UCDAVIS
UNIVERSITY OF CALIFORNIA

Internet of Things

Senior Design Project Course

Communication – Part 2

MCU to Gateway

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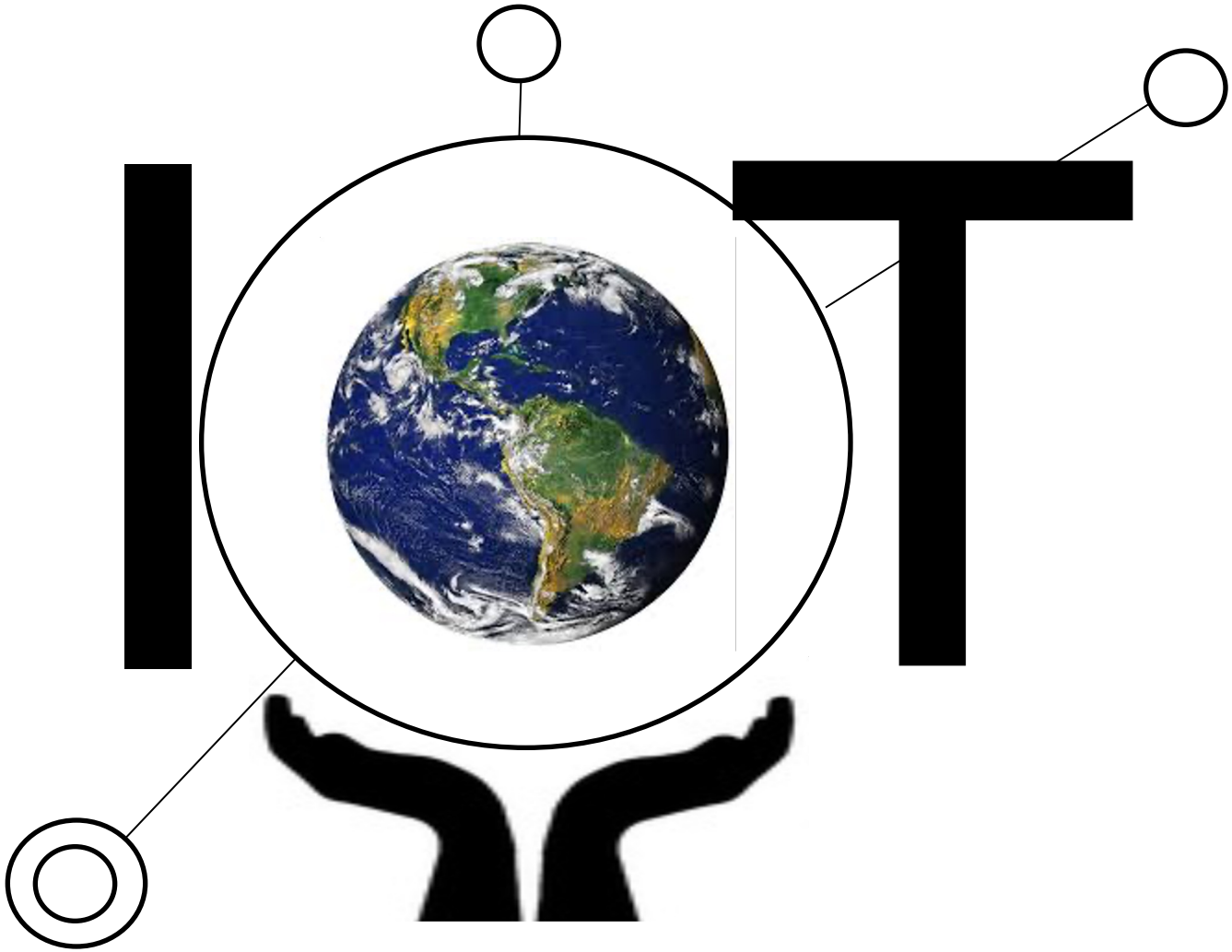
Lets Get Started:



Focus of Today's Lecture: (Review)

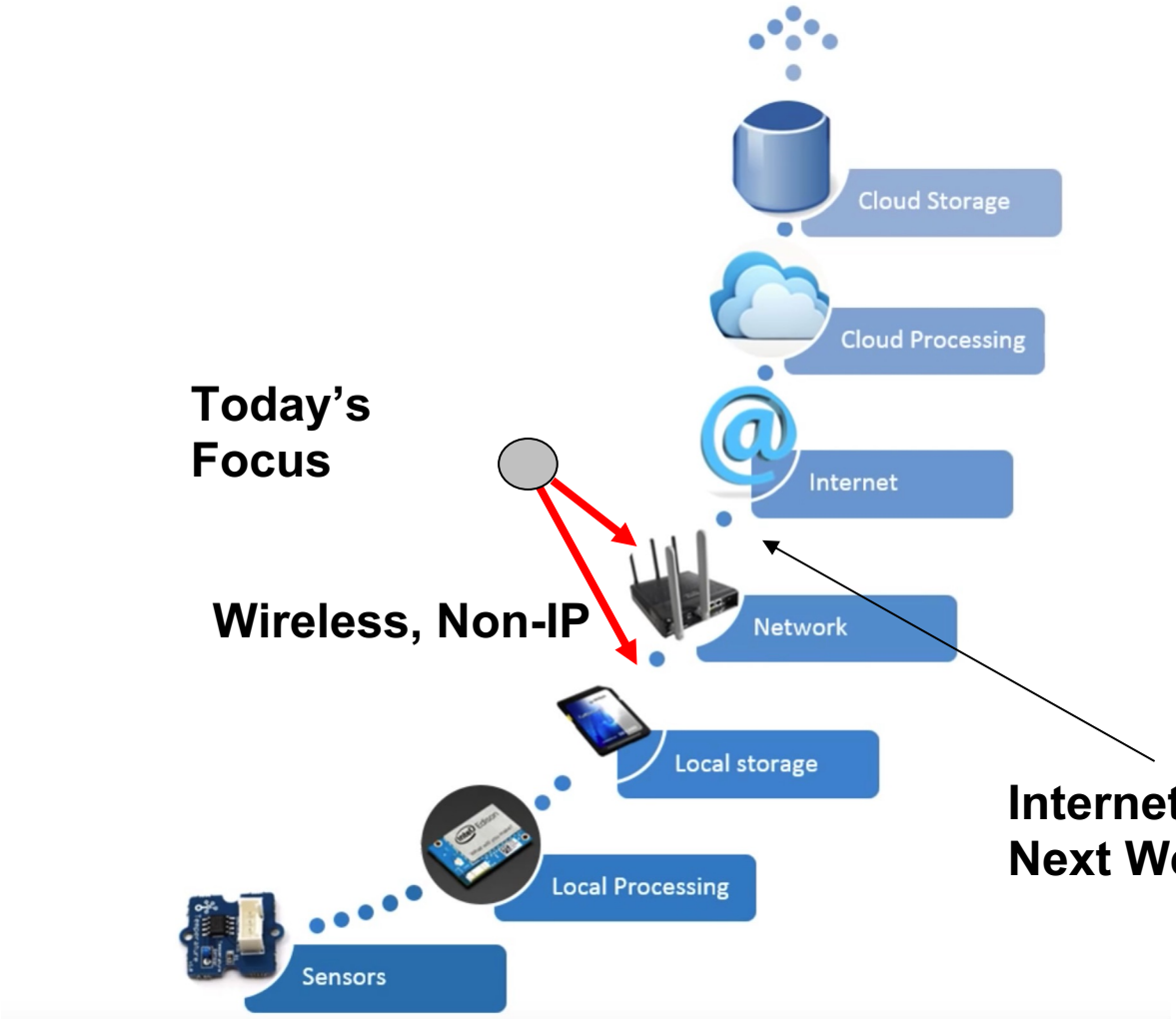
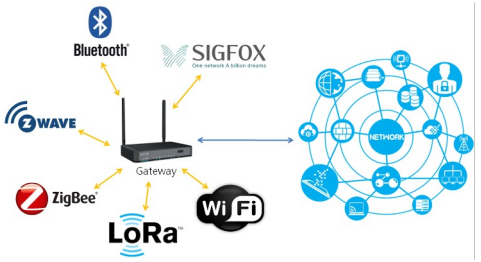


Image source: http://www.cchc.cl/informacion-a-la-comunidad/industria-de-la-construccion/personaje/

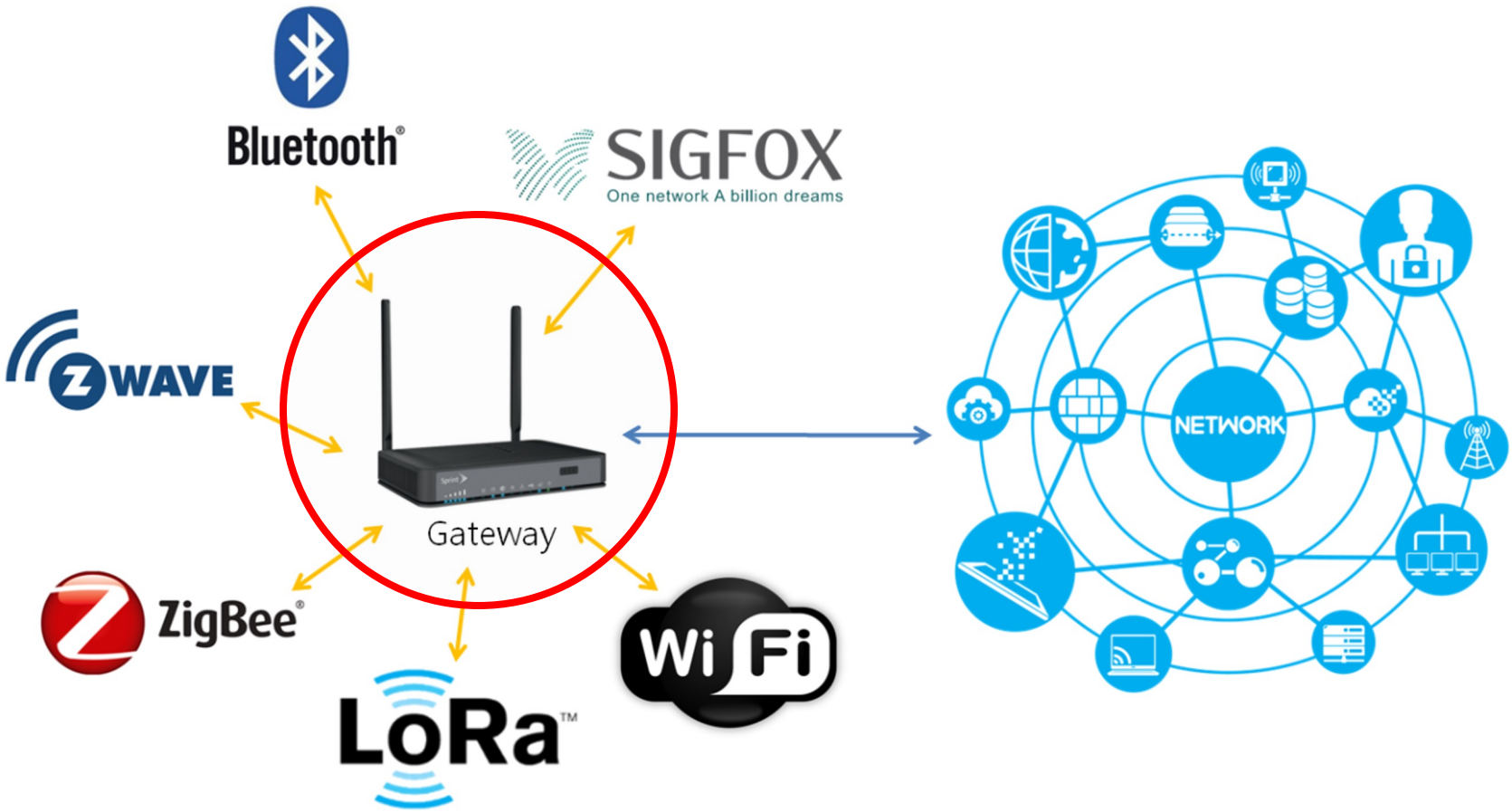
Why Using Gateway? (Review)

1. **Lowering Power**
   - Sensor sends the data to a gateway in short range (requires lower power)
   - gate way send the data to cloud.
2. **Supporting varying** to/from sensor communication **protocols**
   - Each sensor may have a different protocol.
   - Gateway translate it to IP



3. **Filtering the data**
   - Usually small fraction of data is usable.
   - Filtering could be done at gateways.
     (more resources than MCU, reduce communication size, reduce cloud computation load)
4. **Reducing latency**
   - Many IoT devices too small to do the processing themselves, and it take too long to wait for cloud. Gateway (an intermediate computation layer) remedy this.
5. **Improving security**
   - Can afford to make data transmission through gateway more secure.
   - Prevent too many lightly secured sensors to be connected to internet.

Gateway Supporting Various Protocols



Wireless Comm. To/From Gateways

- Wireless communication technologies used for:
  - Connecting the IoT device as local networks
  - Connecting these local networks (or individual IoT devices) to the Internet

- Some of popular wireless technologies are:
  - Near Field Communication (**NFC**) ✓
  - **Bluetooth** ✓
  - **ZigBee** ←
  - Wireless Fidelity (**WiFi**)
  - **Cellular network**
  - Low Power Wide Area Network (**LPWAN**)
  - …

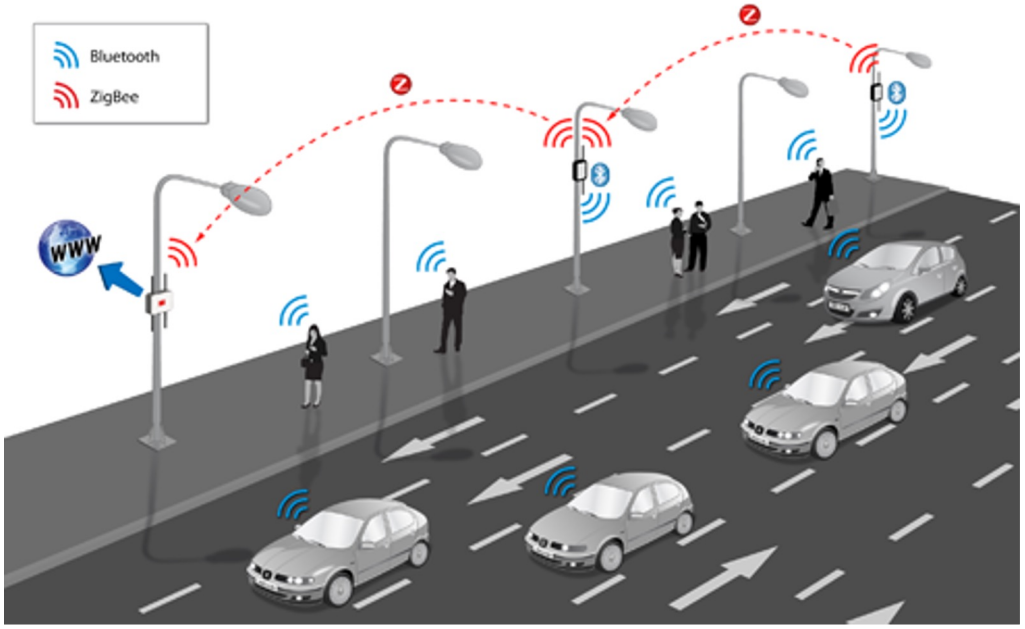
[1] F. Samie, L. Bauer and J. Henkel, "IoT technologies for embedded computing: A survey," *2016 International Conference on Hardware/Software Codesign and System Synthesis (CODES+ISSS)*, Pittsburgh, PA, 2016, pp. 1-10.

ZigBee

ZigBee

- Specification for a suite of high level communication protocols for Personal Area Network (PAN).

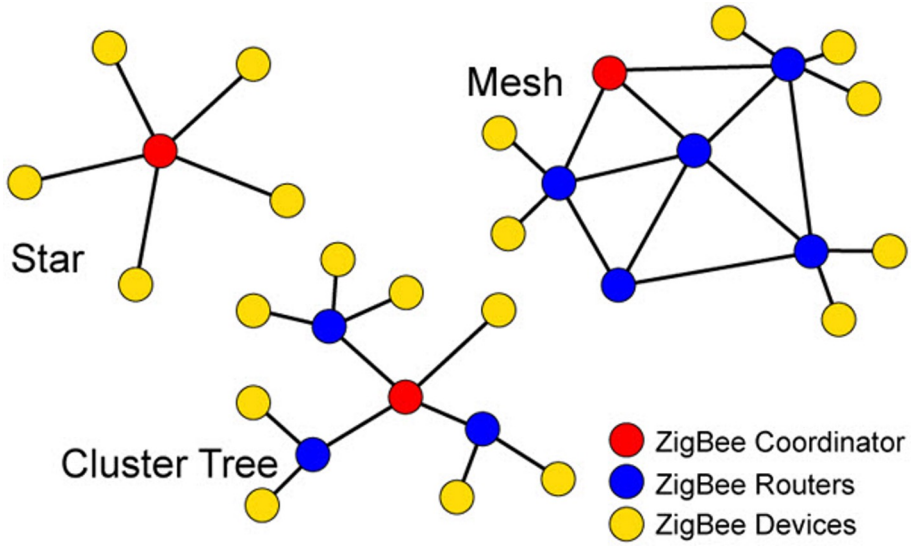
- ZigBee
  - Introduced in 1998
  - Standardized in 2003
  - Revised in 2006



- Characteristics:
  - small-size
  - low-cost
  - low-power
  - **wide transmission range**, depending on the output power
    - Its low power consumption limits transmission distances to 10–100 meters

ZigBee

- Supports different network topologies (e.g. mesh, star, tree).
- **ZigBee coordinator** initiates and manages the devices
- **Mesh and Tree** networks can transmit data over long distances by passing data through a network of intermediate devices to reach further distant.



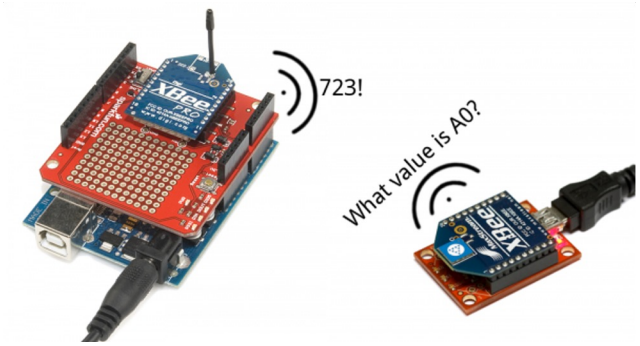
ZigBee

- Specification for a suite of **high level communication protocols** for Personal Area Network **(PAN)** used in **low data rate** applications that require **long battery life** and **secure networking**
- ZigBee networks are secured by 128 bit symmetric encryption keys
- has a defined rate of 250 kbit/s, best suited for intermittent data transmissions from a sensor or input device
- Faces market barriers
  - **Compete with BLE** that provides higher bandwidth at a lower energy consumption

Zigbee and Arduino

- **Xbee** Shield
- **Wireless SD** shield

```
#include <SoftwareSerial.h>
// XBee's DOUT (TX) is connected to pin 2 (Arduino's Software RX)
// XBee's DIN (RX) is connected to pin 3 (Arduino's Software TX)
SoftwareSerial XBee(2, 3); // RX, TX

void setup()
{
  // Set up both ports at 9600 baud. This value is most important
  // for the XBee. Make sure the baud rate matches the config
  // setting of your XBee.
  XBee.begin(9600);
  Serial.begin(9600);
}
```




```
void loop()
{
  if (Serial.available())
  { // If data comes in from serial monitor, send it out to XBee
    XBee.write(Serial.read());
  }
  if (XBee.available())
  { // If data comes in from XBee, send it out to serial monitor
    Serial.write(XBee.read());
  }
}
```

CLICK HERE ↓

More information

WiFi

Wireless Fidelity (WiFi)

- **Wi-Fi** or **WiFi** is a technology for wireless local area networking (WLAN) based on IEEE 802.11 standard.

- Widely adopted
  - Internet access
  - City-wide Wi-Fi
  - Campus-wide Wi-Fi, …

- Range of about **20 meters** (66 feet) indoors and a greater range outdoors.

Wireless Fidelity (WiFi)

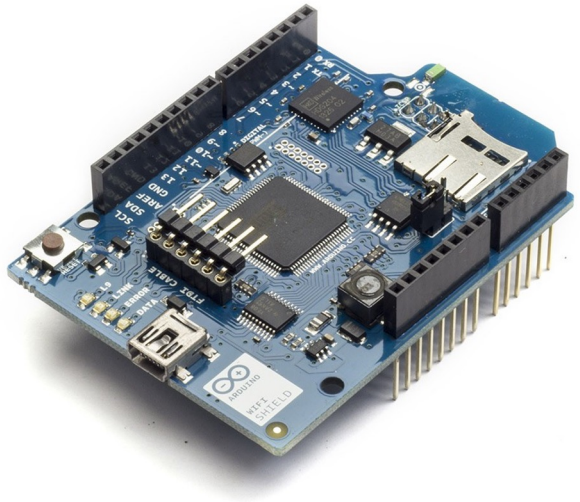
- Most commonly uses the 2.4 gigahertz (12 cm) UHF and 5GHz (6cm) SHF ISM radio bands.

- Flavors:
  - Conventional WiFi (IEEE 802.11 b/g/n)
    - High bandwidth
    - High energy consumption
    - Unsuitable for ultra-low-power IoT devices
  - Low-power WiFi (802.11 ah) or HaLow
    - Extend the range of transmission
      - less data rate
      - Lower power consumption
    - Less interference with existing wireless networks

WiFi and Arduino

- How to connect to a WEP encrypted network named "yourNetwork" with a hex key of "ABBADEAF01", and a key index of 0
- Reference: Arduino WiFi Shield

```
#include <WiFi.h>

char ssid[] = "yourNetwork";      //  your network SSID (name)
char key[] = "ABBADEAF01";    // your network key
int keyIndex = 0;            //your network key Index number
int status = WL_IDLE_STATUS;     // the Wifi radio's status

void setup() {
  // initialize serial:
  Serial.begin(9600);

  // attempt to connect using WEP encryption:
  Serial.println("Attempting to connect to WEP network...");
  status = WiFi.begin(ssid, keyIndex, key);

  // if you're not connected, stop here:
  if ( status != WL_CONNECTED) {
    Serial.println("Couldn't get a wifi connection");
    while(true);
  }
  // if you are connected, print out info about the connection:
  else {
    Serial.println("Connected to network");
  }
}

void loop() {
  // do nothing
}
```



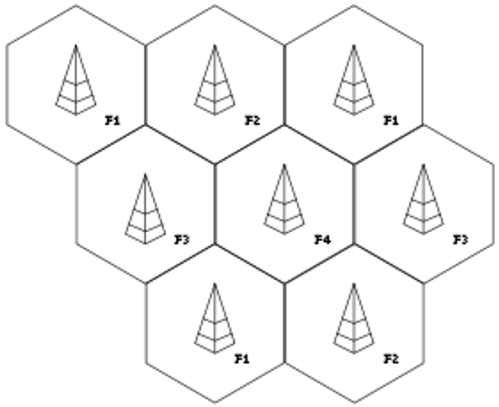
Cellular Network

Cellular Network

- A **cellular network** or **mobile network** is a communication network where the last link is wireless
  - E.g., 3G, LTE, 4G, and 5G

- The network is **distributed over** land areas called **cells**

- Each cells use a **different set of frequencies** from neighboring cells
  - to avoid interference
  - to provide guaranteed service quality within each cell



Cellular Network

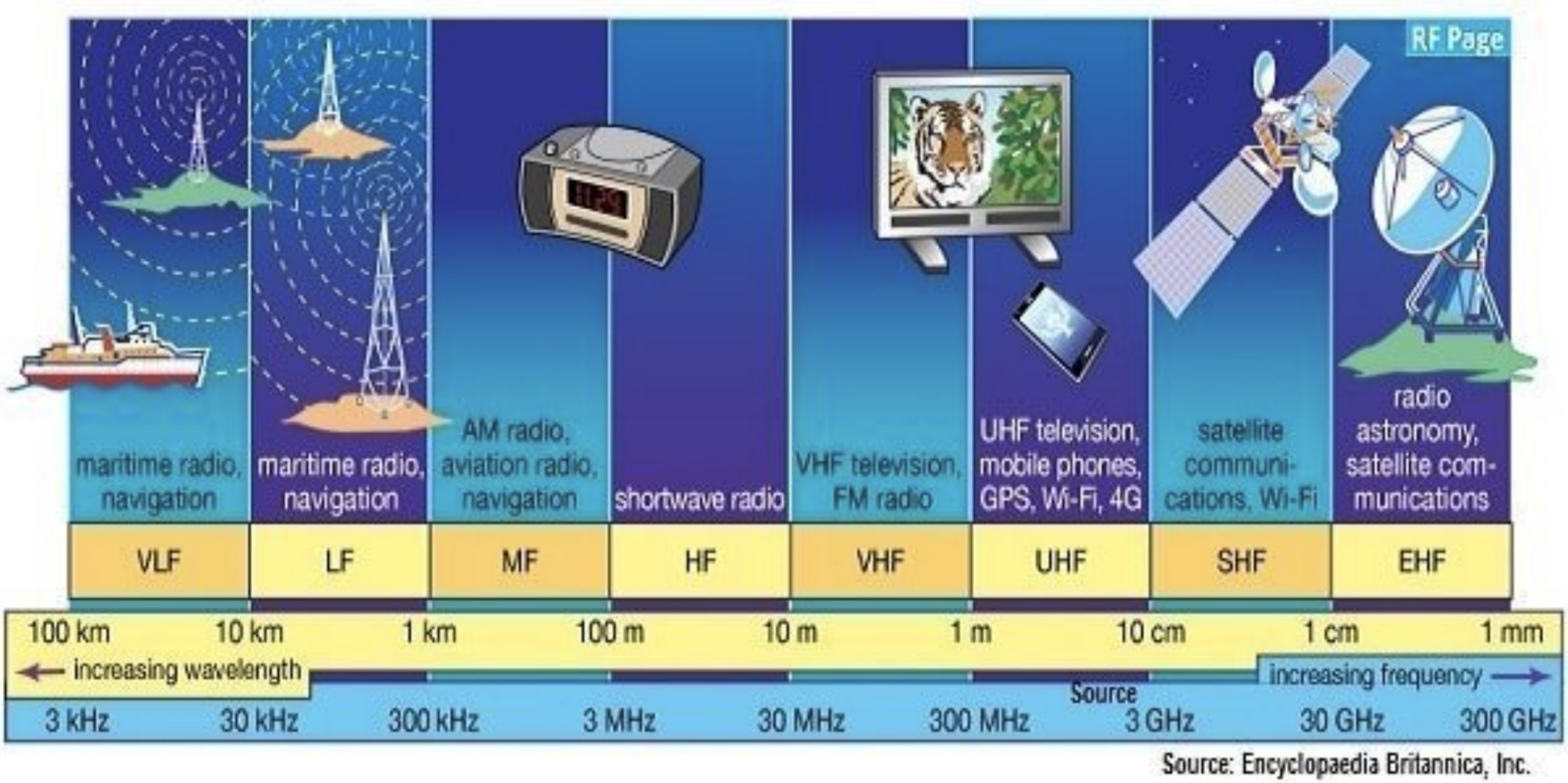
- Cellular networks offer a number of desirable features
  - **More capacity** than a single large transmitter
    - the same frequency can be used for multiple links as long as they are in different cells
  - Mobile devices use **less power** than with a single transmitter or satellite
    - the cell towers are closer
  - **Larger coverage** area than a single terrestrial transmitter
    - additional cell towers can be added indefinitely and are not limited by the horizon

- When it come to IoT
  - Provide reliable high-speed connectivity to the Internet
  - **BUT** It has high power consumption
  - **BUT** It is not suitable for M2M

Low Power Wide Area Network (LPWAN)

- Suited for **low power** applications with **very long rage** transmission
- Support up to **10 Km distance** between end-nodes and gateway
- **Very low data rate** (<1 Kbps)
- Operates in **sub-GHz bands**
  - No globally available band for LPWAN in sub-GHz
- Main technologies:
  - SigFox
  - LoRaWAN
  - Weightless

Radio Frequency bands



Source: Encyclopaedia Britannica, Inc.

Summary of Comm. Technologies

- The communication technology should be chosen based on
  - **Area** constrain (Area to implement the protocol, Area used for antenna)
  - **Power** constrain (Range of broadcast)
  - **Performance** constrain (Requirement for data transmission rate)
  - **Noise** and interference
    - E.g. Bluetooth, WiFi, and ZigBee may face interference due to the coexistence of other devices working at the same frequency

		NFC	Bluetooth	BLE	BT v5	ZigBee	HaLow 802.11 b/g/n	LP WiFi 802.11ah	LPWAN	Cellular network	
										3G	LTE
Range	indoor	<0.2 m	1–100 m	~100 m	<300 m	<20 m	<70 m	<700 m	<10 Km	>5 Km	>5 Km
	outdoor					<1500 m	<230 m	<1000 m			
Bit rate [Mpbs]		0.424	1–3	1	2	0.25	>1	0.15–40	<0.05	0.17	75–300
Throughput [Mbps]		0.22	1.5	0.30	1.5	0.15	2-50	>0.1	<0.05	NA	
freq. [GHz]		0.014	2.4–2.5	2.4–2.5	2.4	2.4	2.4/5	0.9	sub-GHz	0.8–1.9	2.1
Network topology		p2p	scatternet	star, scatternet	NA	star, tree, mesh	star	star	star	NA	

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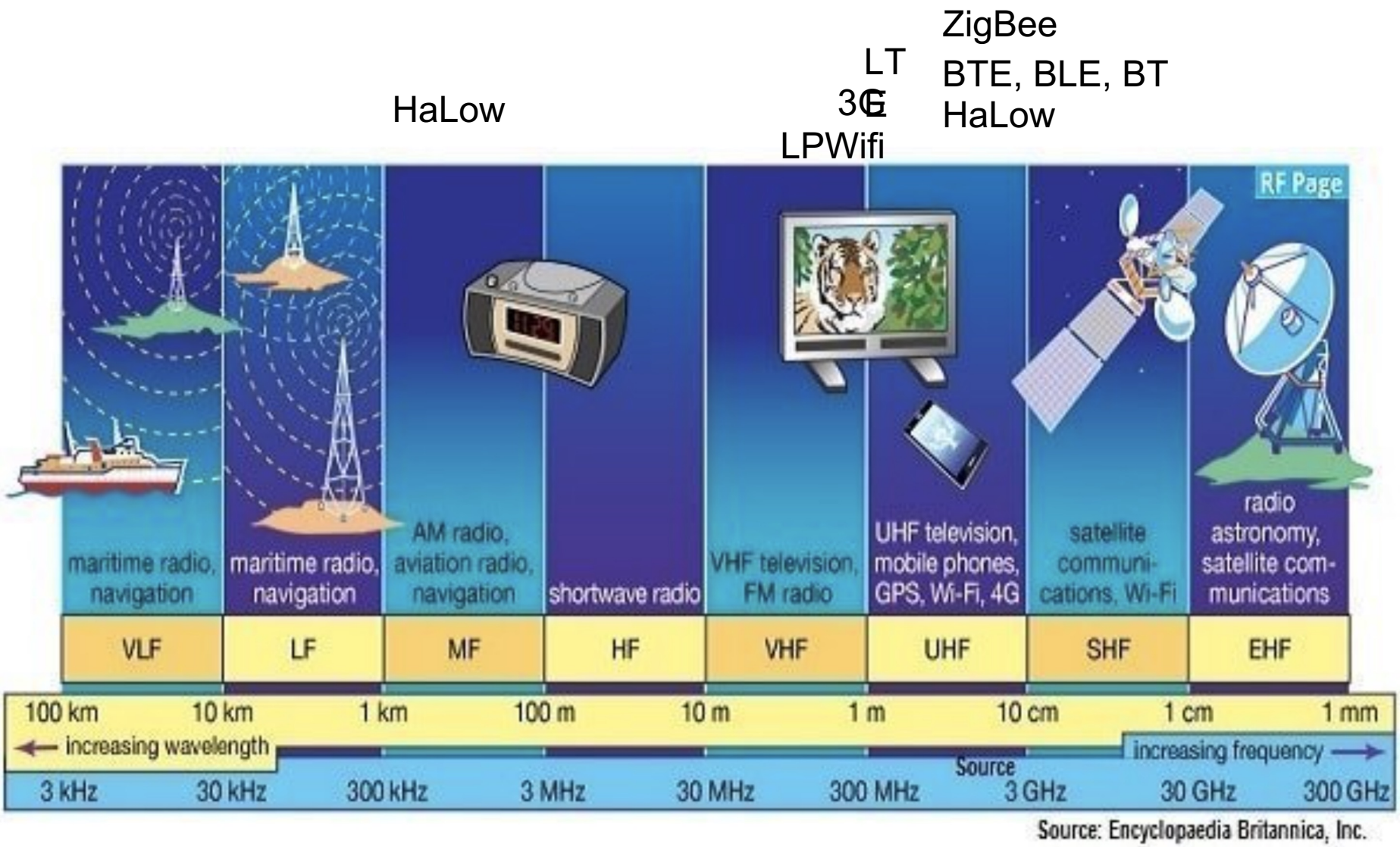
Radio Frequency bands



Timing of Data Transmission:

- **Continuous**
  - Send or receive data continuously
  - E.g. real-time systems such as health monitoring.

- **Sporadic**
  - device collects and stores the data
  - transmits data whenever the connection is available

- **On-demand**
  - **User driven**
    - IoT device can be requested by the operator to send the collected data
  - **Event driven**
    - Communication is done once a specific event happens

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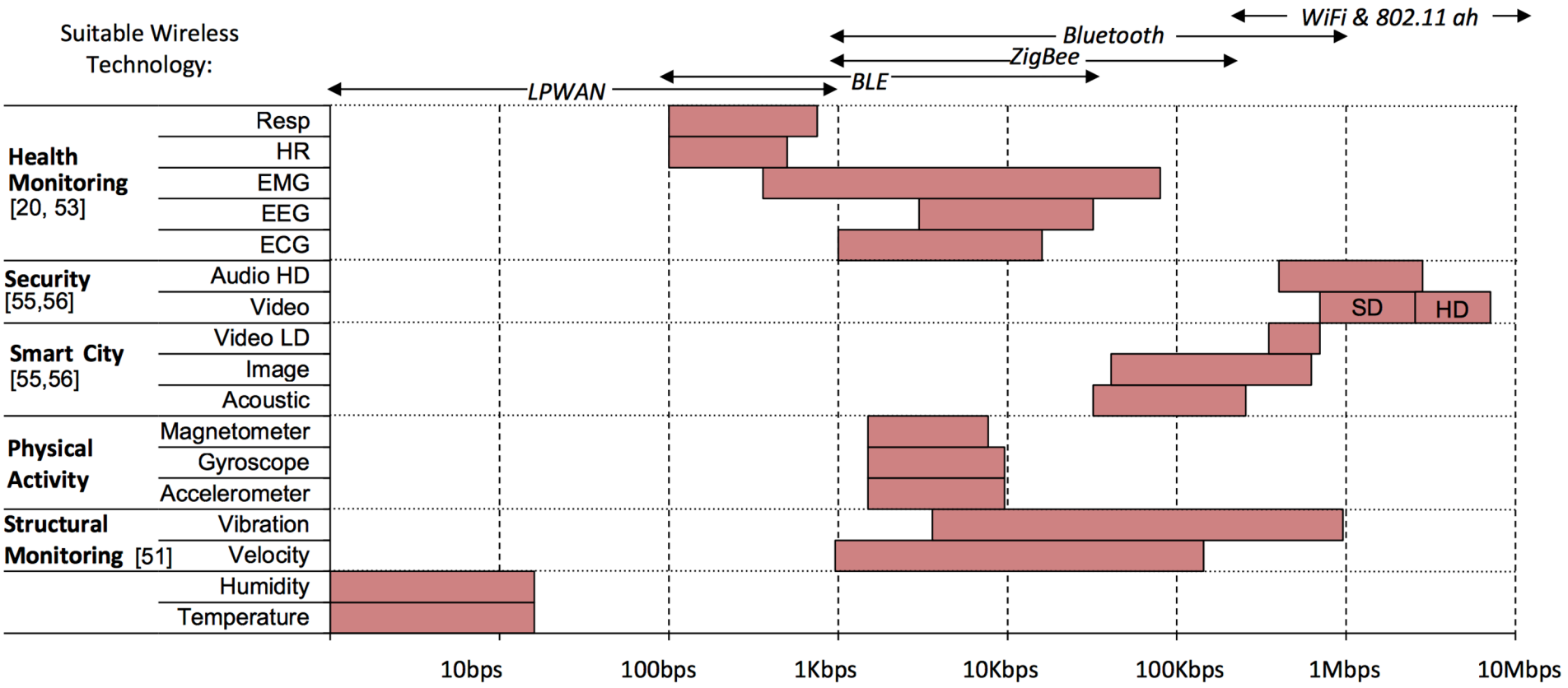
Does Data Rate Decide the Protocol?

- Which communication protocol for which sensing rates?



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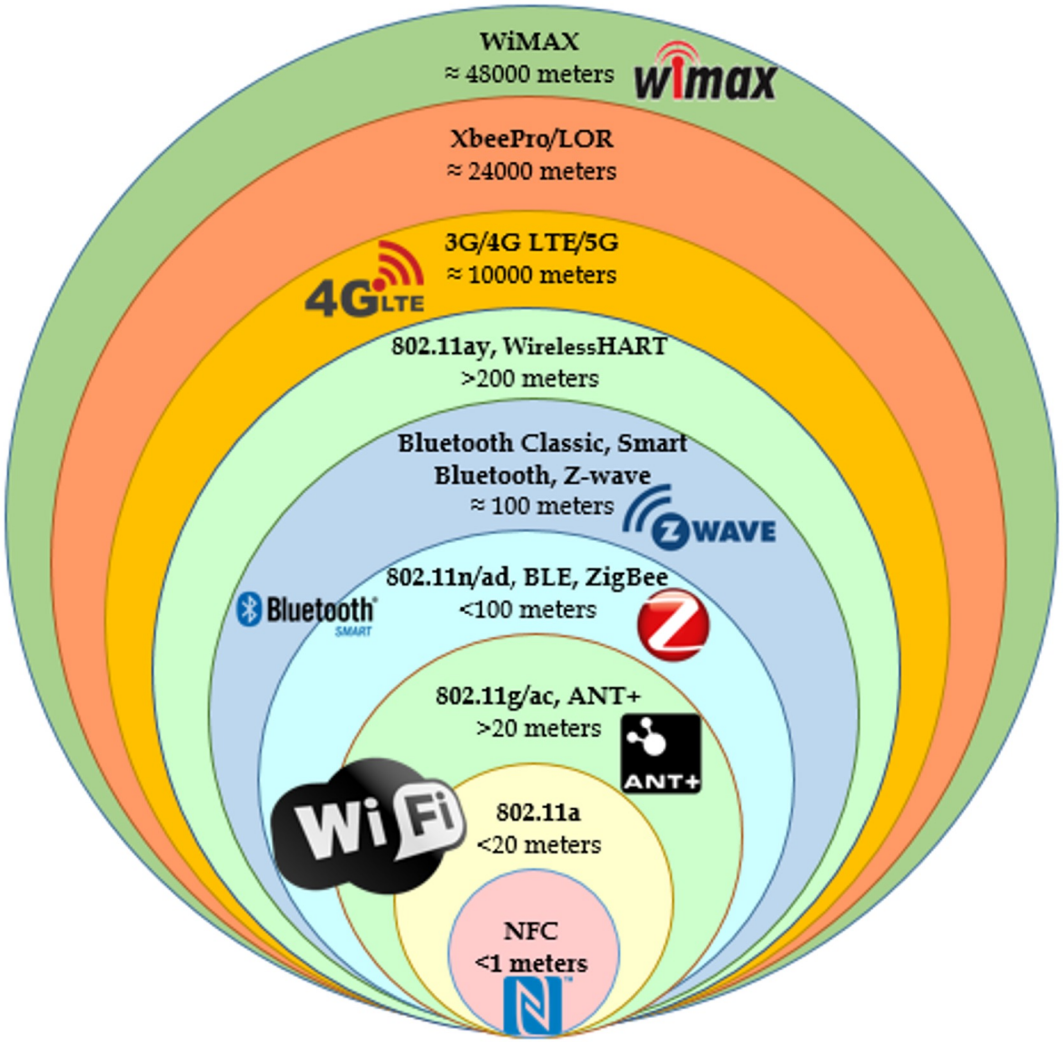
Does Communication Range Decide the Protocol?



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