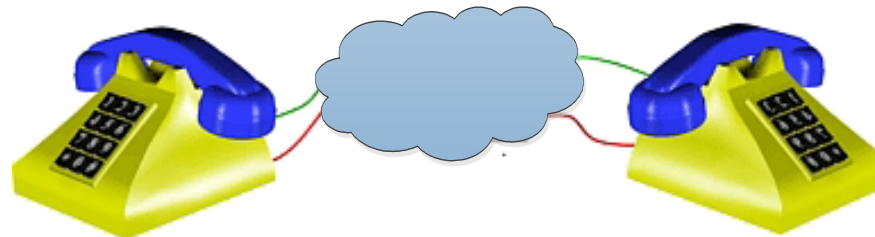
**Attenuation**  
Not Defined

**Noise**  
Defined

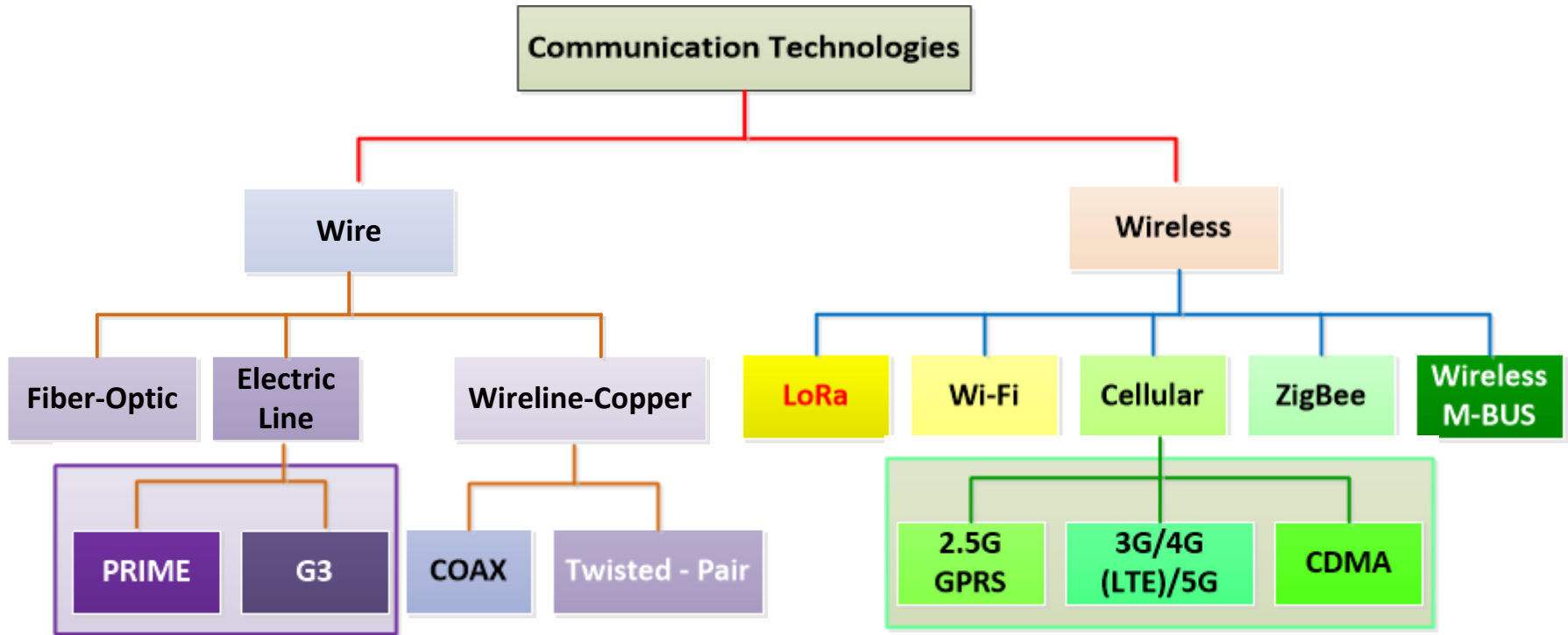
**Noise**  
Defined

**Noise**  
Defined

**Noise**  
Not Defined



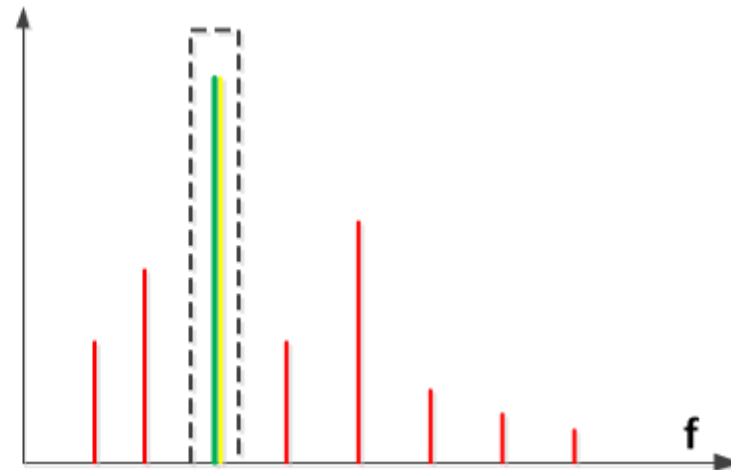
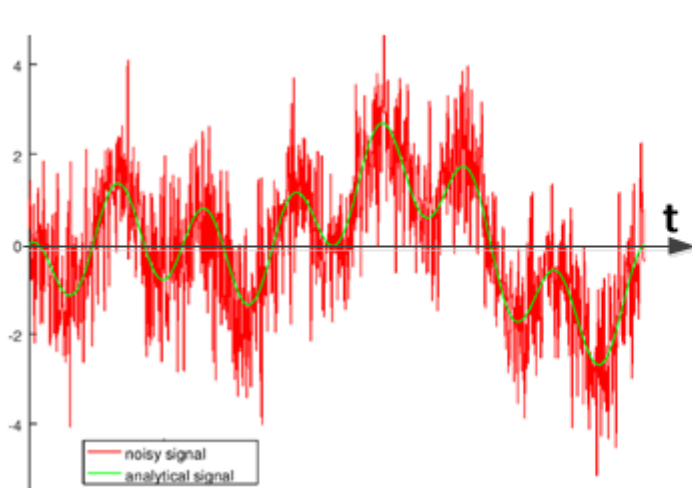
# A variety of communications media are used in Smart-Grid



# Digital Signal Processing – Based on Fourier Transform



1768 במרץ 21	לידה
אוסר, צרפת	
1830 במאי 16 (בגיל 62)	פטירה
פריז, צרפת	
מתמטיקה	ענף מדעי
ד"ר לואי לגראנז'	מנחה
	לדוקטורט
קצין בלגיון הכבוד	פרסים
הפרס הגדול במדעים מתמטיים	והנצחה
לגיון הכבוד	



# Wireline Technologies

- Wired communication is the transmission over a physical wire:
  - Twisted-Pair and Coax
- It is characterized by a very High Bandwidth, for Real-Time and Multimedia applications: Telephony, Video streaming, etc.
- A copper network cable requires special shielding to protect it from electromagnetic interference.
- Used for: Last-Mile, Transport/Backbone and Core networks



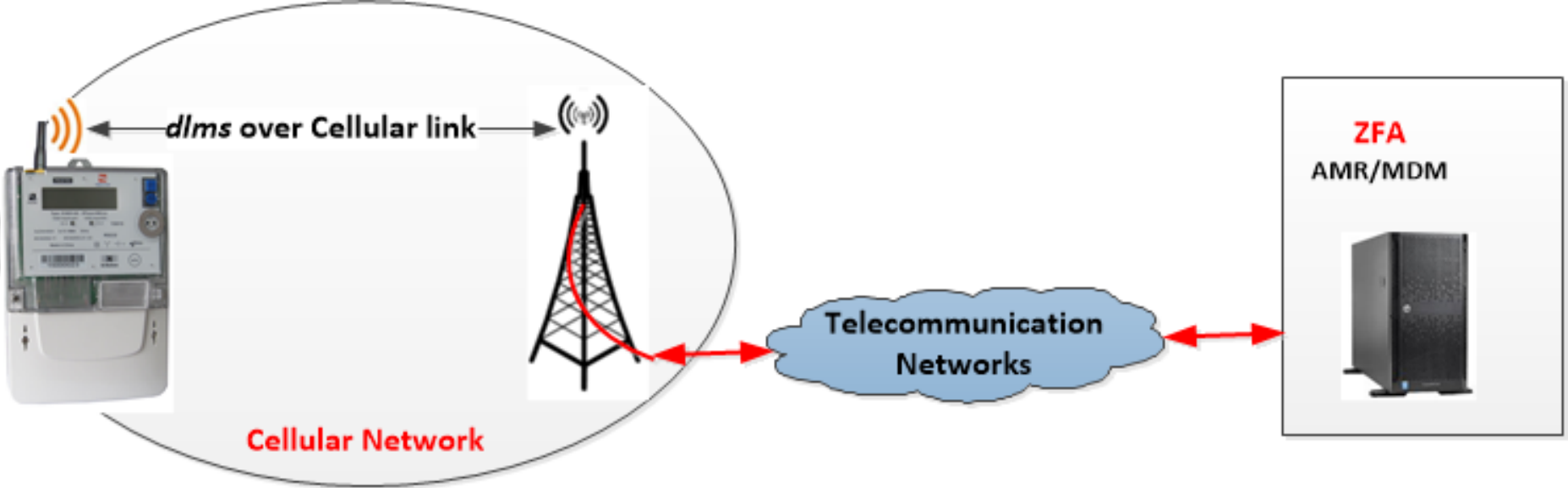
# Fiber-Optic technology

- Fiber-Optic cable is a network cable that contains collection of Glass Fibers
- Fiber-Optic designed for long distance, high-performance data networking and telecommunications.
- Provides the higher bandwidth rated at: 10, 40 and even 100 Gbps.
- Fiber-Optic is less susceptible to interference.
- Fiber-Optics is best choice for Backbone/Transport and Core networks.
- Fiber-Optic cables support much of the world's Internet, Cable Television, and Telephone systems.

# Cellular Technologies

- Developed especially for Mobile devices
- 3G/4G/5G cellular technologies are designed for: High-speed communication for: Voice, **Video** streaming and Real-Time performance
- Data Rates range from 50 Kbps (GPRS), over 10 Mbps (3G) to over 50 Mbps (LTE/4G).
- A Single-Cellphone operates over several kilometers
  - Does not designed to support connecting large number of devices
- Disadvantage: The network is very expensive
- Mainly used for the Last-Mile.

# Cellular communication Point-to-Point



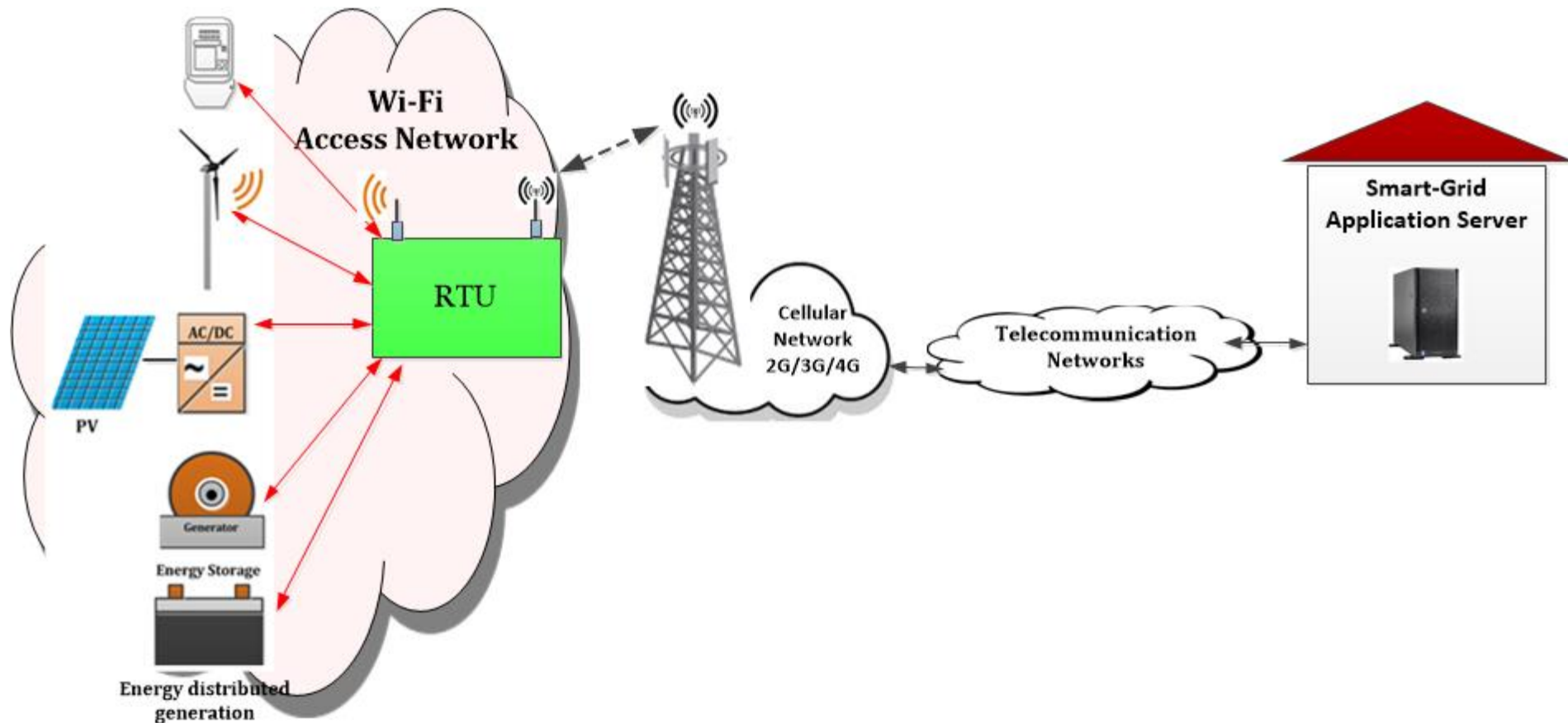


# Wi-Fi (Wireless Fidelity) Technologies

- Dominant technology for Indoor and Office connectivity
- Is perfect for Short-Distance, about 100 m for Hot-Spot
- Is characterized by High Bandwidth for Real-Time and multimedia.
- High Speeds Data transfer rates range from 5 Mbps up to 54 Mbps (for 802.11g)
- Mainly used for LAN (Local Area Network)

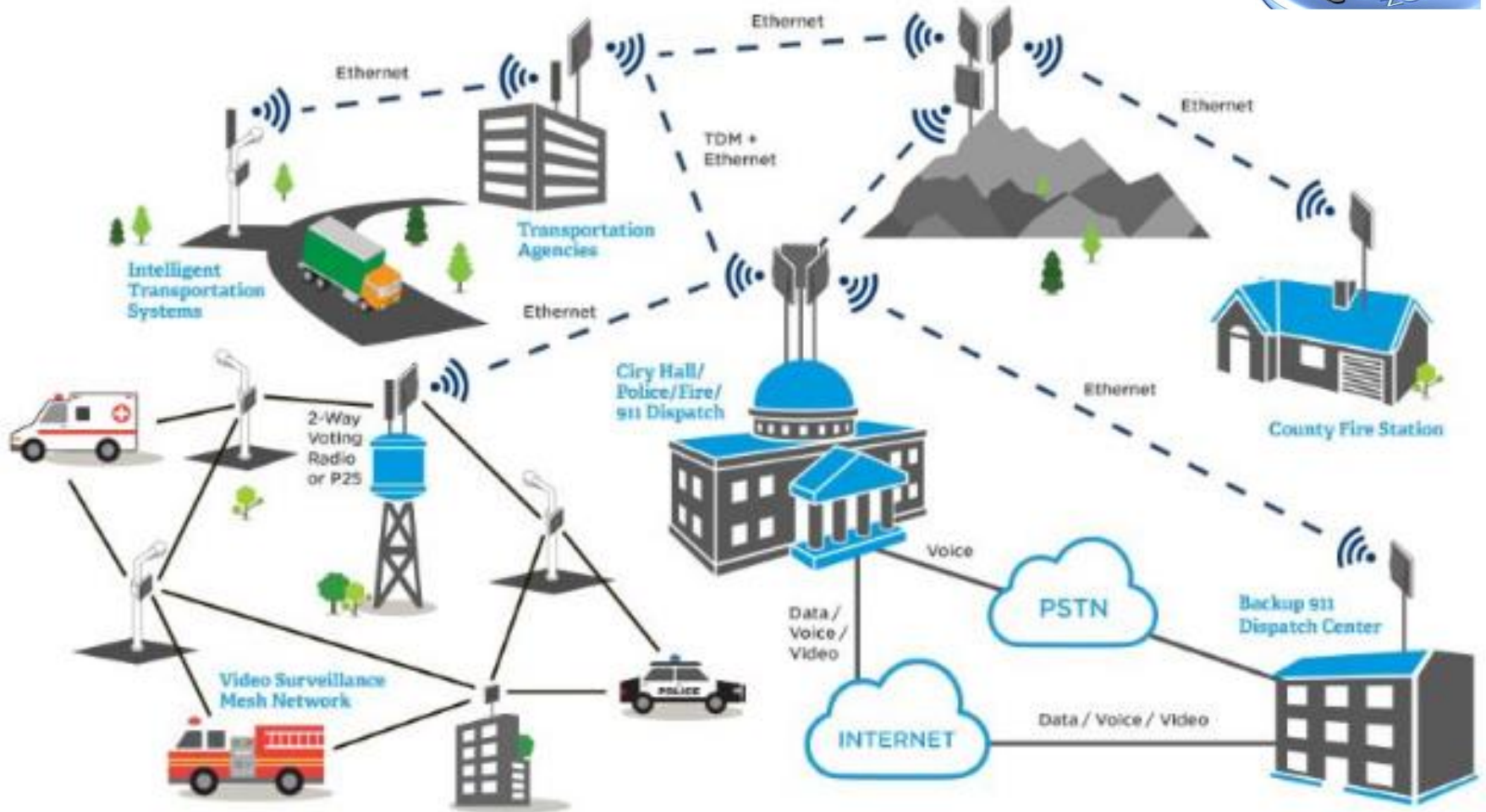


# Wi-Fi Communication Point-to-Multipion



# Municipal Network (Muni)

Wi-Fi Hot-Spots all over the City performs mesh network





# Wireless M-Bus Technology

- The M-Bus (Meter-Bus) European standard for remote reading of Heat meters and for all other types of consumption meters as well as for various sensors.
- Operating on license-free ISM (Industrial, Scientific and Medical) frequency
- Data rate from 2.4 Kbps up to 100 Kbps depending on the mode and frequency
- Practical Range of 500 m at 868MHz and 2,000 m at 169MHz
- Used for LAN (Local Area Network)

# LoRa/LPWAN

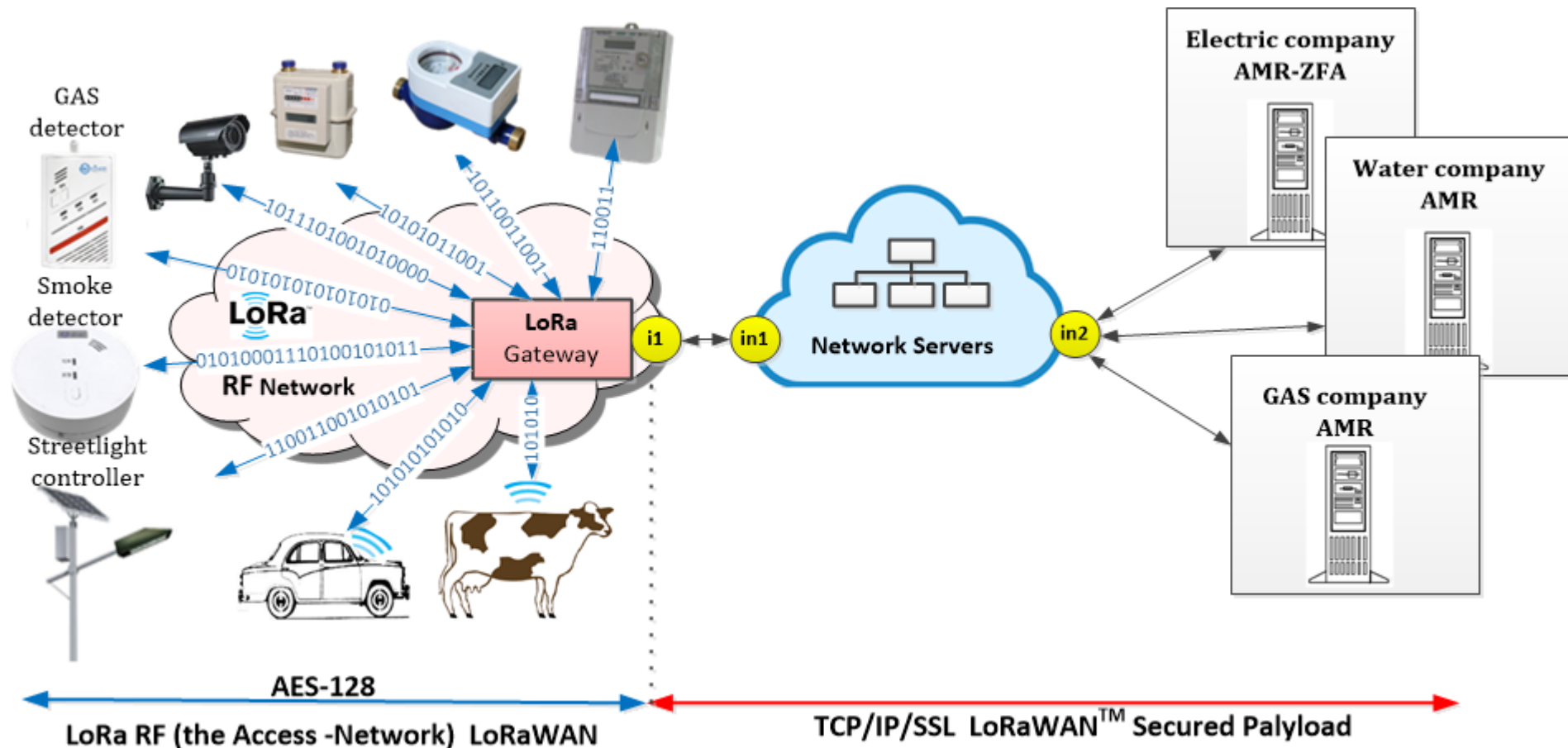
(**L**ong **R**ange **R**adio/**L**ow **P**ower **W**ide **A**rea **N**etwork)

- LoRa is wireless technology with a unique and awesome modulation format (Chirp, multi-symbol)
- Long range: Communication in open areas is for a distance of Tens of km, in an urban areas for over 10km
- Operating on license-free ISM frequency
- New communication technology for Smart-Grid, targeted for M2M (Smart Metering) and IoT deployments.
- Used for WAN (Wide Area Network) Last-Mile Access networks.

# LoRa Network Architecture

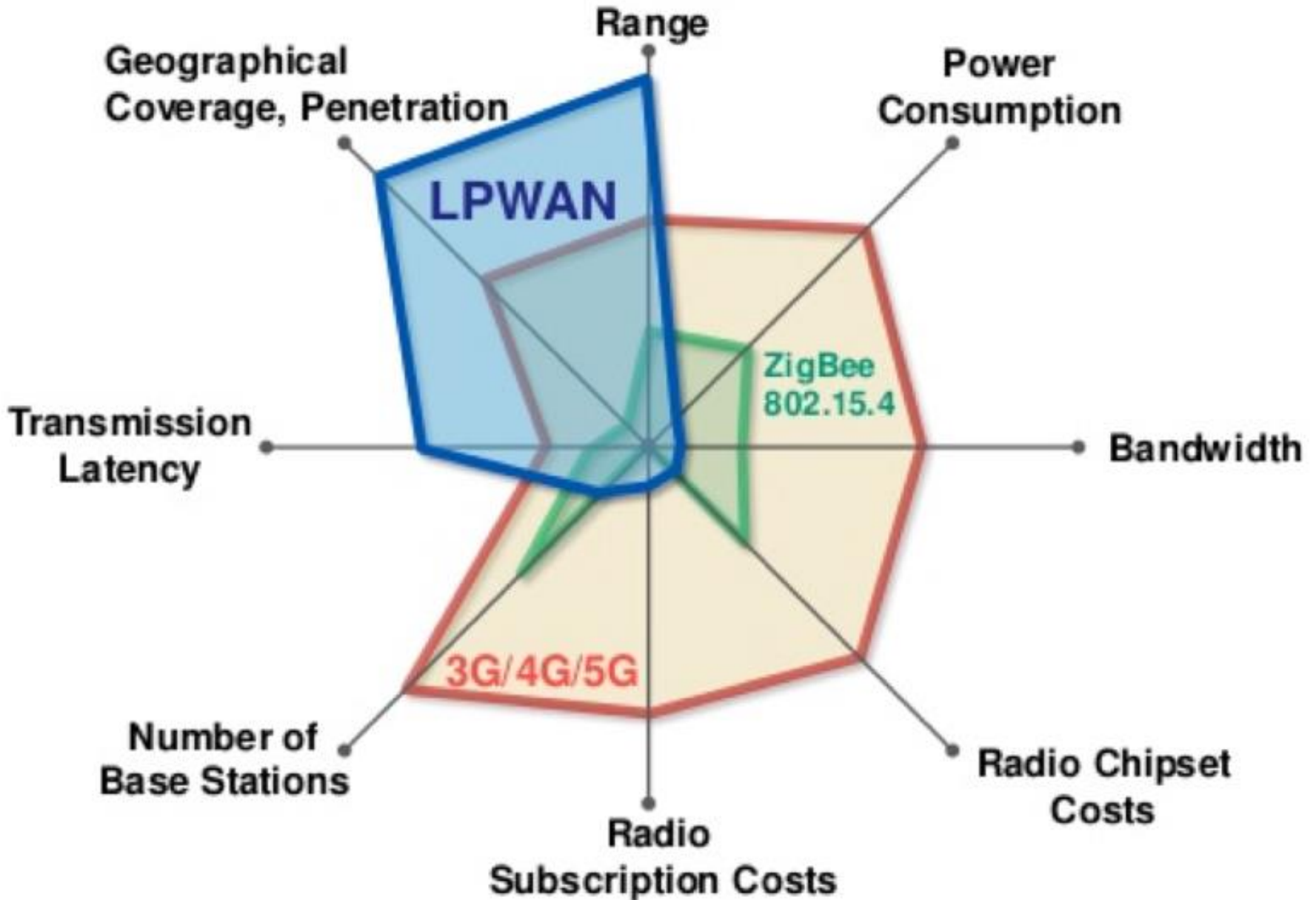
## End-to-End WAN Solution

- LoRa network consists of: Application Servers, Network Servers, Gateways, and End-Devices.



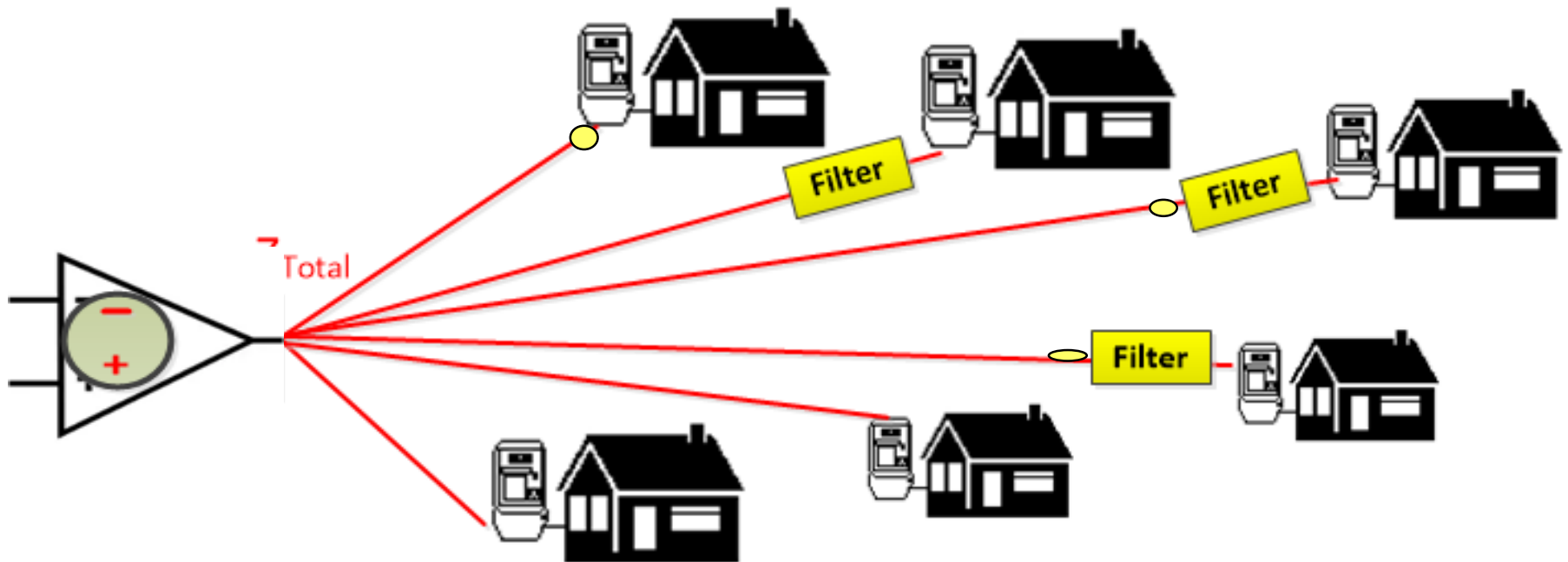


# Cellular and LoRa features comparison



# PLC (Power Line Carrier)- Point-to Multipoint

- Reflection of all the houses impedance towards the Source
- What type of Source should drive the Power Line ????

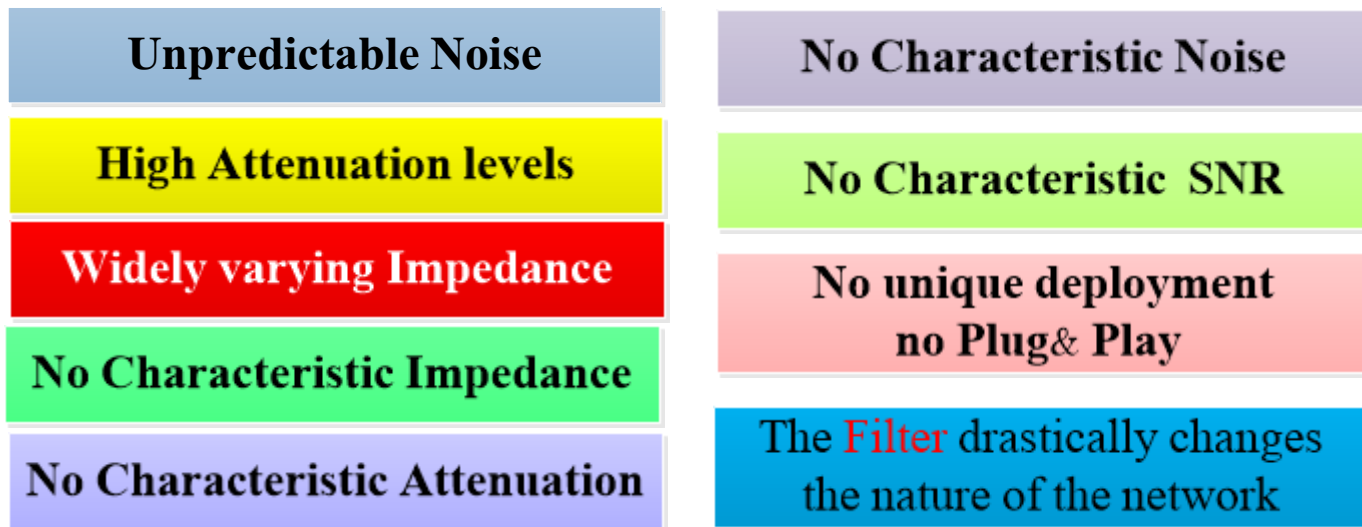


At any moment of measuring the Impedance will get a **probability** result

# PLC (Power Line Carrier)

- Communicates over Electric Power Lines
- Various problems associated with Powerlines Communication

אלו עשר מכות שהביא הקדוש ברוך הוא על ה- PLC בתקשורת ואלו הן



- Used for LAN (Local Area Network), mainly for Smart Metering.

**Powerline are not suitable for Data Communication**



# PLC - CDF ( Cumulative Distribution Function)

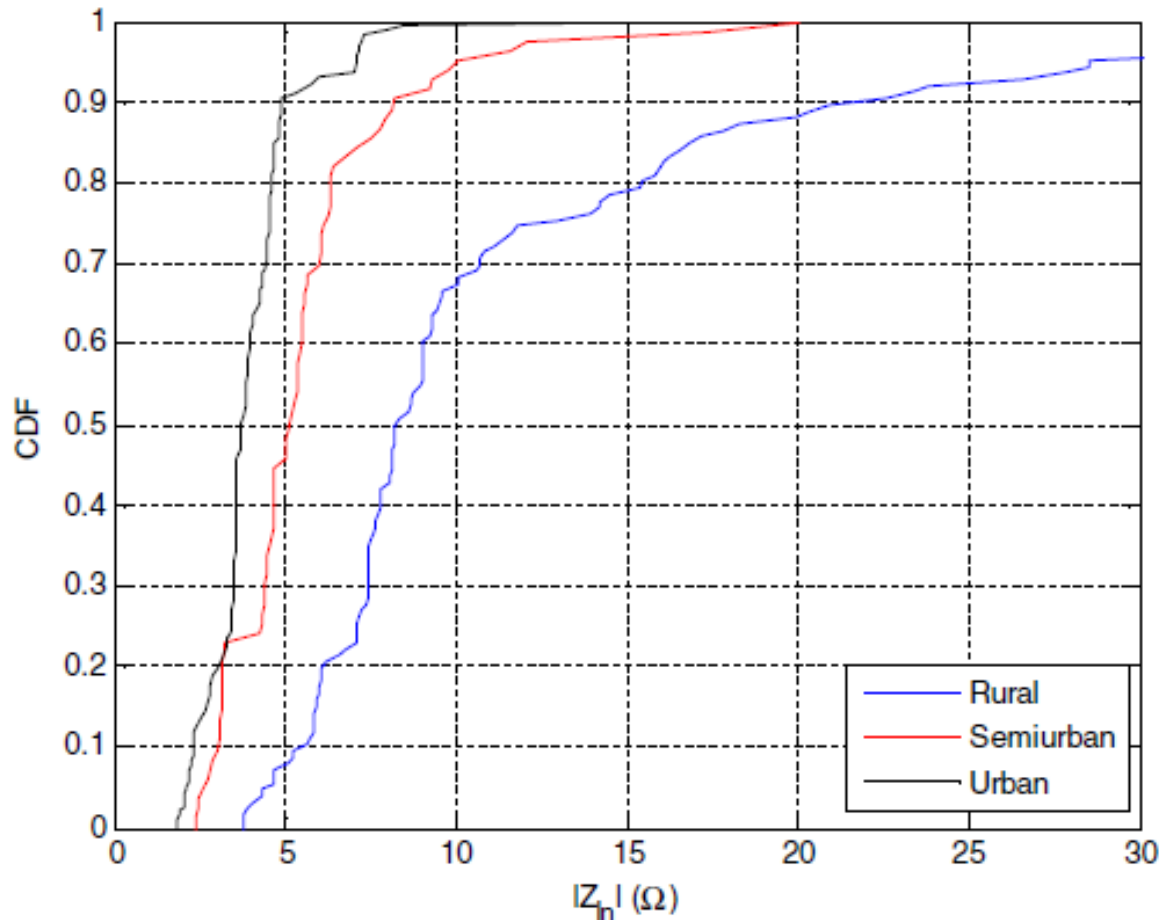
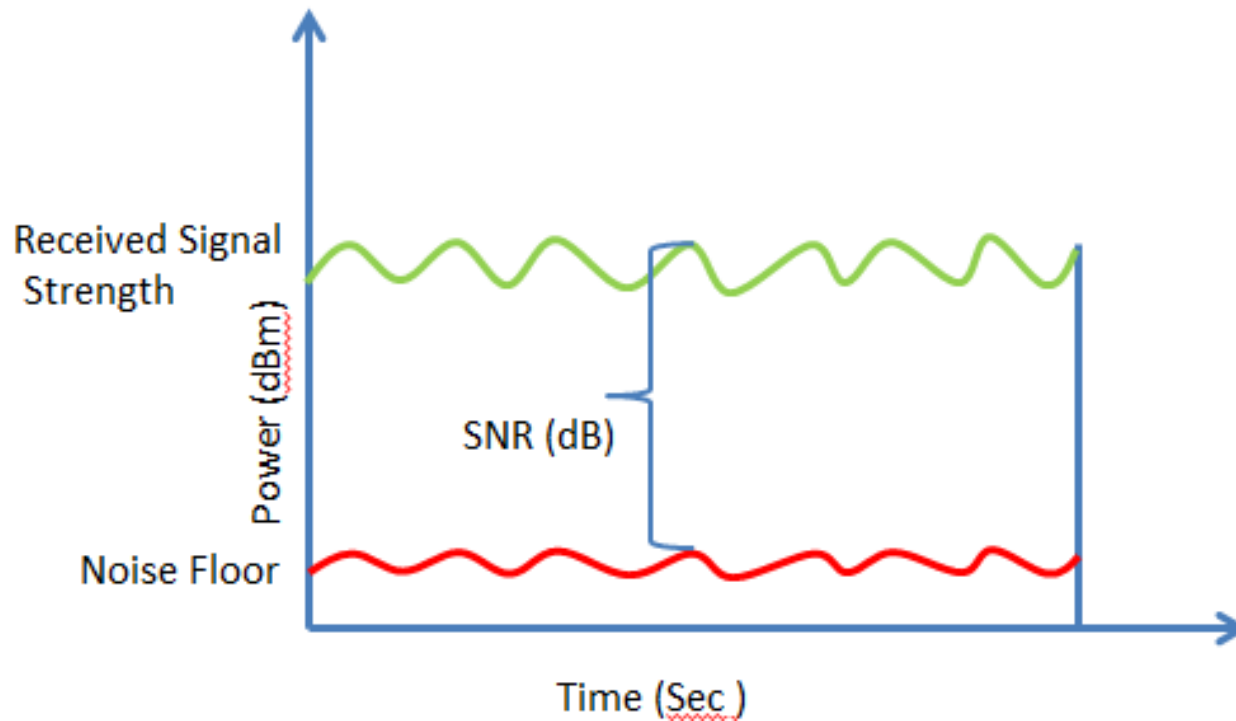


Figure 2 CDF of the frequency-averaged magnitude of the input impedance.

“CENELEC A-Band absolute **impedance** are reported values from **5  $\Omega$  to 17  $\Omega$**  over frequency range 20 to 100kHz  
Minimum impedance indicated to be  $\approx 0$  ohm”

# SNR – Signal to Noise Ratio

$$SNR = \frac{S}{N} = \frac{Signal}{Noise}$$



# SNR - PLC PRIME vs PLC G3

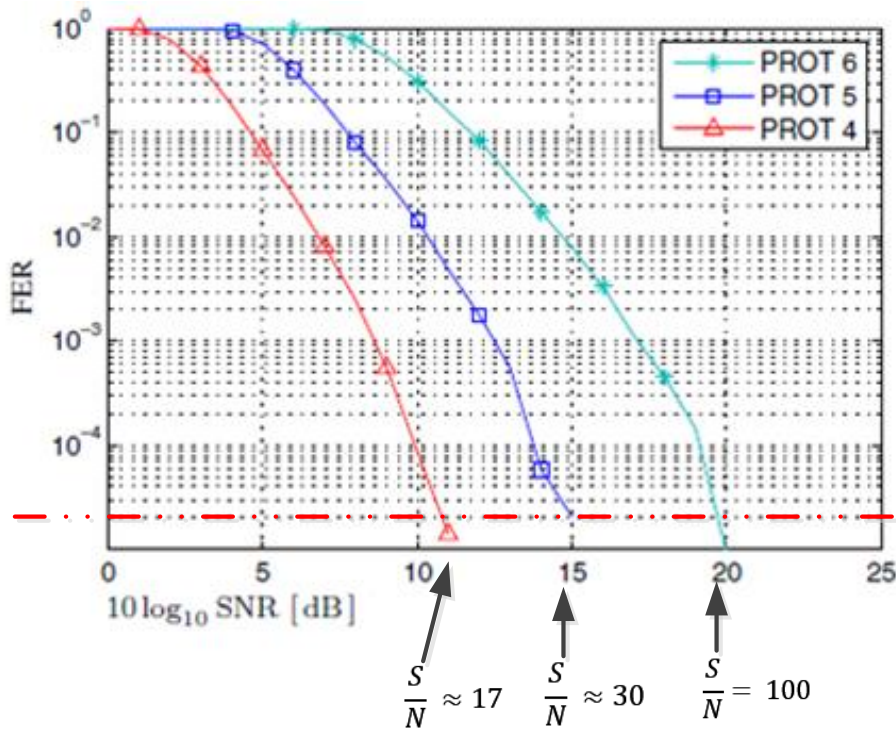


Fig. 6. Simulation Results for PRIME with Power Line Noise.

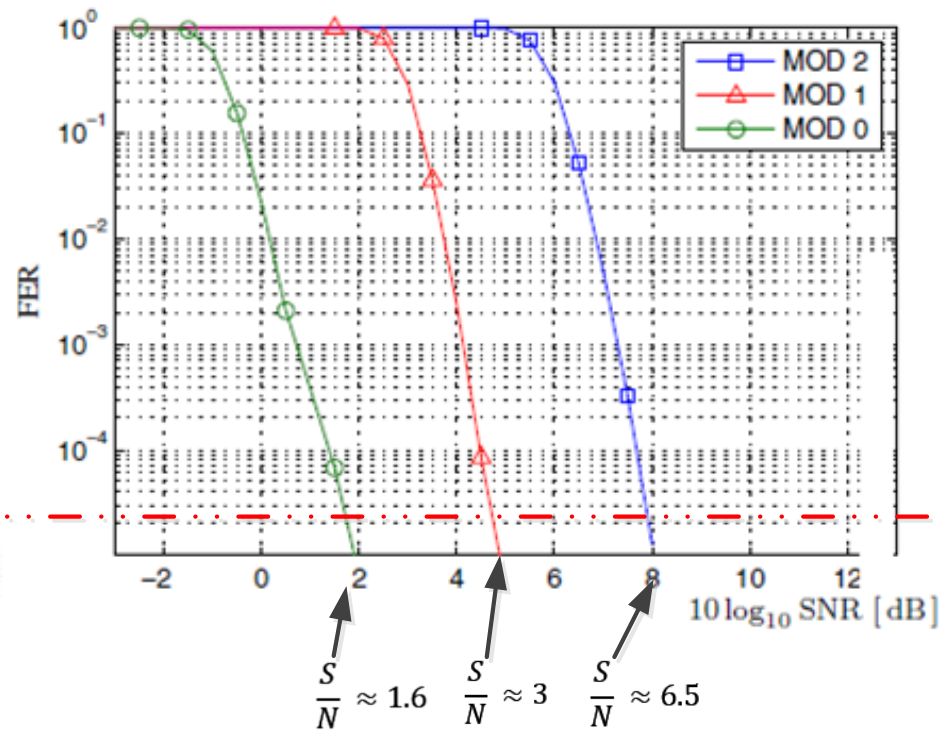
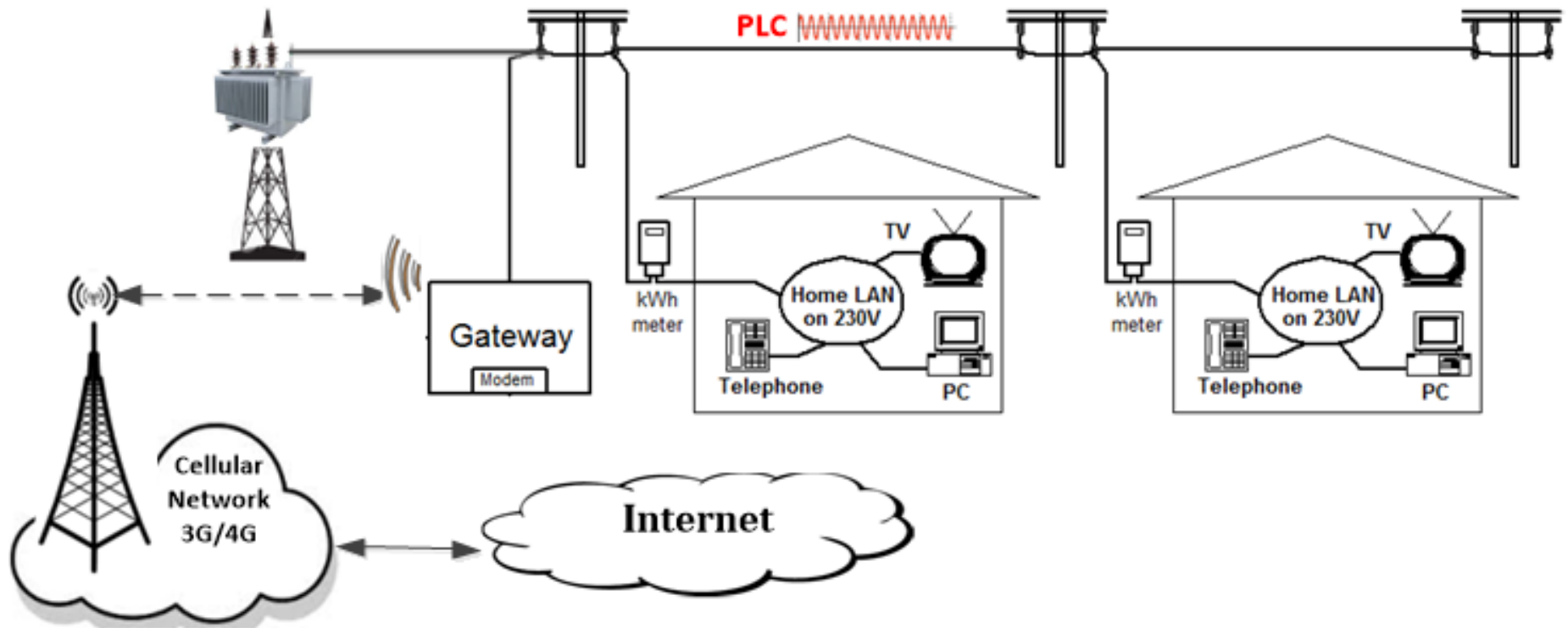


Fig. 5. Simulation Results for PLC G3 with Power Line Noise.

BER = 10<sup>-5</sup> → in every 100,000 detected bits,  
1 bit may be estimated incorrect

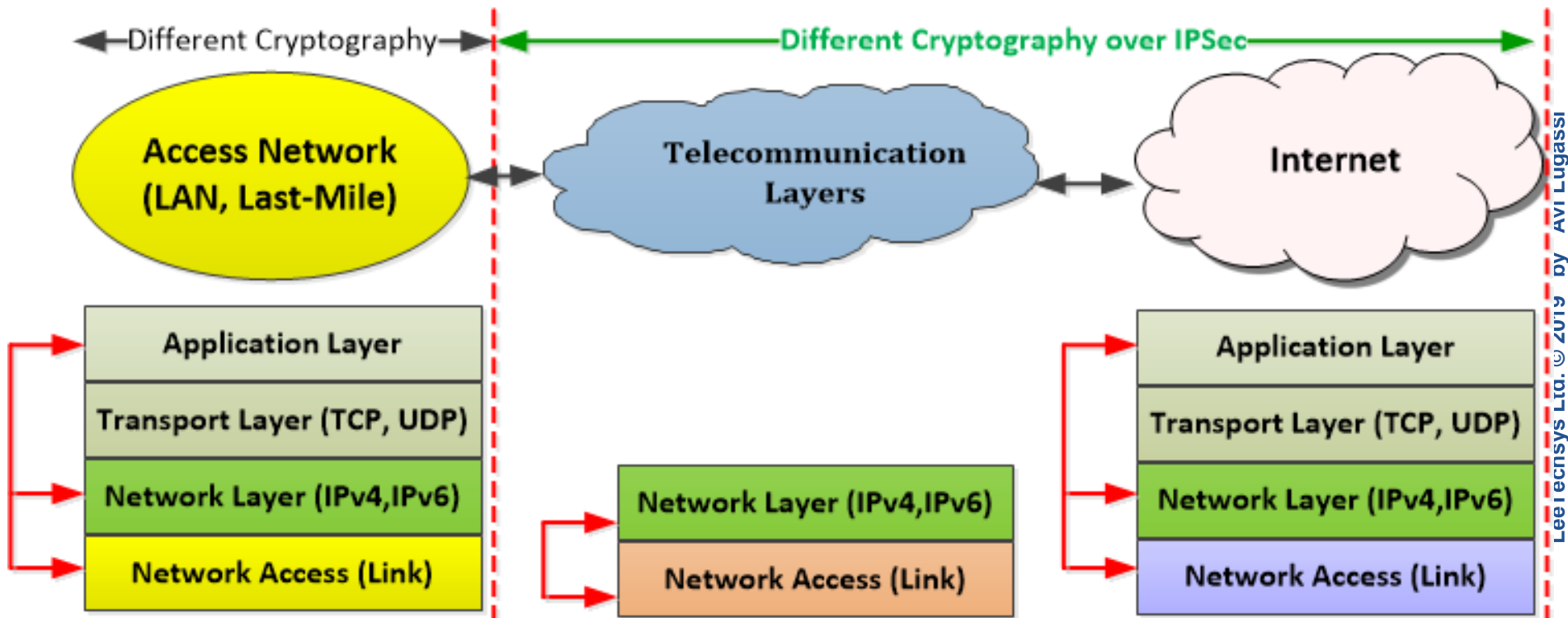
# Broadband - Access & In-home PLC System



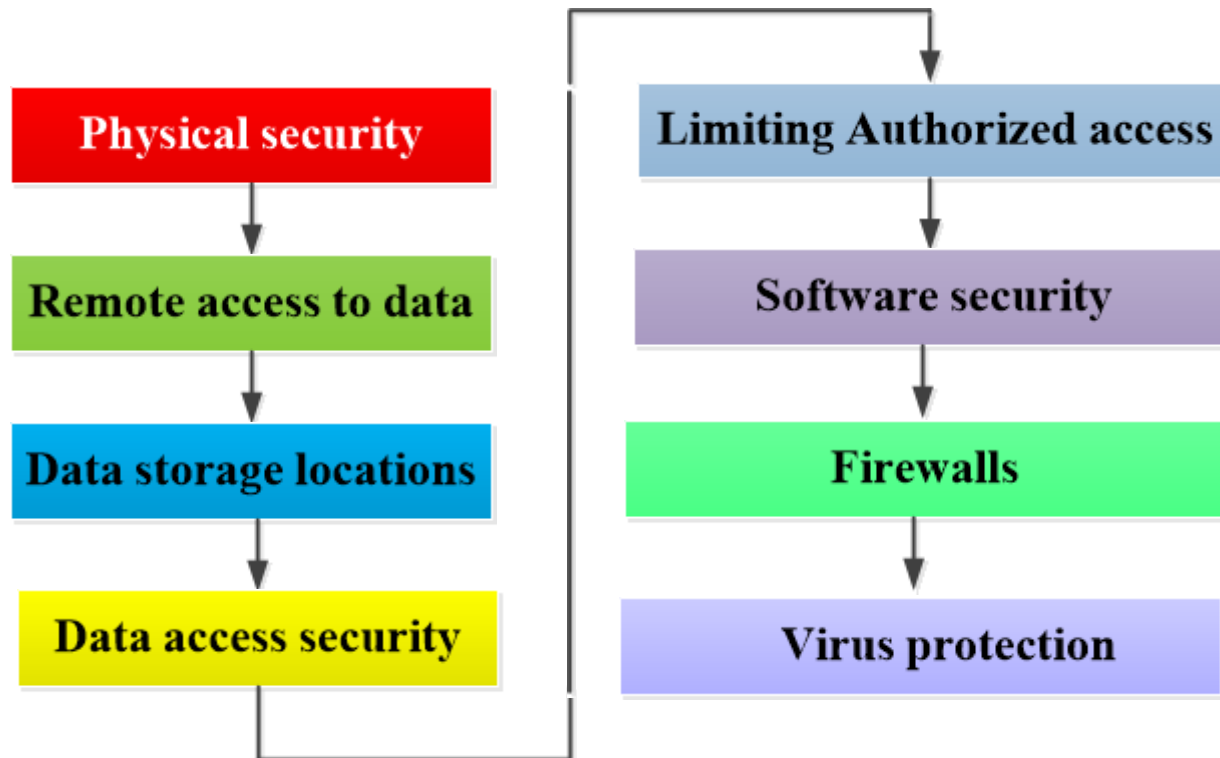


# Smart-Grid End-to-End Data Security

- The communications **networks** must be protected from unauthorized access at all times



# A variety of Smart-Grid Security



# $y(t)$ Carries power but does not carry information



$$Y(t) = A \sin (2\pi f t + \theta)$$

Amplitude

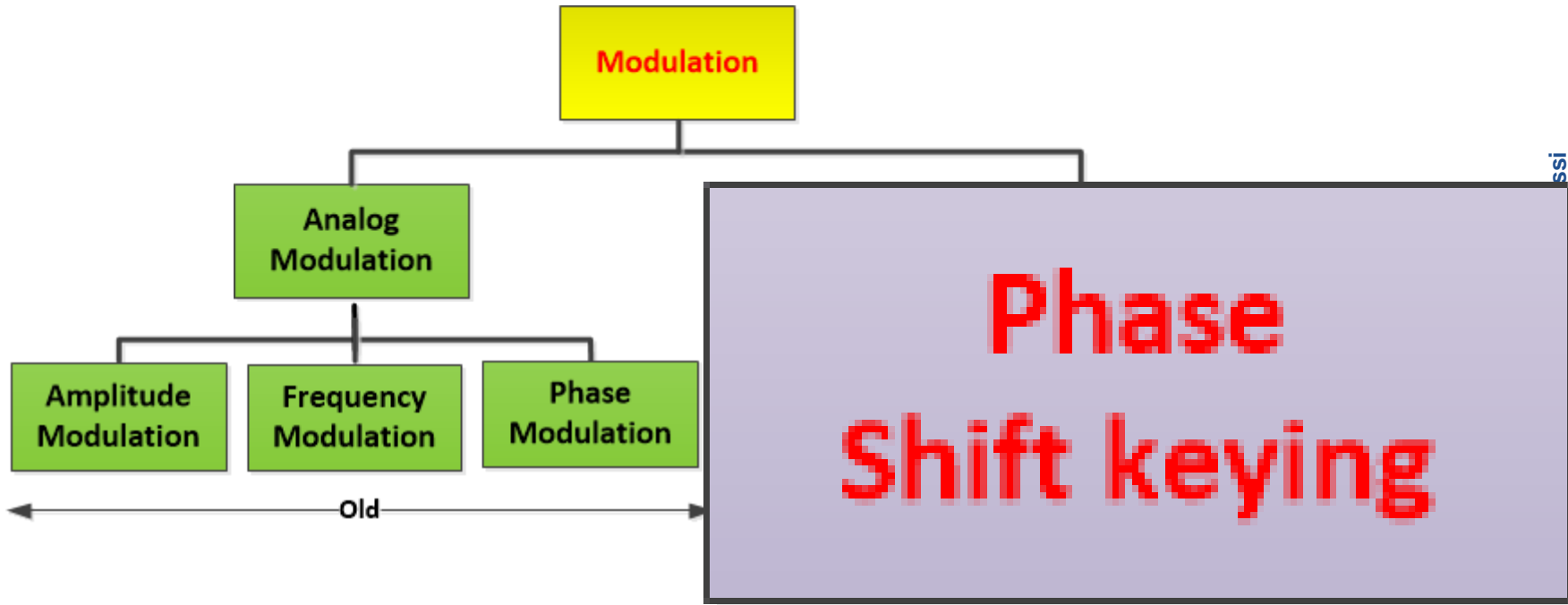
frequency

Phase



# Signal Modulation

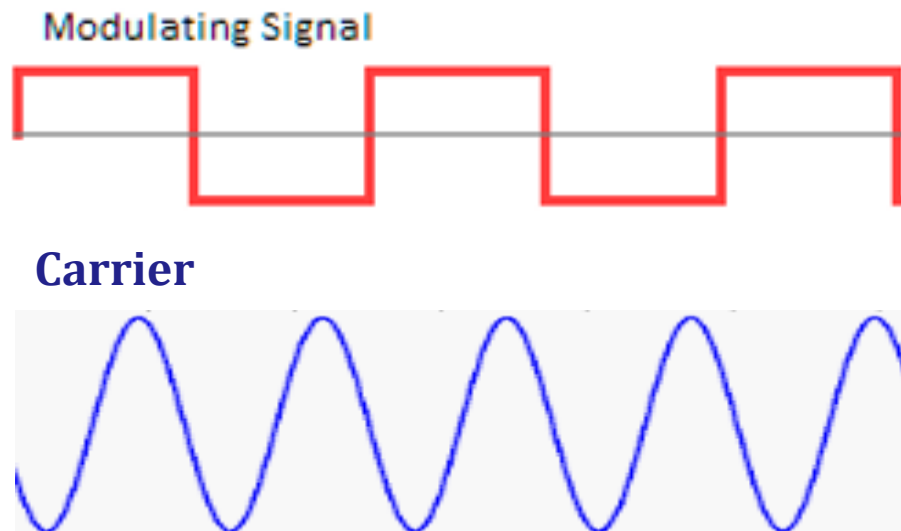
- There are mainly two categories of modulations:
  - Analog Modulation
  - Digital Modulation



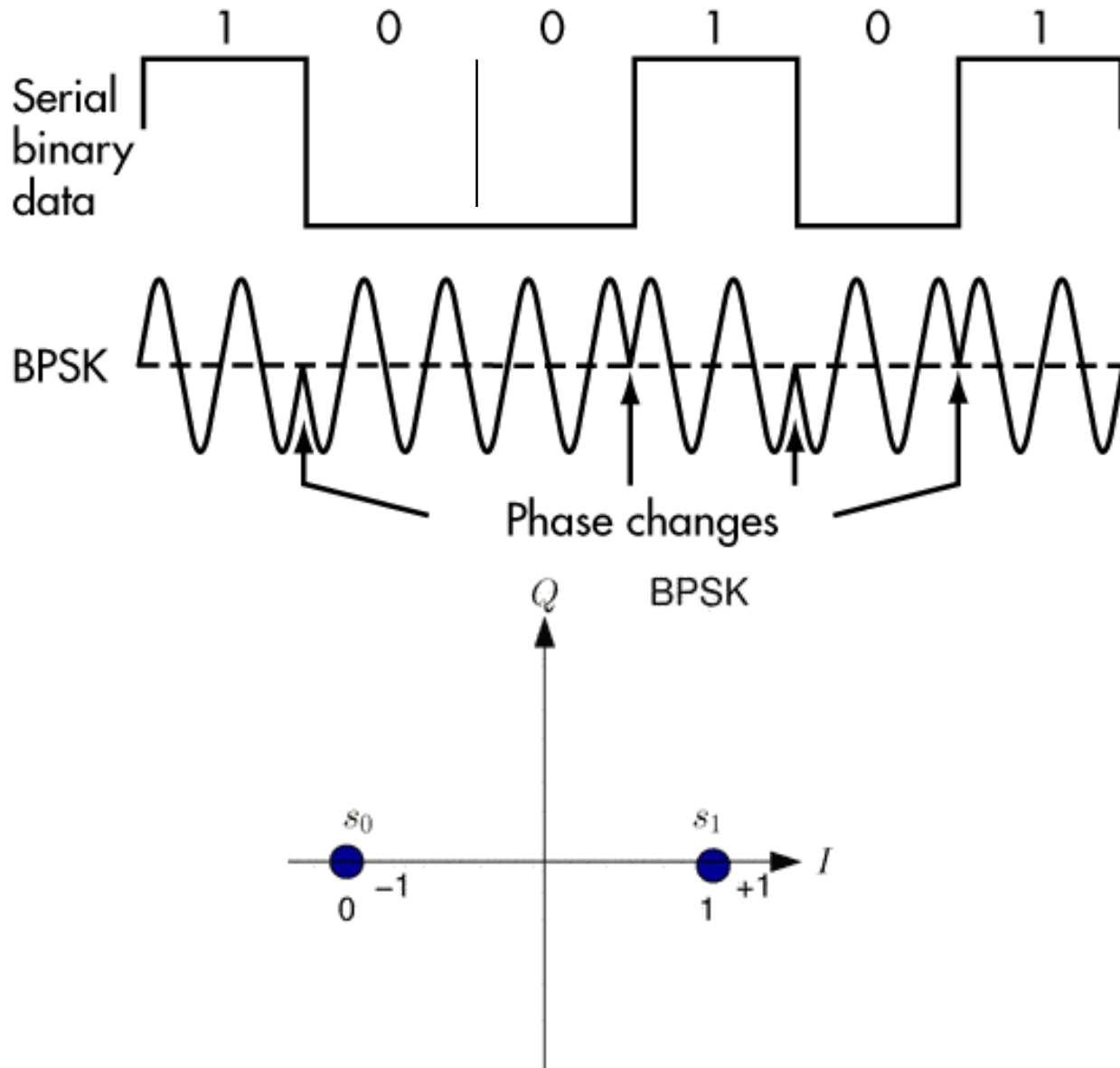


# Digital Modulation

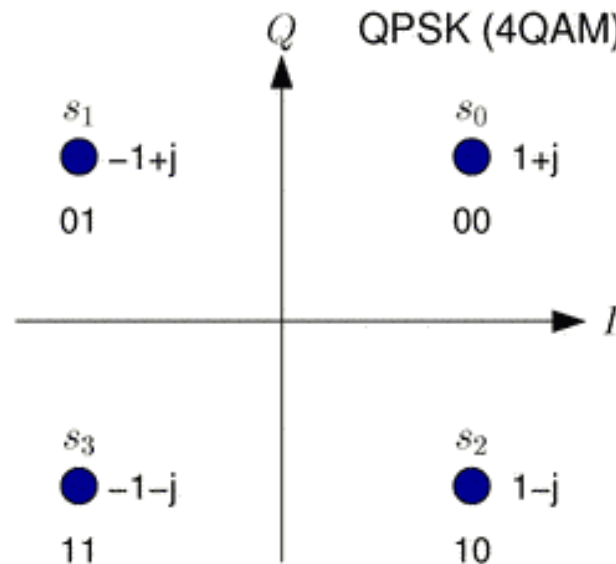
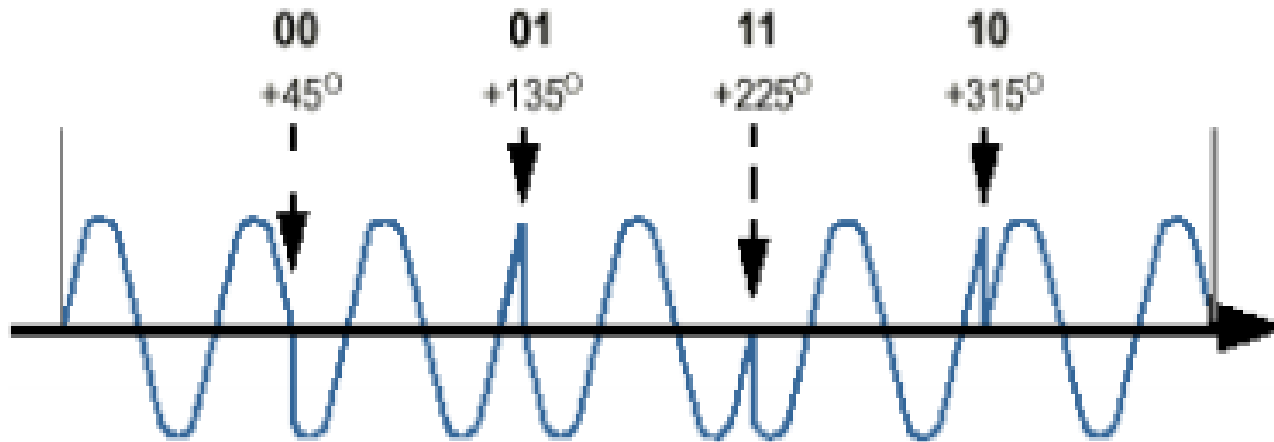
- ASK (Amplitude shift Key)
- FSK (Frequency shift key)
- PSK (Phase shift key)



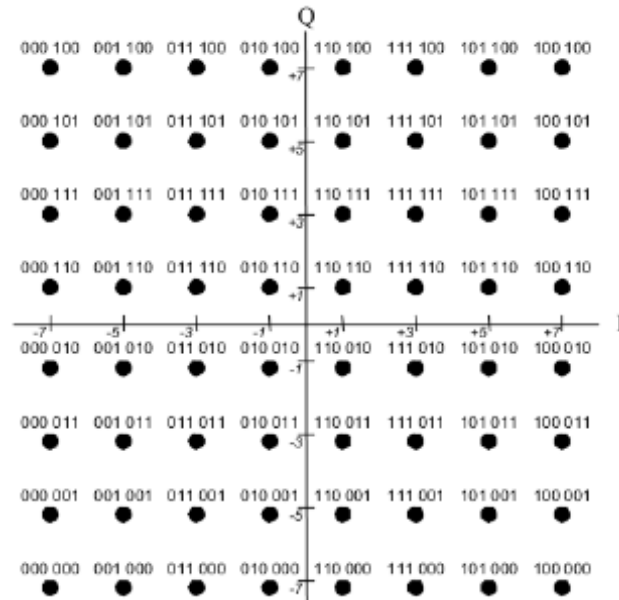
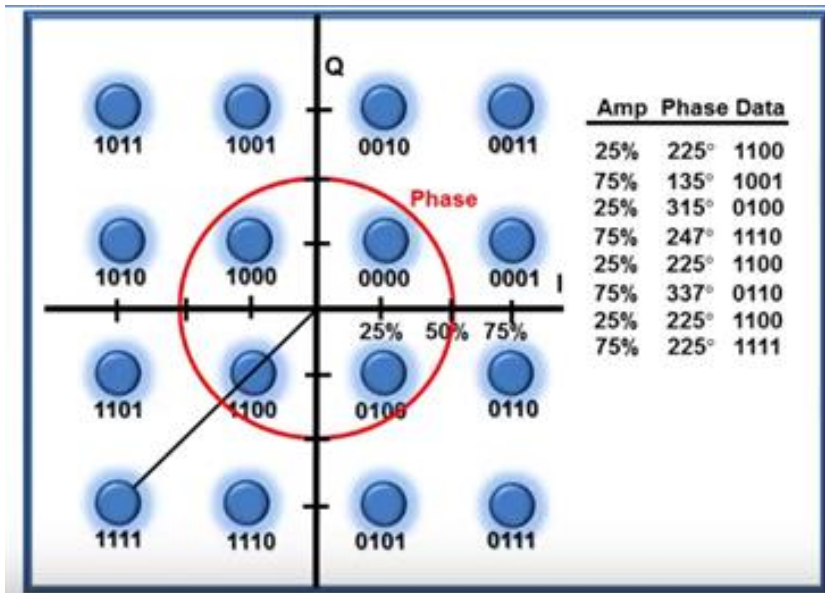
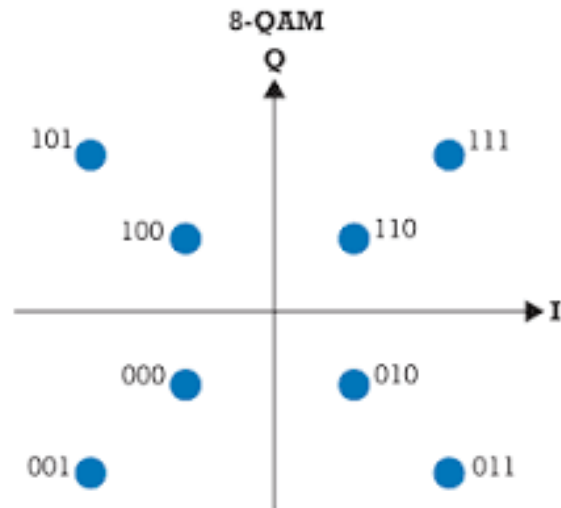
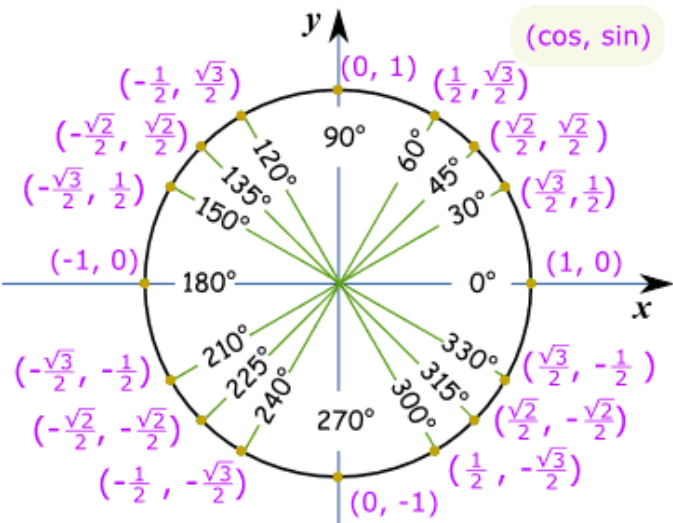
# BPSK Signal Modulation used for old PLC communication



# QPSK (Quadrature Phase Shift Keying)

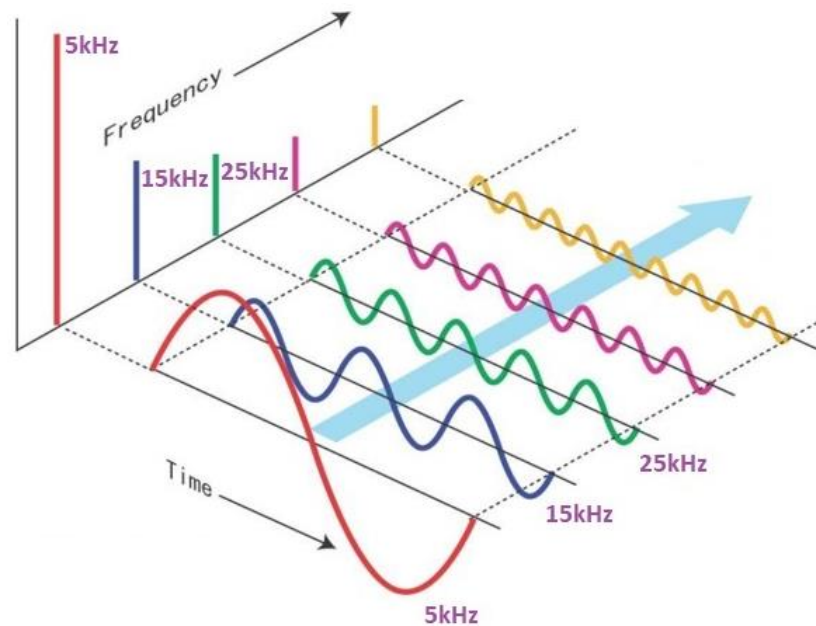
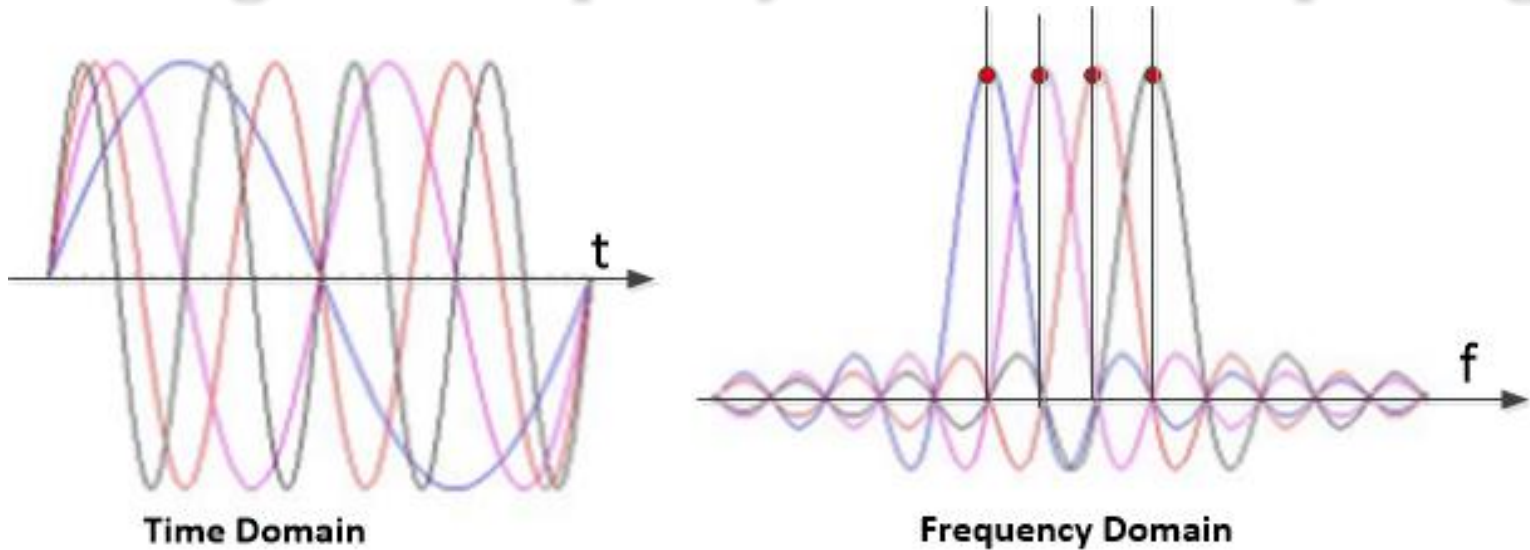


# PSK Modulation Techniques



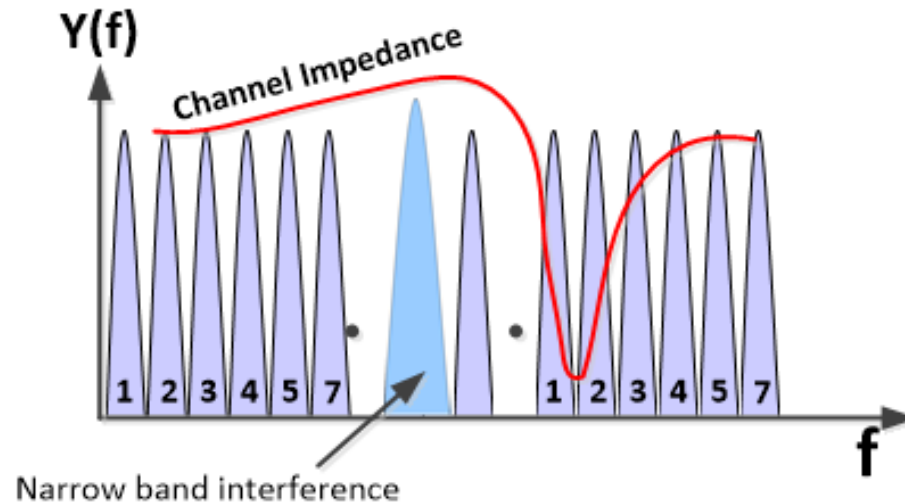
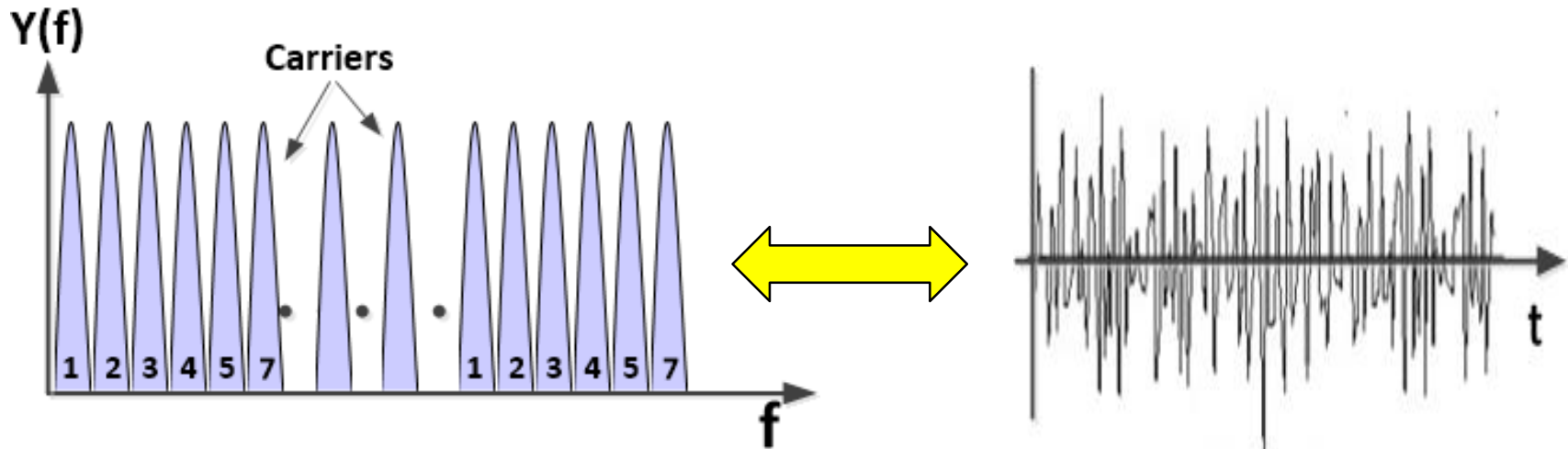
# Multi Carrier $\rightarrow$ OFDM

## Orthogonal Frequency Division Multiplexing

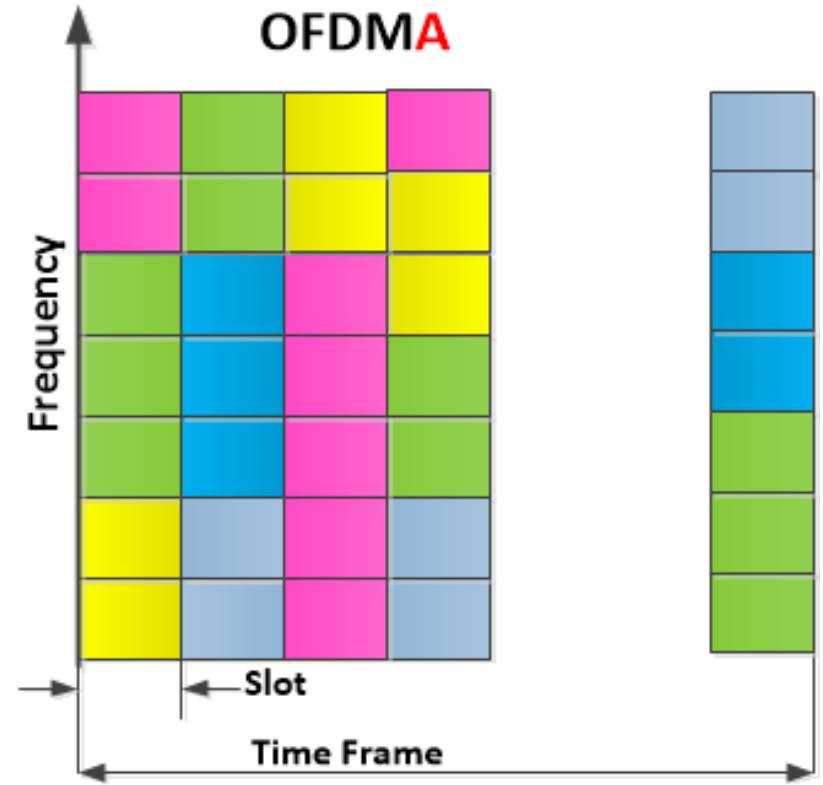
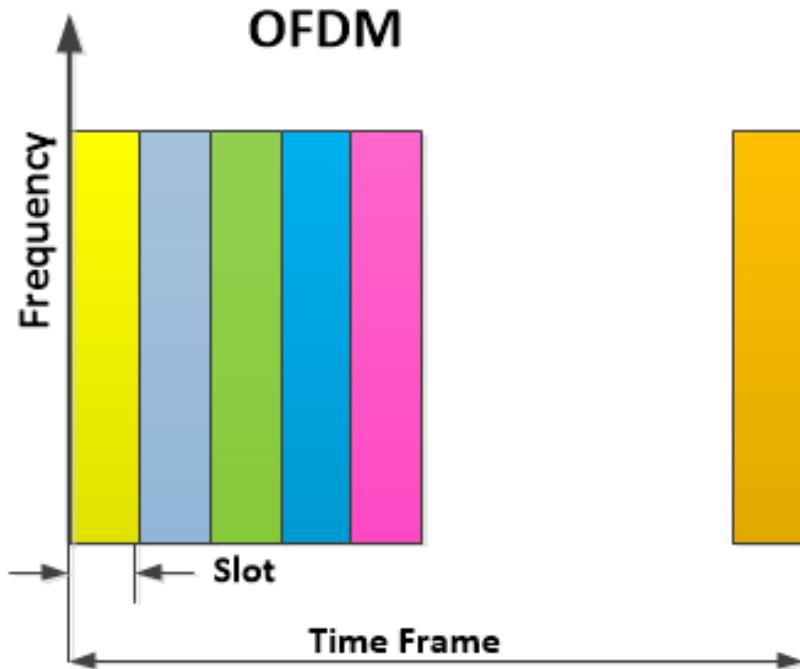




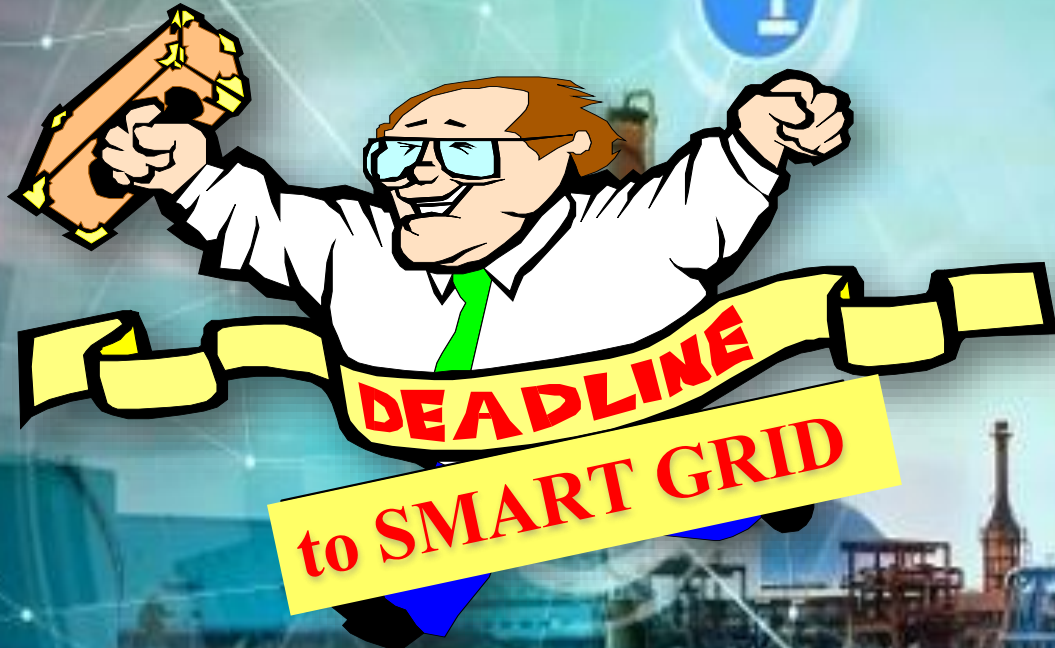
# OFDM Spread Spectrum



# OFDM vs. OFDMA



# Thank you for your attention



By: **Avi LUGASSI**

All rights reserved to LeeTechsys Ltd.

Duplication prohibited unless as expressly permitted by LeeTechsys Ltd.

