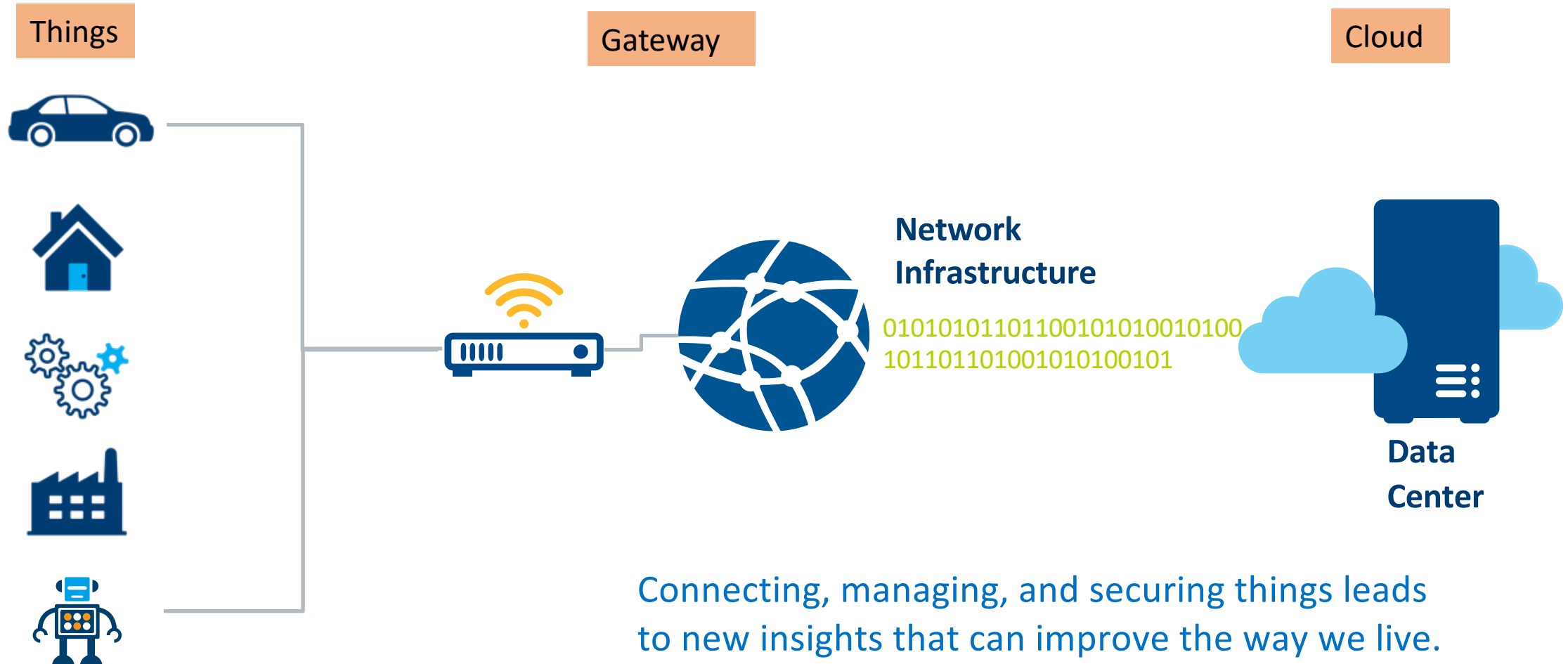# IoT Communications

Dr Priyanka Bagade, IITK

CS698T, Lecture 5

Content Copyrights

- The instructor owns the copyright of the CS698T: introduction to internet of things and its industrial applications course material. It includes lectures, presentations, exams and assignments. It should not be distributed in print or through electronic media without the consent of the instructor. Students can take notes or make their own copies of the content.
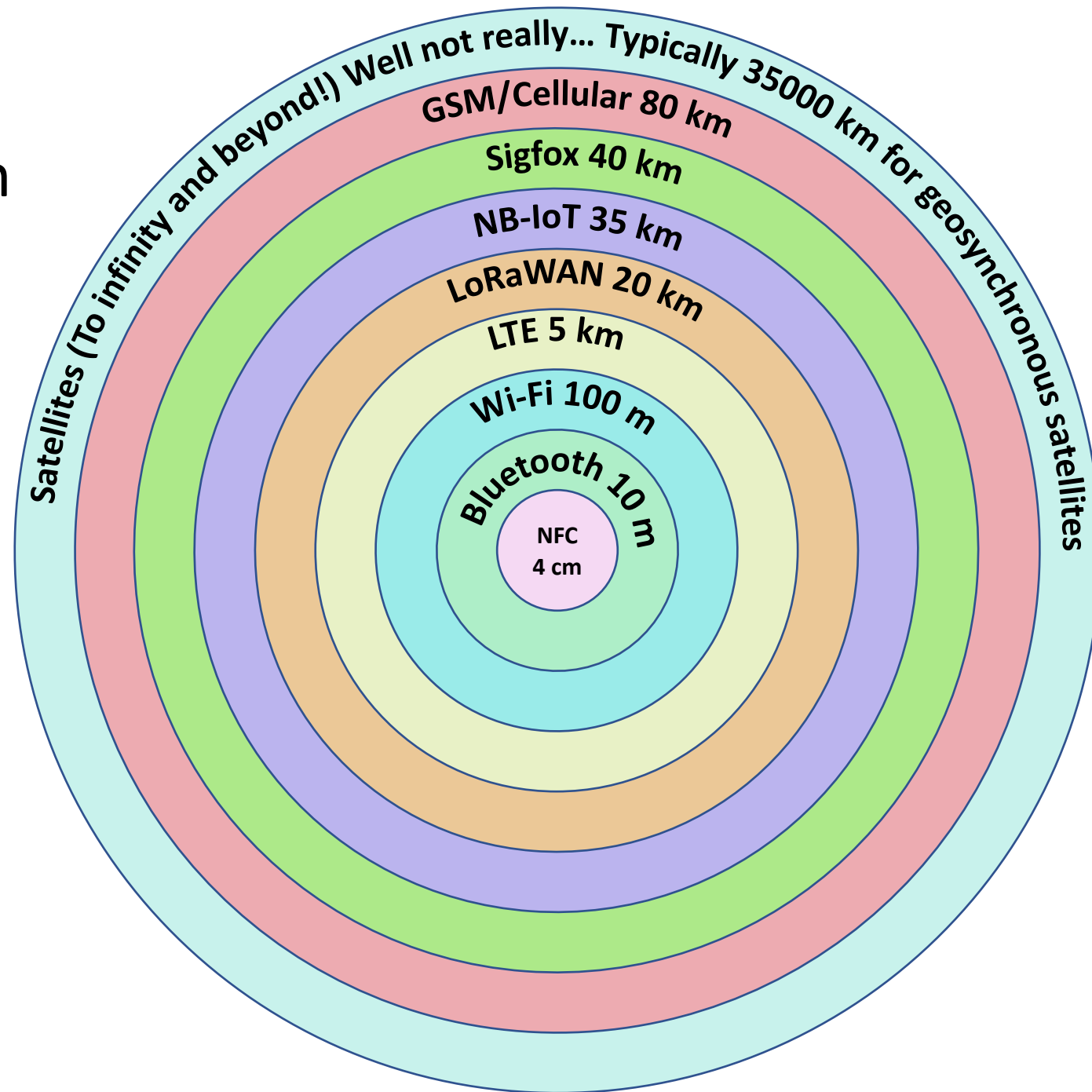
IoT Overview

83B devices will be connected to the Internet by **2024**[1]

Things

Gateway

Cloud

Network Infrastructure

0101010110110010101001010010100
101101101001010100101

Data Center

Connecting, managing, and securing things leads to new insights that can improve the way we live.

1. https://www.saftbatteries.com/energizing-iot/how-iot-world-shaping-2021-and-what-trends-will-influence-future-iot-infographic

IoT
communication
Protocols

Satellites (To infinity and beyond!) Well not really… Typically 35000 km for geosynchronous satellites

GSM/Cellular 80 km

Sigfox 40 km

NB-IoT 35 km

LoRaWAN 20 km

LTE 5 km

Wi-Fi 100 m

Bluetooth 10 m

NFC
4 cm

Cellular Networks

- GSM (2G), 3G, 4G, and 5G

- Enables long range connectivity

- GSM - 2nd generation cellular network technology
  - Mainly developed for voice communication and SMS
  - Range 35km – technology theoretical limit
  - Very low data rate
  - GSM (2G) combined with GPRS (2.5G) and EDGE (2.75G) gives data rate in kbps
  - IoT devices can work with low data rate
  - Already deployed cellular towers
  - Hardware cost is low due old technology
  - Not suitable for battery operated device due to power requirements (2W)
  - Works licensed band – required to pay for the dedicated channel
    - Downlink frequency – 935-960 MHz
    - Uplink frequency – 890-915MHz
    - Contract through a mobile service provide
  - Prone to security attacks
  - Applications - Smart car connectivity, traffic control, wildlife monitoring
  - IoT boards: Particle Electron, Hologram Dash

- 3G – 3rd generation cellular technology
  - Faster data rate
  - Ensures stable and faster connection over long distances

- 4G – 4th generation cellular technology
  - Faster data rate as compared to 3G
  - Allowed users to browse web and stream videos on smartphones

5G

- New cellular protocol after LTE
- High speed and signal quality
- Low latency
- Not yet deployed in India
- Challenges
  - Requires a specific infrastructure with specific antennas and transmitter
  - Expensive to setup new infrastructure
  - LoRAWAN – cheaper and slower solution

LPWAN – Low Power Wide Area Network

- Cellular networks require more power for data transmission
- Zigbee is suitable for PAN (Personal area network) only
  - Use of mesh topology leads to faster depletion of device battery
- Bluetooth, NFC and RFID are not suitable for long range communication

LPWAN – Low Power Wide Area Network

- Low power – well suited for battery operated IoT devices
- Wide range – more than 2km
- Low power and wide range requirements lead to lower data rate
- Best suited for
  - Dense locations
  - Long term monitoring
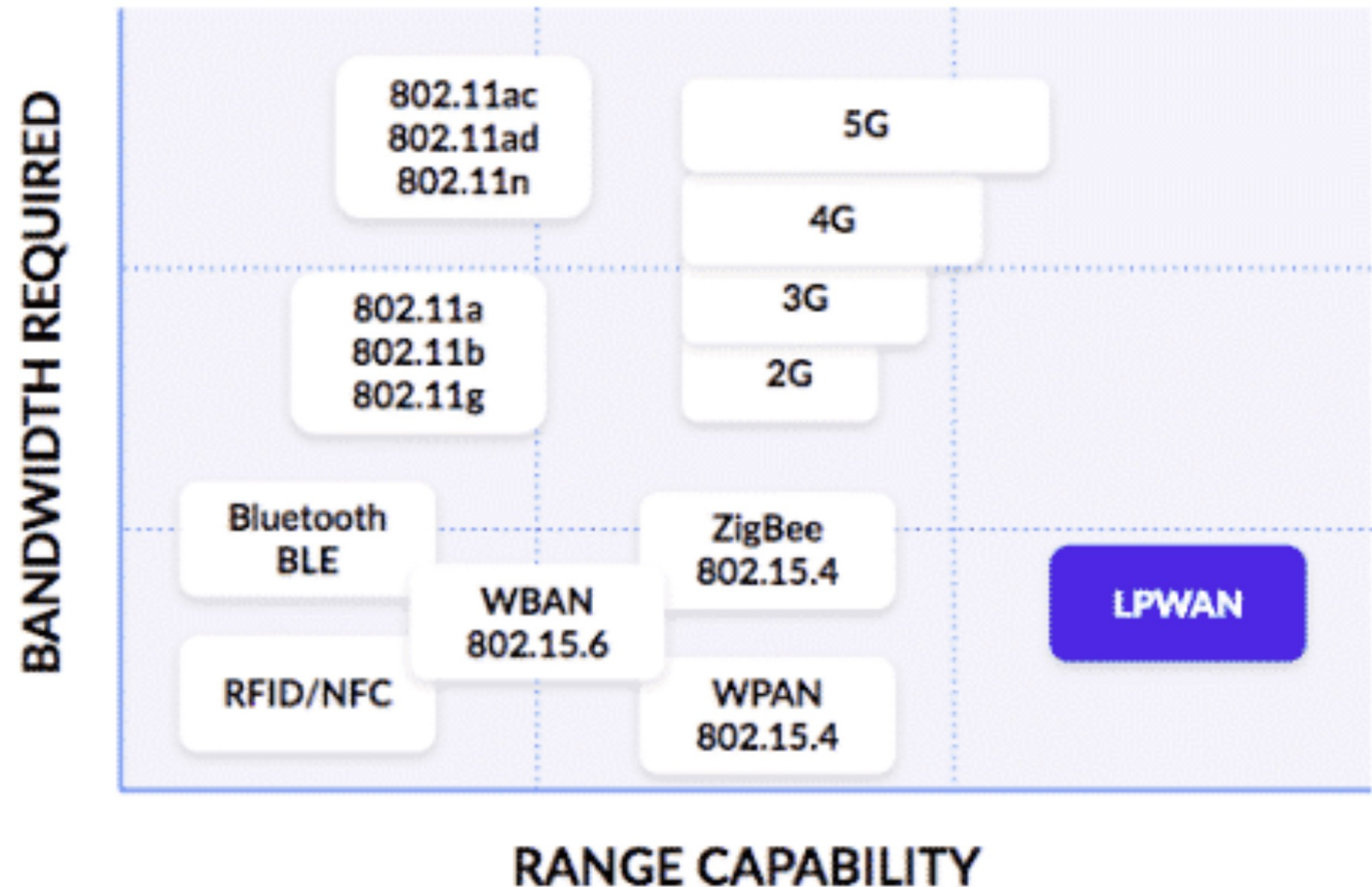
WiMAX

- WiMAX – Worldwide Interoperability Microwave Access
- Applicable in WMAN (Wireless Metropolitan Area Network)
- Range – up to 15km
- Based IEEE 802.16 standards with 2-6 GHz spectrum
- Disadvantages
  - Distortion in uplink – OFDMA modulation (Orthogonal Frequency Division Multiple Access)
  - Higher latency
  - Does not scale for large number of clients
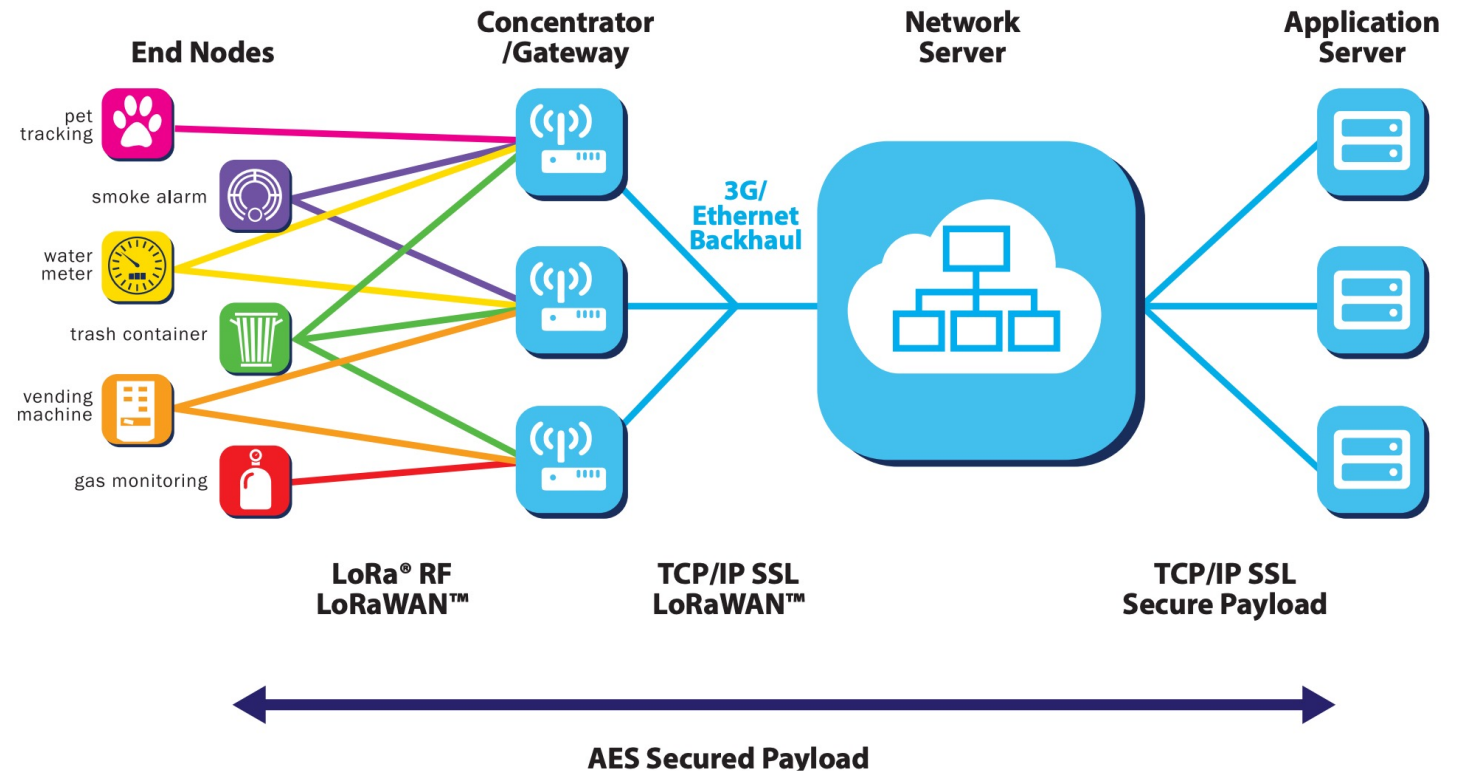- LTE is preferred to avoid above mentioned disadvantages

LoRa

- Low rate, long range, low power protocol
- Non-cellular modulation technology
- Uses ISM bands
- Used for private networks
- Single Chip Vendor (manufacturer) – Semtech
- Multiple service providers – Anyone can buy a LoRa gateway and use it as a base station with one of the service provider to setup their IoT system for the city.
- Uses spread spectrum modulation – multipath diversity
  - Tall buildings in the city scatter/reflect the signal.
  - Multiple versions of the same signal gets received at the base station
  - Allows to transmit the data over long distance with low power irrespective of tall buildings and scatter effect

LoRaWAN

- Communication protocol + network (system architecture for IoT devices)

- Mainly deployed in Europe

- Used for public networks deployed by mobile operators

- Low power wide area network protocol

- Cheaper than 4G and 5G devices ($0.2-$0.5 for LoRa sensors vs $30 for 5G sensors)

- Data rate 0.3kbps to 27kbps

- Covers wider range than 5G

- Mainly developed for industrial IoT sensors to transmit sensors data such as temperature, light, humidity, vibration, sound etc.

- Does not support network IP stack

- Low power networking protocol allows the battery to work more than 10 years once charged as opposed to a 5G device which requires charging every few hours

- End to end security using AES-128 encryption

- Applications: Smart city, smart parking lots, streetlights which can call police in case of emergencies, asset management (well suited for mobile devices)

LoRaWAN Network Architecture

- Supports <mark>star network topology</mark>
  - Mesh topology leads to fast depletion of battery
- The data gets received by multiple gateways
- <mark>Asynchronous data communication as opposed to synchronous data transfer in cellular networks</mark>
  - <mark>Sends data when it is ready.</mark>
  - <mark>Does not periodically check device to send data</mark>
  - Helps with increasing battery life

Image source: https://lora-alliance.org/wp-content/uploads/2020/11/what-is-lorawan.pdf

Sigfox

- Competitor of LoRA
- Uses unlicensed spectrum with ultra narrow band modulation
  - Higher resistance to noise
  - Low interference introduced by ultra narrow band modulation allows data transfer in 100s of devices from the same area at a time
- Multiple chipset manufacturers
  - NXP semiconductors, Texas instruments, ST electronics
- Single operator (connectivity provider) in a country
  - No roaming required
  - Can easily roam with the same device around the world

Sigfox (1)

- Mainly deployed in USA
- Radio module cost is very low ($5)
- Developed mainly for uplink. Downlink speed is very low
- Need to install new base stations similar to LoRa. Cellular based stations can not be used.
- Applications
  - Smart agriculture
  - Water management
  - Supply chain

Sigfox (2)

- Advantage
  - Low power, low data and ==long range protocol==
  - Suitable for devices with ==infrequent data transfer== requirement
- Disadvantages
  - Not many base stations are deployed currently
    - ==Can not work well with devices which roam around==
 - ==Single cloud server available (France) which can lead to data sharing issues across countries==

NB-IoT (Narrowband-IoT)

- Developed by the same authorities who developed 4G and 5G protocols
- Cellular technology used by 4G connected devices
- Does not require to build a specific infrastructure, software is enough to connect a device to NB-IoT – easy to scale
- Disadvantage
  - Requires high communication power
  - Hop by hop security
- Uses licensed spectrum
- Consumes more power and more complex compared to LoRa and Sigfox
- Faster modulation rate allows to handle more data than LoRa and Sigfox
- Not an IP-based communication protocol
- 3GPP Release
- Supports network synchronization as opposed to Sigfox
  - access request will be sent to the base station at the start of the communication
  - Data communication starts after receiving the acknowledgement

NB-IoT (1)

Does not support mobility mainly developed for stationary IoT devices
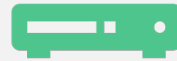
Low bandwidth support – 180 kHz. GSM supports 200kHZ bandwidth

High latency up to 10 seconds Low as compared to LoRa and Sigfox

NB-IoT (2)

Advantages

- Good indoor and populated city coverage as it relies on 4G coverage
- Faster response time than LoRa
- Better QoS
- No limit of number of messages per day. Sigfox has a limit of 140 message/day
- Optimized for lost cost, low data rate and stationary sensors

Drawback

- Can be used for stationary sensors only. Not suitable for IoT devices which roam around.

LTE-M Machine Type Communication

Allows IoT devices to connect to 4G network directly without any need of a gateway

Specified by 3GPP Release 13 - Uses licensed spectrum

Long battery life

      devices go in PSM (Power Saving Mode) when not transmitting the data

      Periodic wake up time to transmit data

High bandwidth and high data rate -> great for mobile IoT devices

Supports VoLTE – voice over commands can be used to control the IoT device

Supports secure communication, high system capacity, lower latency, higher throughput

Lower latency, high bandwidth -> higher data rate

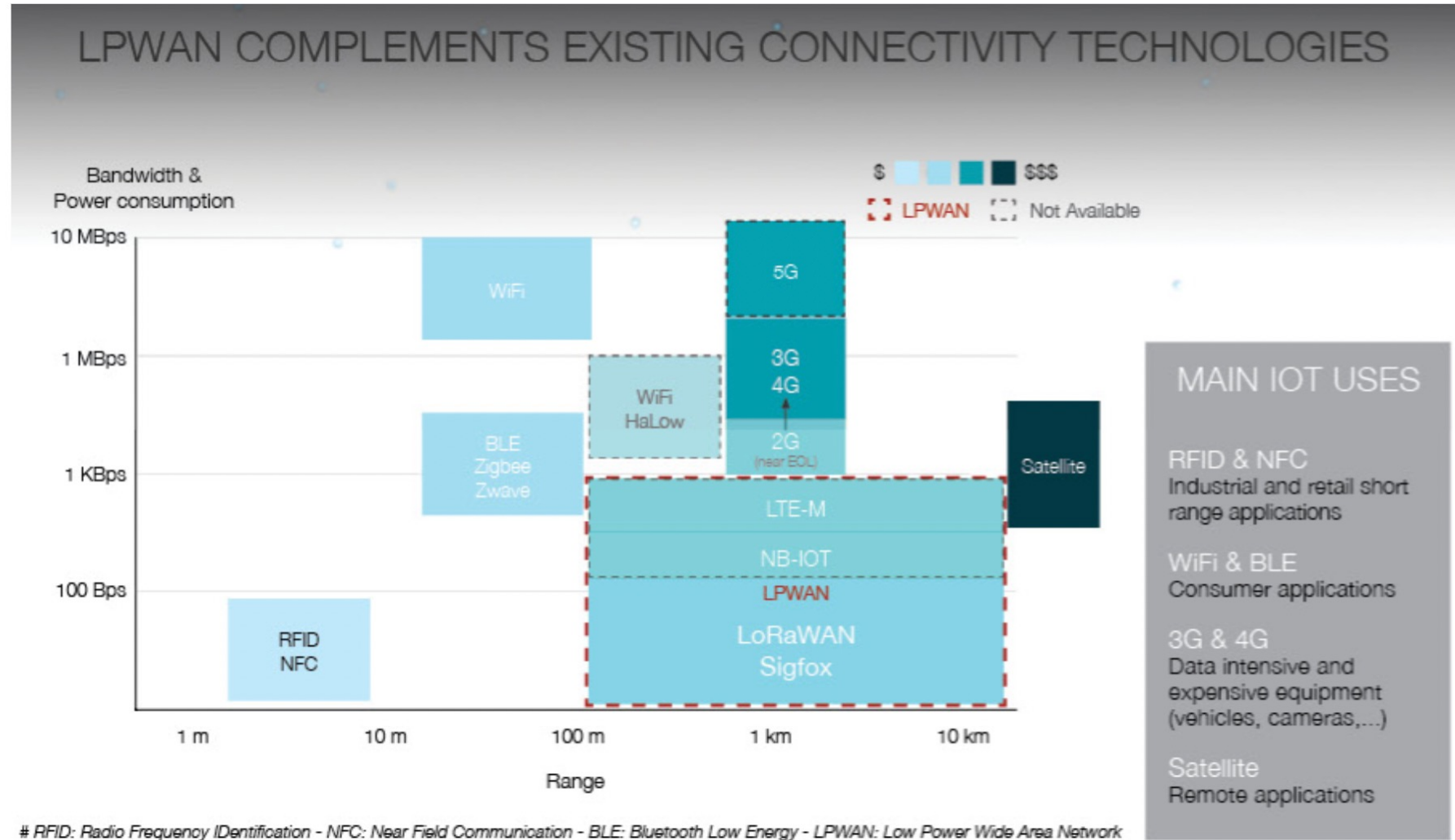Uses less power as compared to GPRS and EDGE cellular technologies

Comparison of Sigfox vs LoRa vs NB-IoT

Factors	Sigfox	NB-IoT	LTE-M
Message size	12 byte	200byte	higher
Frequency spectrum	Unlicensed	Licensed	Licensed
Device cost	Very low	Medium	High
Sim card	NA	~$1	~$1-$3
IT integration cost	Low	High	Low

Satellite

- Good for broadband wireless communication and global tracking when no other service is available
- Can be used to send SMS, phone calls, broadband internet connections in airplanes
- Very expensive communication due to requirement of dedicated global frequency/channel
- Range > 10000km
- Output power – 1.6 W to send an sms – not really suitable for IoT devices due to battery capacity requirement

Summary of IoT communication protocols

Source: IP carrier

Reading material

- LoRaWAN video - https://www.youtube.com/watch?v=rQ1AEA06Byw&t=379s

- LoRaWAN white paper: https://lora-alliance.org/wp-content/uploads/2020/11/what-is-lorawan.pdf

- Stiller, Burkhard, Eryk Schiller, Corinna Schmitt, and S. Ziegler. "An Overview of Network Communication Technologies for IoT." *Handbook of Internet-of-Things, S. Ziegler and JM, Eds. Cham, Switzerland: Springer* (2020).

Questions?

IoT Communications Layers

Application Layer

Transport Layer

Network/Internet Layer

Data Link Layer (RFID)

Physical Layer