

# Business Analytics and Emerging Trends

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Instructor: Dr. Murat Tunc



# Internet of Things

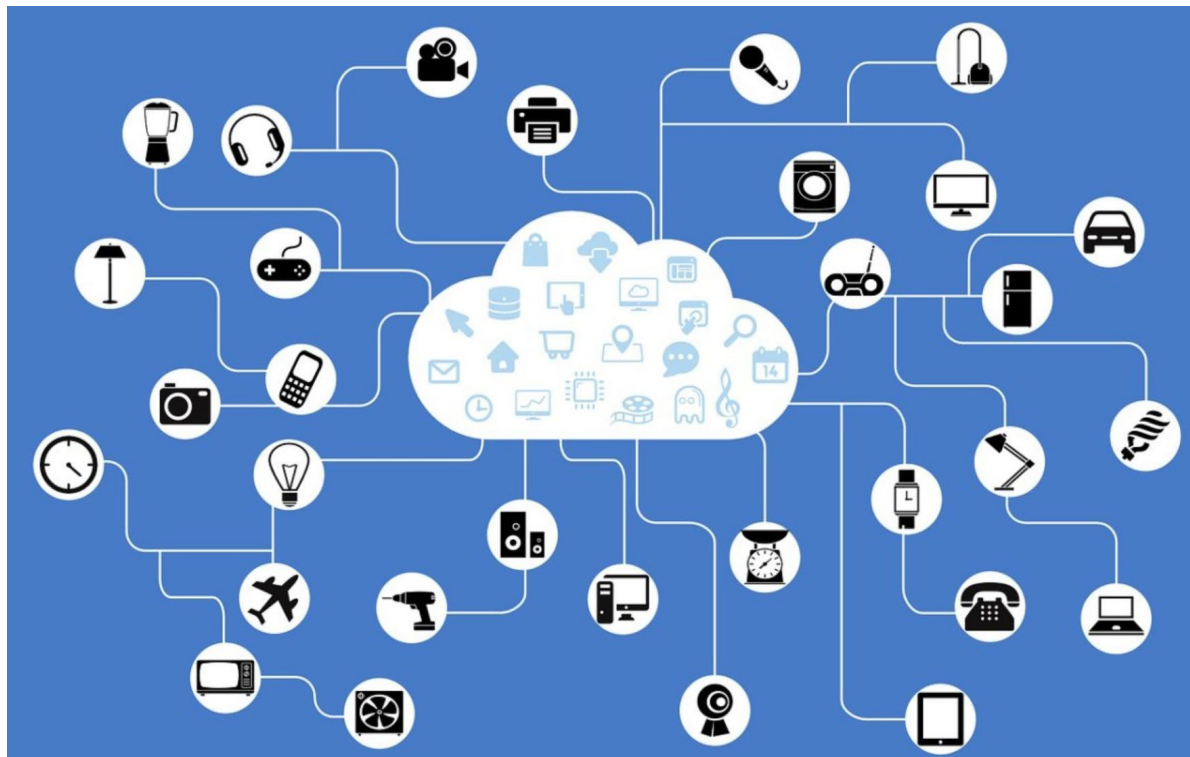
Instructor: Dr. Murat Tunc

Module 5

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# What is Internet of Things?

- A system involving **connected devices** that **gather data**, **connect** with the Internet, **generate analytics**, and **adapt behavior** based on the analytics



# Internet of Things - Layers

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**Sensors**

Collecting data



**Connectivity**

Sending data to cloud



**Data Processing**

Making data useful



**User Interface**

Delivering information to user



# Internet of Things Architecture

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Data gathering

Connectivity

Data processing






User Interface



# How do devices gather data?

- Sensors / Actuators

- **Detect** the feature **quantity** of a measurement object and **convert** this quantity into a **readable signal**

Five senses	Sight	Hearing	Smell	Taste	Touch
As behavior	-See the thing -Feel the light	-Listen the sound -Feel the shaking -Take the balance	-Smell the thing	-Feel the taste	-By touching, feel the heat, force, or texture
Sensory organ as human	Eye 	Ear 	Nose 	Tongue 	Skin 
Typical sensors as machinery	-Image sensor -Light intensity sensor	-Acoustic sensor -Ultrasonic sensor	-Gas component sensor	-Liquid component sensor	-Tactile sensor -Pressure sensor -Temperature sensor -Humidity sensor -Displacement sensor



# Sensors on smart phones

- **Accelerometer**
- **Gyroscope**
  - Measures orientation
- **Magnetometer**
  - Detects magnetic fields
- **GPS**
  - communicate with the satellites
  - determine our location on Earth
- **Light sensor**
  - Measures the light in the vicinity
  - Adjusts the display's brightness
- **Barometer**
  - measures atmospheric pressure
  - how high we are above the sea level
- **Thermometer, Microphone, Pedometer...**



*Accelerometer*



*Gyroscope*



*Compass*



*GPS*



*Light sensor*



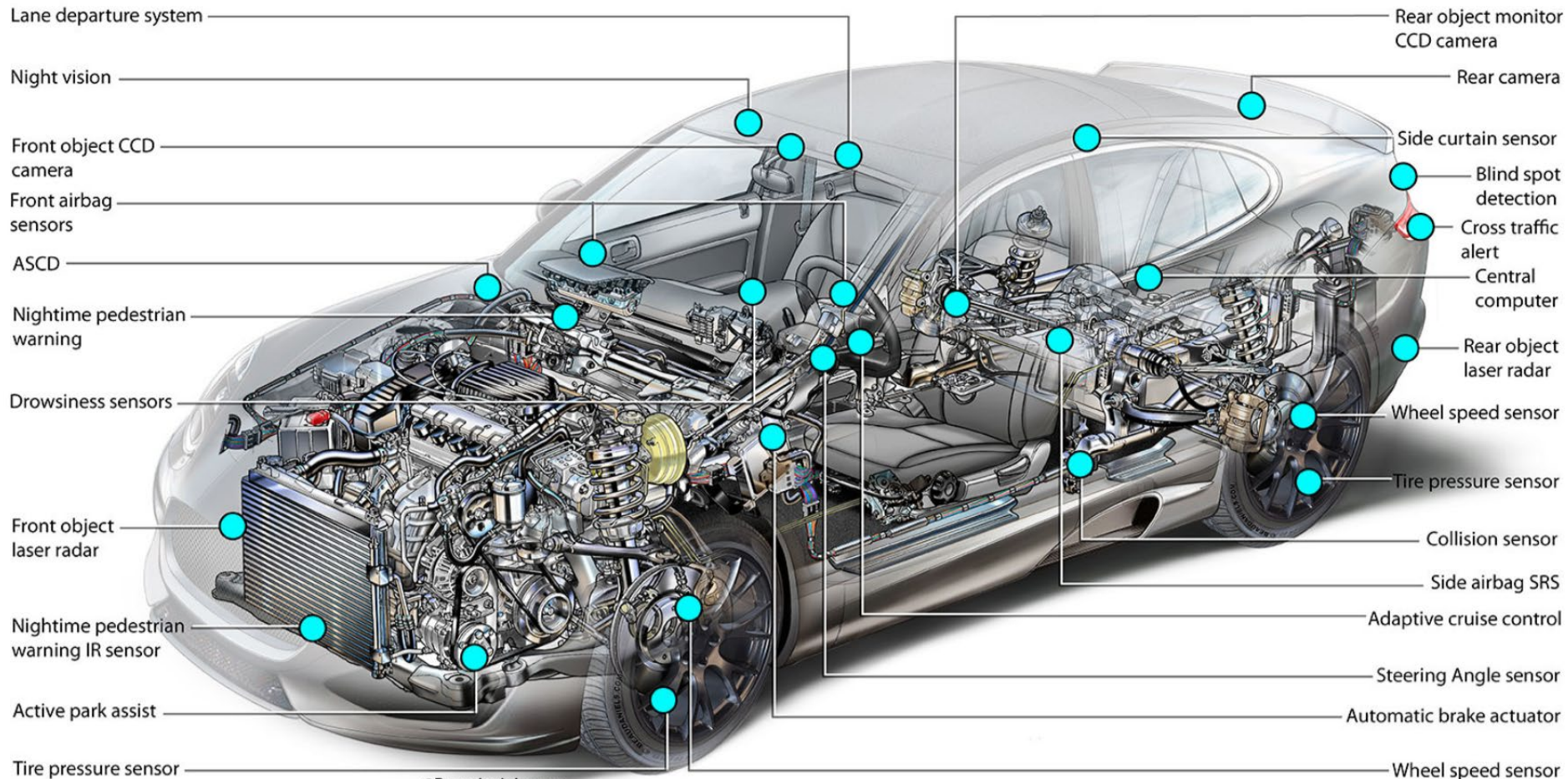
*Barometer*





# Vehicle Sensors

## Vehicle Sensors



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# Internet of Things Architecture

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Data gathering

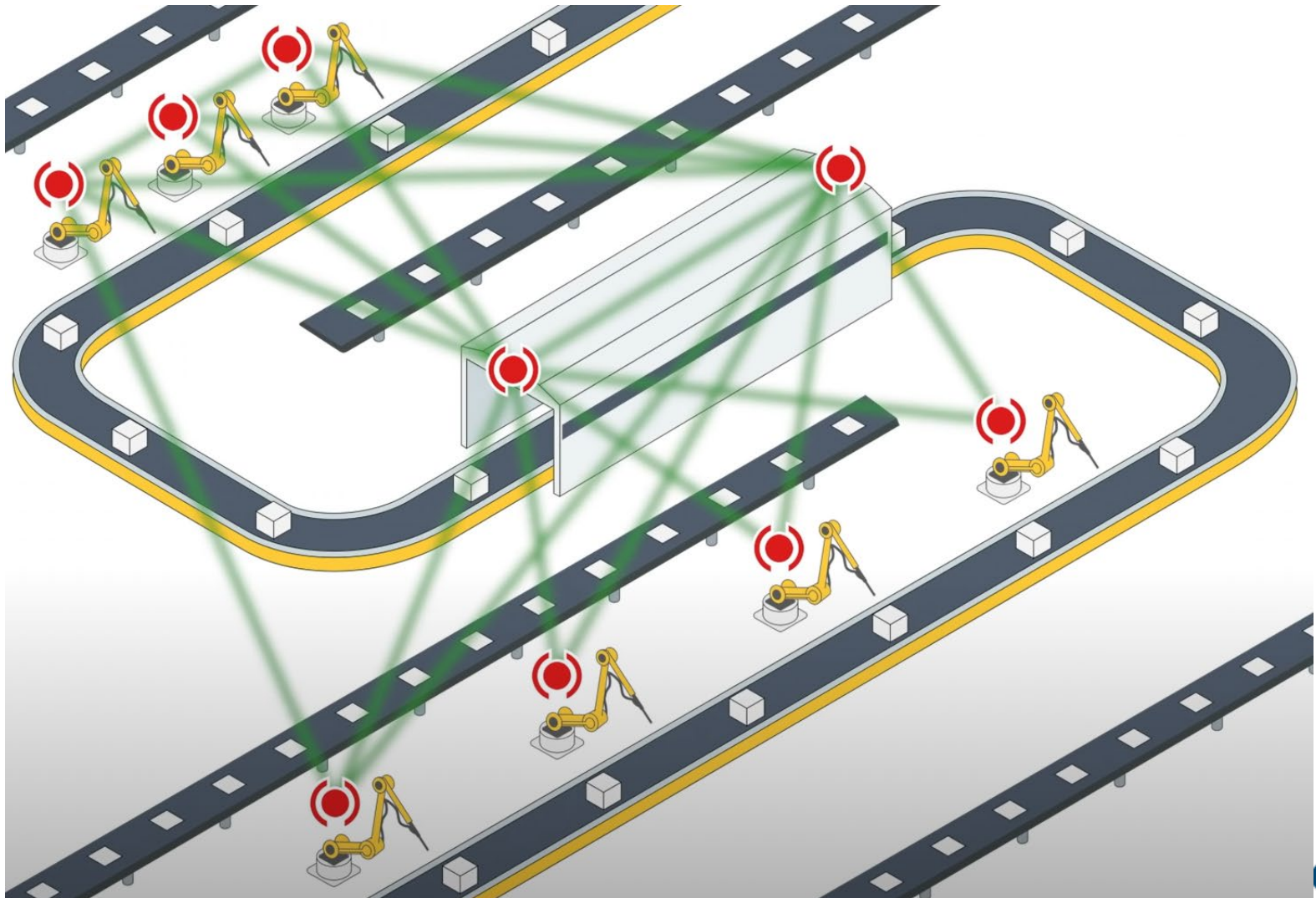
Connectivity

Data processing

User Interface



# Wireless Sensor Networks



# Communication Protocols

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- Options for connectivity are **various**
  - Cellular, satellite, WiFi, Bluetooth, RFID, NFC, LPWAN, Zigbee
- Four **models** for connectivity
  - 1) Device to Device
  - 2) Device to Cloud
  - 3) Device to Gateway
  - 4) Backend Data Sharing



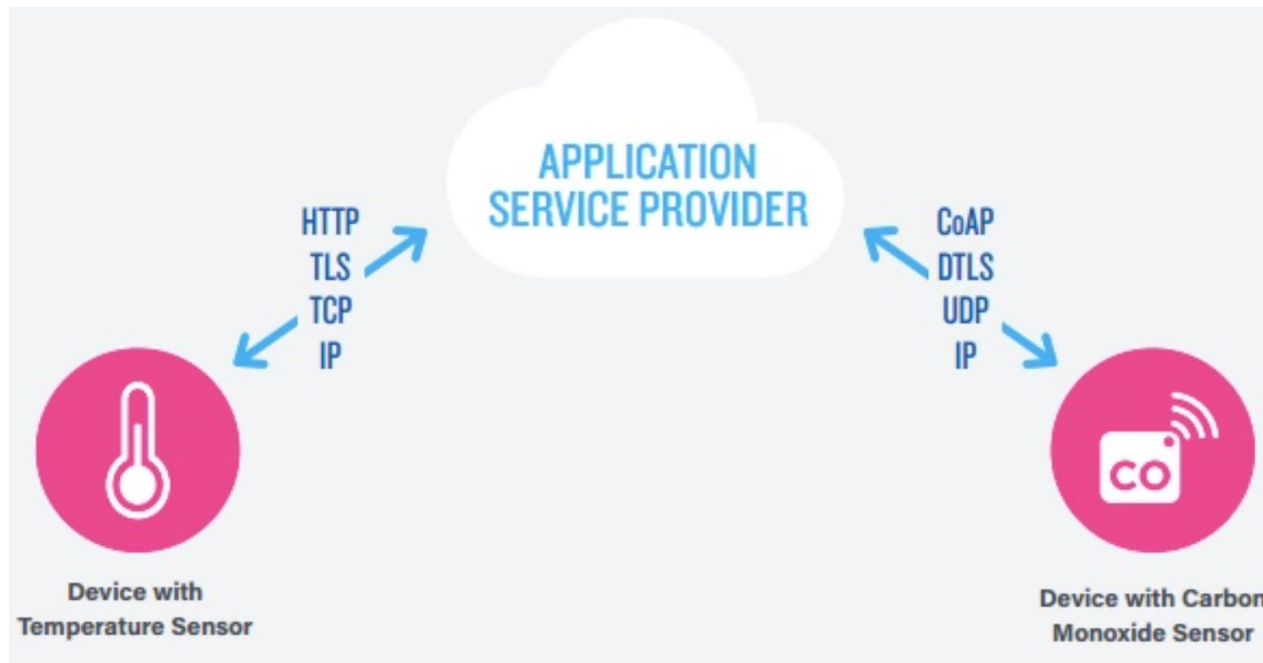
# Device to Device

- **Direct** communication with each other
  - Via IP network, hardwire or bluetooth
  - **Example:** Smart watch and pacemaker
- **Low power** consumption
  - Ideal for products to have a long battery life



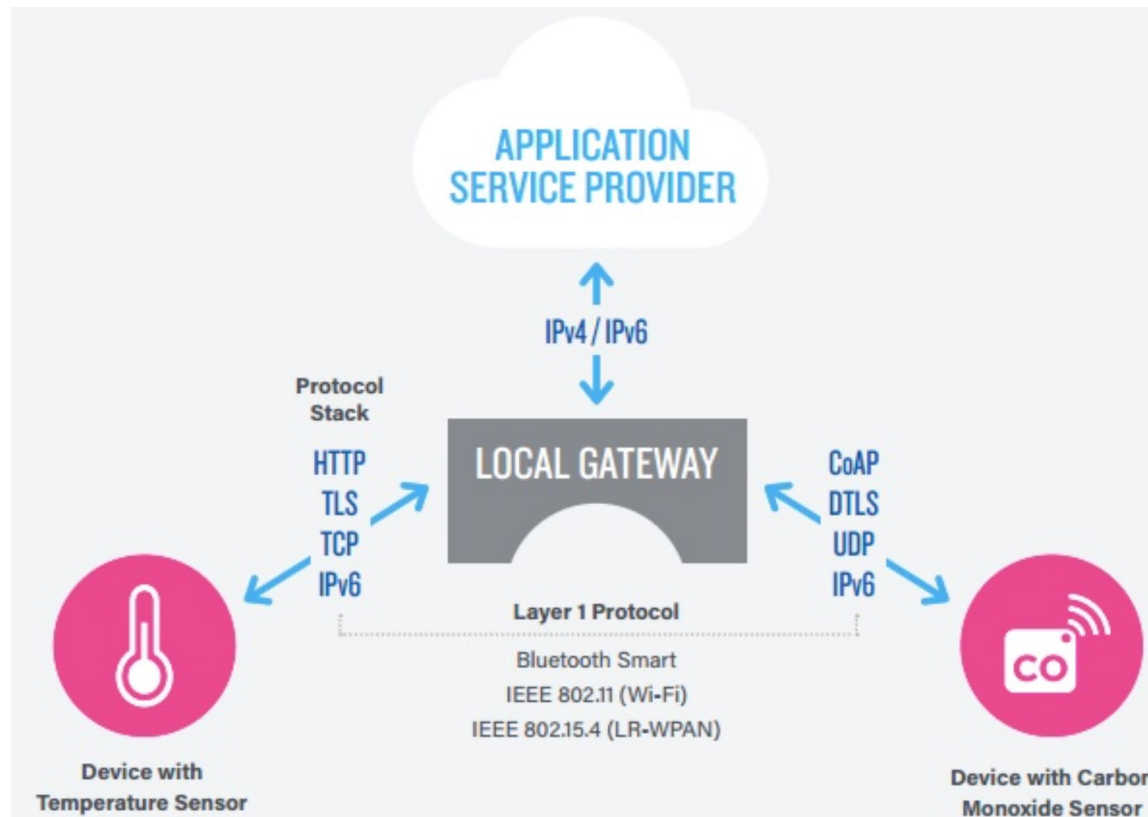
# Device to Cloud

- Via ethernet, WiFi or cellular
  - **Example:** Webcams to watch home while on vacation
  - Tag on an animal to find where it is
- Difficulty for inter product **compatibility**
  - Due to the differences in manufacturer design



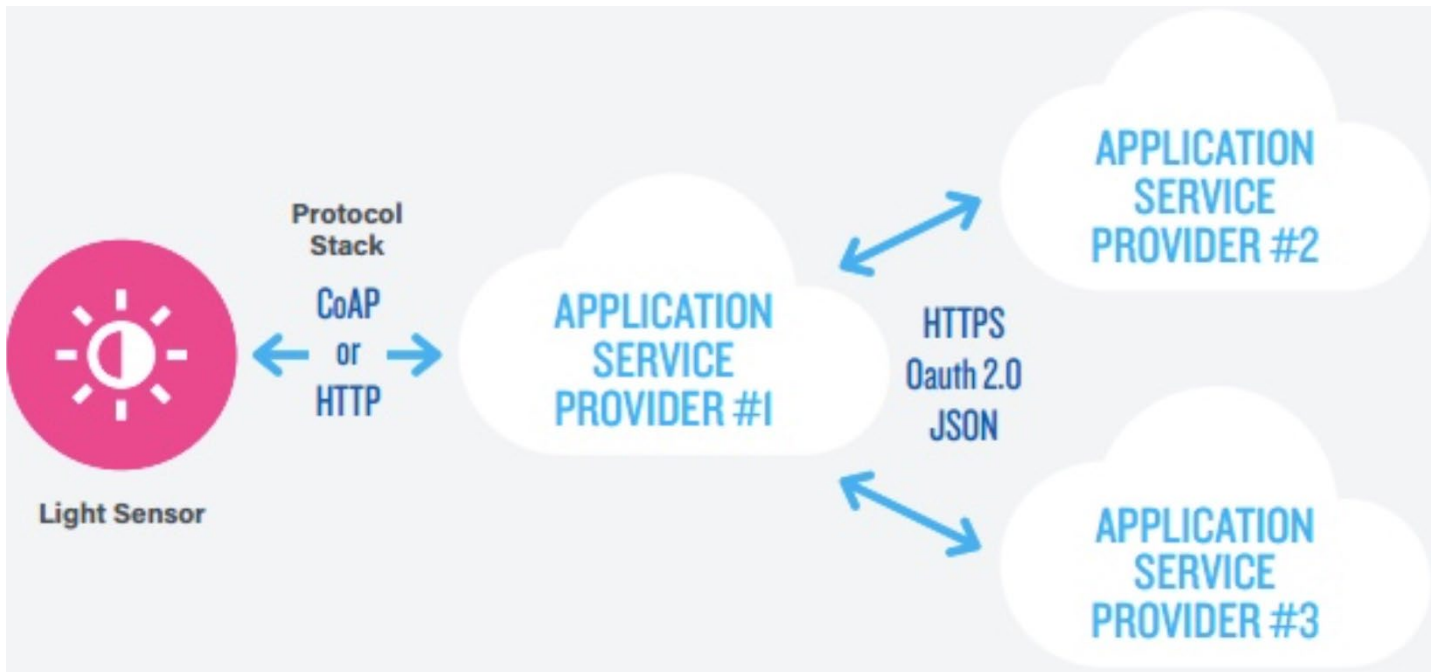
# Device to Gateway

- **Intermediary** between IoT device and a cloud service
  - Fitness device connects to the cloud **through** Nike+ app
  - Home appliance connects to a **hub** like Samsung SmartThings



# Backend Data Sharing

- **Extends** single device to cloud model
  - Sensor data can be accessed by authorized **third parties**
- Export, analyze smart object data from a cloud service
  - Combine with data from other sources
  - **Map My Fitness**: Data from Fitbit, Adidas miCoach, etc.

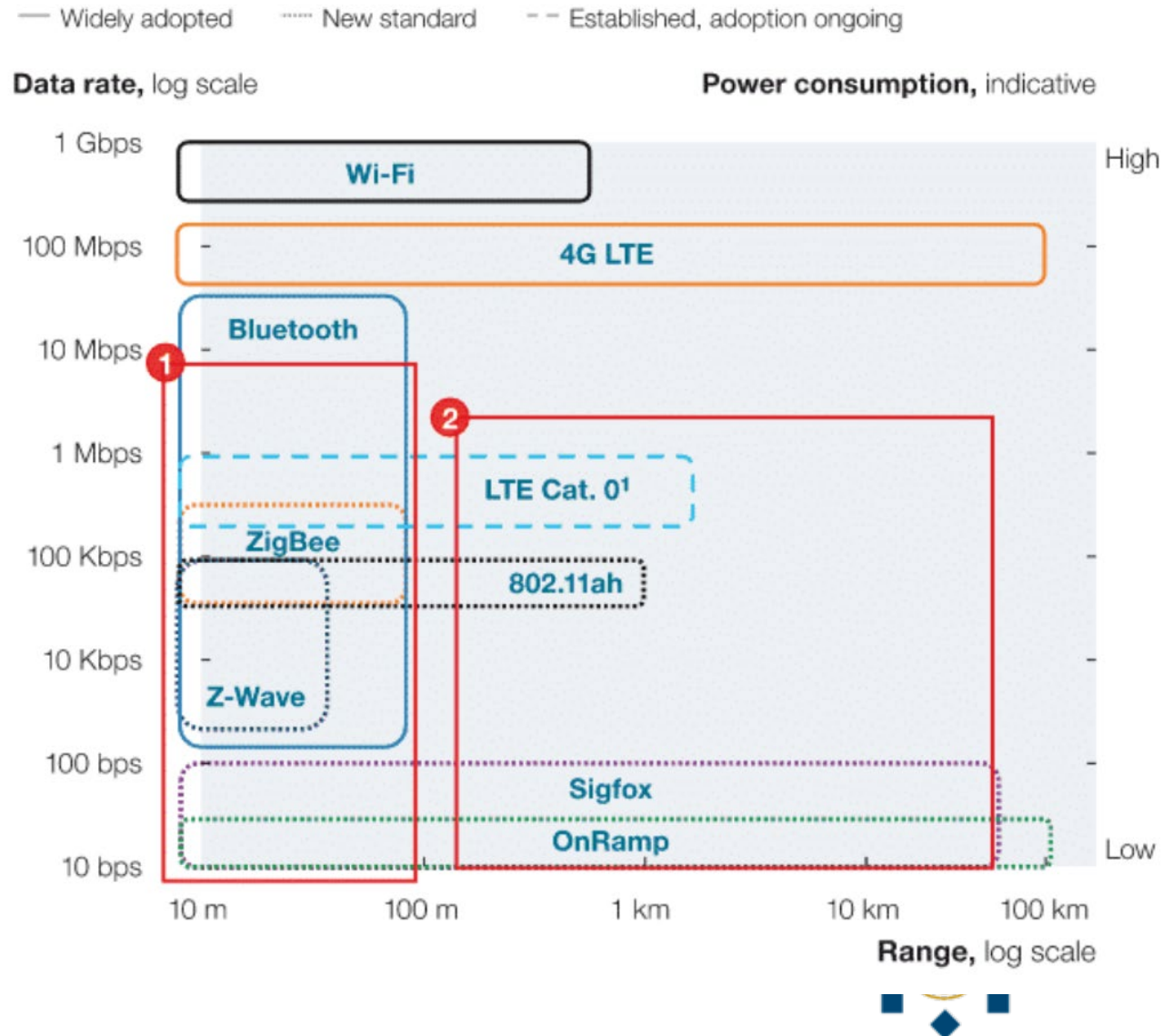




# Communication Protocols

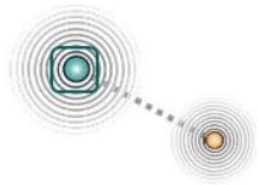
- **Tradeoff** between

- Power consumption
- Range
- Bandwidth

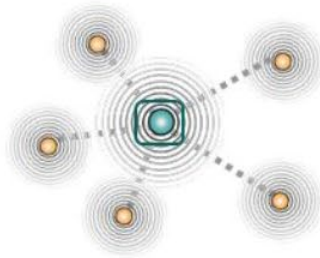


# IoT Network Topology

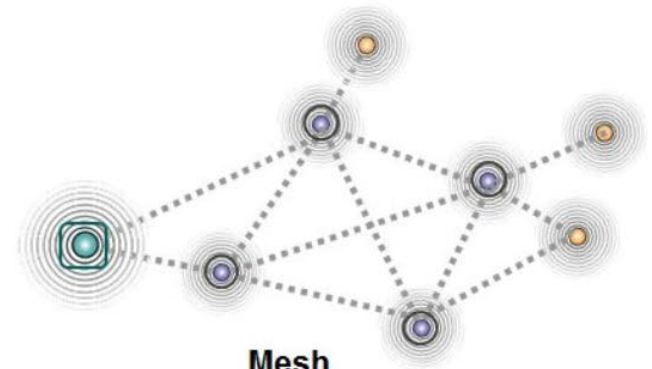
- IoT Network Topology
  - Point-to-Point
  - Star
  - Mesh
  - Hybrid



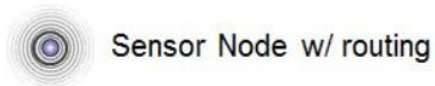
**Point-to-Point**



**Star**



**Mesh**



# Internet of Things Architecture

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Data gathering

Connectivity

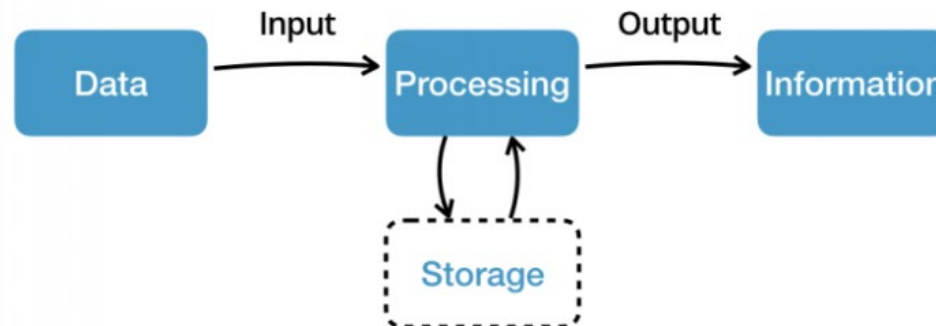
Data processing

User Interface

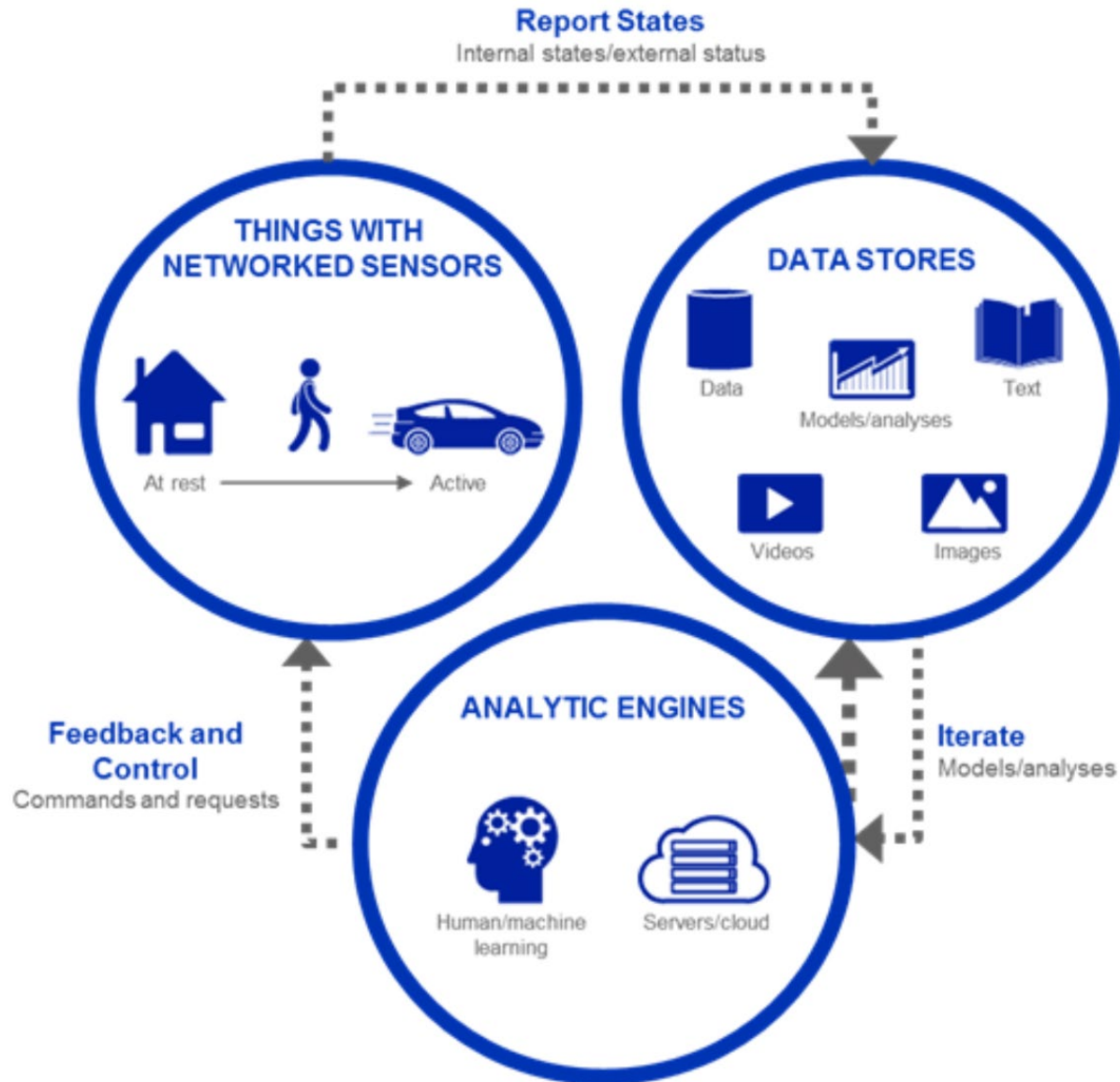


# Data Processing

- Once the sensor data gets to the cloud
  - Software performs **processing** on data
- Numerous algorithms and data processing elements
  - Ultimately become **information**
- Considerations
  - Storage
  - Frequency of updates
  - Desired output type



# Data Processing



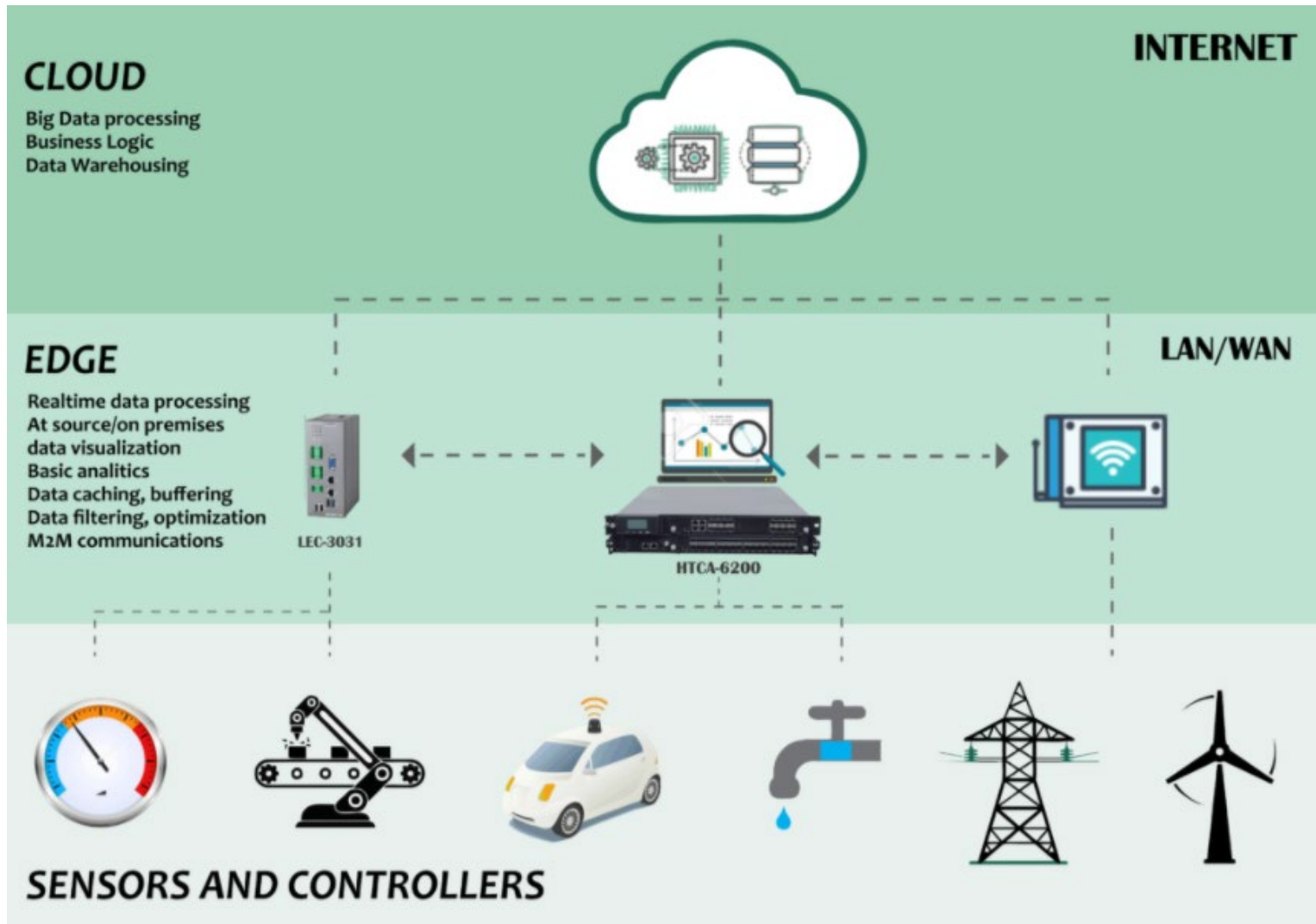
# Edge Computing

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- The round-trip time can take **too long**
  - Sending data, processing, analyzing, returning instructions
- Edge computing
  - A smart edge device
  - Aggregate data, analyze it and fashion responses if necessary
  - All within **relatively close physical distance**
  - Reducing delay
- Edge devices also have upstream connectivity for sending data to be further processed and stored



# Edge Computing





# Internet of Things Architecture

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Data gathering

Connectivity

Data processing

User Interface



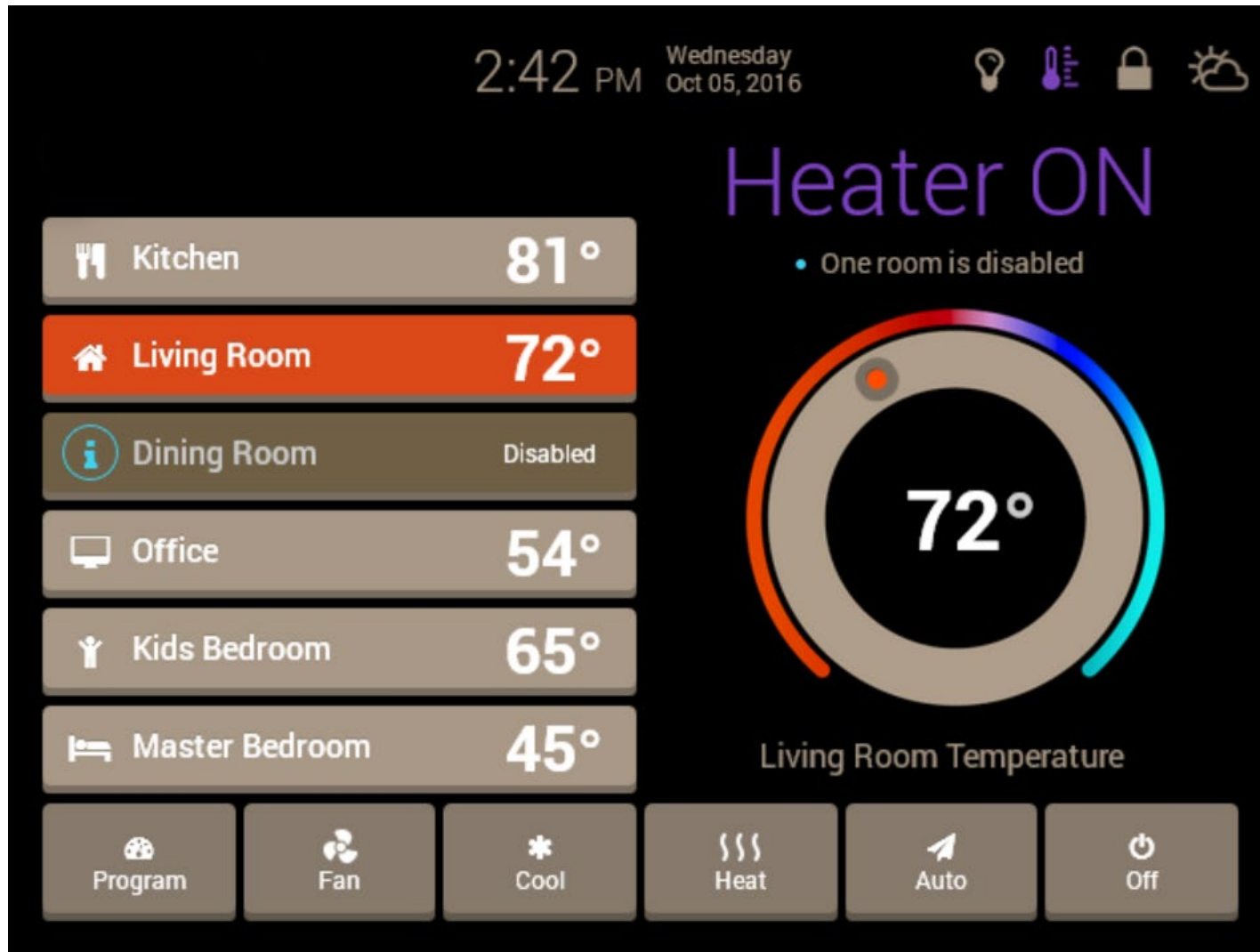
# User Interface

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- Information is made useful to the **end-user**
- Ways to interact
  - Alert (email, text)
  - Automatic **notifications**
  - Monitoring information proactively
  - Controlling system remotely
- Considerations
  - Connectivity
    - Real-time information or not, when the last update was received
  - Performance
    - Massive data to be presented, pagination (only a part of the data is loaded)
  - Simplicity
    - What the user needs to see, visualization



# User Interface



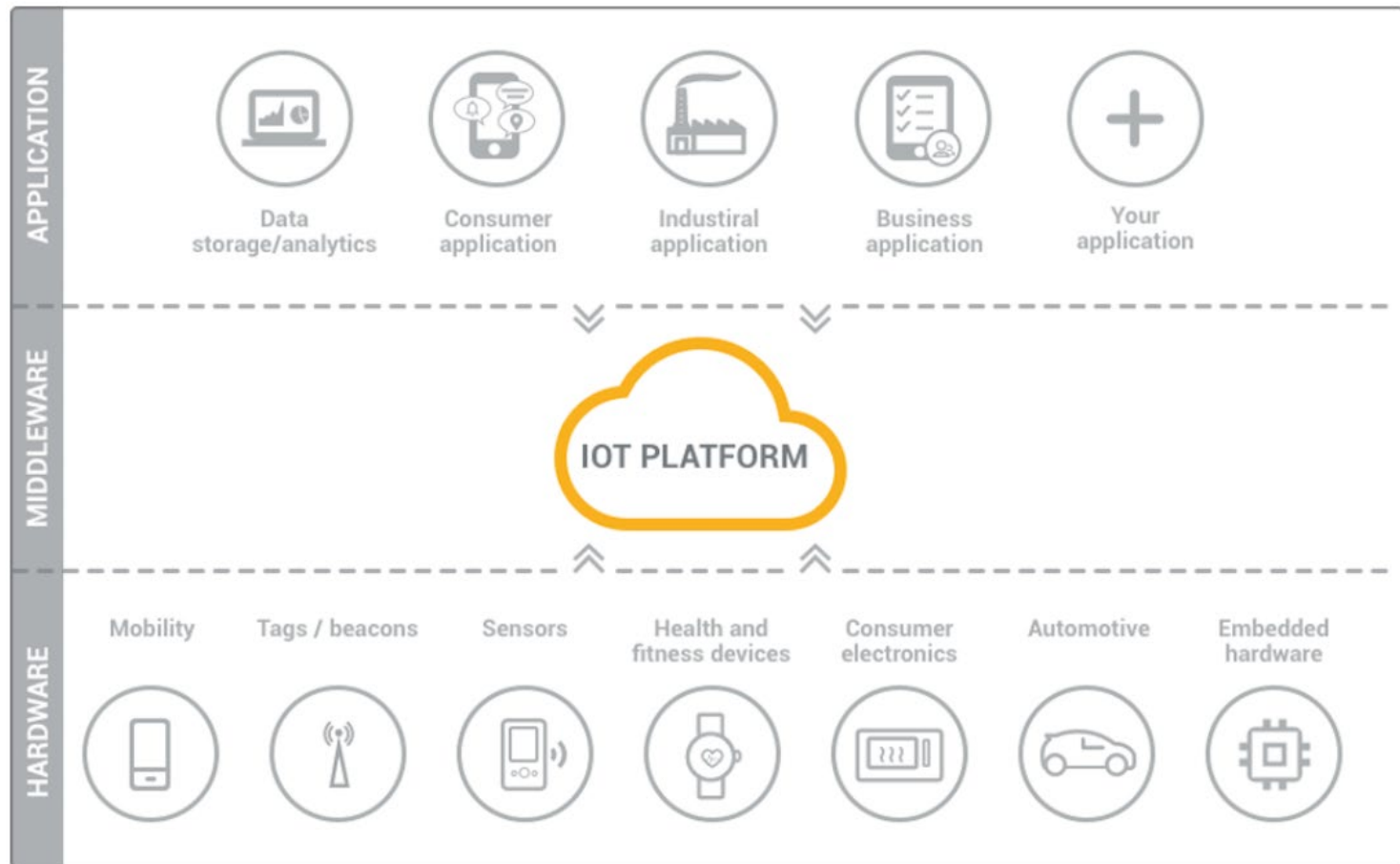
# IoT Platforms

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# What is an IoT Platform?

- **Middlemen** that connects the hardware to the cloud



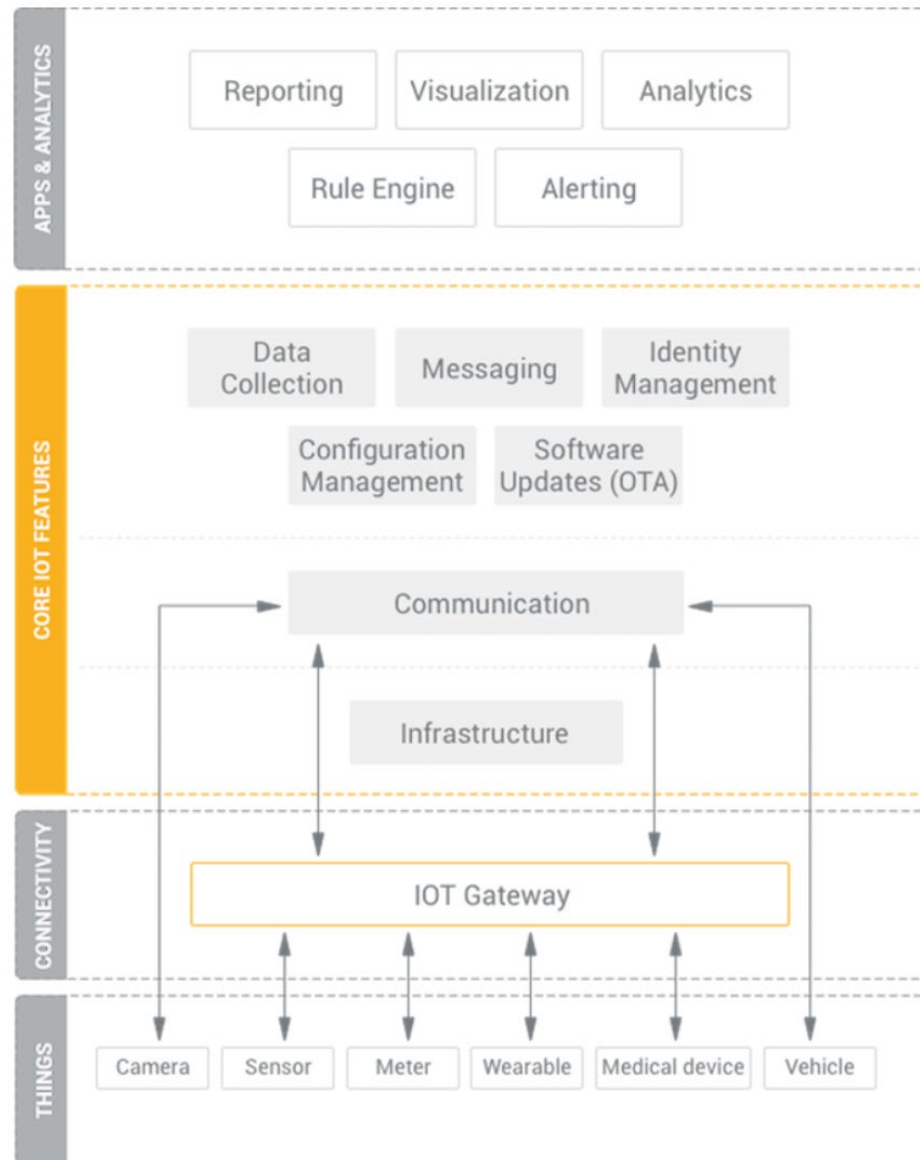
# Elements of IoT Platform

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- An IoT platform can be decomposed into several **layers**
- **Infrastructure** level
  - Enables the functioning of the platform
  - Internal messaging, orchestration of IoT solution clusters
- **Communication** layer
  - Where devices connect to the cloud
- **Core layer** for IoT features
  - Data collection, device management, configuration management, messaging
- **Analytics** layer
  - Data processing, visualization, rule engine, reporting



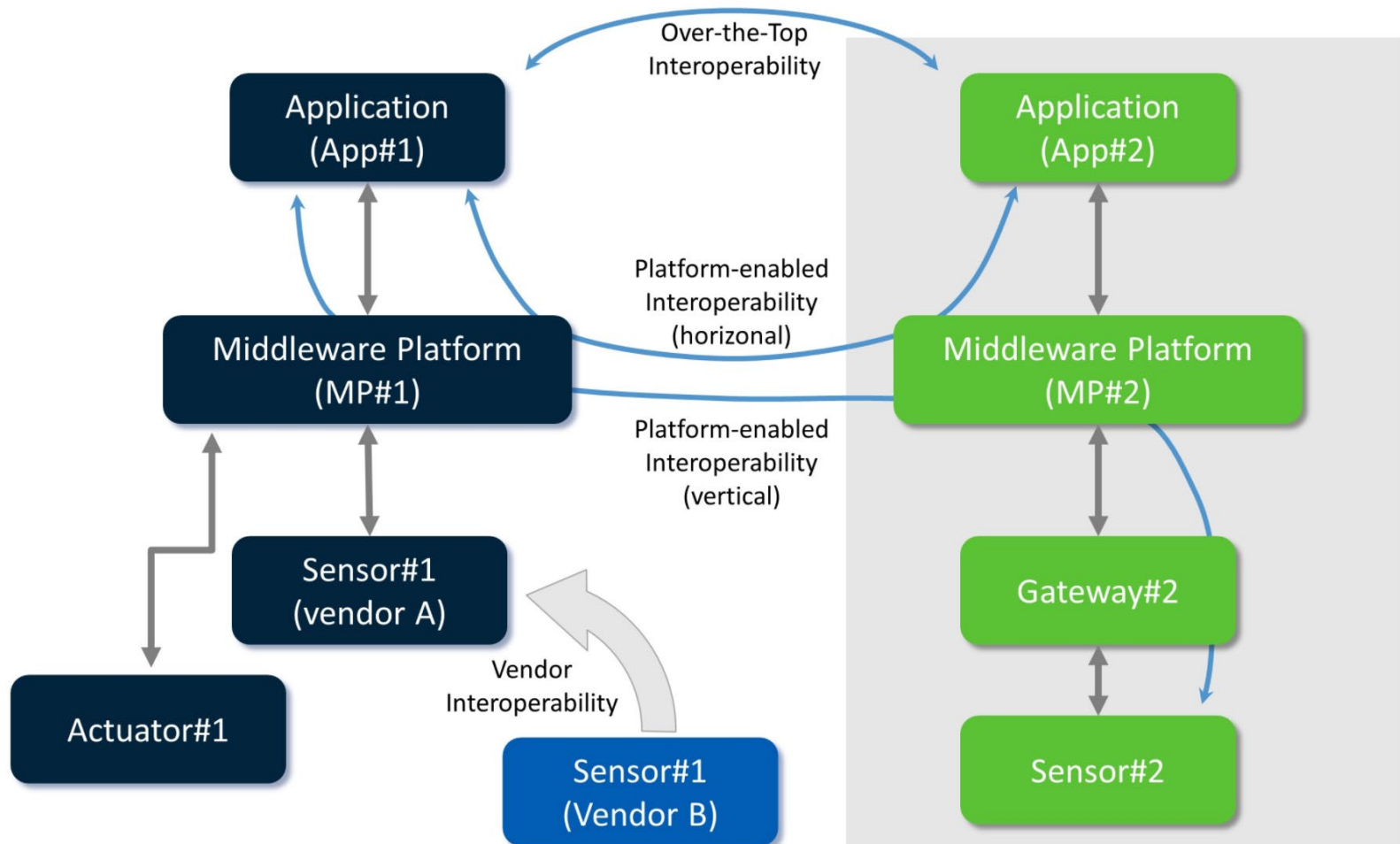
# Elements of IoT Platform





# Interoperability Issues in IoT Platforms

## IoT Interoperability Permutations



# Interoperability Issues in IoT Platforms

- App #1 can improve the performance by using **data from sensor #2**
  - 3 possibilities
- 1) App #1 might be able to **access App #2**
  - **a)** Over-the-top interoperability (horizontal)
    - Via an external data exchange
  - **b)** Platform enabled interoperability (horizontal)
    - Through the middleware platform
- 2) App #1 might be able to **access Sensor #2**
  - Platform enable interoperability (vertical)
    - Through the middleware platform



# Interoperability Issues in IoT Platforms

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- Interoperability
  - Apps able to discover **other resources**
    - Other apps, other middleware platforms, other sensors, etc.
  - Apps able to discover **other services**
    - Published data stream, usage tracking, etc.
- Horizontal vs vertical
  - **Positioning** based definition
    - Similar positioning in terms of structure (horizontal)
    - Lower (or higher) positioned devices (vertical)
  - **Quality** based definition
    - Similar quality, but better fit in terms of taste (horizontal)
    - Increased quality (vertical)



# Interoperability Issues in IoT Platforms

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- App #1 can improve the performance by finding **a better sensor #1** from another vendor
- Better sensor #1
  - Better **performance**
  - Low **cost**
  - Greater **reliability**
- Technology and **vendor** interoperability
  - In the vertical sense (replace with a **higher quality sensor**)



# Now and beyond

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# Applications

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- **Household** appliances
  - Smart washing machine, dryer
- **Automobiles**
  - Autonomous vehicles
- **Factories**
  - Efficient production lines
- **Healthcare**
  - Heart-rate tracking, fitness, smartwatches
- **Cities**
  - Traffic control



# IoT Disrupting Traditional Business

## THE INTERNET OF THINGS REQUIRES A MINDSET SHIFT

Because you'll create and capture value differently.

		TRADITIONAL PRODUCT MINDSET	INTERNET OF THINGS MINDSET
<b>VALUE CREATION</b>	Customer needs	Solve for existing needs and lifestyle in a reactive manner	Address real-time and emergent needs in a predictive manner
	Offering	Stand alone product that becomes obsolete over time	Product refreshes through over-the-air updates and has synergy value
	Role of data	Single point data is used for future product requirements	Information convergence creates the experience for current products and enables services
<b>VALUE CAPTURE</b>	Path to profit	Sell the next product or device	Enable recurring revenue
	Control points	Potentially includes commodity advantages, IP ownership, & brand	Adds personalization and context; network effects between products
	Capability development	Leverage core competencies, existing resources & processes	Understand how other ecosystem partners make money

SOURCE SMART DESIGN





# Current Issues

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- Standards and Regulations
- **Privacy**
- Security
- Interoperability



# Future of IoT – 5G

## Future of IoT connectivity

High speed and  
bandwidth



Low latency and  
higher throughput



Data slicing and dicing



Network for  
virtualization



Delivery time reduction



Predictive analytics



# Readings

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- Haller, S., Karnouskos, S., & Schroth, C. (2008). The internet of things in an enterprise context. In FutureInternet Symposium (pp. 14-28). Springer, Berlin, Heidelberg.
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