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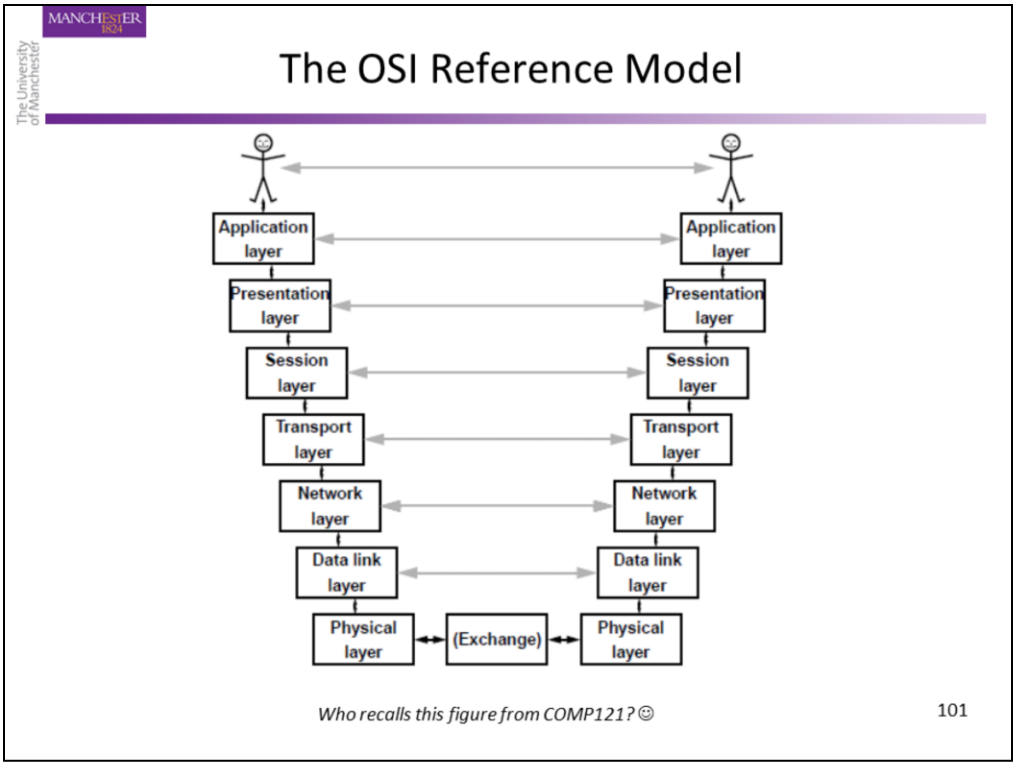
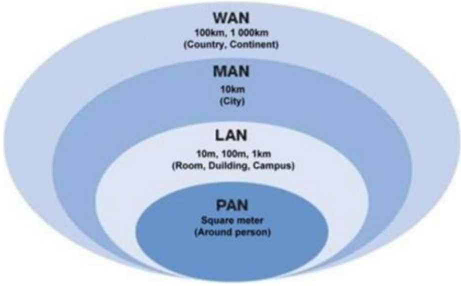
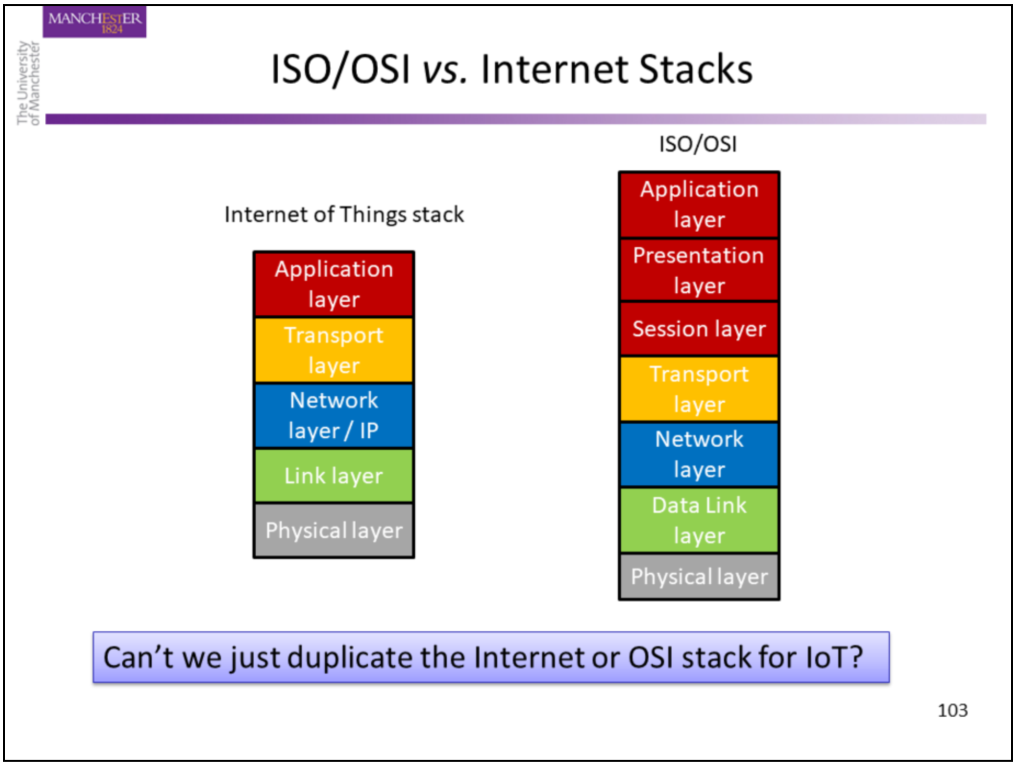
PART II



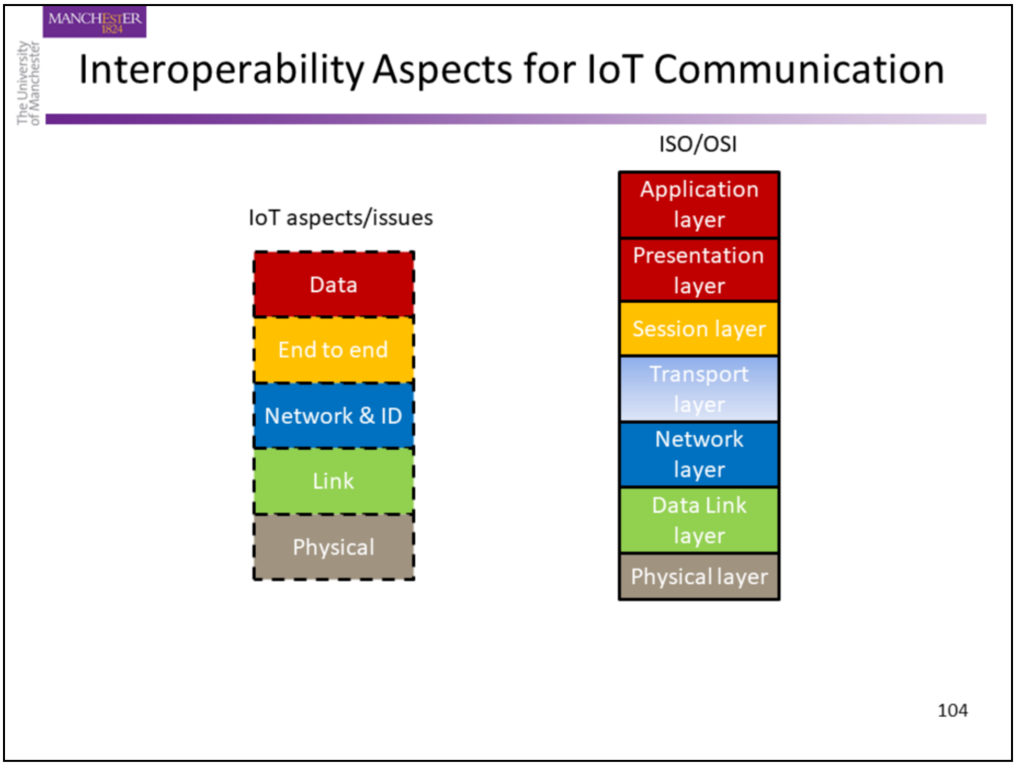
- Open Systems Interconnection model

Categorization of Wireless Networks





- The OSI stack was created based on the assumption of single technology stacks. This is not the case for IoT which is characterized by high technology heterogeneity.
- The Internet stack abstracts the Physical layer due to, typically, fully homogeneous networks but this is not the case for IoT where different power constrained devices at the edge are utilized.
- Many of the low-level IoT devices used in constrained networks do not support fully IP compliant communication.
- Consequently, protocols such as 6LoWPAN, are needed to extend IP communication to constrained networks.
- The “simplicity” does not fit the heterogeneous and complex nature of IoT systems; thus a different communication strategy is required, which, however, borrows elements from the Internet and OSI stacks.



IoT aspects to be considered for IoT protocol stacks:

- Physical aspect

This interoperability aspect is similar to the OSI Physical Layer. This aspect originates from the requirement to not exclude any available technology. This aspect does not impose the adoption of any specific technology. As an example, consider that a device with radio capabilities employs the Zigbee protocol while an application for a smartphone using the data produced by the device at the edge communicates with the database on cloud services through Wi-Fi or 3G cellular communication.

- Link aspect

As with the physical layer, the Link aspect should support the heterogeneity of networking solutions (although more limited than in the Physical layer) and underpin security solutions as well. In addition, this layer must provide upper layers with standardized capabilities and interfaces. Again, the idea is not to limit the implementation of data link layer but rather ensure the coexistence of several solutions for the link layer.

Some Protocols for IoT Systems

	Internet	WiFi	Z-Wave	ZigBee (3.0)	6LoWPAN
Application	HTTP, RTP, FTP, etc	HTTP, RTP, FTP, etc	Z-Wave and Application commands	Application	HTTP
Transport	TCP, UDP, ICMP	TCP, UDP, ICMP	Routing layer	ZigBee Device ZigBee PRO APR Layer	UDP, ICMP
Network	IP	IP	Transfer layer	ZigBee PRO NWK Layer	Adaptation layer IPv6 with 6LoWPAN
Data Link	Ethernet MAC	MAC layer IEEE 802.11	Proprietary MAC	MAC layer IEEE 802.15.4	MAC layer IEEE 802.15.4
Physical	Ethernet PHY (802.3)	IEEE 802.11 a/b/g.... 2.4 GHz & 5GHz	Proprietary PHY 908 MHz/860 MHz	PHY layer IEEE 802.15.4 (2.4 GHz)	PHY layer IEEE 802.15.4 (2.4 GHz)

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- Network and ID aspects

The Network aspect should provide those functionalities as required by the network layer of the OSI stack. Providing a common communication platform for every possible networking solution can be the bottleneck for IoT systems. Alternatively, the ID aspect should provide identification functionalities and where necessary resolution functionalities between locators (descriptors of the location of a given IoT element in the network) and identifiers (unique descriptors of the Digital Artefact; either active or passive). Consequently, this interoperability aspect takes care of the addressing issue in between any two systems irrespective of the particular technologies they utilize.

- End-to-end aspect

This aspect takes care of reliability, transport issues, translation functionalities, proxy/gateway support and parameter configuration when the communication crosses different networking environments. By providing additional interoperability aspects on top of those of the Network and ID aspect, this aspect provides the final component for achieving a global M2M (machine-to-machine) communication model.

- Data aspect

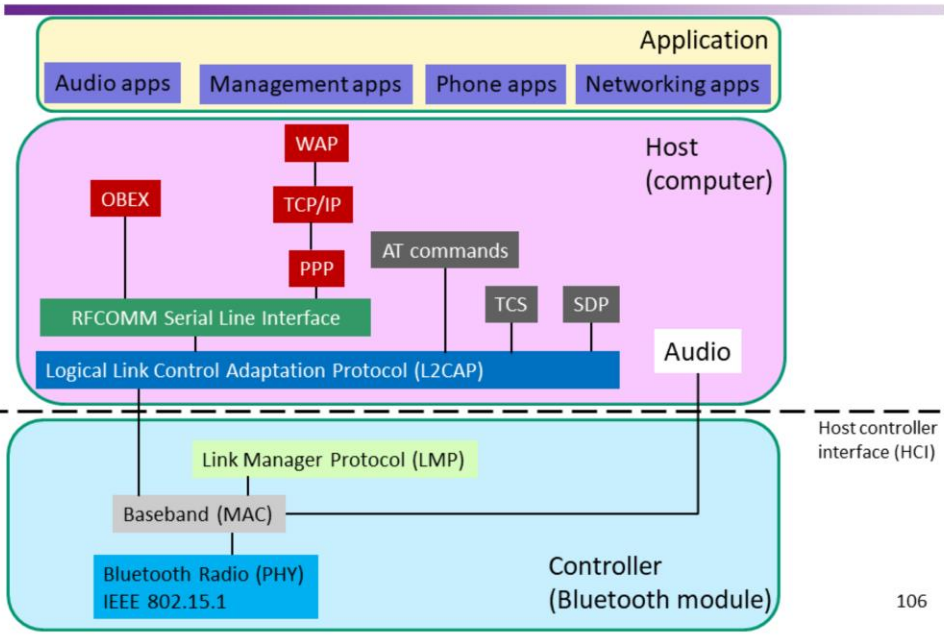
The topmost aspect of the IoT Communication Model is related to data definitions and transfers where the goal of this aspect is to model data exchange between any two actors in the IoT. To realize this, the data aspect needs to model the following characteristics:

1. Capability of providing structured attributes for data description

2. Capability of being translated (possibly by compression /decompression) one to each other, e.g. CoAP is a translatable to HTTP by decompression or XML is translatable to EXI by compression, IPv4 is translatable to IPv6 by mapping

3. Constrained device support.

Bluetooth Protocol Stack



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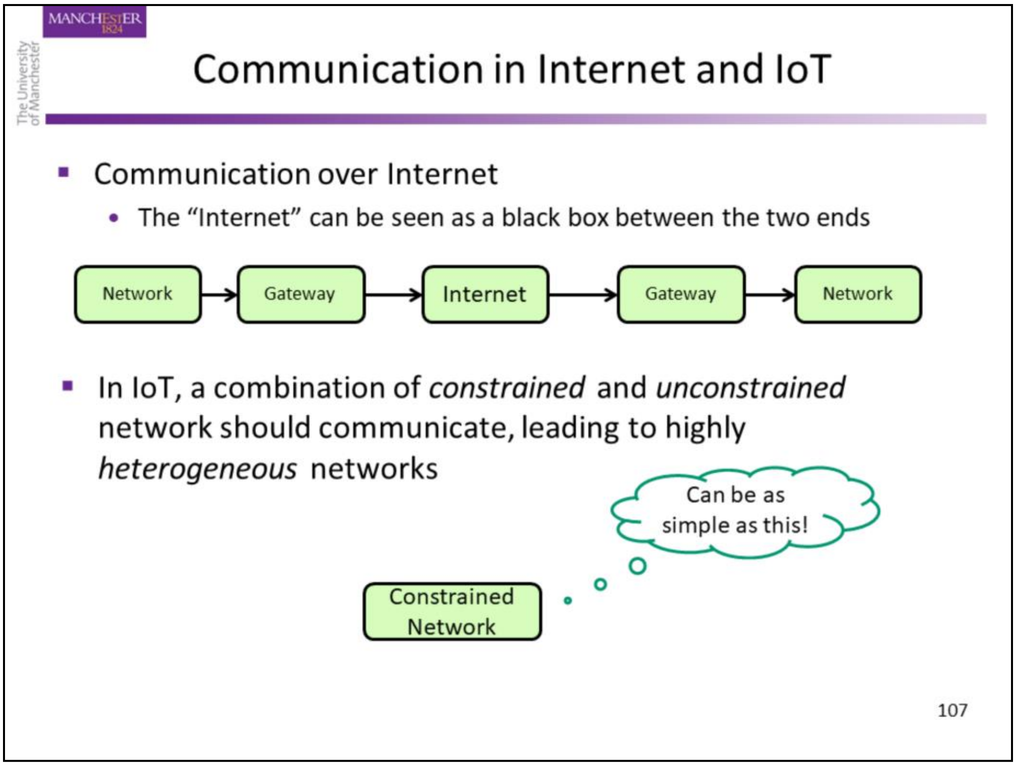
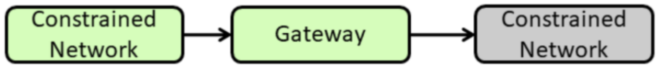


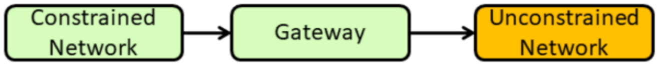
- *Unconstrained networks* feature high-speed communication links (e.g., offering transfer rates in the Mbit/s range or higher). A primary example is the wired Internet that we all know. Link-level transfer latencies are also small and mainly affected by congestion events in the network rather than by the technology utilized for the physical layer.
- *Constrained networks* feature relatively low transfer rates, typically smaller than 1 Mbit/s. These networks typically involve large latencies. These latencies are due to several factors including: (1) the low-bitrate supported by the physical layer technology and (2) the power-saving policies and mechanisms of the terminals populating these networks. These mechanisms, for instance, can include hibernation states or a policy for the periodic power off of their radios.

More IoT Specific Communication Approaches

- Several constrained networks connected with diverse network technologies



- Another case with a constrained network on the one end and an unconstrained network on the other end



- Constrained networks intermediated by an unconstrained network (e.g., the Internet)
  - Most typical case for IoT

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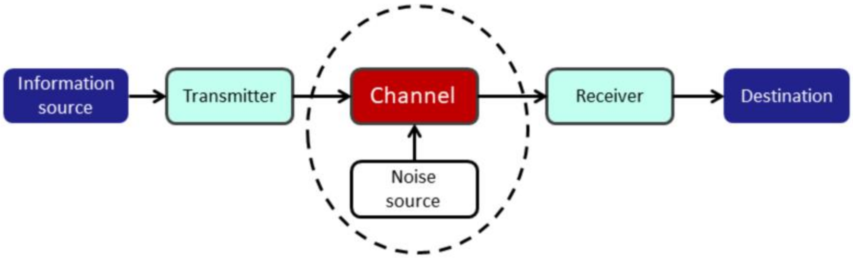
PHYSICAL LAYER AND WIRELESS TECHNOLOGIES FOR IOT

A General Communication System

- Channel can be wired or wireless
  - Emphasis is placed in wireless channels in this course
- Communication is subject to different types of **noise**, **interference**, and **losses**
  - Each medium is subject to different loss mechanisms



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Wavelengths, Signal Frequencies, and Antennas

- Signals ideally propagate at speed of light
  - $c = \lambda f$ [m/sec], *c*: speed of light $3*10^8$ m/sec
  - f = signal frequency [Hz]
  - λ = wavelength [m]
- Antennas have different shapes and sizes
  - Antenna design is an important subject and active research area
  - A common antenna type is ¼ wave antenna
    - That is the physical size of the antenna should be ¼ of the signal wavelength
    - Assume signal transmission at 1 MHz. What's the size of an ¼ wave antenna?
    - Now, calculate again at the ISM band (2.4 GHz)

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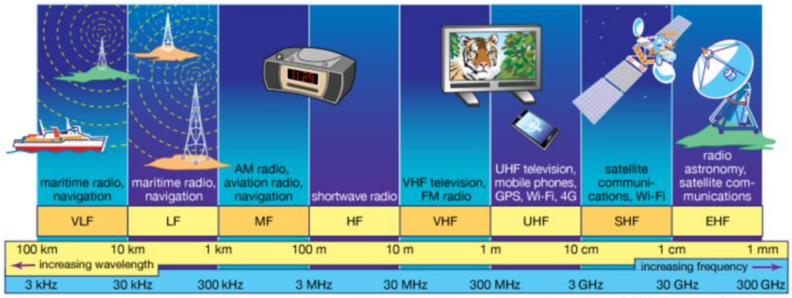
Frequency Spectrum

- Entities such as ITU regulate the management of the spectrum
  - There are several organization across different geographical regions
- There are unlicensed spectrum ranges
  - Industry, Science, Medicine (ISM) frequency band at 2.4 GHz



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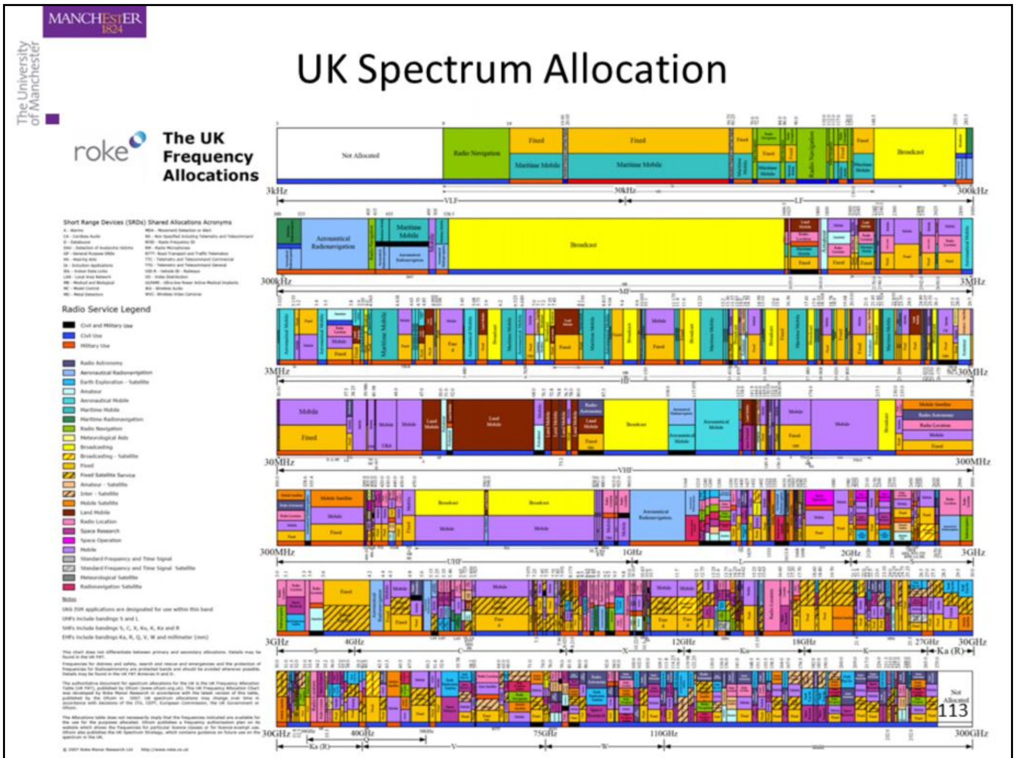
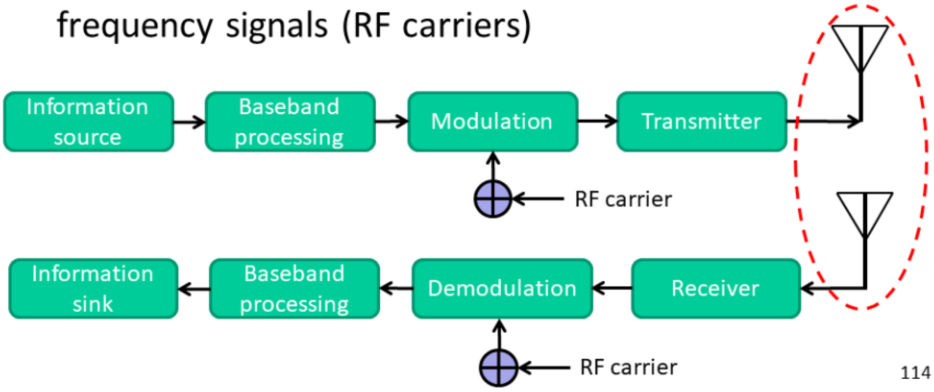
- More recently another ISM band has been allocated at 5 GHz for unlicensed use.

UK Spectrum Allocation



Basic Communication Mechanism

- Baseband frequencies typically relate to those frequencies of digital circuits producing the "digital information"
- Baseband signals are propagated by modulating higher frequency signals (RF carriers)



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dB as a Metric for Communication Power/Quality

- deciBell is not an S.I. unit but is commonly used to describe the power of various features of communication systems
  - E.g., noise power, channel losses, Rx/Tx power, etc
- deciBell are defined as $dB = 10\log_{10}\left(\frac{P_1}{P_0}\right)$
- P_0 is a reference power
  - If P_0 = 1 Watt then the ratio is in dBW
  - If $P_0 = 10^{-3}$ Watt = 1 mW then the ratio is in dBm
- dB can also be used for ratios of fields, e.g. $\vec{E}$ or voltage
  - In this case $dB = 20\log_{10}\left(\frac{V_1}{V_0}\right)$

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Some Practice with dB

P1 (W)	dBW	dBm
1	?	?
10	?	?
100	?	?
10,000	?	?
1,000,000	?	?
0.1	?	?
0.001	?	?
0.00001	?	?
0.000001	?	?
0.00000001	?	?

$$dB = 10\log_{10}\left(\frac{P_1}{P_0}\right) \Rightarrow$$

$$\Rightarrow \frac{P_1}{P_0} = 10^{\frac{dB}{10}} \Rightarrow P_1 = P_0 10^{\frac{dB}{10}}$$

- 10dB + 3dB = 13 dB
- You can't simply add dB's
- 10W + 2W = 20W!!!!!! WRONG!

- Decibels are logarithms!!!

Fill in the Table in dBW and dBm

P1 (W)	dBW	dBm
1	?	?
10	?	?
100	?	?
10,000	?	?
1,000,000	?	?
0.1	?	?
0.001	?	?
0.00001	?	?
0.000001	?	?
0.00000001	?	?

- +/-3 is double/half the power
- +/-6 is how much?

$$dB = 10\log_{10}\left(\frac{P_1}{P_0}\right)$$

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