Institute for the Wireless Internet of Things
at Northeastern University

# EECE5155: Wireless Sensor Networks and the Internet of Things

Josep Miquel Jornet
Associate Professor, Department of Electrical and Computer Engineering
Director, Ultrabroadband Nanonetworking Laboratory
Member, Institute for the Wireless Internet of Things
Northeastern University
jmjornet@northeastern.edu
www.unlab.tech

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# Module T6: Data Storage and Cloud

# The Internet of Things

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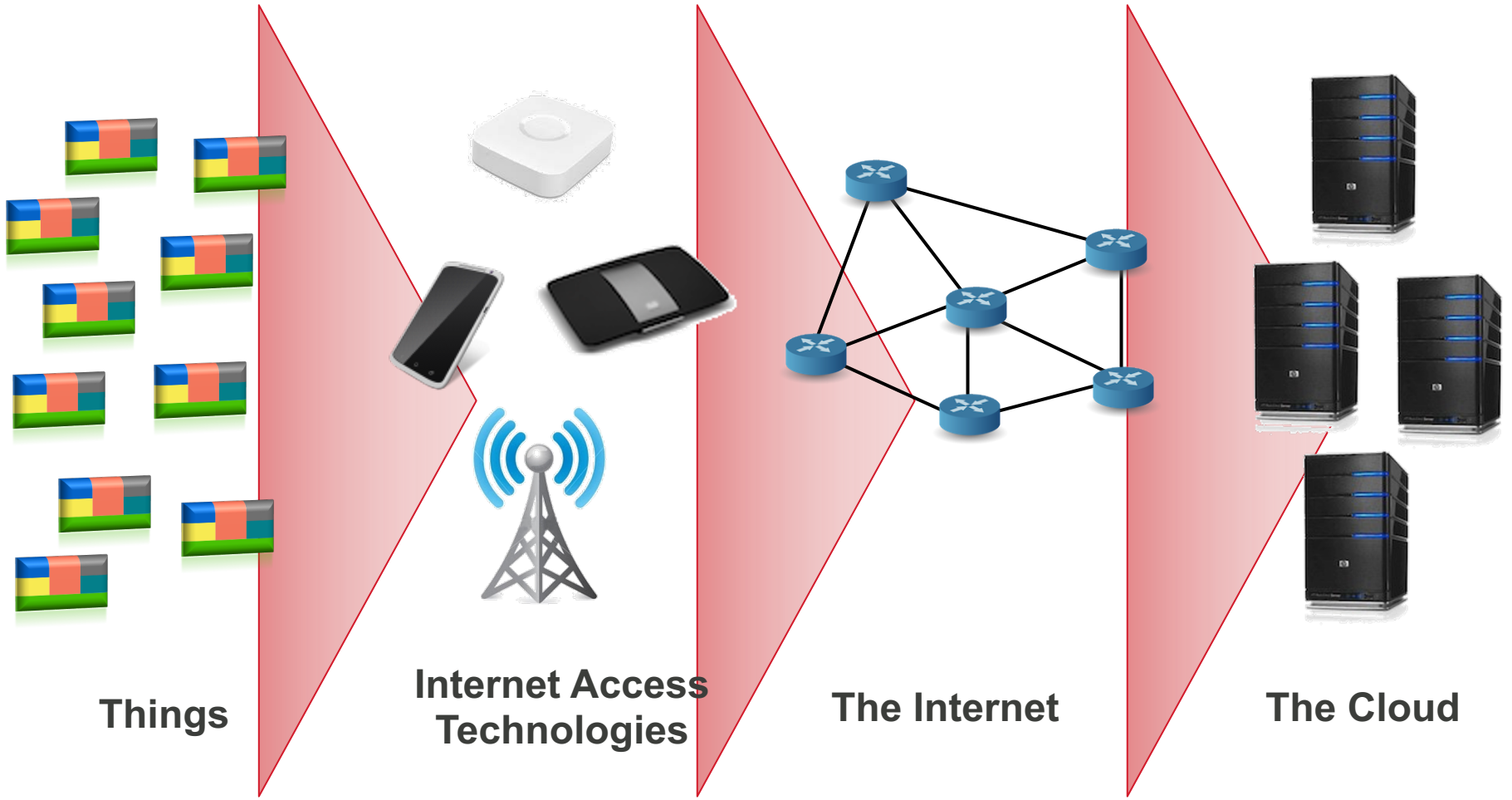

# Cloud Computing

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- A class of on-demand compute services available over the Internet
- The services include:
  - **Infrastructure as a Service (IaaS):** Basic functionality, such as computation and data storage
  - **Platform as a Service (PaaS):** Specialized functionality, such as machine learning and parallel data set processing
  - **Software as a service**
  - **Security as a service**
  - **…**
- Offers many appealing benefits for customers, including:
  - Scalability
  - Affordability
  - Manageability

# Cloud Deployment Patterns



- Three types of deployment:
  - **Public Cloud:**
    - Offers services for use by any registered customer
    - Services are accessed over the Internet and are powered by computers and other infrastructure located in the data centers, which are owned by the Cloud providers
    - Unless customers pay for higher quality of service, Cloud providers will often run services for many different customers on a single hardware server
      - **The "noisy neighbor effect":** When any of the services exhibits "bursty" behavior (times when their resource utilization peaks far beyond normal), other services on the same hardware may experience intermittent periods of diminished performance

# Cloud Deployment Patterns

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- Three types of deployment:
  - **Private Cloud:**
    - Operated for the benefit of a single organization
    - Often deployed on dedicated infrastructure that eliminates the noisy neighbor problem
    - Whether operated directly by the organization itself or by a third party, the main value is its **high level of privacy and isolation** from the Internet
    - Very relevant as Cloud security and privacy concerns become more and more important

# Cloud Deployment Patterns

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- Three types of deployment:
  - **Hybrid Cloud:**
    - Combines aspects of both public and private cloud implementations
      - E.g., dedicated servers on a public cloud

# Why Do We Need the Cloud for IoT?

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- Large number of connected devices
  - How/where to store the data?
- Difficulty to process large sets of data locally
- Communications backend storage and processing limited
- Need remote access to the data
- …

# Cloud Computing and the IoT

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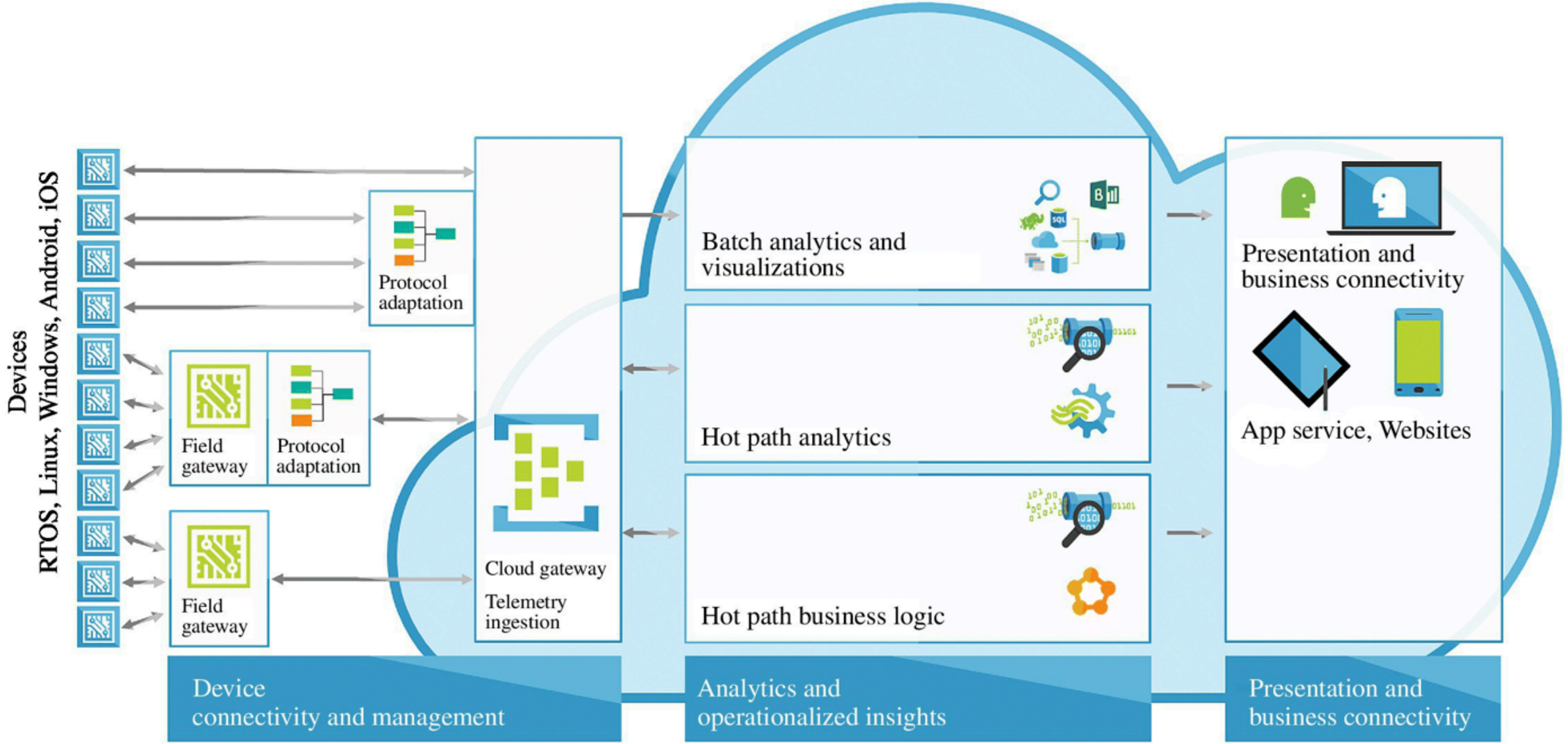

# Cloud Computing and the IoT

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- The cloud offers features and benefits extremely well suited for the IoT:
  - **Cloud services are designed to "scale as you go":**
    - Start at low-cost, low-capacity deployment and then easily move up to more powerful server hardware as your solution grows → You only pay for what you use
    - On the contrary, in a self-hosted scenario, you are responsible for selecting and procuring server hardware to meet the demands of your IoT solution, in light of not only your current peak's demand, but also your future expectations

# Cloud Computing and the IoT

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- The cloud offers features and benefits extremely well suited for the IoT:
  - IoT devices are often mobile or deployed in a variety of locations
    - They need to connect to the server side from different places → Public clouds are generally reachable from anywhere on the Internet
  - Cloud service providers offer IoT-specific services like high-speed telemetry ingestion and simplified device management
  - Once the IoT data is in the cloud, it can be used by a variety of cloud-based tools (e.g., stream analytics, data mining)

# Common IoT Application Scenarios:
# Remote Monitoring

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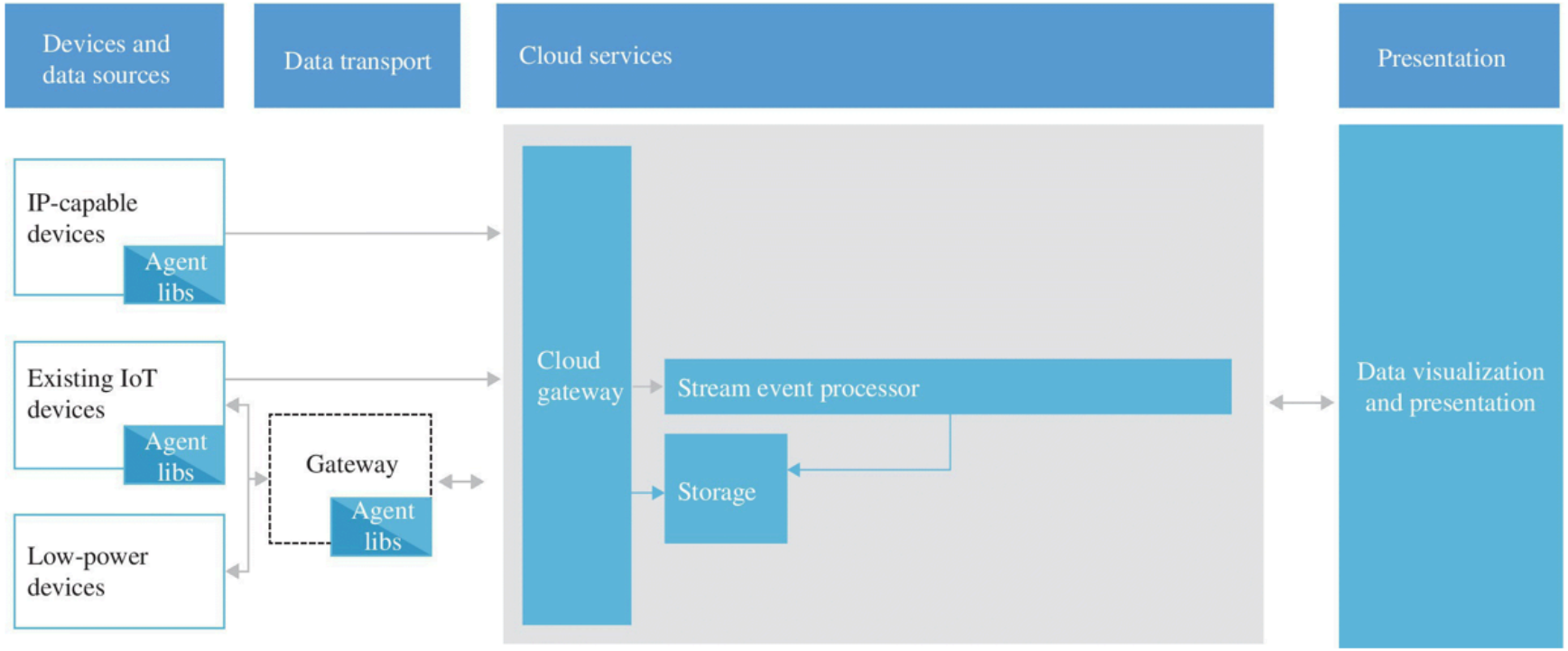
- Devices send data to the cloud, and the cloud stores the data in some kind of high-performance queue for processing by the enterprise application
- Remote monitoring often includes anomaly detection (detecting when sensor values deviate from established thresholds or "normal" values)
- This is sometimes called hot path analysis or data in motion analysis because it involves processing the data as it transits through the system in real time



# Common IoT Application Scenarios:
# Asset Management

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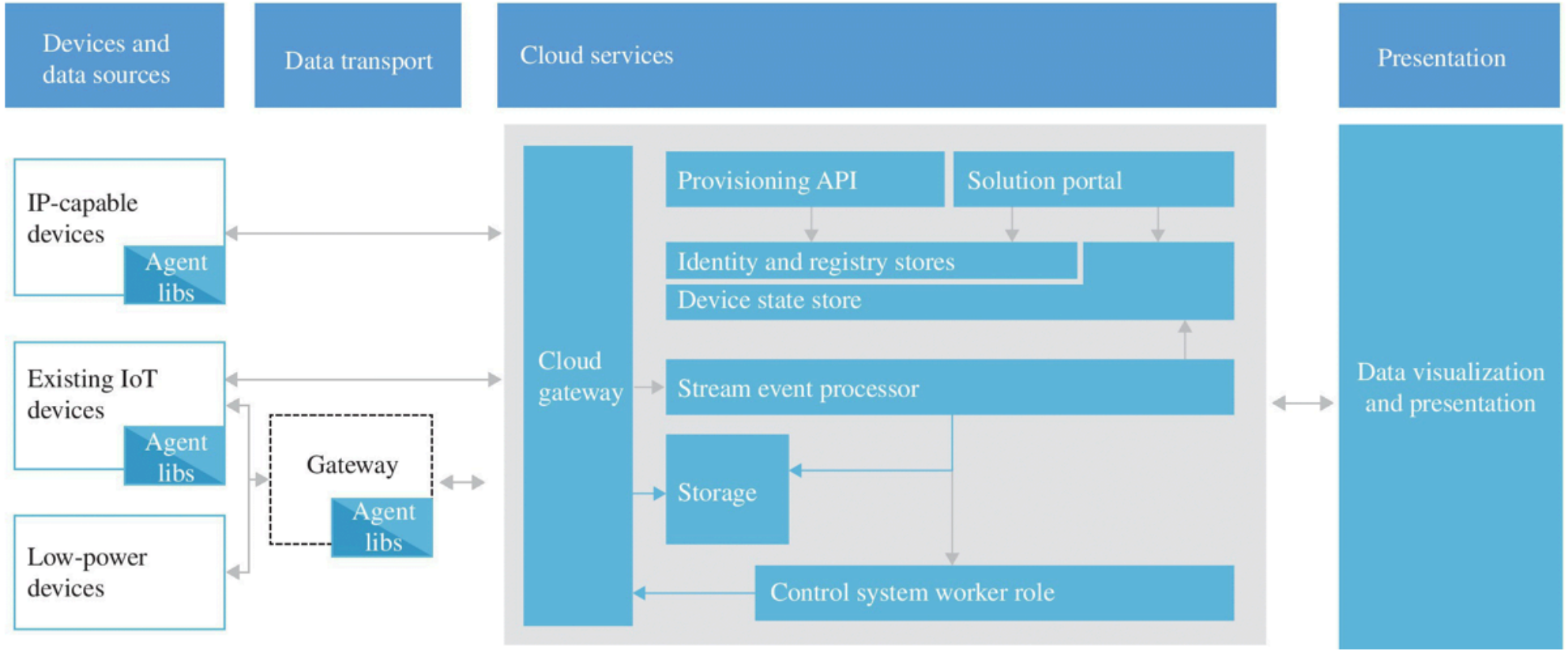
- Builds on remote monitoring by adding capabilities of command and control to the system
  - Asset management adds a new communication path where the cloud communicates back to IoT devices
    - This communication path can be used for control (starting, stopping, resetting devices), updating (firmware, software, configuration), and security (managing access rights, ownership)



# Common IoT Application Scenarios:
# Predictive Maintenance

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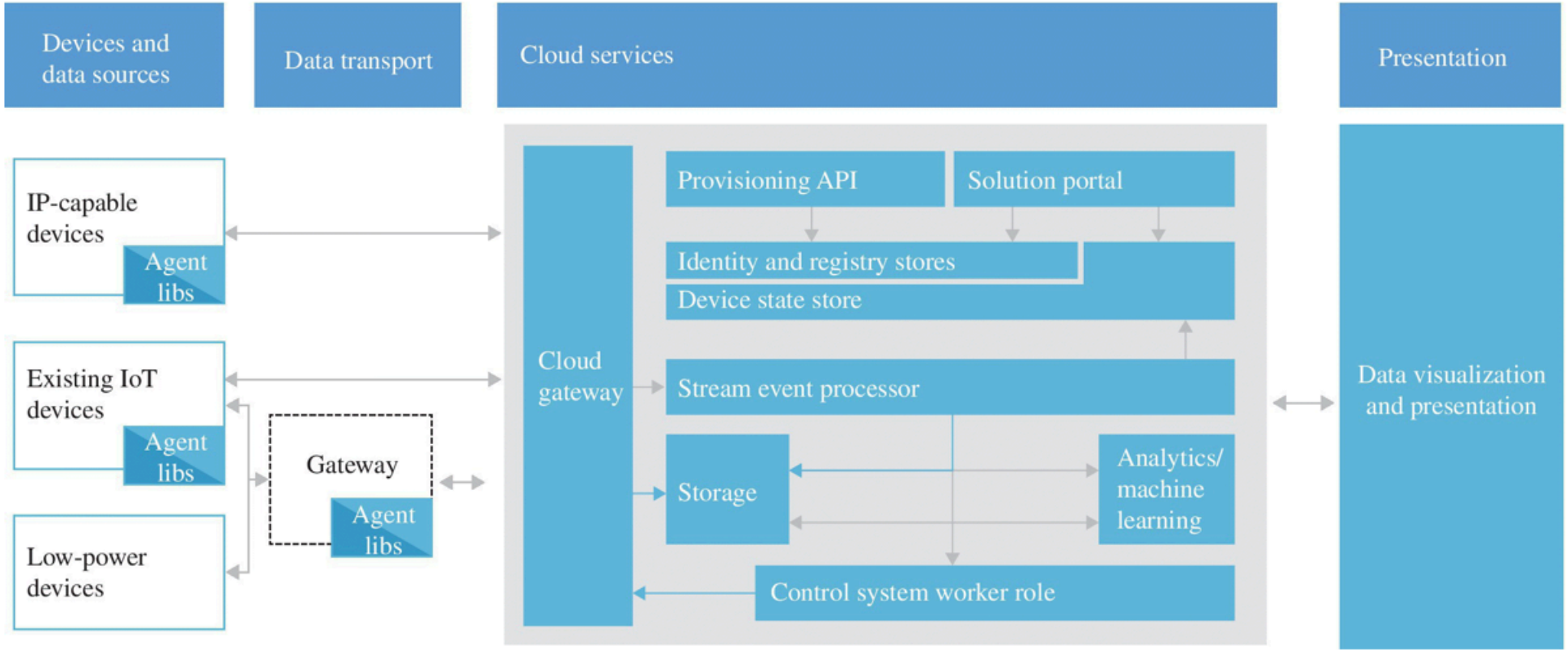
- Brings in additional cloud services like machine learning and distributed analysis tools:
  - These services operate on structured and unstructured data to mine for insights not immediately apparent in the telemetry.
  - This activity is sometime called cold path analysis or data at rest analysis because the analysis is generally performed on data that has been placed into a data lake or other storage container, where the data is "resting" rather than flowing through the system



# Any Downside of Using the Cloud?

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- Storing and extracting data from the cloud incurs delay
- Data center might be geographically remote
- Delay can be quite significant for sensing-actuation applications
- Security, Privacy
- …

# Cloud Security and IoT

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- **The stakes are high:**
  - Before IoT, the biggest impact of a computer security breach was usually financial
  - Now with IoT, security breaches can result in physical damage in the real world or even loss of human life
    - It is therefore imperative to take security very seriously

- **Encrypting communications between client and server is just the beginning:**
  - Encrypting data assures that it cannot be observed or altered in transit, but it does nothing to guarantee that the data can be trusted
  - For trust, both the sender and receiver need to provide each other with irrefutable identity credentials.

# Cloud Security and IoT

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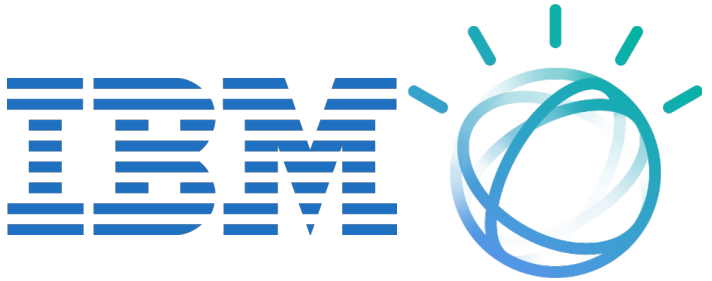
- **Physical tampering is IoT's "analog hole":**
  - Even with secure communications and credentials, IoT sensors can be tampered with to provide misleading data.
  - There is no single solution for this kind of tampering, but some approaches include redundant sensors, sensors within physically secured enclosures, and sensors that monitor other sensors.

- **You cannot secure software that you cannot update:**
  - All software is vulnerable to exploits:
    - It's just a matter of time and effort on the part of hackers until the exploits are discovered
  - Software updates are the primary defense against exploits—once an exploit is discovered, software makers can correct the defect in the code and then send out an updated version with the fix
  - However, if there is no mechanism to update the software running on a device, then it can't be fixed and the exploit remains forever

# Some Clouds




Microsoft Azure

Google Cloud

# Amazon Web Services IoT

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- **Type of Service:** IaaS, PaaS
- **Cost:** Different tiers:
  - Based on number of messages/data
  - Type of service
- **Openness of the platform:**
  - Open-source friendly
  - Hybrid
- **Libraries for platforms:**
  - Java, JS, php, Python, .net, …
- **Protocols used:**
  - MQTT, HTTP(s), Websockets
- **Authorization policies:**
  - Different authorization processes at transport/application layers, …

# Microsoft Azure IoT

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Microsoft Azure

- **Type of Service:** IaaS, PaaS
- **Cost:** Different tiers
  - Time, data, service
- **Openness of the platform:**
  - Open-source friendly
  - Hybrid
- **Libraries for platforms:**
  - Java, JS, php, Python, .net, …
- **Protocols used:**
  - MQTT, HTTP, HTTPS, AMQP, over Websockets
- **Authorization policies:**
  - Different protocols at transport/application layer, (certificates, i.e., SSL/TLS)

# IBM Watson IoT

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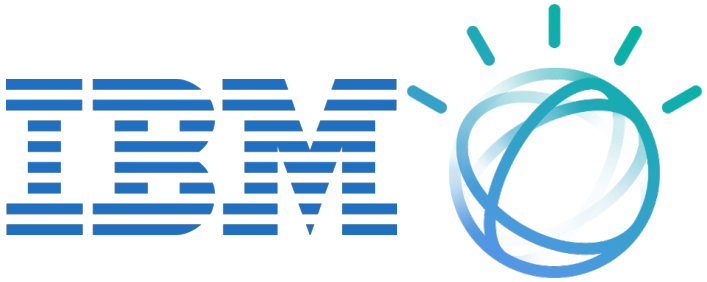

- **Type of Service:** IaasS, PaaS, …
- **Cost:** Different tiers (free, paid)
  - Based on data amount (not time)
- **Openness of the platform:**
  - Open-source friendly
  - Hybrid
- **Libraries for platforms:**
  - Java, JS, php, Python, .net, …
- **Protocols used:**
  - MQTT, HTTP, HTTPS, AMQP, over Websockets, …
- **Authorization policies:**
  - **…**

# Google Cloud

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Google Cloud

- **Type of Service:**
  - IaaS, PaaS, SaaS, …
- **Cost:** Different tiers (free, paid)
  - Based on data amount and time
- **Openness of the platform:**
  - Open-source friendly
  - Hybrid
- **Libraries for platforms:**
  - Java, JS, php, Python, .net, Node.js, …
- **Protocols used:**
  - MQTT, HTTP, HTTPS, AMQP, over Websockets, SMTP, …
- **Authorization policies:**
  - **…**

# Oracle Cloud

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- **Type of Service:**
  - IaaS, PaaS, SaaS, DaaS, …
- **Cost:** Different tiers (free, paid)
  - Based on data amount and time
- **Openness of the platform:**
  - Open-source friendly
  - Hybrid
- **Libraries for platforms:**
  - Java, JS, php, Python, .net, Node.js, …
- **Protocols used:**
  - MQTT, HTTP, HTTPS, over Websockets, FTP, …
- **Authorization policies:**
  - **…**

# Many Others…




xively
by LogMeIn
HEROKU
ubidots
IOTSENS
GRUPO GIMENO IoT Division

# Conclusions

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- The cloud is here to help you both initially set but also scale your application in time
  - Many platforms offer free service for small scale applications (e.g., start-up companies)

- If you rely on an existing platform for data streaming (e.g., Sigfox, LoRaWAN), you might be constrained to their options
  - Or you could always create an intermediate "server"
    - Security? Reliability?

- Many options, many flavors, your choice

# Course Contents

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- **Module T1:** Introduction to the Internet of Things ✓
- **Module T2:** Data Acquisition ✓
- **Module T3:** Local Data Processing ✓
- **Module T4:** Data Communication ✓
- **Module T5:** Data Streaming ✓
- **Module T6:** Data Storage & Cloud ✓
- **Module T7:** Data Analytics

# Next Steps

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- **Research paper video presentation:**
  - Due on December 13
- **Homework assignment:**
  - Due on December 13
- **Third laboratory assignment:**
  - Optional, due on December 15