# IoT Communications

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CS698T, Lecture 5

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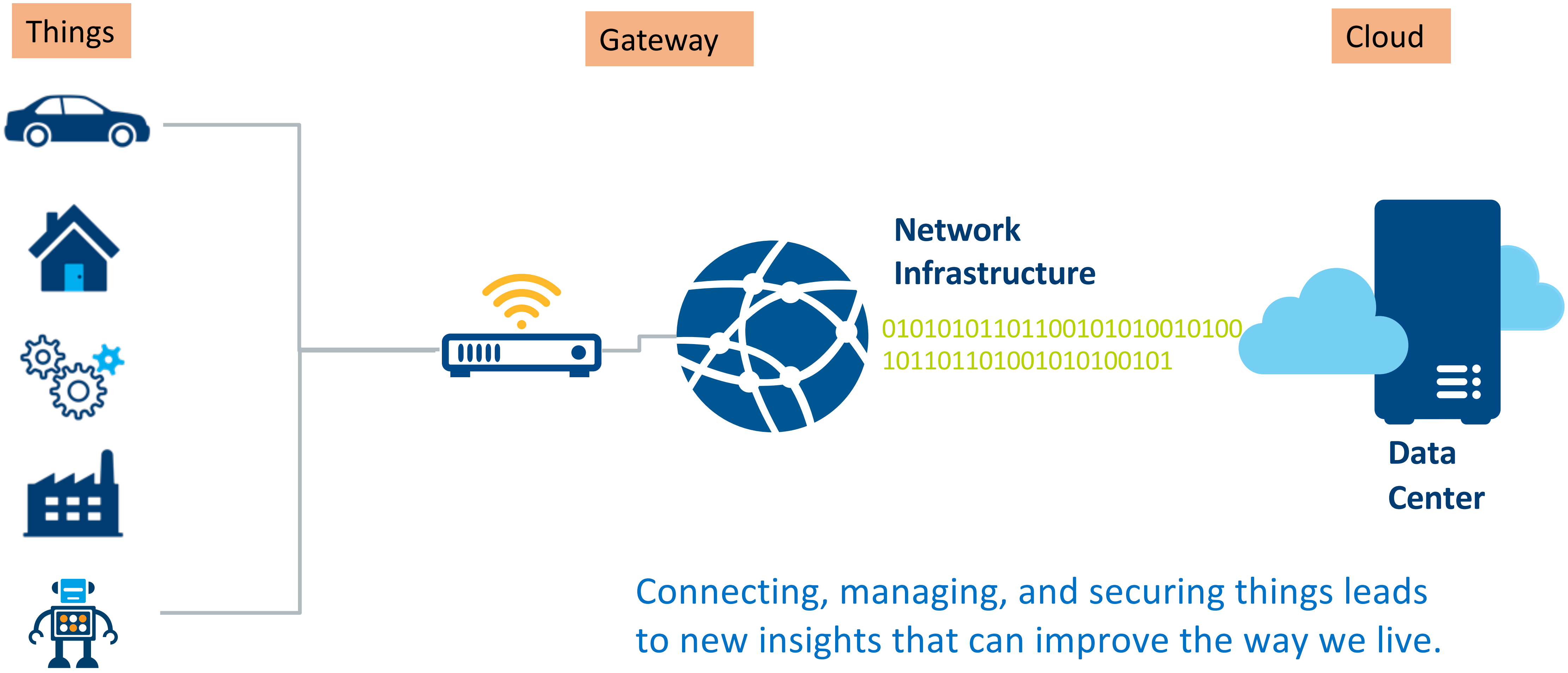
# IoT Overview

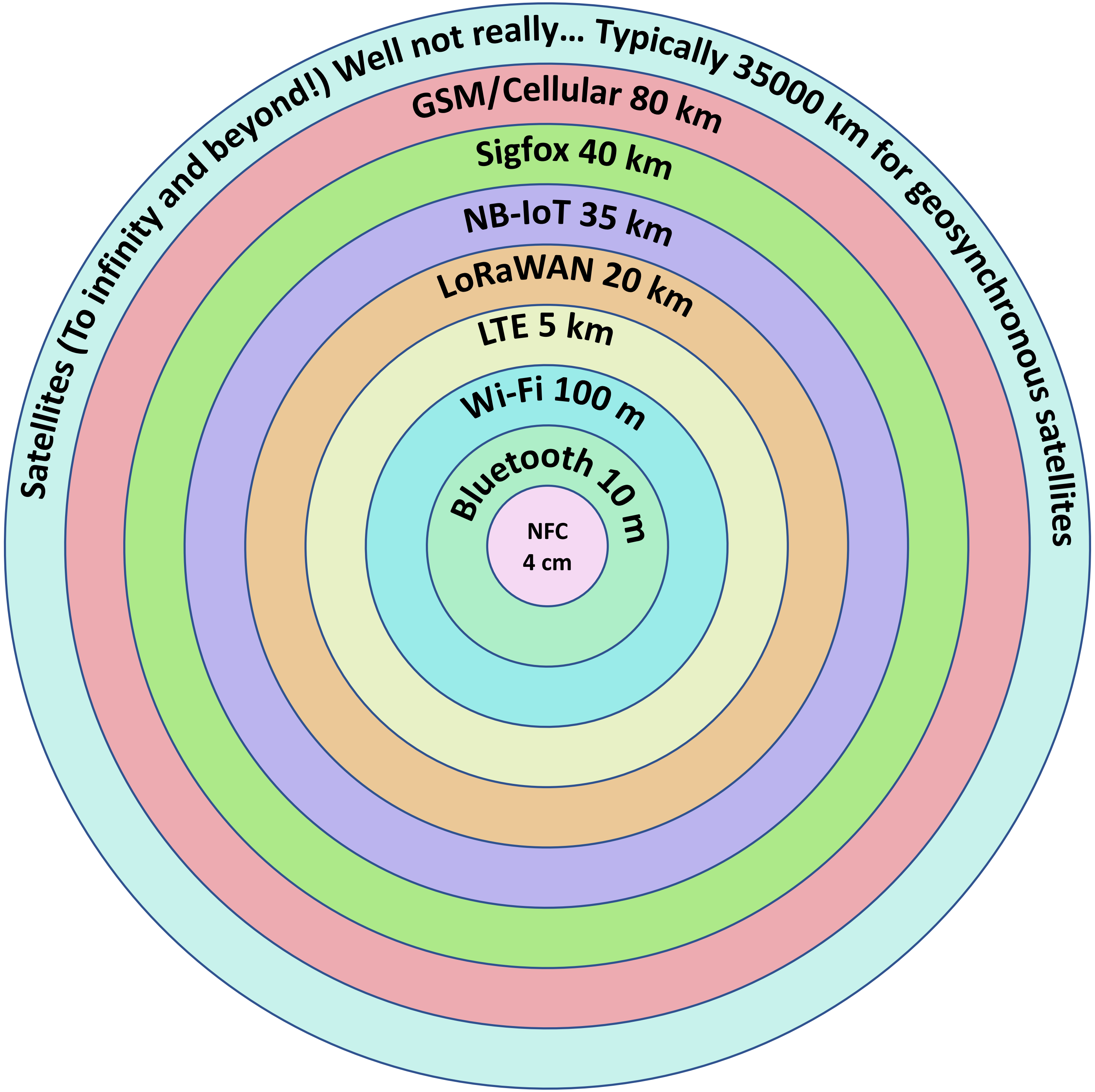
## 83B devices will be connected to the Internet by **2024**[1]




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



# 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

Synchro
us
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# 5G

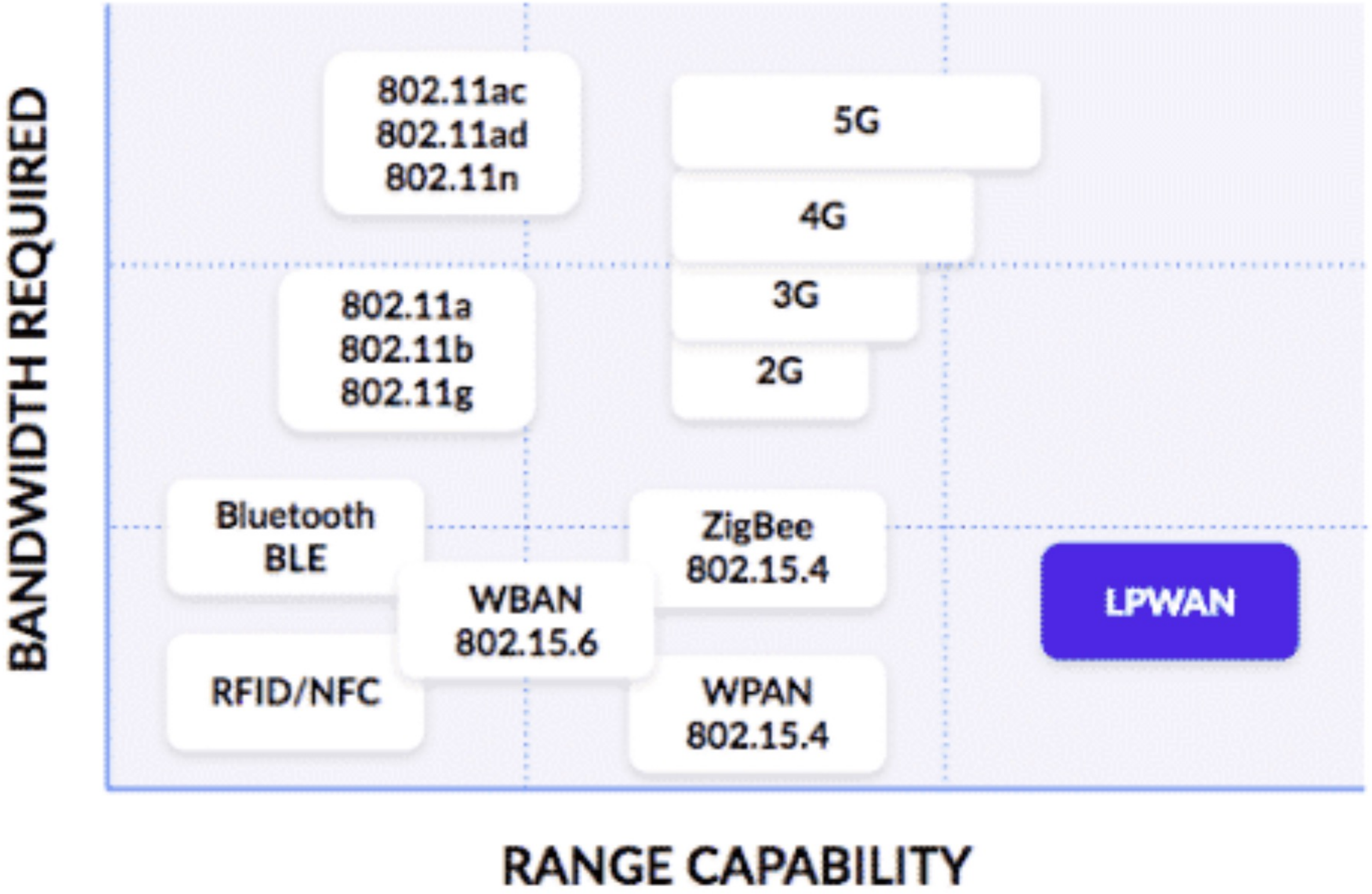
- New cellular protocol after LTE
- High speed and signal quality
- Low latency
- Not yet deployed in India
- Challenges
  - Requires a specific infrastructure with specific antennas and transmitter
  - Expensive to setup new infrastructure
  - LoRAWAN – cheaper and slower solution

# 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




Source: https://www.iotforall.com/lpwan-benefits-vs-iot-connectivity-options

# 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

Not used anymore

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

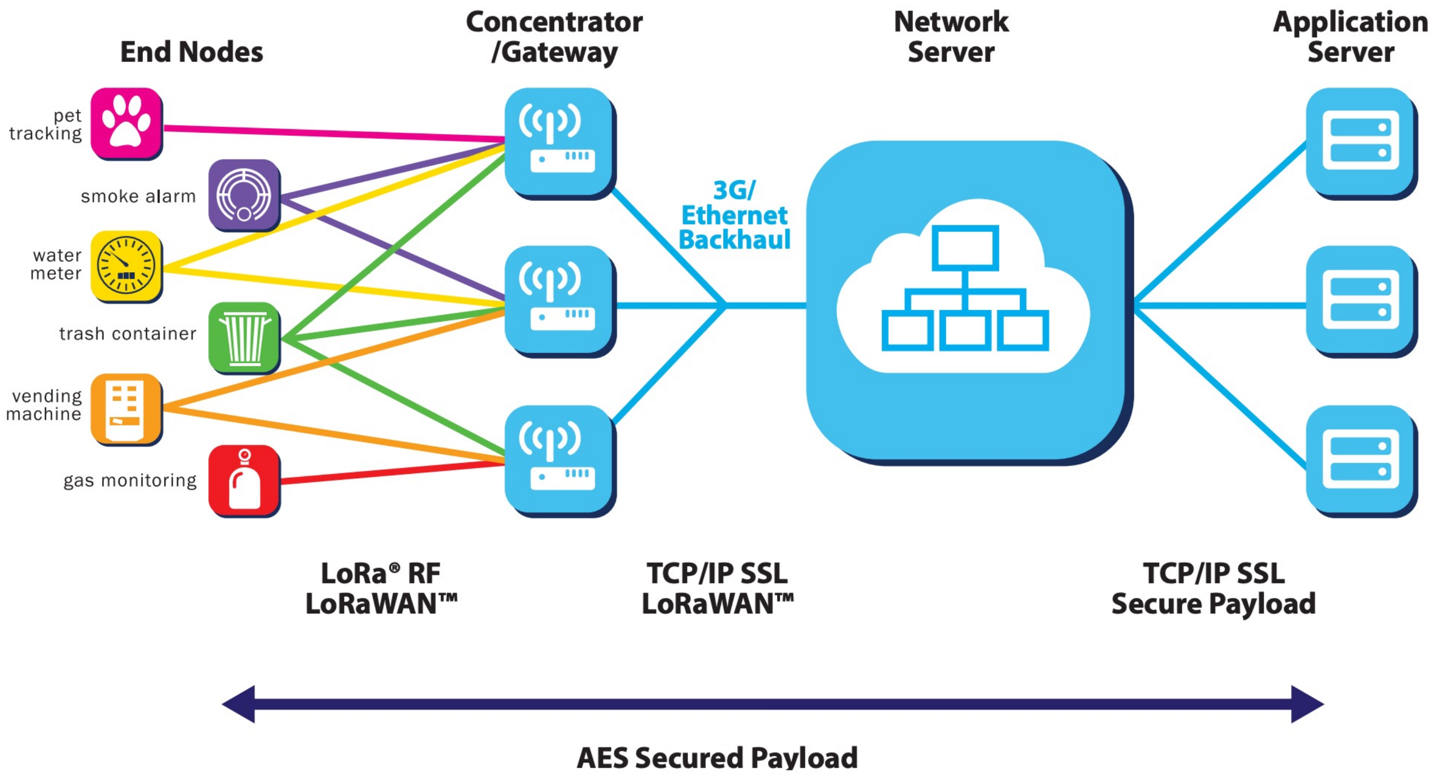



Image source: https://lora-alliance.org/wp-content/uploads/2020/11/what-is-lorawan.pdf

# 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

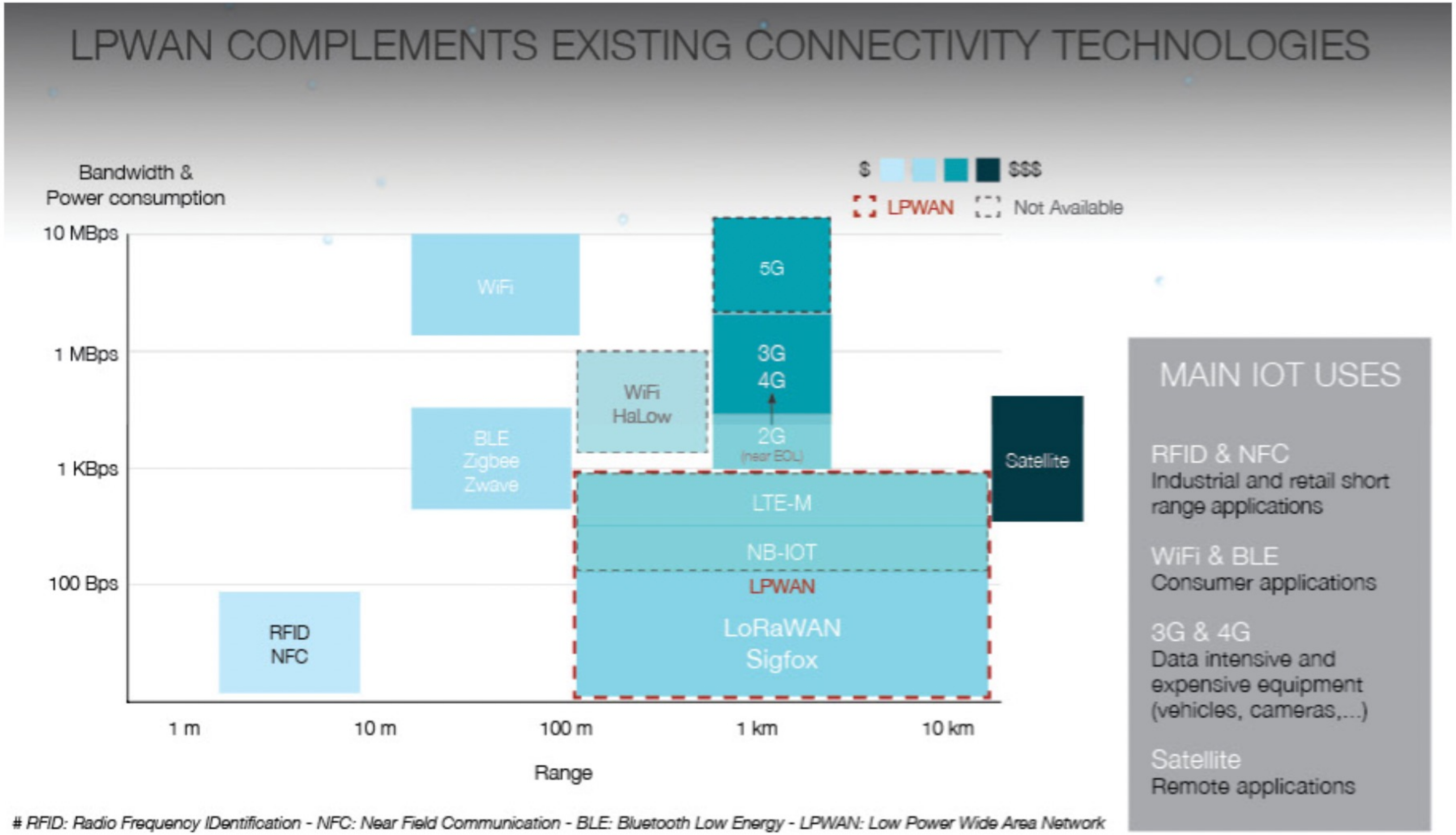
# Comparison of Sigfox vs LoRa vs NB-IoT

| 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