ADSE1310-1 24V Internet of Things

Communication Technologies for IoT

Overview

We will discuss

- Sampling and Quantization.
- Different communication technologies for IoT devices.

By the end of the lecture, you should be able to

- Understand the concepts behind sampling and quantization for IoT sensors.
- Understand different choices when it comes to communication technologies and select the right one for a given use case.

Analog and Digital Signals

Analog Signal

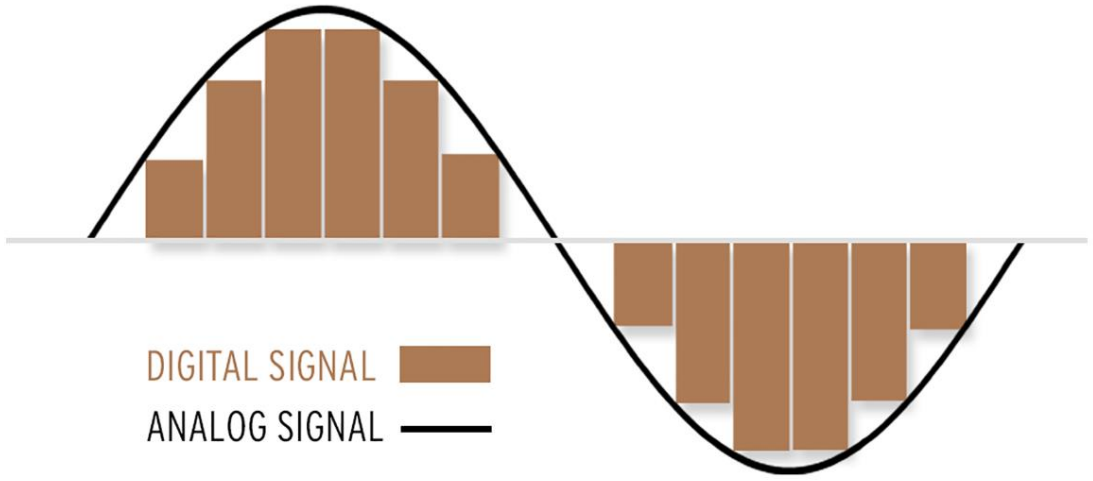
- Continous both in Time and Value.
- Infinite resolution. Infinite number of values in any given range.

Digital Signal

- Discrete values within a given range.
- Finite resolution

Analog to Digital Converter (ADC)

- System which converts analog signals to digital.

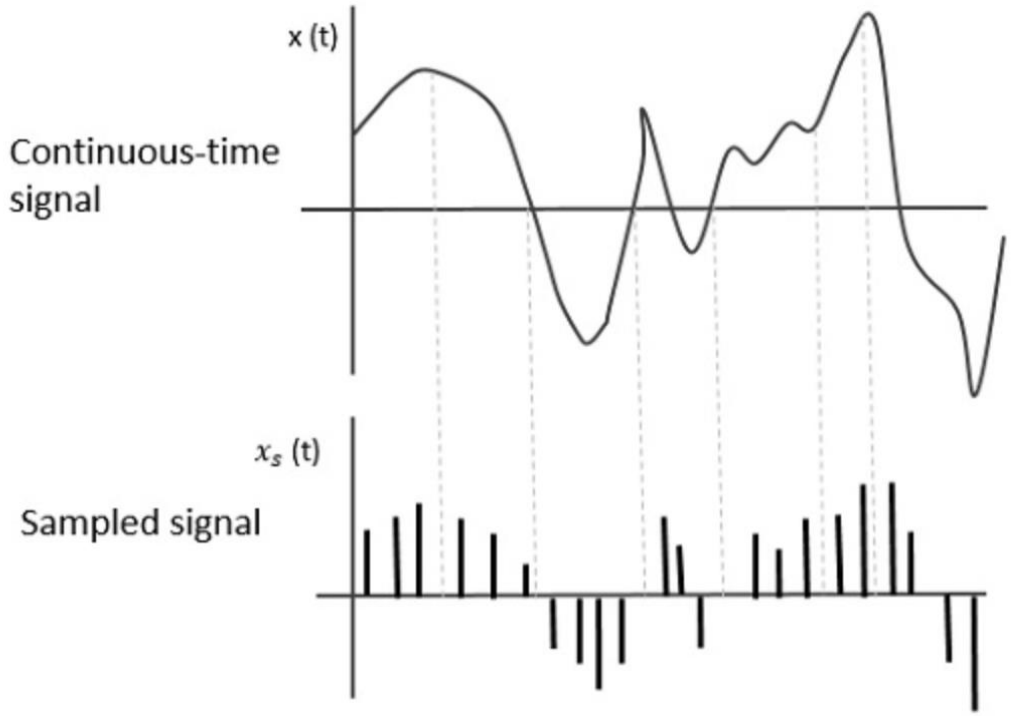


https://www.klipsch.com/blog/digital-vs-analog-audio

Sampling

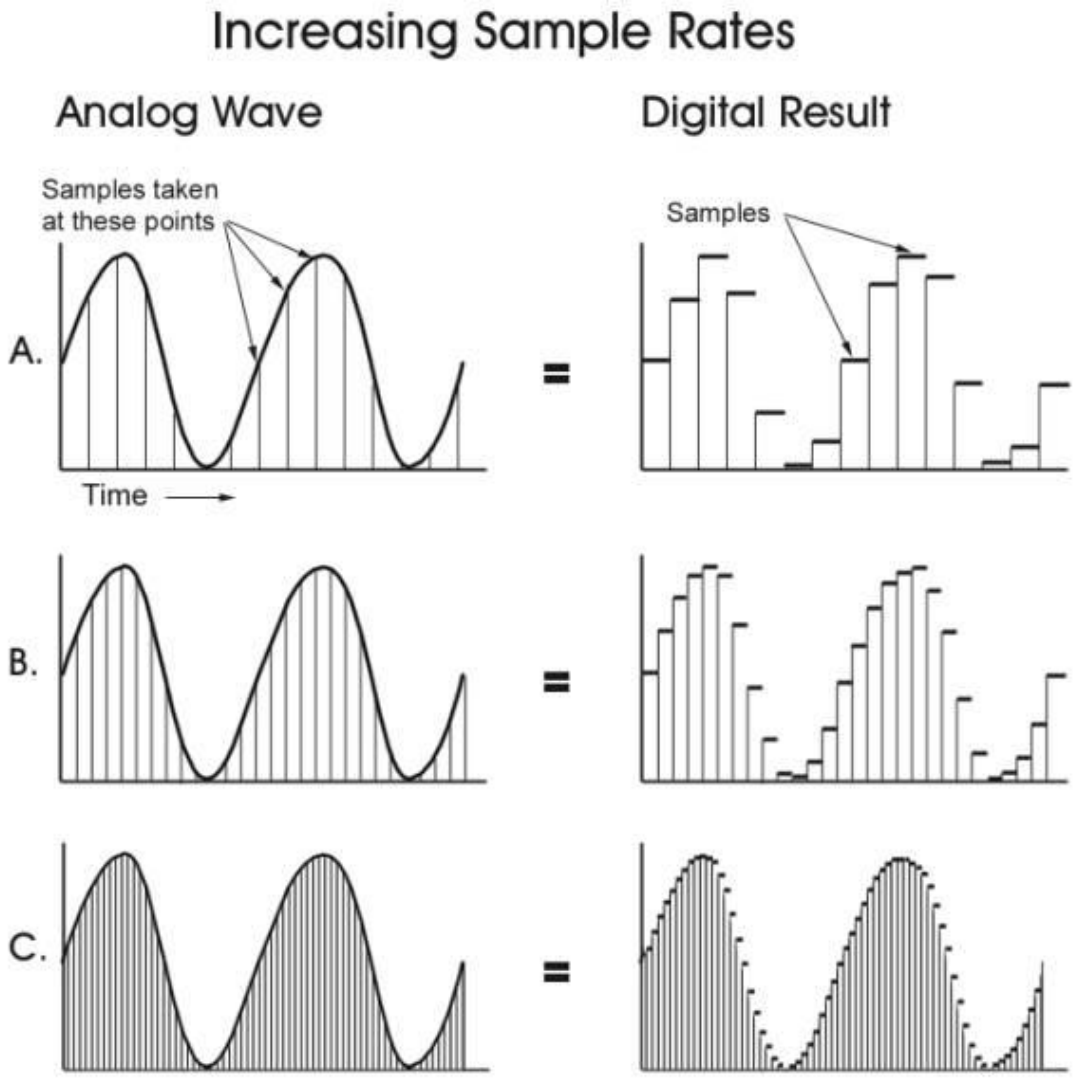
- Measuring the analog signal at regular intervals in Time.
- It represents how often do we collect data.
- Allows us to process real-word signals.

Sampling



https://www.tutorialspoint.com/digital_communication/digital_communication_sampling.htm

Higher the sampling rate, better can we capture the original signal.



https://www.izotope.com/en/learn/digital-audio-basics-sample-rate-and-bit-depth.html

Sampling

- Sampling rates can vary from, for example, 1 million times per second to much lower rates, such as 16 kHz (16 000 samples per second).

- Sampling rate depends on the use-case.

What sampling rate is enough for these kind of sensors?

- Temperature Sensors
- Soil moisture sensors
- Heart Rate sensor

Sampling

- Temperature Sensors ---> Once every few seconds.
- Soil moister sensors. ---> Once every hour
- Heart Rate sensor ---> A few times every second

Sampling

- Sampling is taking regular snapshots or "samples" of the continuous signal at specific intervals.

- Higher the sampling rate, the better.

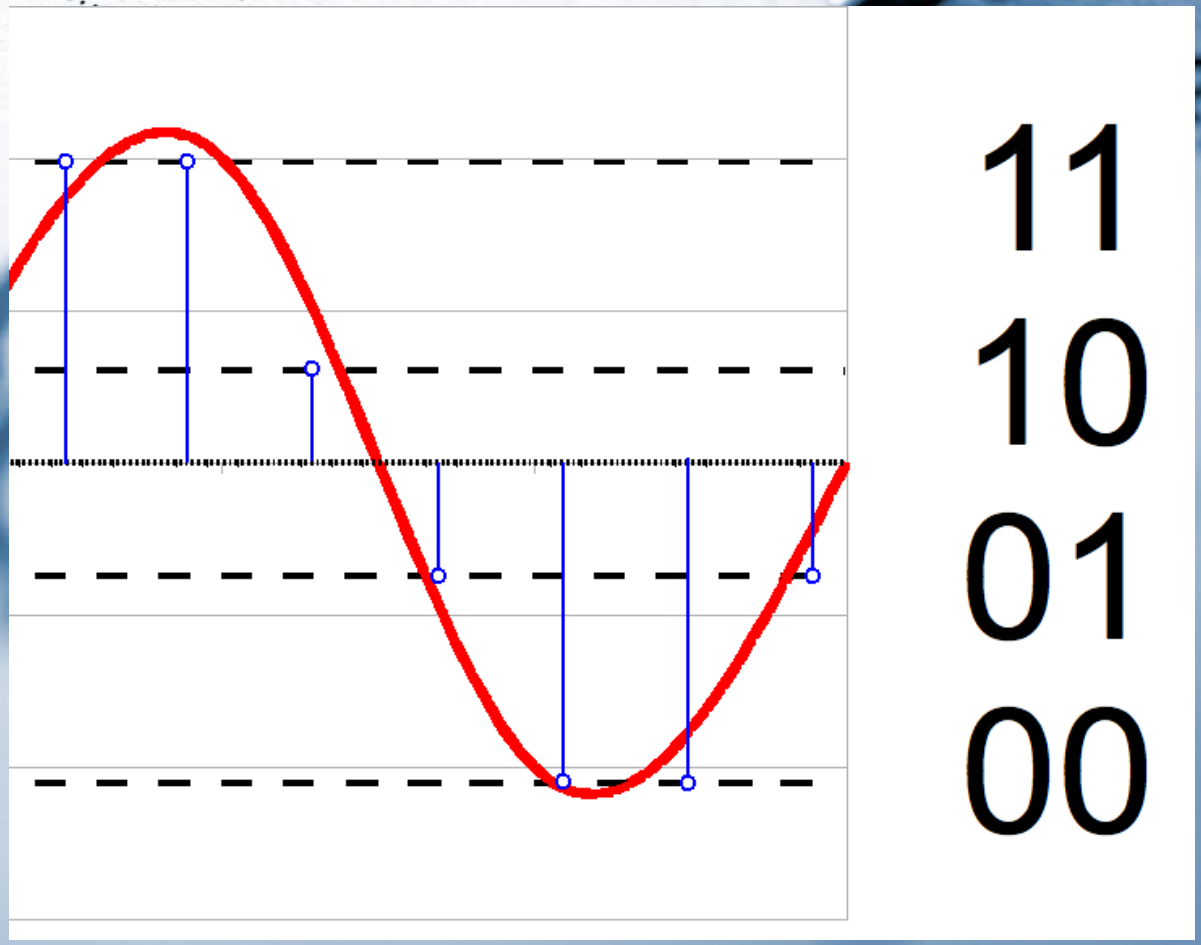
Quantization

- Taking the sampled values and assigning each sampled value to the nearest value from a predefined set of values (or levels)
- Allows us to represent, process and store real-word signals.
- If you use n bits, you can represent 2^n distinct levels

Quantization

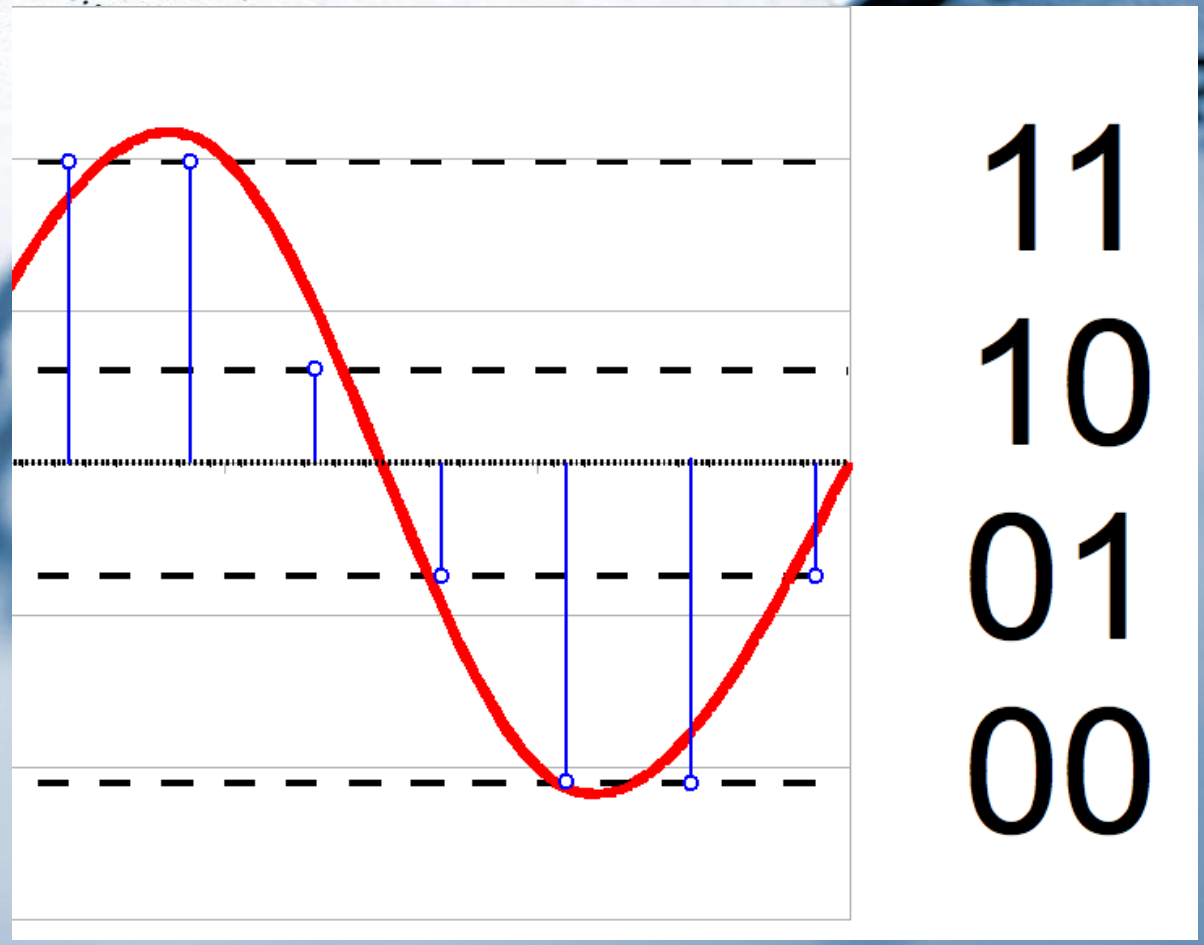
- Let's say we are measuring an temperature signal which ranges from 0 to 30 degrees and we have only 4 levels or discrete values (0,10,20,30). We have only two bits.

- If we measure the signal and it is 21, which value should we assign to it?



Quantization

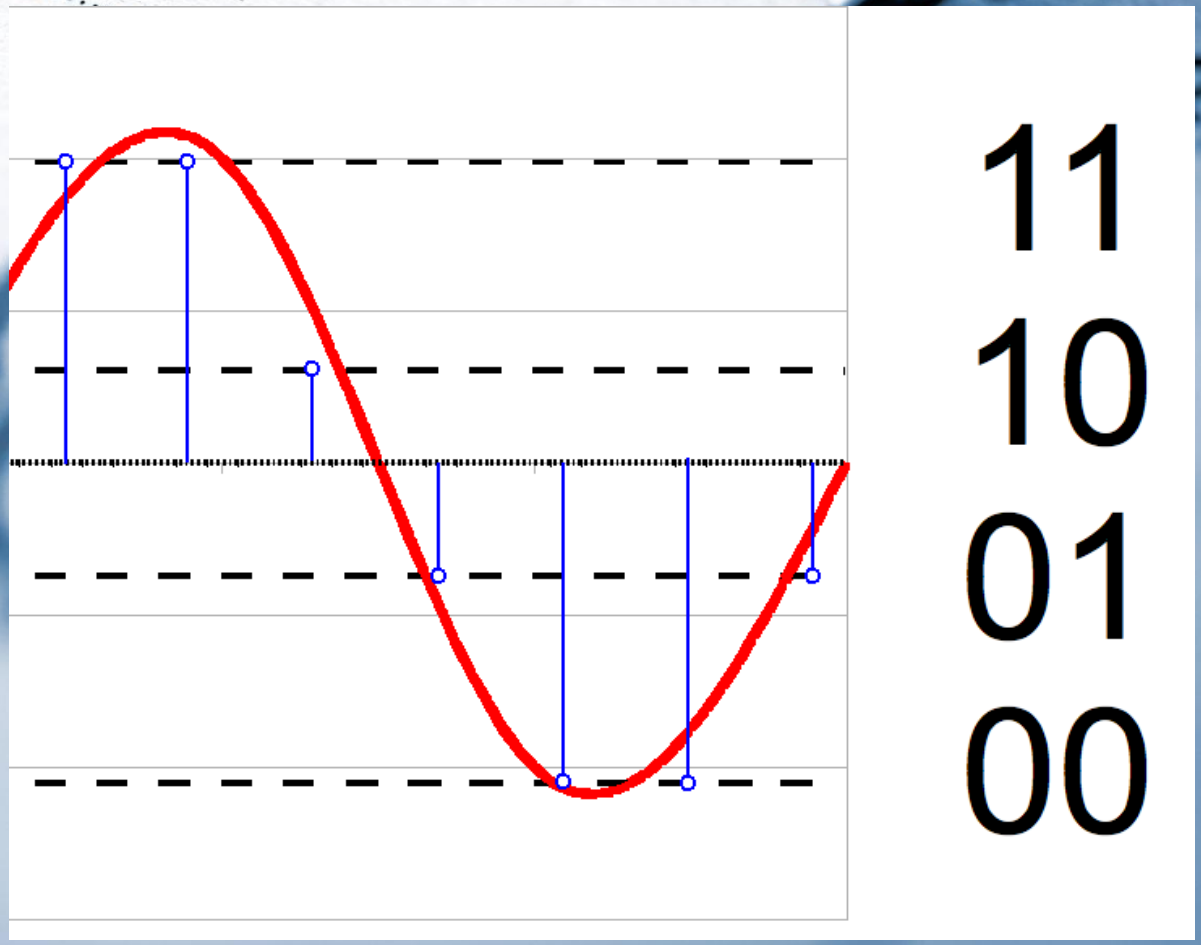
- Let's say we are measuring an temperature signal which ranges from 0 to 30 degrees and we have only 4 levels or discrete values (0,10,20,30). We have only two bits.
- If we measure the signal and it is 24, which value should we assign to it?



Quantization

- Let's say we are measuring an temperature signal which ranges from 0 to 30 degrees and we have only 4 levels or discrete values (0,10,20,30). We have only two bits.

- If we measure the signal and it is 26, which value should we assign to it?



Quantization

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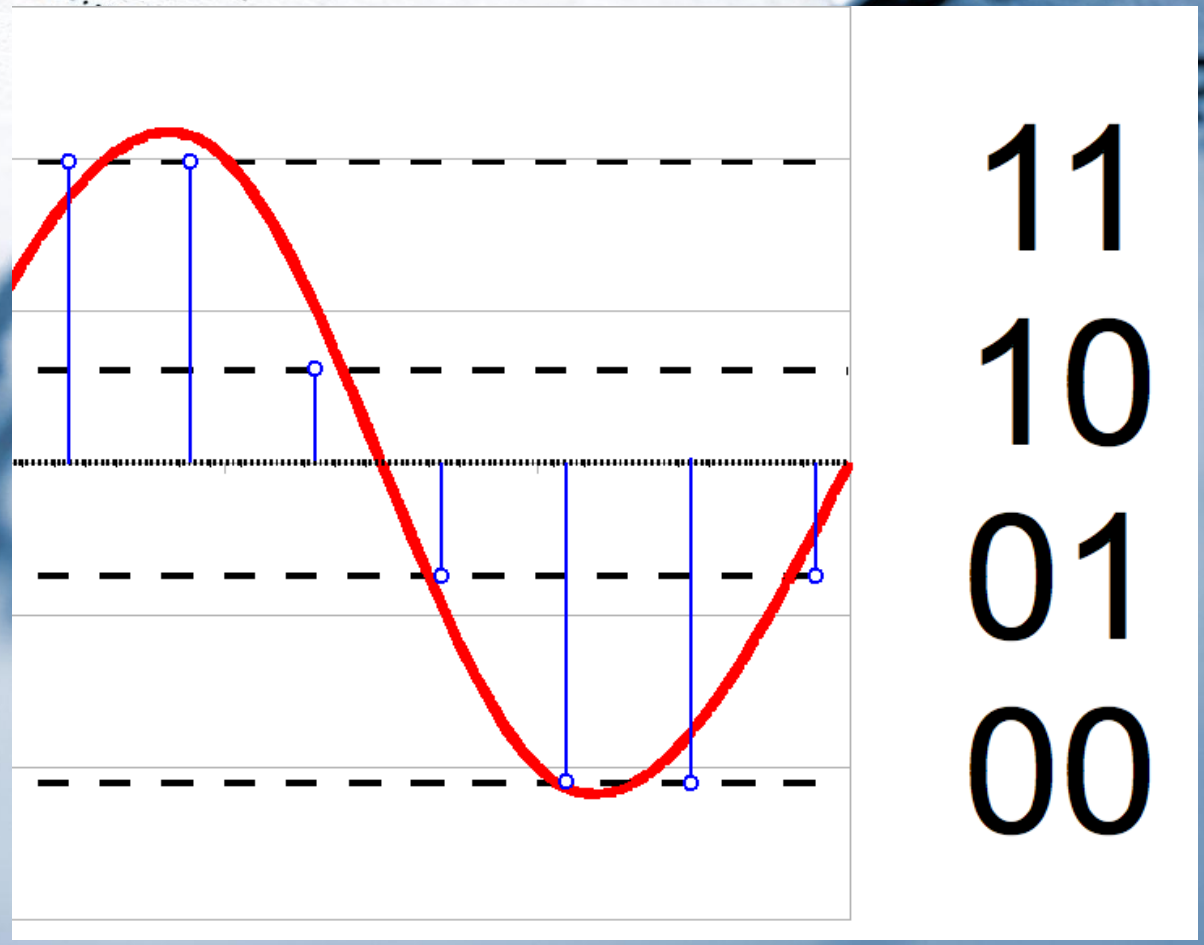
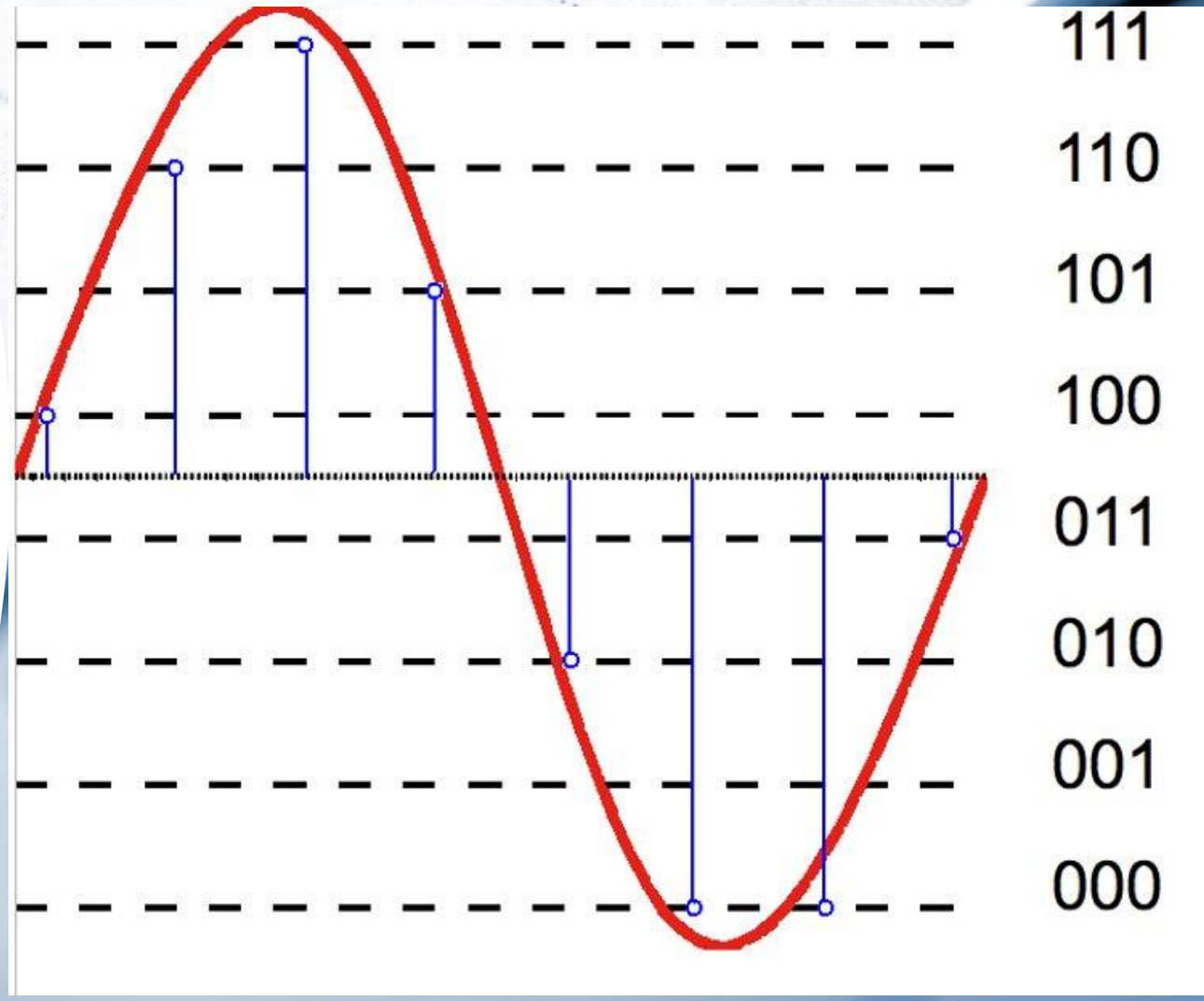
- If we measure the signal and it is 29, which value should we assign to it?



Quantization

- Let's say now we have 3 bits. We now have 8 levels or discrete values (0,5,10,15,20,25,30,35).

- If we measure the signal and it is 21, which value should we assign to it?



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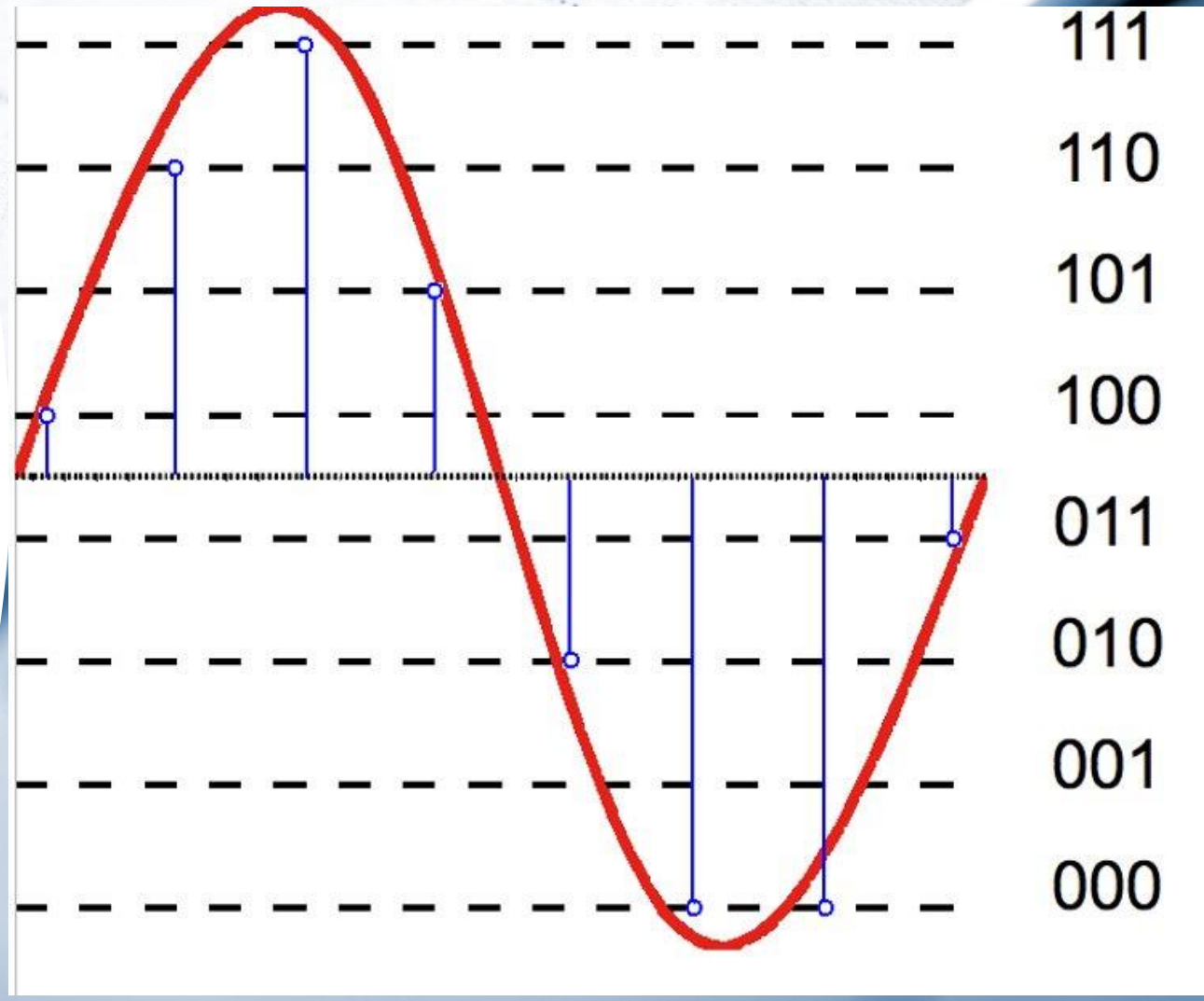

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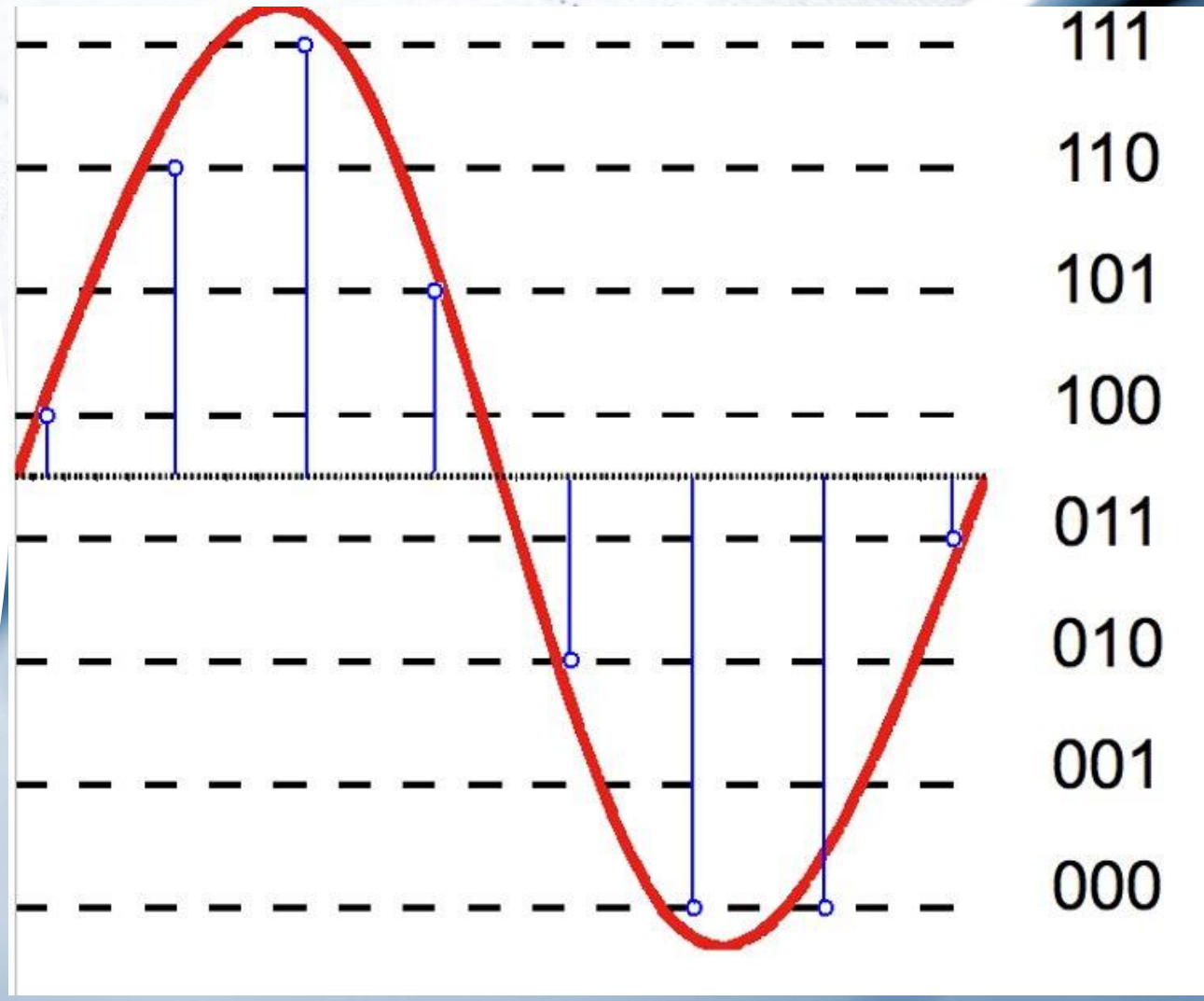

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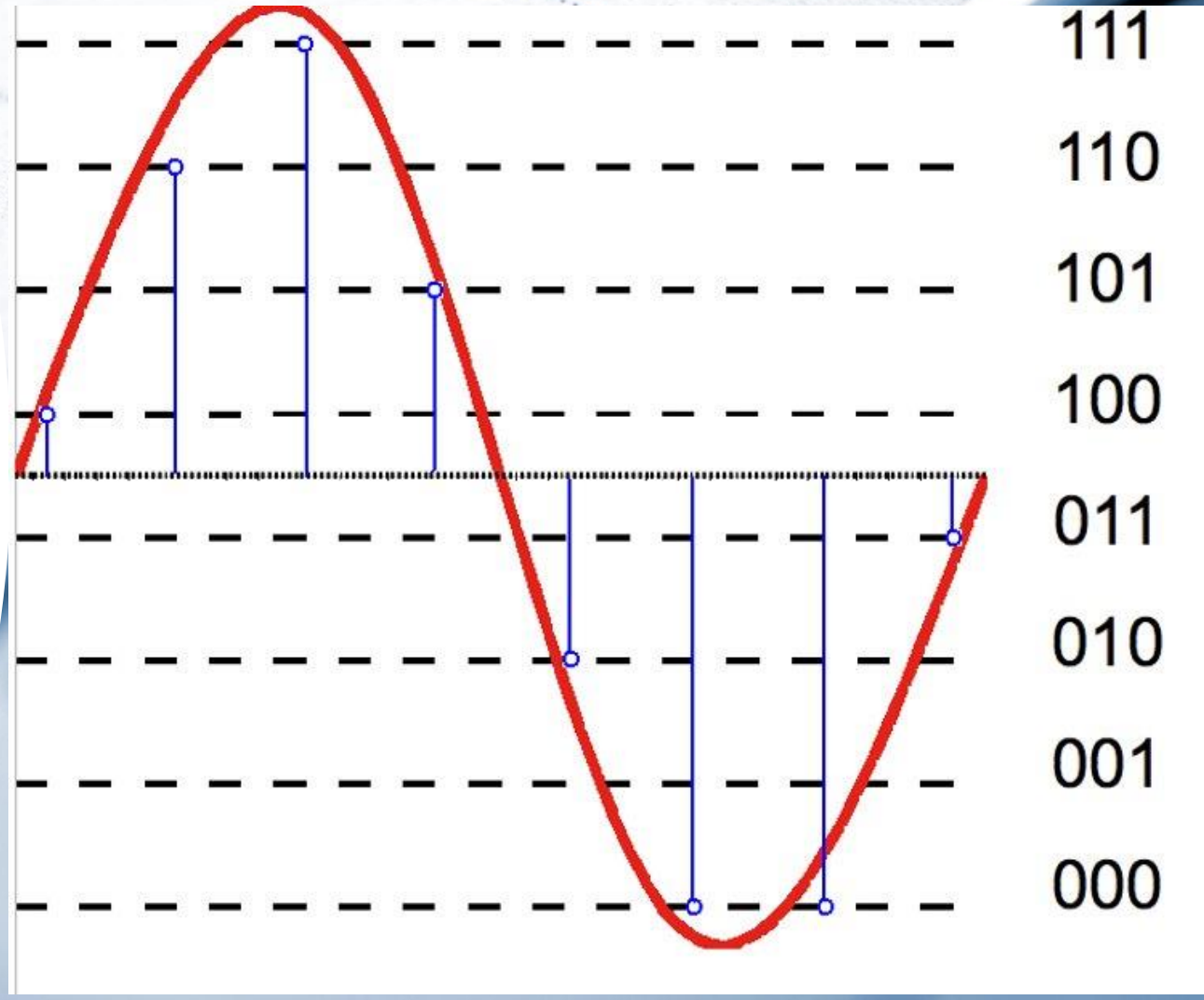


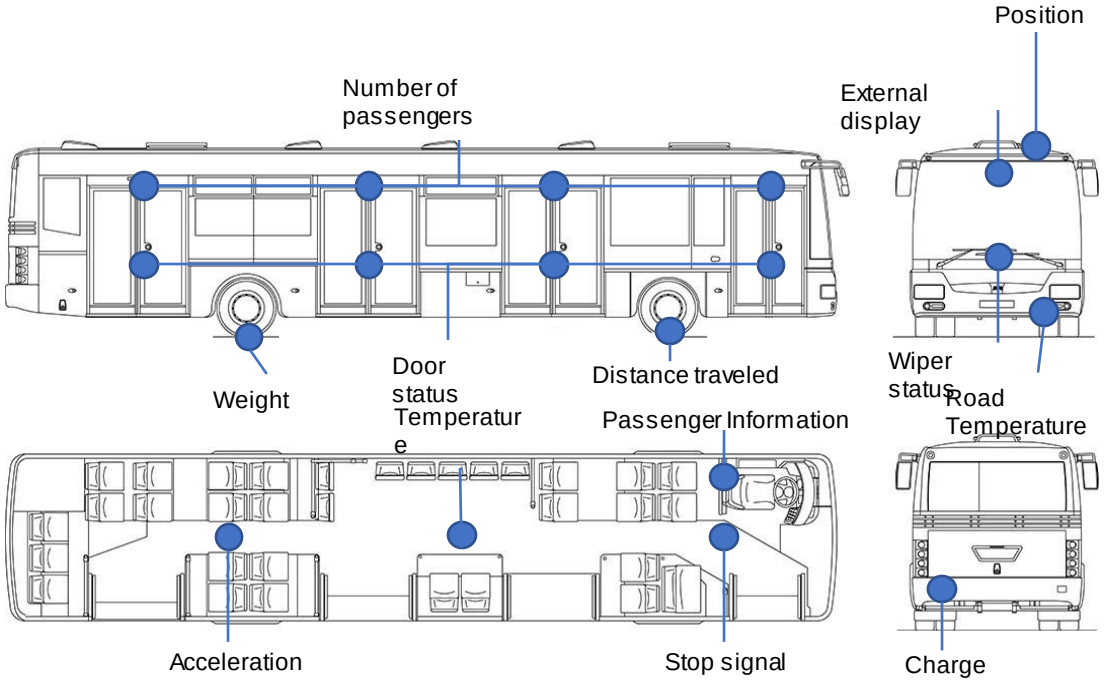
Sampling & Quantization

Increasing the sampling rate enhances our ability to capture analog signals more rapidly.

The number of bits used in quantization directly influences the precision of the digital representation: more bits allow for finer distinctions between signal levels and more precise representation of analog signals.

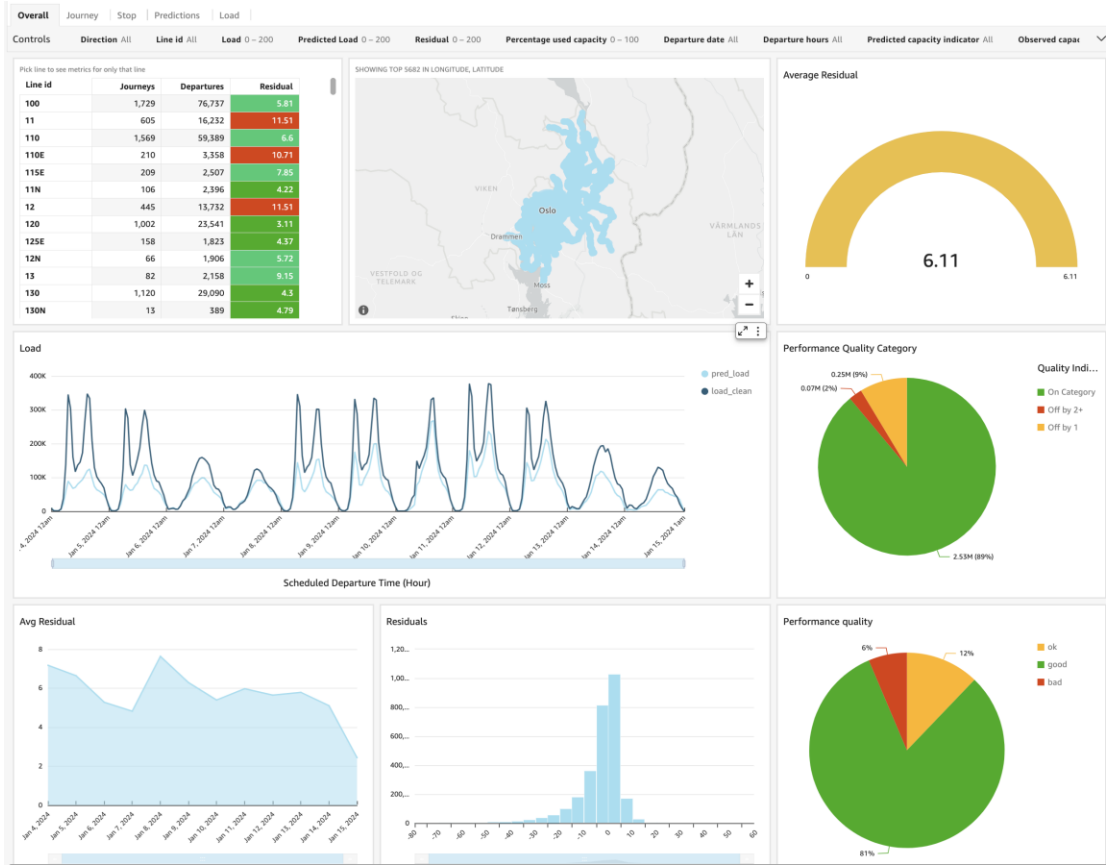
Communications for IoT

Sensors in Ruter busses



Sensors in Ruter busses

Data to Insights



IoT Communications

There are three types of communication technologies

1. Wired communication technologies
2. Wireless communication technologies
3. Mobile/Cellular communication technologies

Wired Communication Technologies

Ethernet

- One of the most common communication standard.
- Used for high speed, reliable and secure communication.
- Throughput ranging from 10Mbps, 100Mbps to 10Gbps

RS-232

- Serial communications.
- Used for low-speed communications over short distances.
- Common throughput is from 2.4k, 9.6k to 19.2k (bits/s)

Wireless Communications

In wireless communication, we have many options.

- WiFi
- LoraWAN
- ZigBee
- Bluetooth
- Z-Wave
- Etc.

Wireless Communications

WiFi

- Widely used technology which provides high-speed connections.
- Operates in different radio bands (2.4 GHz and 5 GHz).
- Requires setting up network on the devices.
- Used for devices which require high data throughput, such as smartphone, computers, etc.
- Can have speed up to 10Gbs

Wireless Communications

Bluetooth

- Operates at 2.4GHz
- Provides lower range than Wi-Fi. Ranges is from 10meter to 100 meters which is affected by the density of obstacles such as walls.
- Speed up to 3 Mbps. Suitable for transmitting small chunks of data. Examples?
- Setting up a Bluetooth connection generally is easier than setting up Wi-Fi
- Requires lower power than Wi-Fi

Wireless Communications

Wi-Fi Vs Bluetooth. Which one should you use?

- Security camera with high definition video streaming
- Remote monitoring from anywhere.
- Low power temperature or humidity sensors.
- A wearable device which monitors heartbeat and sends it to a smartphone.

Wireless Communications

Wi-Fi Vs Bluetooth. Which one should you use?

- Security camera with high definition video streaming --> Wi-Fi
- Remote monitoring from anywhere --> Wi-Fi
- Low power temperature or humidity sensors --> Bluetooth
- A wearable device which monitors heartbeat and sends it to a smartphone --> Bluetooth

Wireless Communications

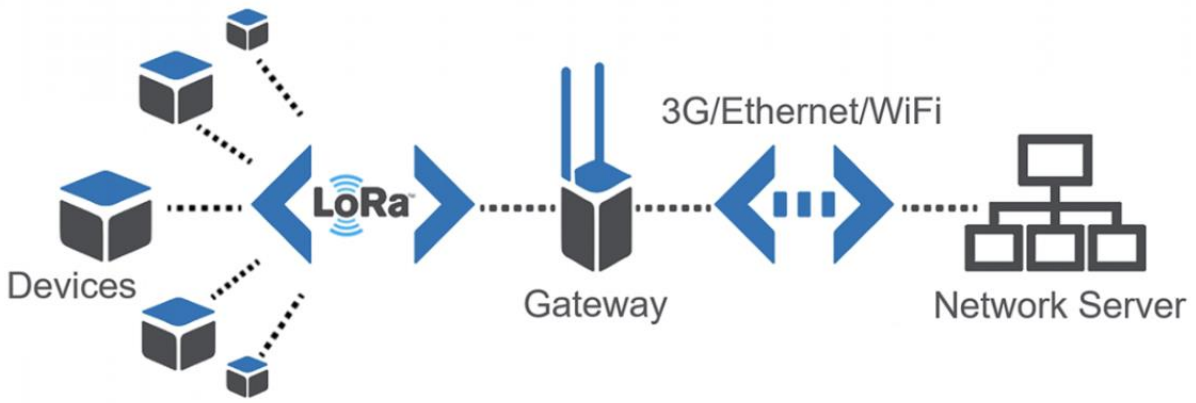
LoRaWAN

- Stands for Long Range Wide Area Network.
- Operates on 169 MHz, 433 MHz, 868 MHz or 915MHz depending on the region.
- Similar to Bluetooth (suitable for devices sending small packets of data periodically) but for long range.
- Not suitable for real-time data.
- Provides Long Range Coverage of up to 15 km in LOS (Line of sight).

Wireless Communications

LoRaWAN

Requires a gateway in between to connect to internet.



https://interline.pl/Information-and-Tips/LoraWan

Wireless Communications

LoRaWAN

- Provides ultra-low power radio communication. Ideal for devices which can last up to 15 years on a single battery.
- Best suited for outdoor environments.
- Examples : Street lighting, Smart parking, Temperature monitoring, etc.

Wireless Communications

ZigBee

- Wireless protocol designed for low power and low data rate application but for short range and within a localized area.
- Operates at 2.4 GHz.
- Offers reliable and low latency communication.
- Suitable for real-time control.
- Common applications are smart lightning, smart measurements.

Wireless Communications

ZigBee

Wireless Communications

LoRaWAN Vs Zigbee – Which one to use?

- Sensors across agricultural fields to monitor soil moisture, temperature, and nutrient levels, etc.
- Home automation
- Placing sensors in forests, rivers, and urban areas to monitor environmental factors

Wireless Communications

LoRaWAN Vs Zigbee – Which one to use?

- Sensors across agricultural fields to monitor soil moisture, temperature, and nutrient levels, etc. --> LoRaWAN
- Home automation --> Zigbee
- Placing sensors in forests, rivers, and urban areas to monitor environmental factors --> LoraWAN

Wireless Communications

- WiFi
- LoraWAN
- ZigBee
- Bluetooth

Cellular Communication Technologies

In Cellular communication technologies, we also have many options.

- NB-IOT (Narrowband IoT)
- LTE-M (Long term evolution for Machines)
- 2G,3G,4G,5G

Cellular Communication Technologies

NB-IoT

- Offers low data transmission (max 159 kbps uplink) and low power consumption.
- Ideal for sensors sending data few times a day.
- Supports battery of up to 10 years.
- Suitable for remote locations and best suited for stationary devices.

Cellular Communication Technologies

LTE-M

- Offers high data transmission than NB-IoT up to 1Mpbs uplink.
- Suitable for mobile (non stationary) devices.

Cellular Communication Technologies

5G

- Provides high connectivity speeds. Download speeds can be between 10 and 20 Gbps. Provides similar speeds to Wi-Fi. In some cases, it can have higher speed than Wi-Fi.
- Provides ultra-low latency. Less than 10 milliseconds.
- Ideal for high speed real-time applications.

Cellular Communication Technologies

NB-IoT vs LTE-M vs 5G. Which one to use?

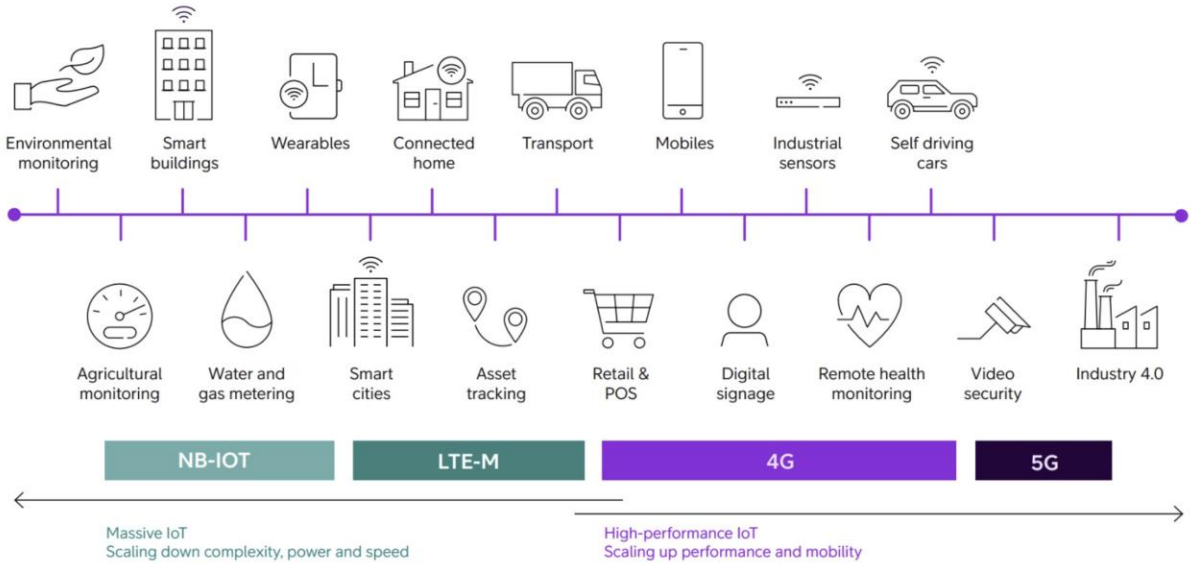
- Smart agriculture. Sensors monitoring soil properties and reporting back a few times a day
- Low resolution video streaming.
- Ruter's busses
- Driverless cars.

Cellular Communication Technologies

NB-IoT vs LTE-M vs 5G. Which one to use?

- Smart agriculture. Sensors monitoring soil properties and reporting back a few times a day --> NB-IoT
- Low resolution video streaming --> LTE-M, 5G
- Ruter's busses --> LTE-M, 5G
- Driverless cars --> 5G

Cellular Communication Technologies



https://business.teliacompany.com/internet-of-things/iot-connectivity/managed-iot-connectivity?gclid=CjwKCAiAtt2tBhBDEiwALZuhAEKXXhNOwvm5LWtEhEtI15Ky0wZKCxNmKckawyijEbkJyIWNB2t-KxoCovsQAvD_BwE

IoT Communication Technologies

To Summarize:

- We have many choices when it comes to communication technologies for IoT devices.
- The choice of the communication technologies depends on many factors such as
  - Short range and long range
  - Low speed and high speed
  - Low latency and high latency (real-time vs non real-time)
  - Power utilization.
  - Cost

Cellular Communication Technologies

Exercise. Which communication technologies would you use based on the following information?

- Oslo kommune plans to deploy a network of sensors throughout the city to monitor air quality, temperature, humidity, etc.
- Some of the areas will be remote and can be underground.
- The sensors should work on battery power and have a long battery life.
- These sensors should send data periodically. Real-time is not a requirement.
- It should be a cost effective solution.

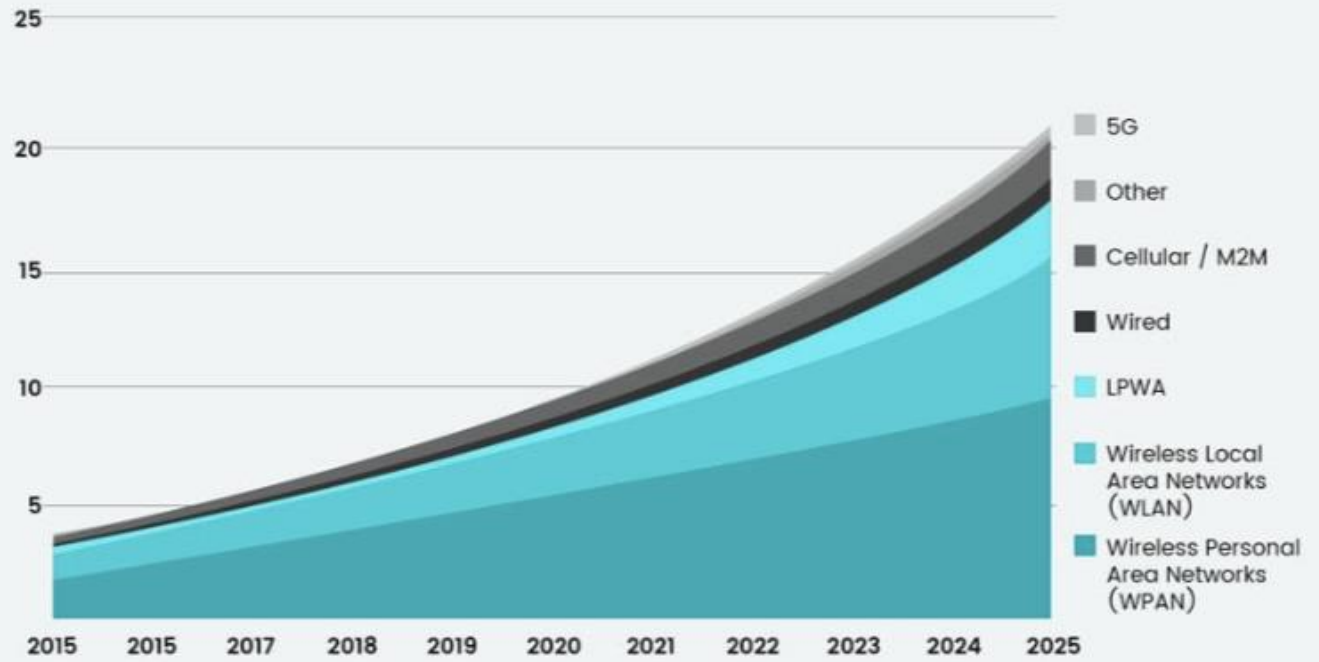
Cellular Communication Technologies

Exercise. Which communication technologies would you use based on the following information?

LoRaWAN or NB-IoT

Global number of connected IoT devices

Number of global active IoT connections (in billions)



SOURCE: IoT Analytics

Very

Break 15 Min

Overview

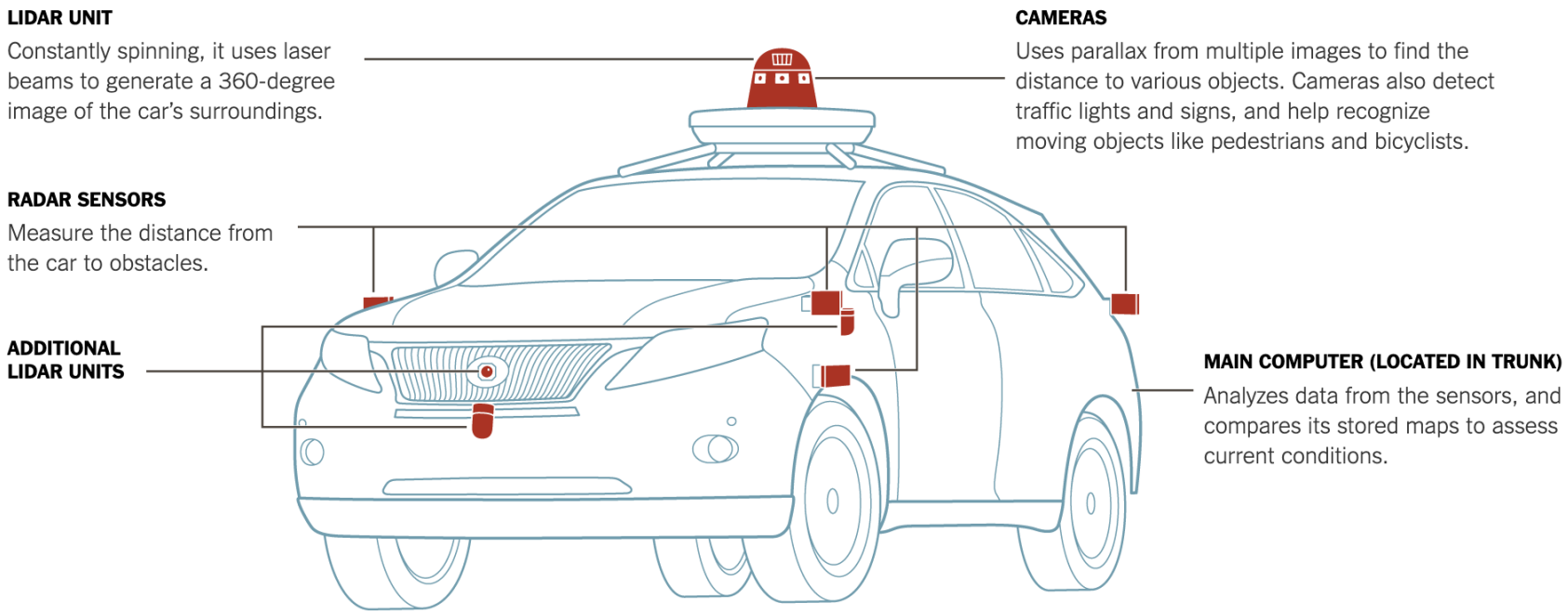
We will discuss

- Sampling and Quantization.
- Different communication technologies for IoT devices.

By the end of the lecture, you should be able to

- Understand the concepts behind sampling and quantization for IoT sensors.
- Understand different choices when it comes to communication technologies and select the right one for a given use case.

Self Driving Cars



By Guilbert Gates | Source: Google | Note: Car is a Lexus model modified by Google.

https://www.nytimes.com/2018/03/19/technology/how-driverless-cars-work.html

Self Driving Cars

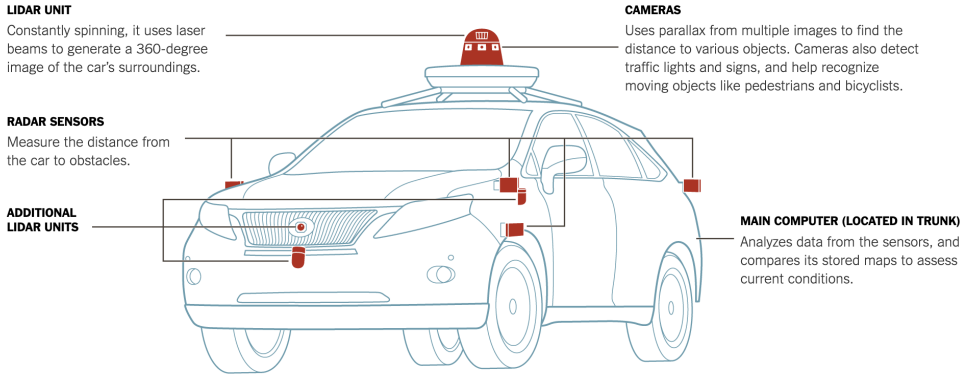
Radar (Radio Detection and Ranging)

Detects the distance and speed of objects around the vehicle.

Works well in various weather conditions (fog, rain, etc.)

Relatively cheaper than LiDAR and cameras.

Lower resolution than LiDAR and cameras. Difficult to identify small objects and distinguishing them from similar objects.



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Self Driving Cars

LiDAR (Light Detection and Ranging)

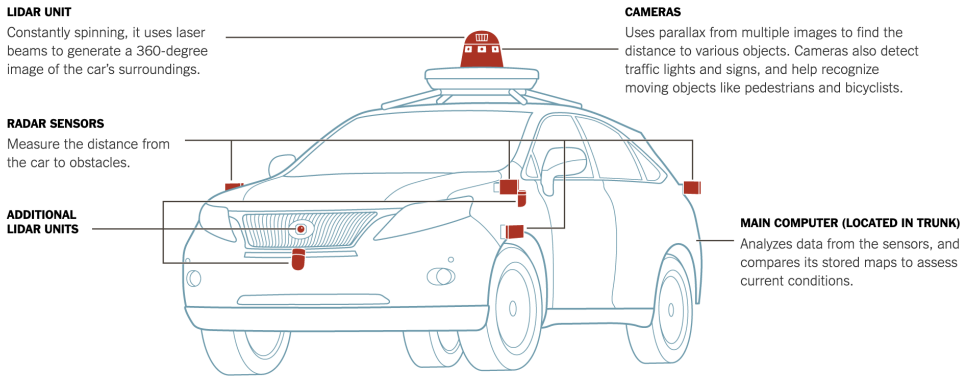
Uses pulsed laser beams to create a detailed 3D map of the surroundings.

Good at obstacle detection and creating high-resolution environmental models

Accurate distance and size measurement for detected objects.

Works in any lighting conditions but struggles in bad weather conditions like fog, rain, or snow.

Typically more expensive than radar and cameras.



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Self Driving Cars

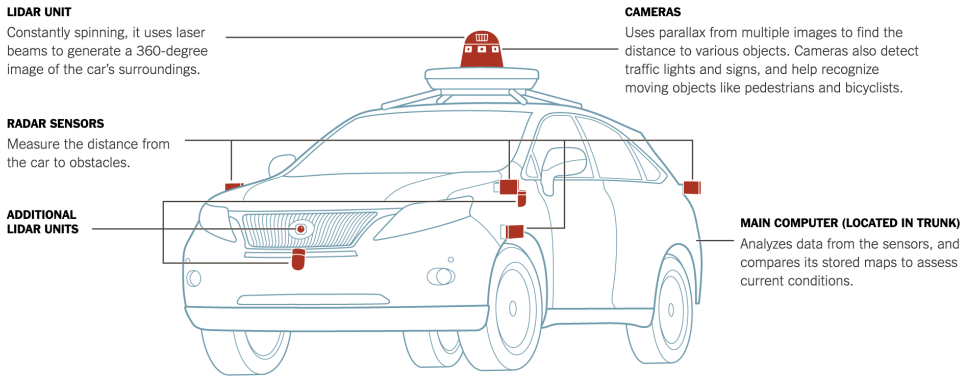
Cameras

Provide high-resolution images and provides detailed visual data like reading signs and signals.

Capture color information, which is beneficial for identifying traffic lights and other important visual information.

Less expensive compared to LiDAR systems.

Performance can be significantly impacted by lighting conditions, darkness or glare.



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Self Driving Cars

Ruter's Self Driving Cars

15 selvkjørende biler er på vei

I disse dager starter testingen av selvkjørende biler i Groruddalen. Målet er å få 15 stykker på veien og flere til å droppe sin egen bil.

Wasim Riaz og Olav Olsen (foto)

Mange kommer nok til å legge merke til de røde bilene med sensorer på taket og 13 kameraer på karosseriet: Innen ett år skal det etter planen være 15 selvkjørende kjøretøyer i Groruddalen.

De aller første kjøretøyene har allerede vært i trafikk et par ganger, men står for det meste i en garasje på Grorud. Nå starter testperioden gradvis. Fra nyttår vil de kjøre regelmessig i trafikken i Groruddalen.

Hensikten med prosjekt er å

Fem NIO ES8 starter i disse dager med testkjøring i Groruddalen. Innen ett år skal det være 15 selvkjørende kjøretøyer i Groruddalen. Disse skal være supplement til ordinært kollektivtilbud.

Self Driving Cars

Feature	LiDAR	Radar	Camera
Obstacle Detection			
Velocity Measurement			
Distance Measurement			
3D Environmental Mapping			
Adverse Weather Operation			
High-Resolution Imaging			
Color Information			
Traffic Sign Recognition			
Night Vision			
Pedestrian Tracking			

Self Driving Cars

Feature	LiDAR	Radar	Camera
Obstacle Detection	x	x	x
Velocity Measurement			
Distance Measurement			
3D Environmental Mapping			
Adverse Weather Operation			
High-Resolution Imaging			
Color Information			
Traffic Sign Recognition			
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Self Driving Cars

Feature	LiDAR	Radar	Camera
Obstacle Detection	x	x	x
Velocity Measurement		x	
Distance Measurement			
3D Environmental Mapping			
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Self Driving Cars

Feature	LiDAR	Radar	Camera
Obstacle Detection	x	x	x
Velocity Measurement		x	
Distance Measurement	x	x	
3D Environmental Mapping			
Adverse Weather Operation			
High-Resolution Imaging			
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Self Driving Cars

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Velocity Measurement		x	
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Self Driving Cars

Feature	LiDAR	Radar	Camera
Obstacle Detection	x	x	x
Velocity Measurement		x	
Distance Measurement	x	x	
3D Environmental Mapping	x		
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Self Driving Cars

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Obstacle Detection	x	x	x
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3D Environmental Mapping	x		
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High-Resolution Imaging			x
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Self Driving Cars

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Obstacle Detection	x	x	x
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3D Environmental Mapping	x		
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Self Driving Cars

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Self Driving Cars

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Adverse Weather Operation		x	
High-Resolution Imaging			x
Color Information			x
Traffic Sign Recognition			x
Night Vision	x	x	x
Pedestrian Tracking	x	x	x

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Thank You

Questions?