# Internet of Things

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Module 5

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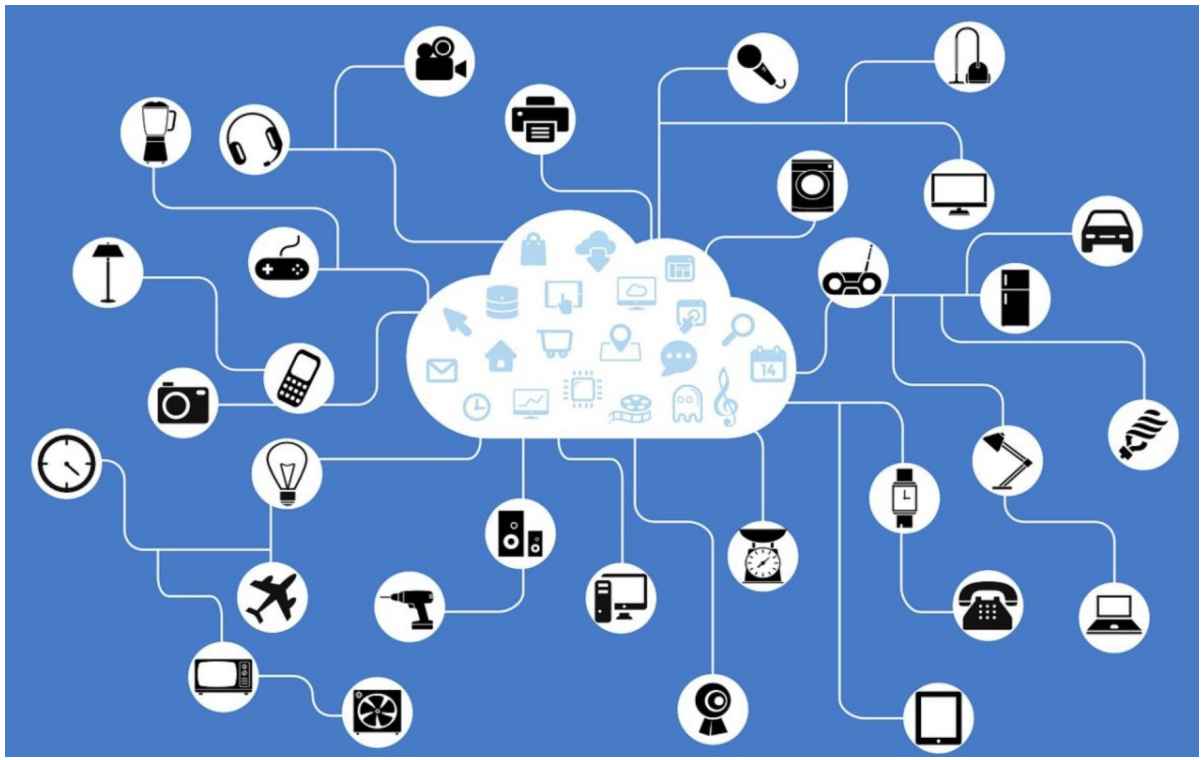
# What is Internet of Things?

- 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

# Internet of Things Architecture

Data gathering

Connectivity

Data processing

User Interface

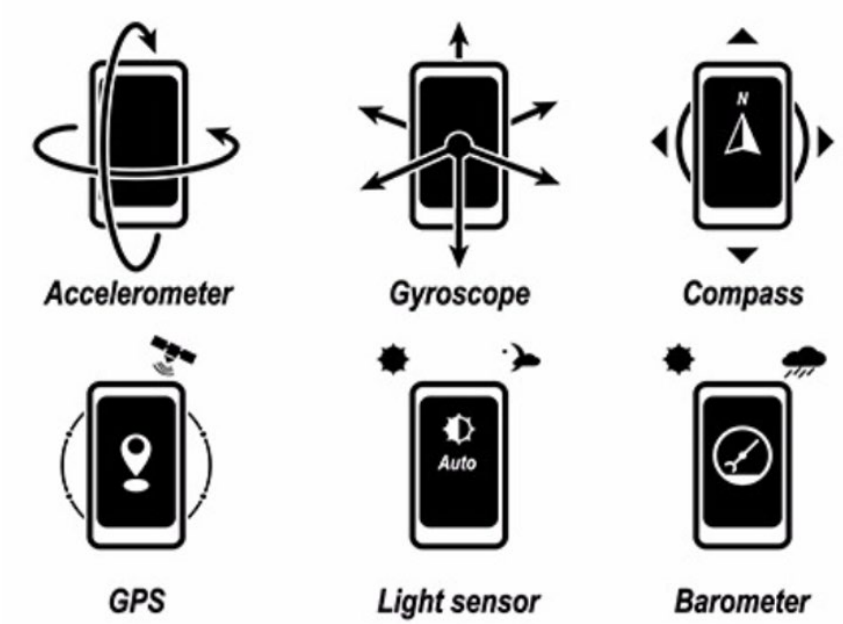
# How do devices gather data?

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

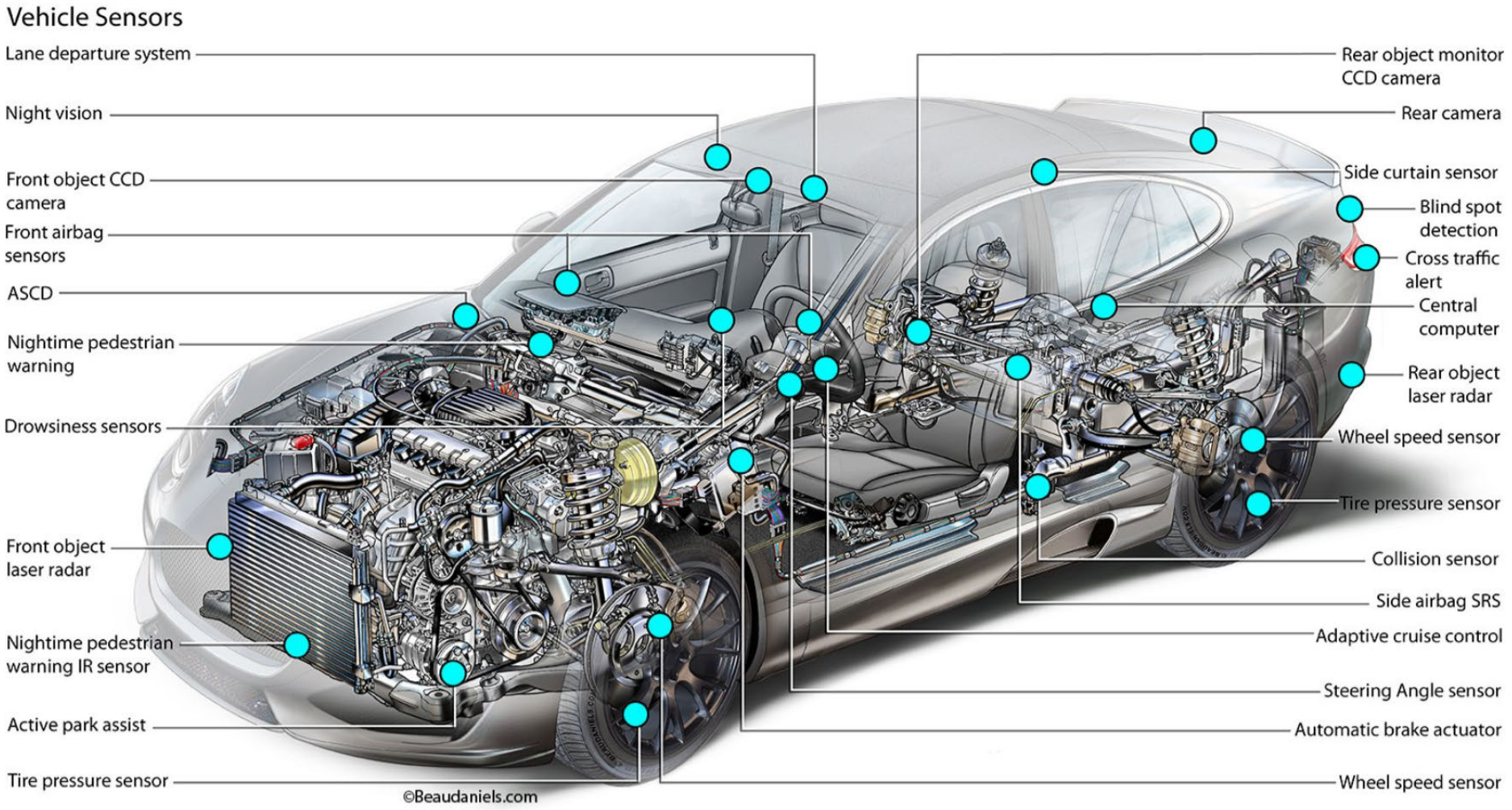
| Five senses | Sight | Hearing | Smell | Taste | Touch |
|---|---|---|---|---|---|
| As behavior | -See the thing<br>-Feel the light | -Listen the sound<br>-Feel the shaking<br>-Take the balance | -Smell the thing | -Feel the taste | -By touching, feel the heat, force, or texture |
| Sensory organ as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



# Vehicle Sensors



# Internet of Things Architecture

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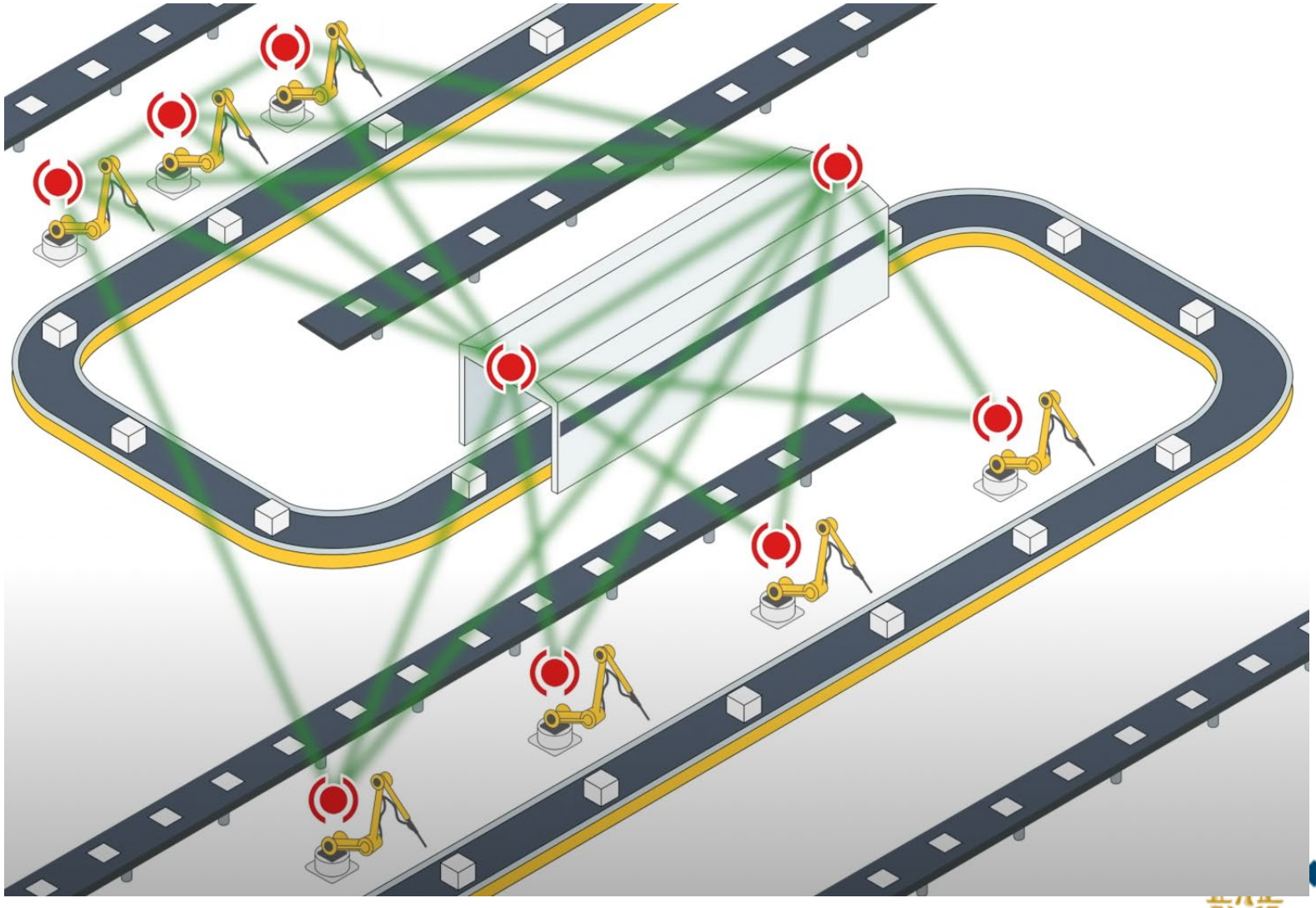
# Wireless Sensor Networks



# Communication Protocols

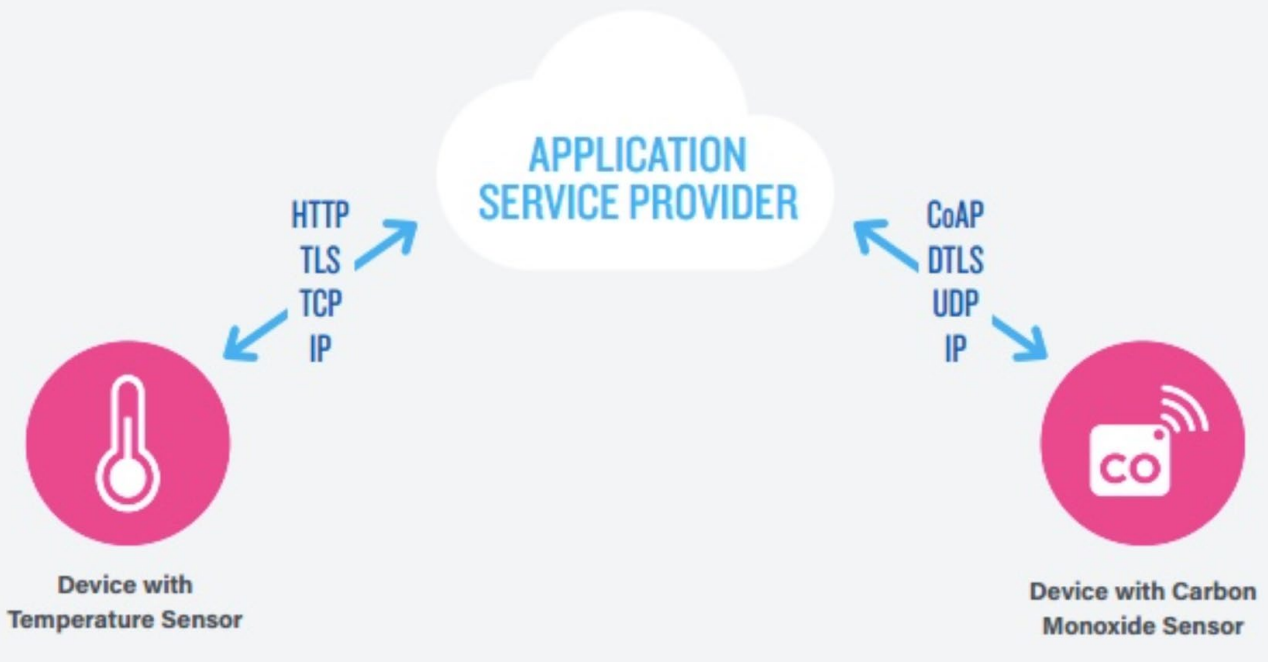
- Options for connectivity are **various**
  - Cellular, satellite, WiFi, Bluetooth, RFID, NFC, LPWAN, Zigbee
- Four **models** for connectivity
  - 1) Device to Device
  - 2) Device to Cloud
  - 3) Device to Gateway
  - 4) Backend Data Sharing

# 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

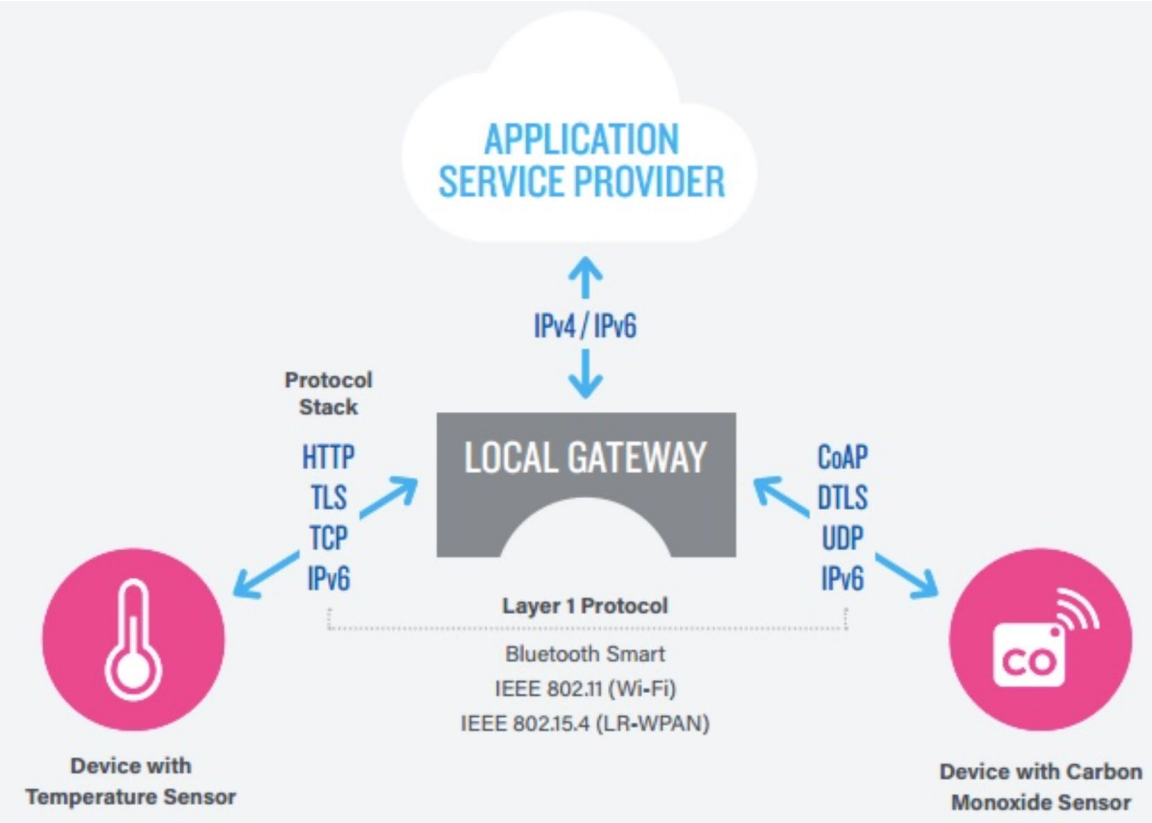
# Device to Cloud

- 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



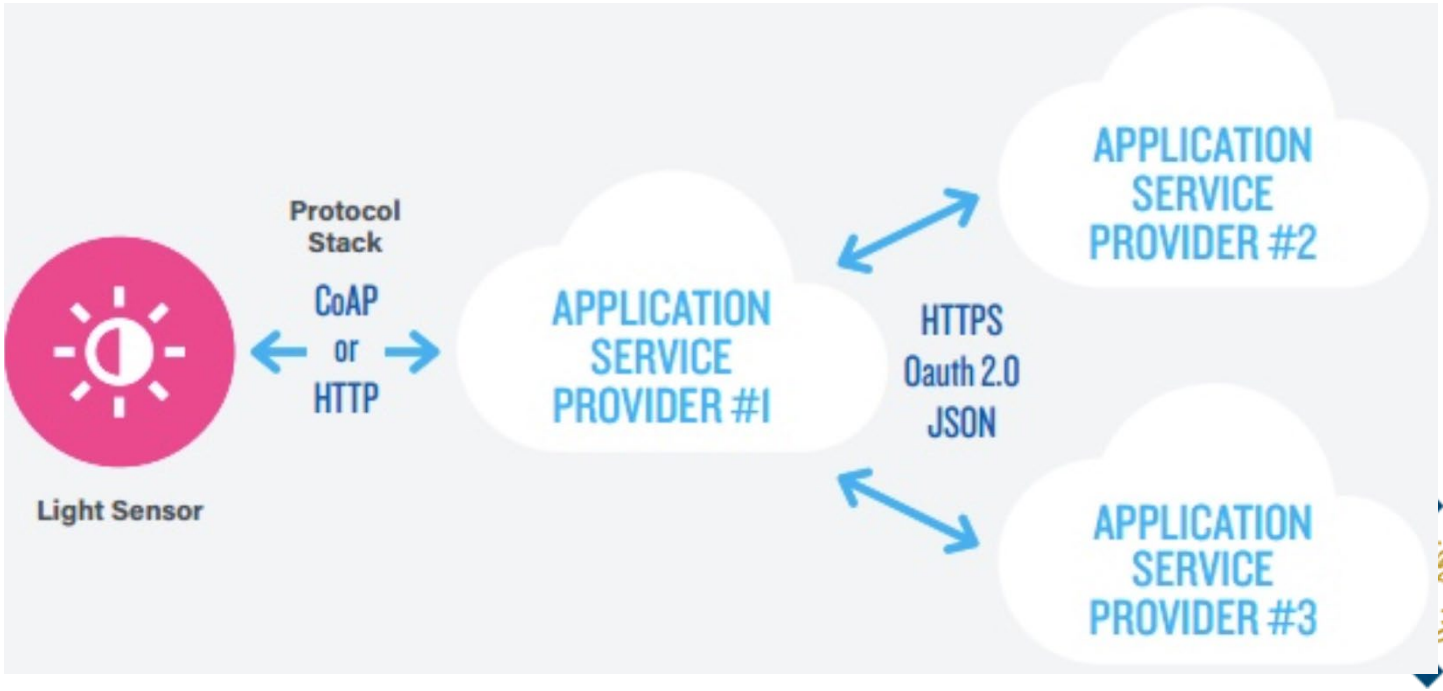
# Device to Gateway

- **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



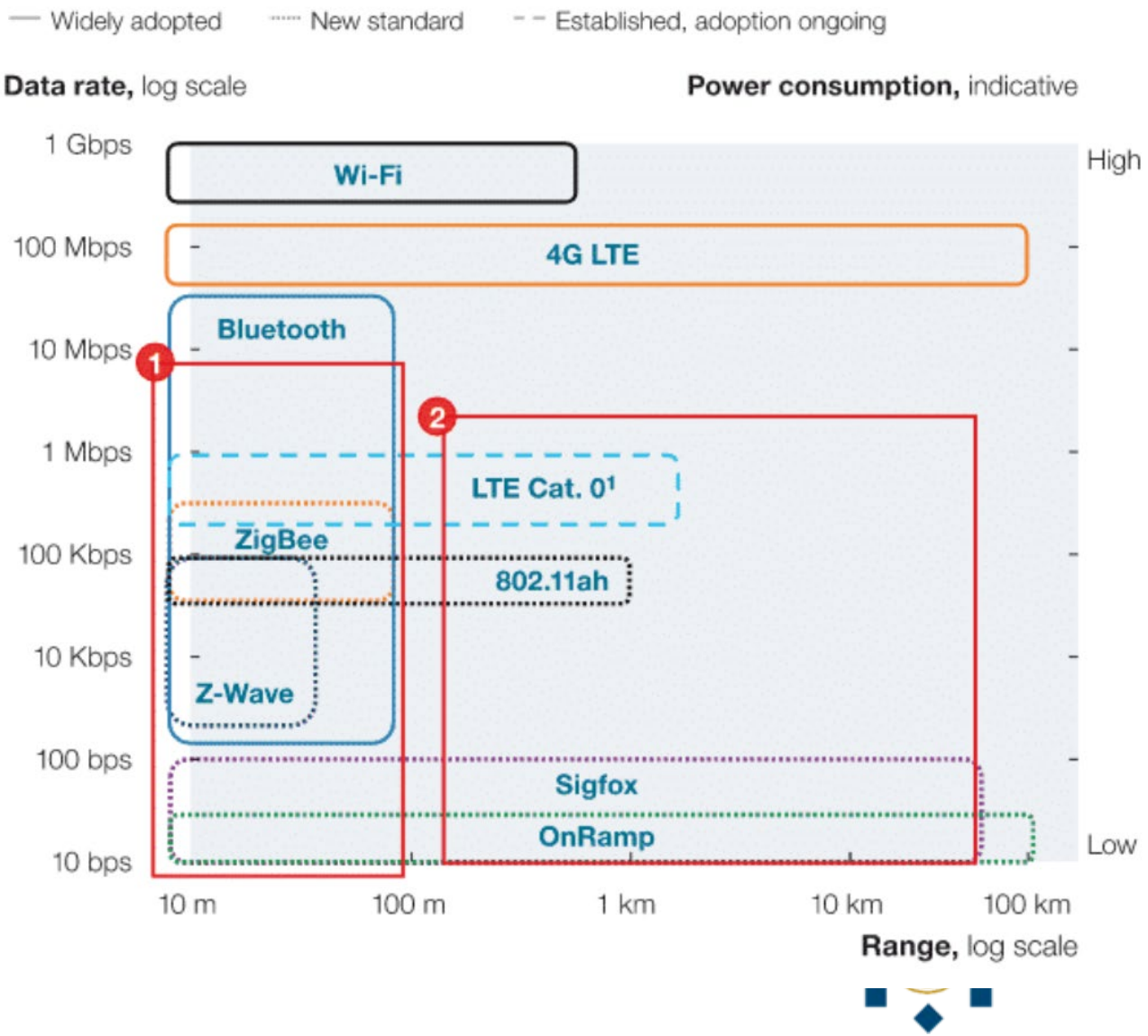
# Backend Data Sharing

- **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.



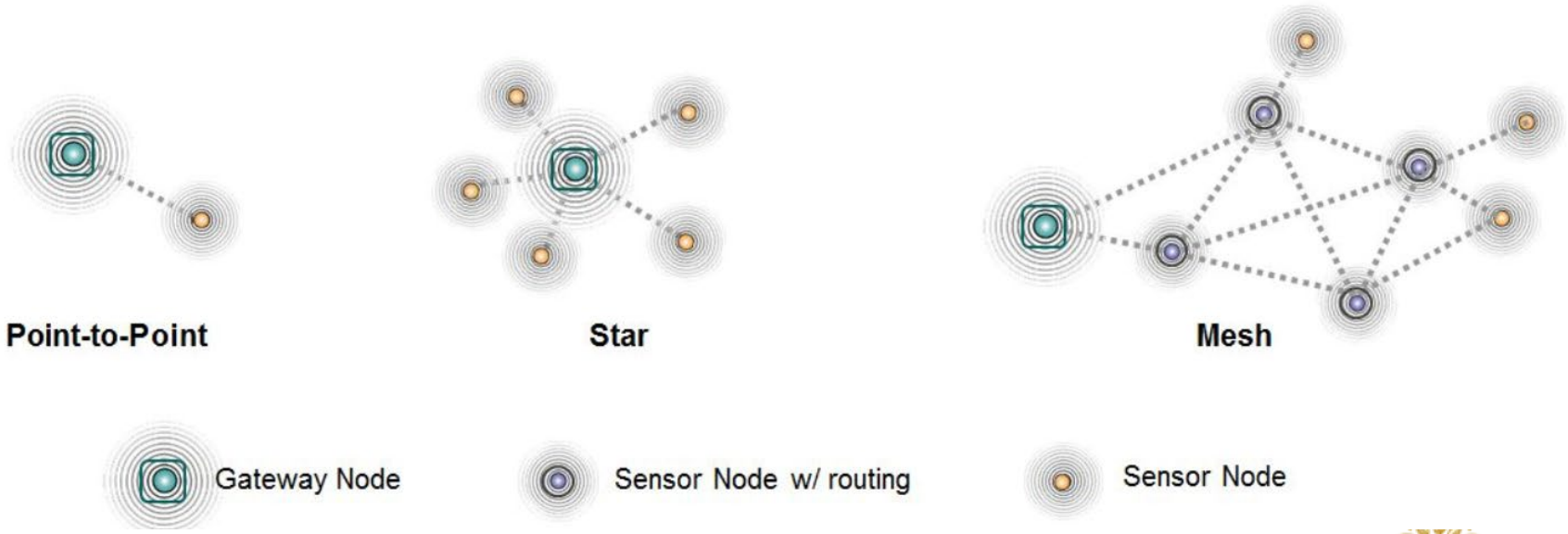
# Communication Protocols

- **Tradeoff** between
  - Power consumption
  - Range
  - Bandwidth



# IoT Network Topology

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



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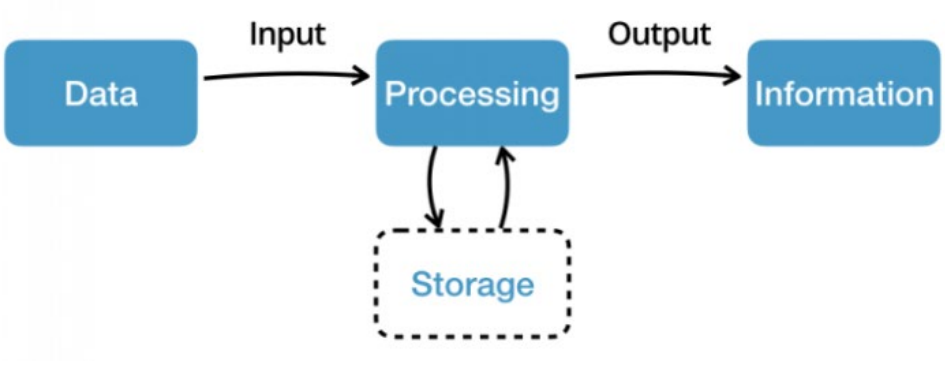
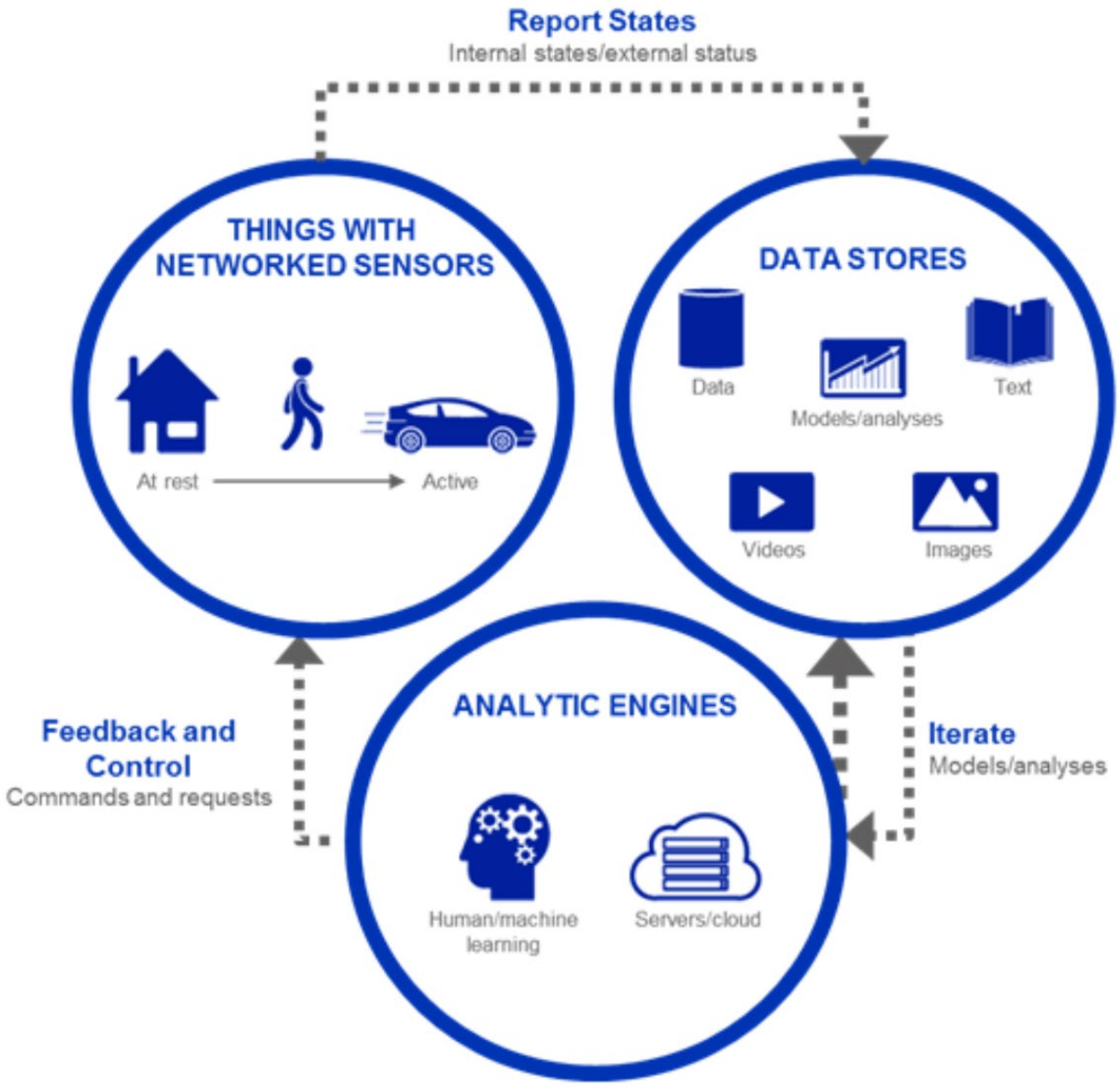
# Data Processing

- 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



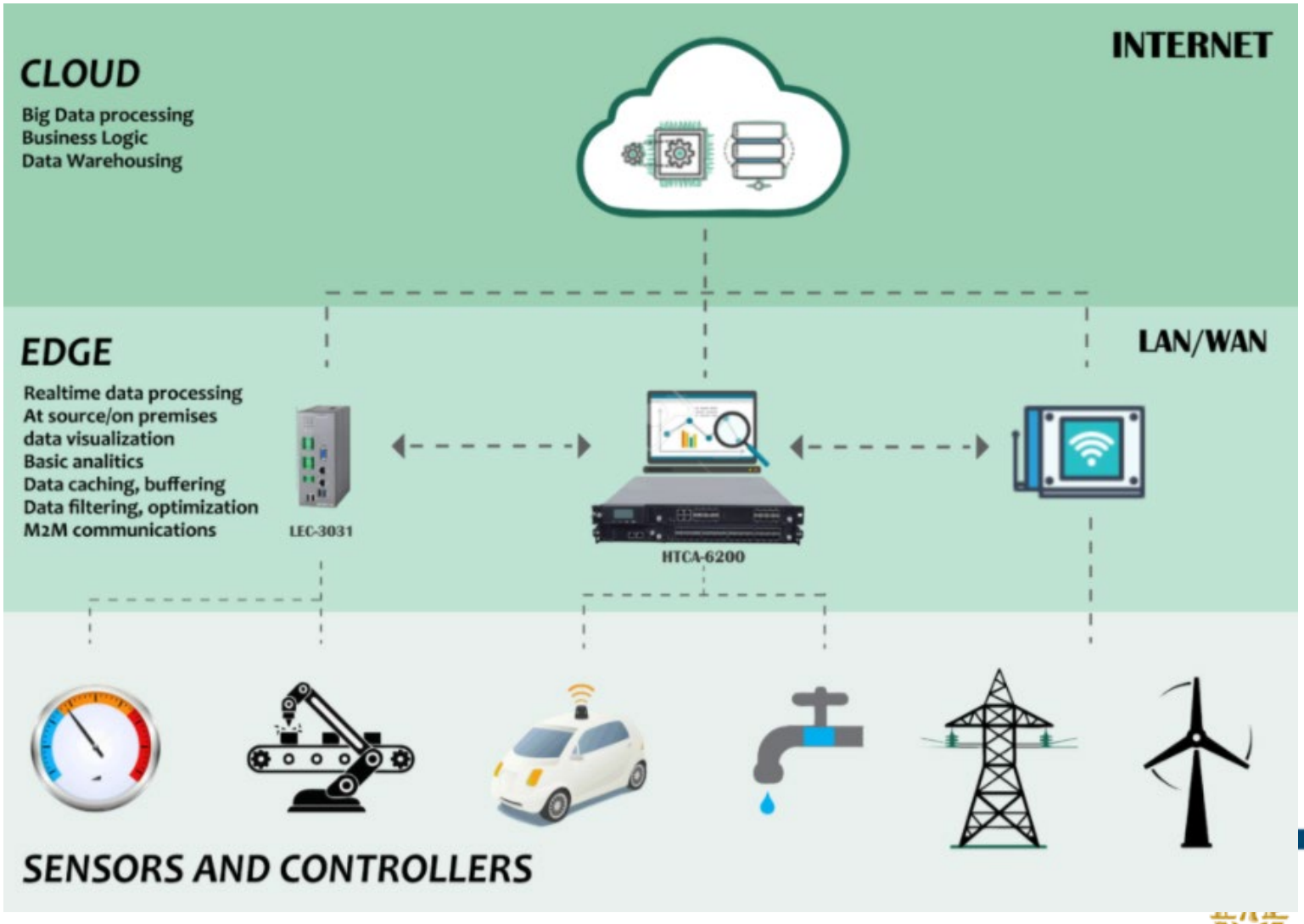
# Data Processing



# Edge Computing

- 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

Data gathering

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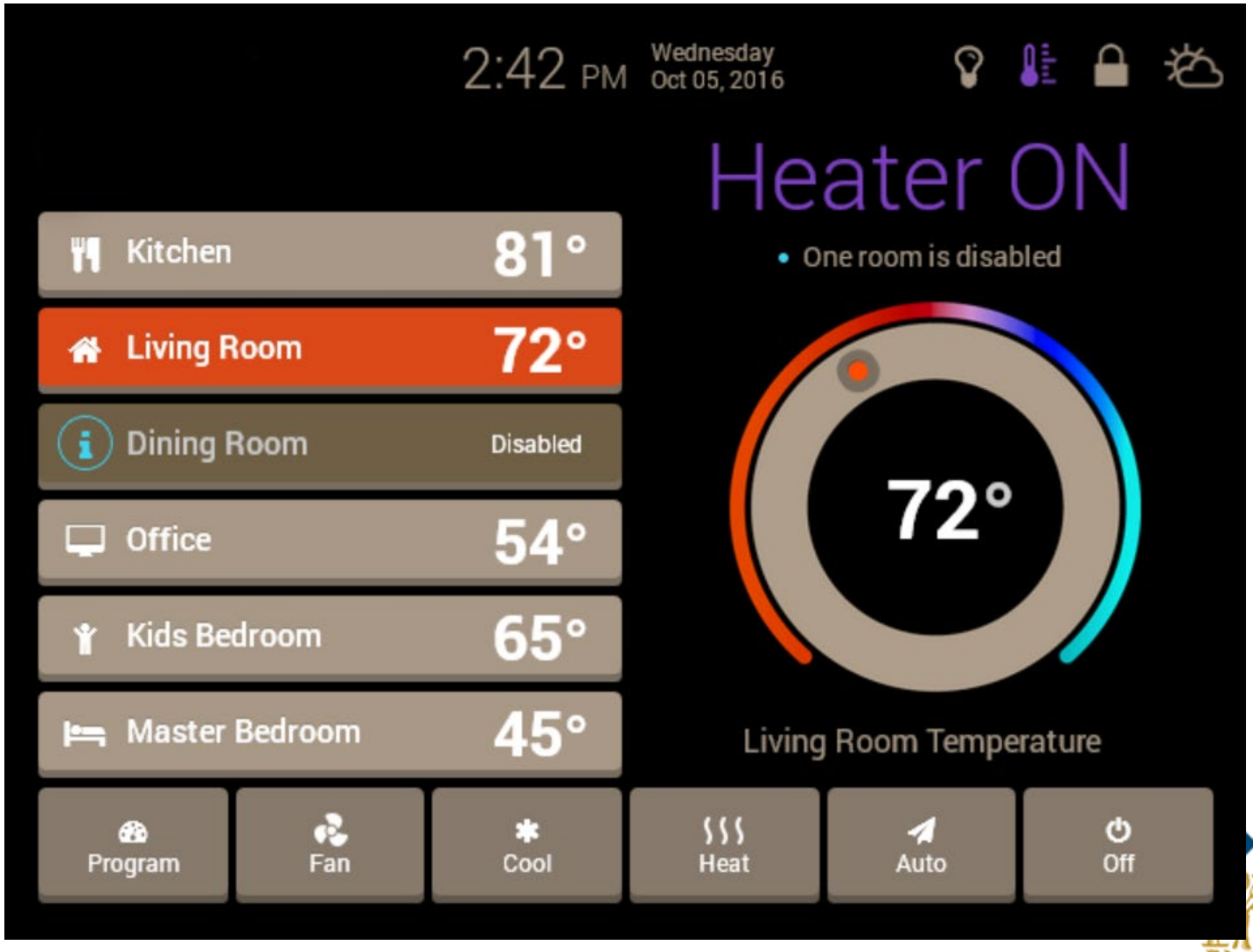
# User Interface

- 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

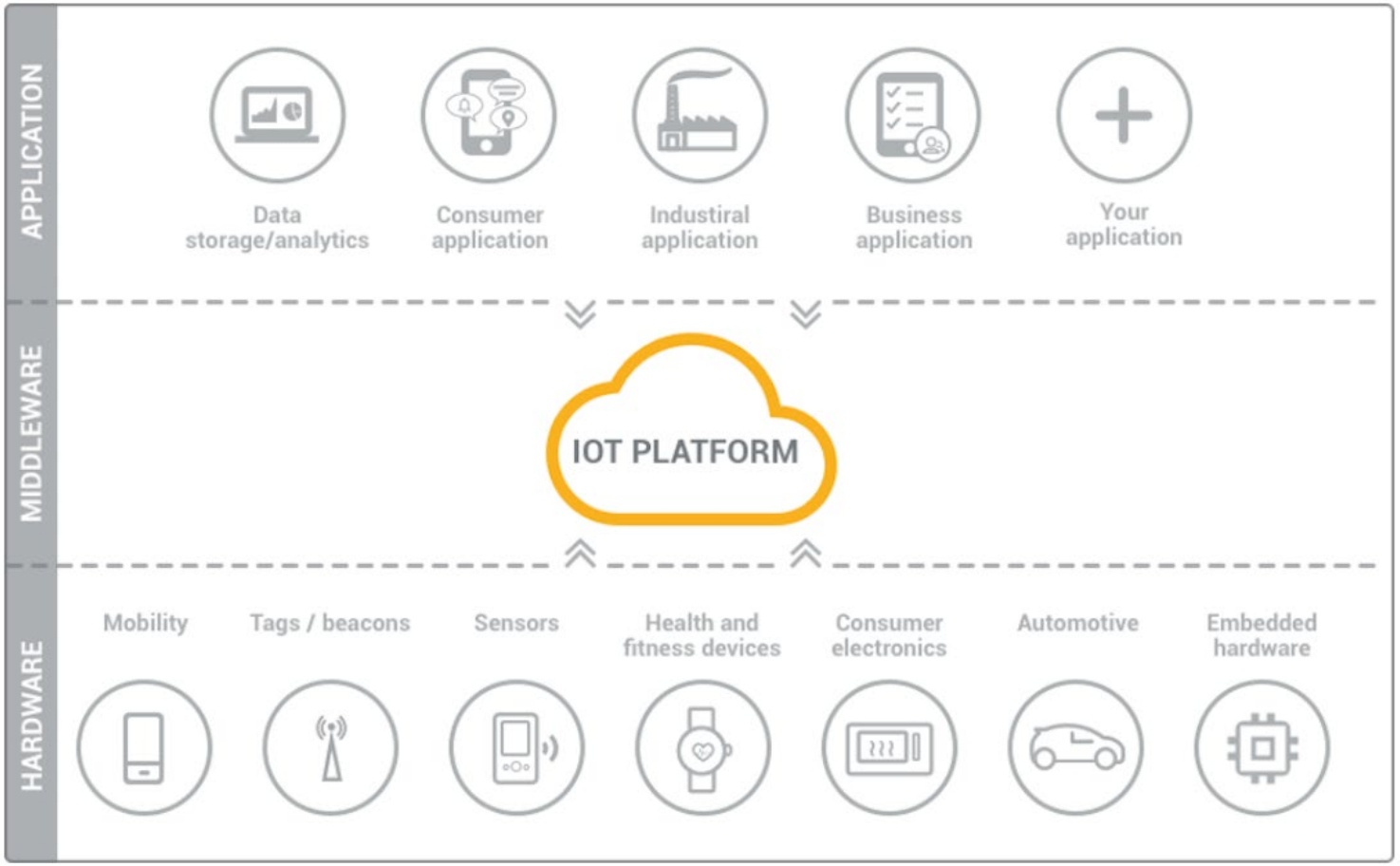
# User Interface



# IoT Platforms

# What is an IoT Platform?

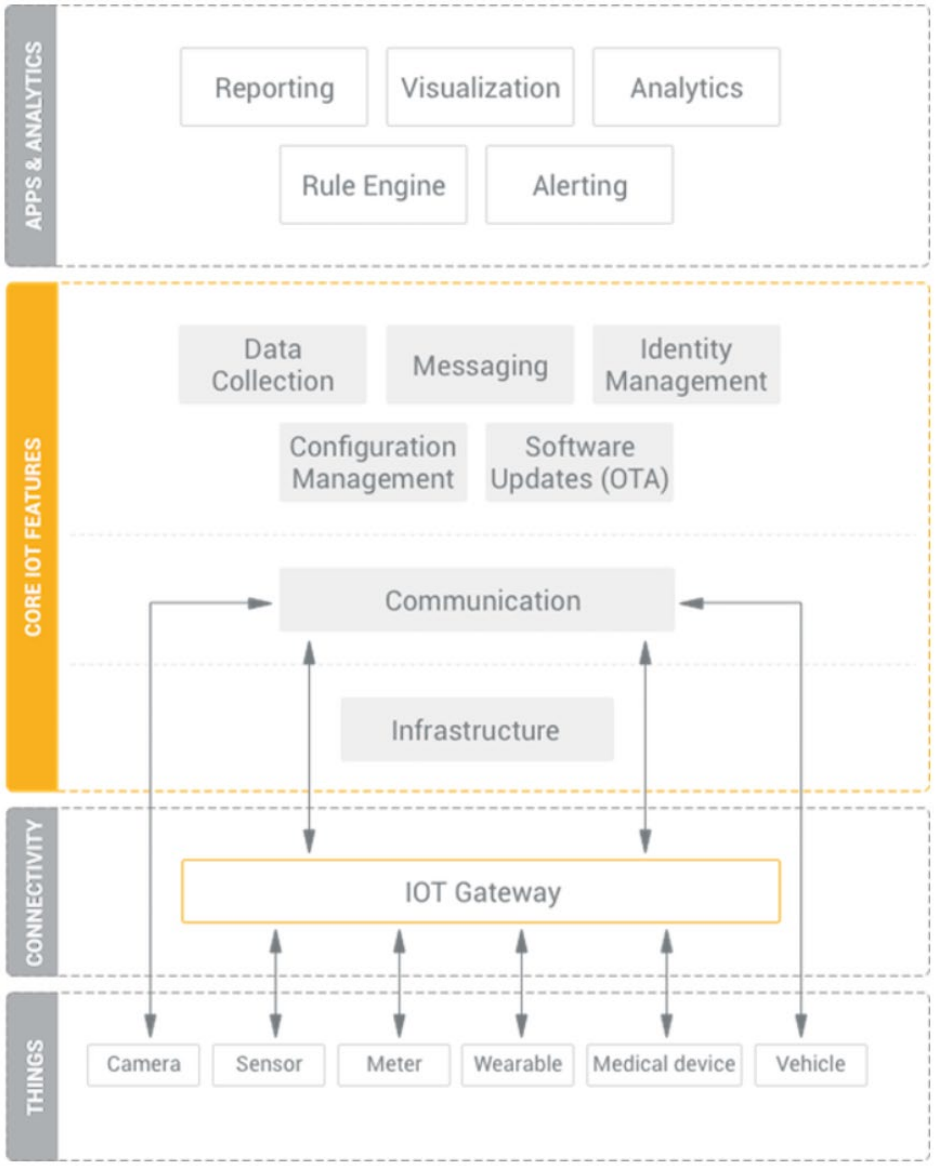
- **Middlemen** that connects the hardware to the cloud



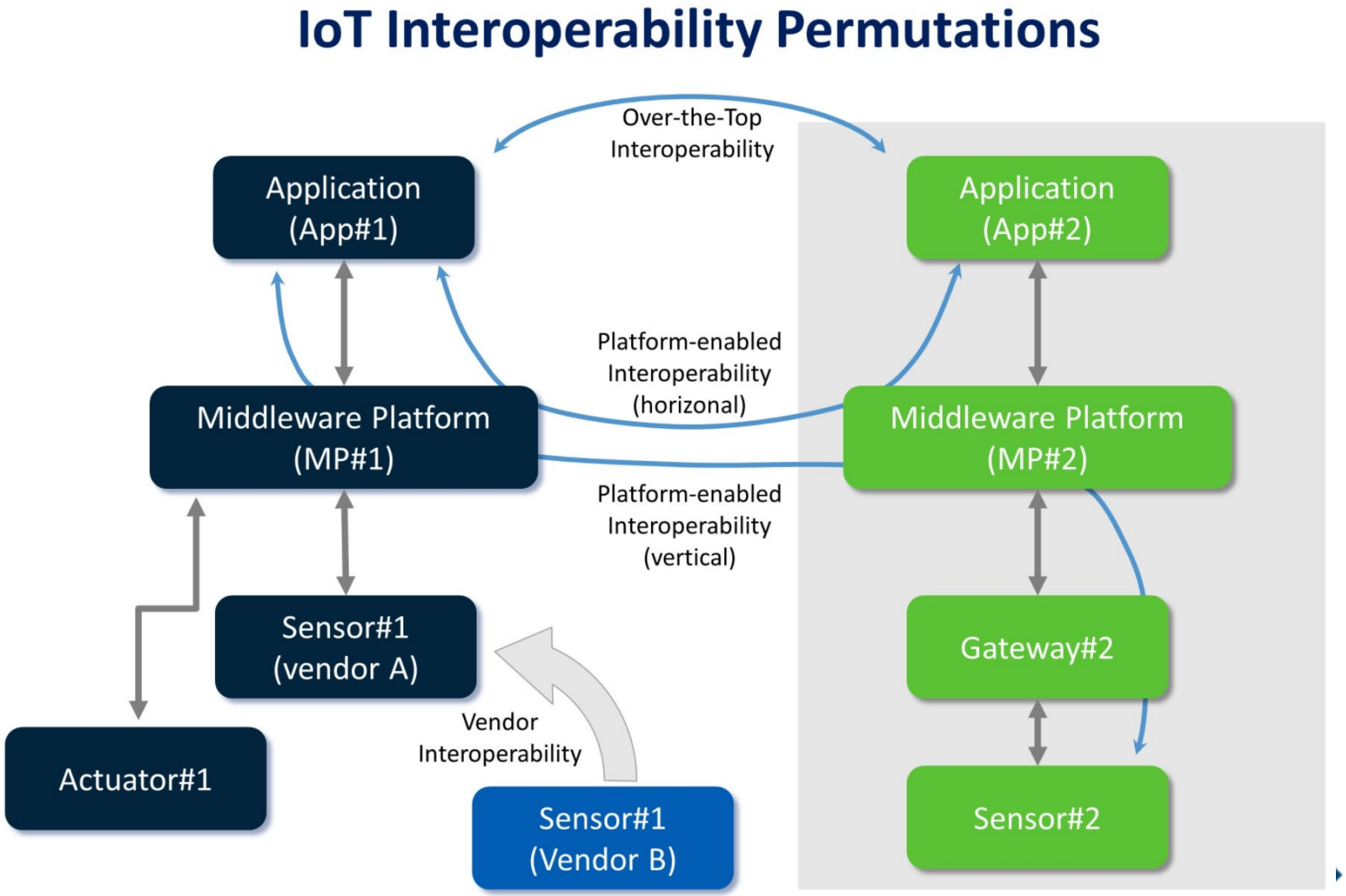
# Elements of IoT Platform

- 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



# 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

- 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

- 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

# Applications

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

# IoT Distrupting 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 |
|---|---|---|---|
| **VALUE CREATION** | 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 |
| **VALUE CAPTURE** | 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 |

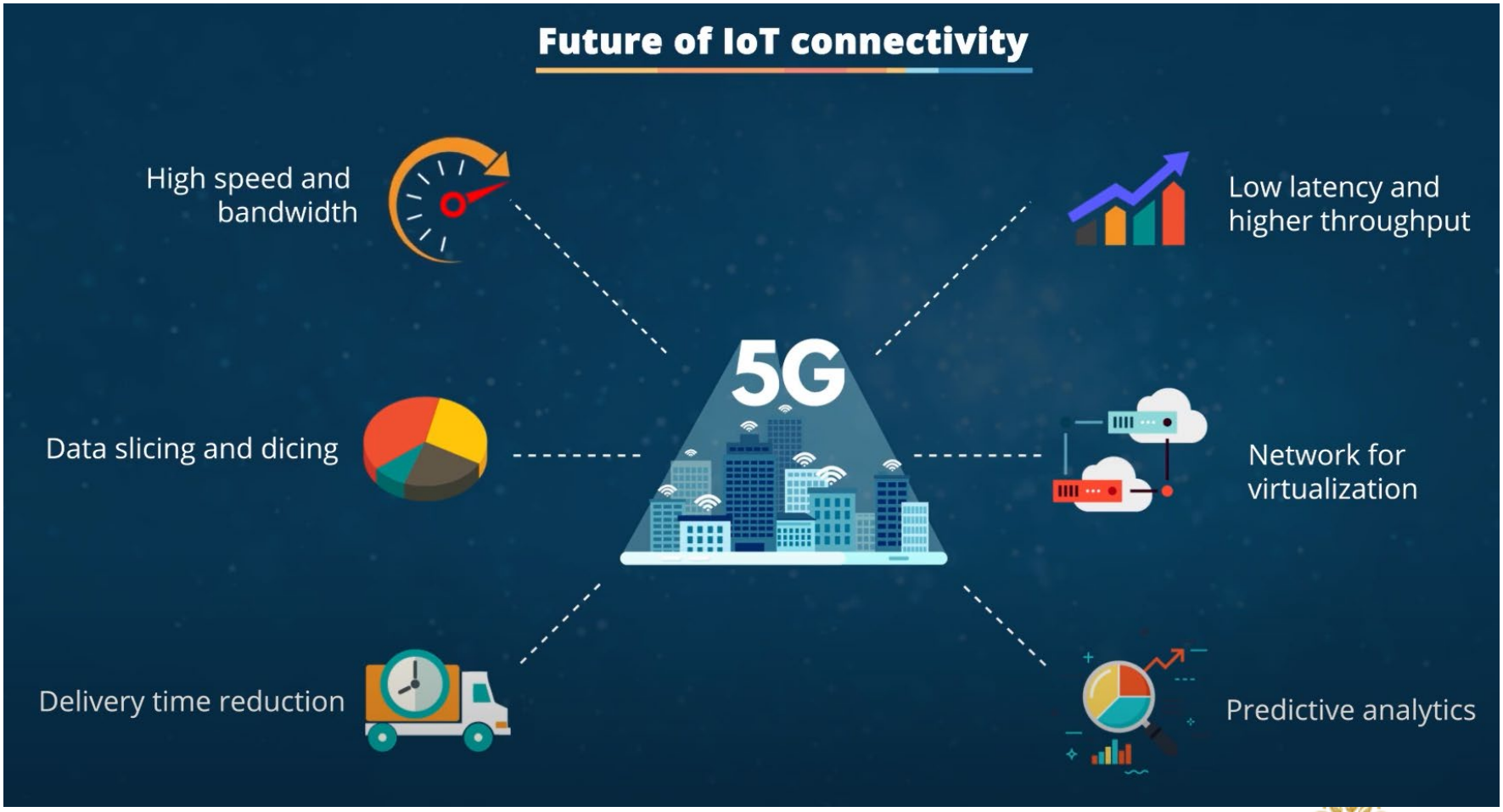
**SOURCE** SMART DESIGN

HBR.ORG

# Current Issues

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

# Future of IoT – 5G



# Readings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