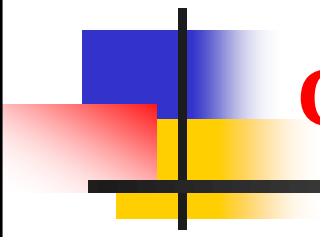


Chapter 6

IoT PLATFORM

Applications

Services/Interfaces

Cloud Infrastructure

Communication

Devices

Things

Applications

Services/Interfaces

Cloud Infrastructure

Communication

Devices

Things

Heterogeneity, domain knowledge, re-usability, flexibility, maintainability, reliability, efficiency and scalability , ….

Interface definition, identification, pub/sub, semantics, query, composition, process management, command and control, ….

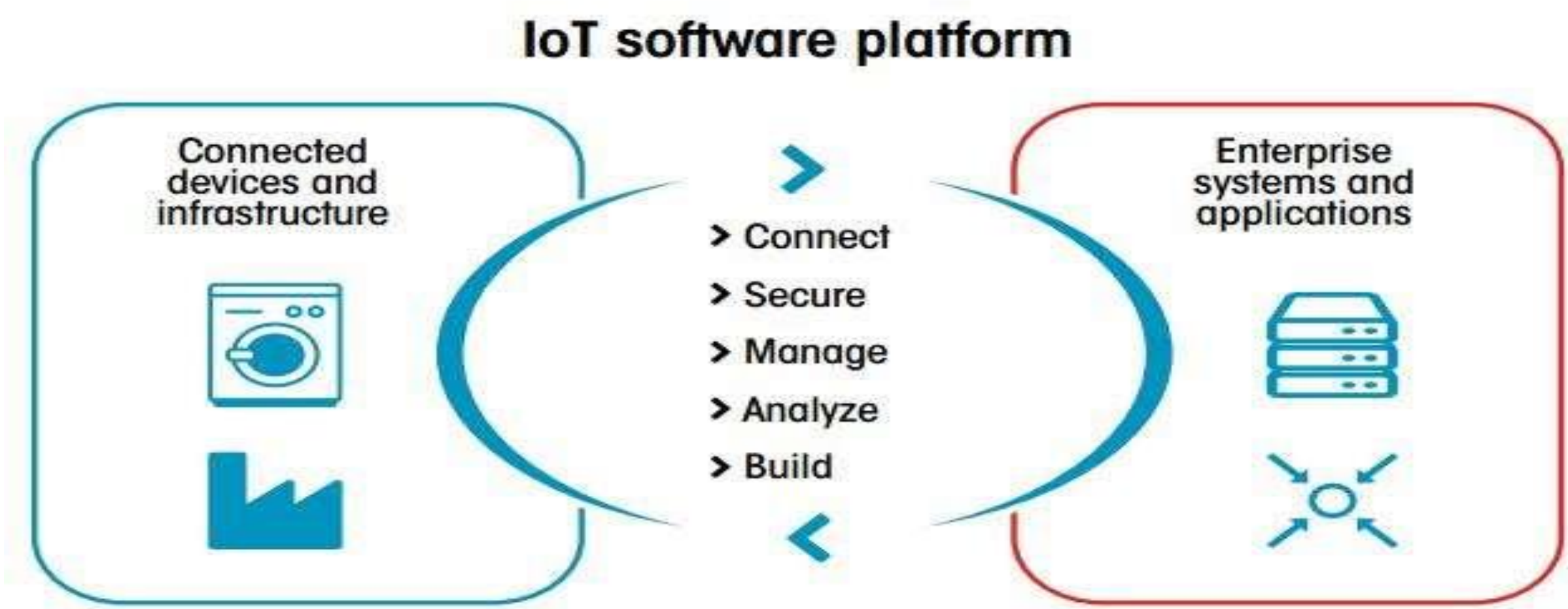
Back-end service, middleware/gateway solutions, discovery, access, directory services, security, access control, accounting, ….

Heterogeneity of underlying devices, QoS, different data patterns and requirements (bandwidth and delay measure are not sufficient), …

Various hardware/software platforms, heterogeneity of communication technologies, energy/resource constraints , …

Describing the Things, Observation and Measurement and interaction attributes, …

IoT Platforms



What is an IoT platform?

- An IoT platform is an application or service that provides built-in tools and capabilities to connect every “thing” in an IoT ecosystem. By providing functions including device lifecycle management, device communication, data analytics, integration, and application enablement.
- An IoT platform harmonizes the many moving parts that contribute to your IoT system. An IoT platform is the foundation for building IoT solutions that deliver value to your business, your customers, your customers’ end users, and your partners. By enabling you to maintain visibility, security, and control over connected assets, IoT platforms enable you to start and scale IoT projects efficiently so you can launch customer-centric services and remain competitive in an evolving market environment.

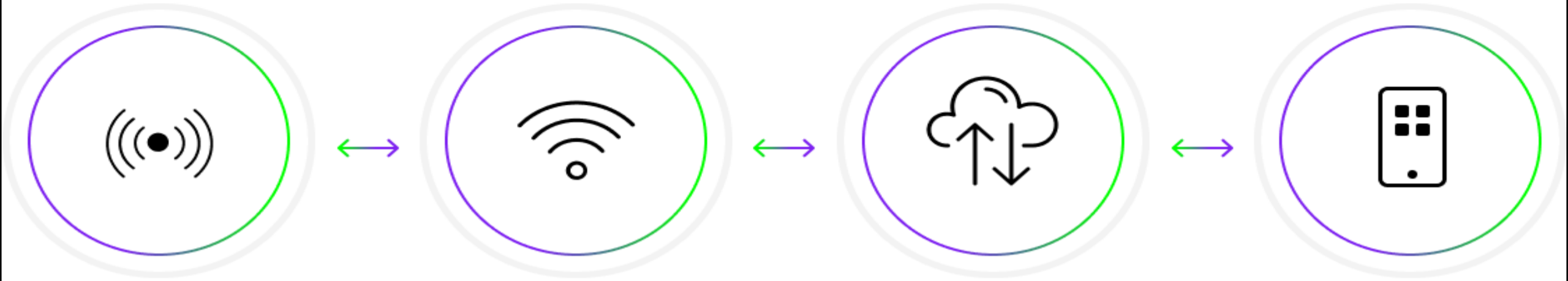
WHY USE AN IOT PLATFORM?

- An IoT platform is critical to building an IoT ecosystem, it simplifies IoT, making it more secure, regardless of where you are on your IoT journey to build smart, connected products.
- IoT is a complex ecosystem that spans a network of devices and software applications touching multiple parts of the physical and digital landscapes. It is rare for an organization to maintain in-house expertise across all the relevant domains to build a complete set of IoT capabilities. As a result, in the “buy versus build” debate over IoT capabilities, most enterprises see value in buying an IoT platform to provide an out-of-the-box set of key capabilities, on top of which the business can build differentiating logic and applications.

IOT PLATFORM CAPABILITIES

- At a basic level, IoT platforms should allow you to connect and manage your devices with ease, offer application enablement and integration tools, and analyze your IoT data for actionable insights.
- IoT Platform between things/devices and business applications
  - **connect** devices to gather information
  - **secure** communication with devices and applications
  - **manage** devices to control their behavhior
  - **analyze** data, e.g., with AI
  - **build** applications, also interacting with CRM/ERP/…

IoT System Architecture



Sensors

Sensors / Devices / Tags & beacons / Actuators / Gateways

Connectivity

Network protocols / WiFi / BLE

IoT Platform

Data storage & processing / Analytics / Visualization / Connectivity & device management / Security

Applications

Apps / APIs/ CRM / ERP

Hardware layer | Connectivity layer | Middleware layer | End-user layer

Benefits of IoT Platforms

- IoT platforms offer a plethora of advantages for businesses across various sectors. Some of the benefits are as follows:

  1. Real-time Monitoring

  Imagine having a watchful eye over the devices and sensors round the clock. IoT platforms enable just that, allowing businesses to swiftly detect any issues as they arise and respond in real-time. This proactive approach minimizes downtime and ensures uninterrupted operations.

- **2. Enhanced Efficiency**

  By leveraging automation and real-time insights, IoT platforms streamline operations, cut down on costs, and supercharge productivity. Tasks that once required manual intervention can now be automated, freeing up valuable time and resources for more strategic efforts.

- **3.Improved Customer Experience**
  Picture a scenario where every interaction with the customers feels tailor-made for their needs. IoT platforms make this a reality by enabling personalized interactions, offering better recommendations, and providing immediate support. This level of attentiveness cultivates customer loyalty and satisfaction, fostering long-term relationships.
  4. Data-driven Decisions
  With IoT platforms, businesses gain access to a treasure trove of data that offers invaluable insights into customer behavior and preferences. Armed with this understanding, organizations can make informed choices, fine-tune strategies, and outpace competitors in a constantly changing market landscape.

- **5. Heightened Security**
  In today's digital landscape, security is paramount. IoT platforms provide robust security measures, including realtime monitoring and rapid response to security threats. This proactive approach helps safeguard sensitive data and ensures the integrity of operations, instilling confidence in customers and stakeholders alike.
  6. Scalability
  As businesses grow and evolve, so do their needs. IoT platforms offer the flexibility to easily accommodate additional devices and sensors, ensuring scalability without compromising performance or efficiency. Whether it’s expanding operations or adapting to changing market demands, IoT platforms provide the agility needed to stay ahead of the curve.

What are the Key components of an IoT platform?

- **1. Connectivity**

  This layer serves as the foundation for IoT platforms, facilitating seamless communication between devices and the internet. It encompasses protocols, gateways, and APIs that enable devices to establish connections and exchange data reliably.

  2. Device Management

  Managing the lifecycle of IoT devices is crucial for ensuring their efficient operation. This layer handles tasks such as device onboarding, provisioning, and maintenance. It includes features like firmware updates, remote configuration, and monitoring to ensure devices are functioning optimally throughout their lifecycle.

- **3. Data Management**
  As IoT devices generate vast amounts of data, effective management of this data is essential. This layer handles tasks related to data storage, processing, and analysis. It includes features such as data ingestion, storage optimization, real-time processing, and advanced analytics to derive actionable insights from the data generated by IoT devices. An IoT platform helps businesses manage data at scale
  4. Application Enablement
  It provides tools and APIs for developers is essential for building applications that interact with IoT devices and data. This layer offers development frameworks, APIs, SDKs, and other tools that empower developers to create innovative applications tailored to specific use cases and business requirements.

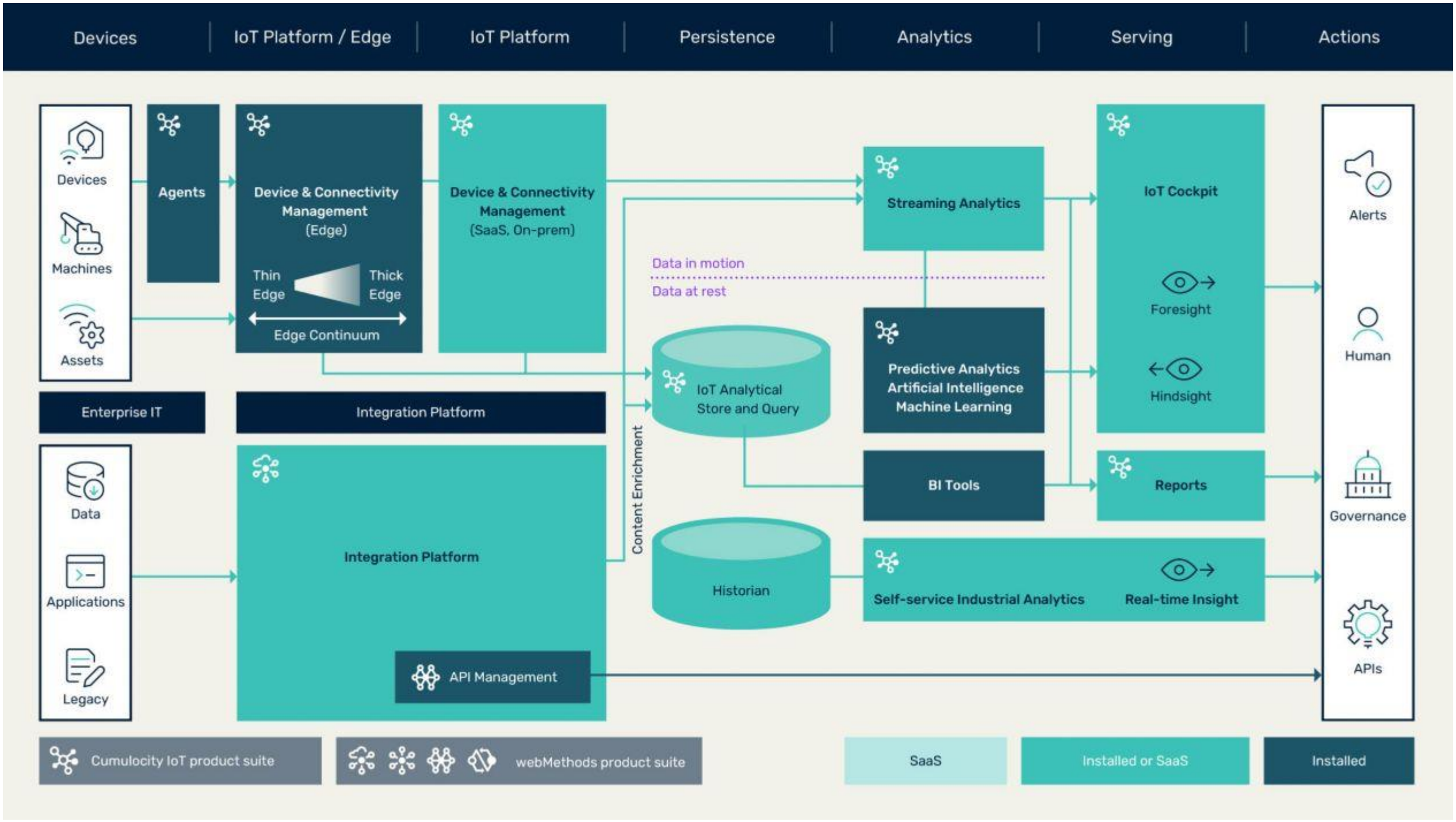
- **5. Cloud Computing Services**
  Leveraging cloud-based services is instrumental in scaling IoT platforms and handling the massive amounts of data generated by IoT devices. This layer encompasses various cloud services such as storage, computing, and analytics. It includes features like cloud storage, serverless computing, and machine learning to efficiently process and analyse IoT data in the cloud.
  6. Interoperability and integration
  This layer enables diverse devices, like sensors, cameras, and wearables, to communicate seamlessly with the IoT platform. This ensures accurate data transmission to the cloud, enhancing scalability and fostering innovation in the IoT ecosystem.

- **7. Security**
  By utilizing the security features inherent in IoT platforms, organizations can effectively protect the integrity and confidentiality of data within their IoT systems. This step includes incorporating encryption, access controls, and authentication methods to mitigate security risks and ensure the security of sensitive information against unauthorized access.
  8. Analytics
  IoT platforms often come equipped with advanced analytics capabilities, including rule engines, event stream processing, machine learning, and data visualization tools. These analytics functionalities empower organizations to analyse data either at the edge or in the cloud, enabling them to derive actionable insights. Through the utilization of analytics, organizations can make informed decisions, enhance operations, and boost efficiency within their IoT ecosystems

- **9. Application Development**
  Enabling the development of custom applications is crucial for extending the capabilities of IoT platforms. This layer provides developers with the necessary tools, resources, and documentation to build and deploy applications that interact with IoT devices and data. It includes features such as APIs, SDKs, development environments, and testing tools to streamline the application development process.

HOW DOES AN IOT PLATFORM WORK?

- An IoT platform works by supporting the connectivity and communication between all the components in your IoT ecosystem through one application. It connects your devices and sensors—from registering one new device to bulk connecting thousands of devices. It allows you to remotely manage your devices and device groups, for example, by updating device firmware and software.
- An IoT platform then facilitates data transmission and applies analytics to the collected data. It allows you to access IoT device data at both a granular and high-level view.


Devices
IoT Platform / Edge
IoT Platform
Persistence
Analytics
Serving
Actions
Devices
Machines
Assets
Agents
Device & Connectivity Management (Edge)
Thin Edge
Thick Edge
Edge Continuum
Device & Connectivity Management (SaaS, On-prem)
Streaming Analytics
Data in motion
Data at rest
IoT Analytical Store and Query
Predictive Analytics Artificial Intelligence Machine Learning
IoT Cockpit
Foresight
Hindsight
Alerts
Human
Governance
APIs
Enterprise IT
Integration Platform
Content Enrichment
BI Tools
Reports
Data
Applications
Legacy
Integration Platform
API Management
Historian
Self-service Industrial Analytics
Real-time Insight
Cumulocity IoT product suite
webMethods product suite
SaaS
Installed or SaaS
Installed

- Finally, an IoT platform integrates this device data with other business applications and systems of record, so you can generate insights and make impactful decisions.

1. Connect

Connect, view, and group IoT devices and assets in bulk over networks. Manage and monitor your devices.

2. Analyze

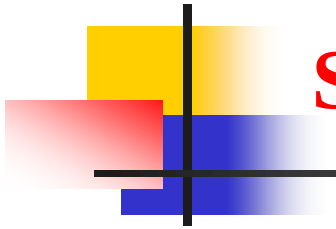
Exponentially increase your insights with powerful analytics. Monitor conditions and generate real-time analytics.

3. Integrate

Integrate device data with enterprise apps, cloud apps, big data apps, data lakes, and third-party ecosystems. Assemble integration flows easily and start automated actions based on IoT events.

4. Act

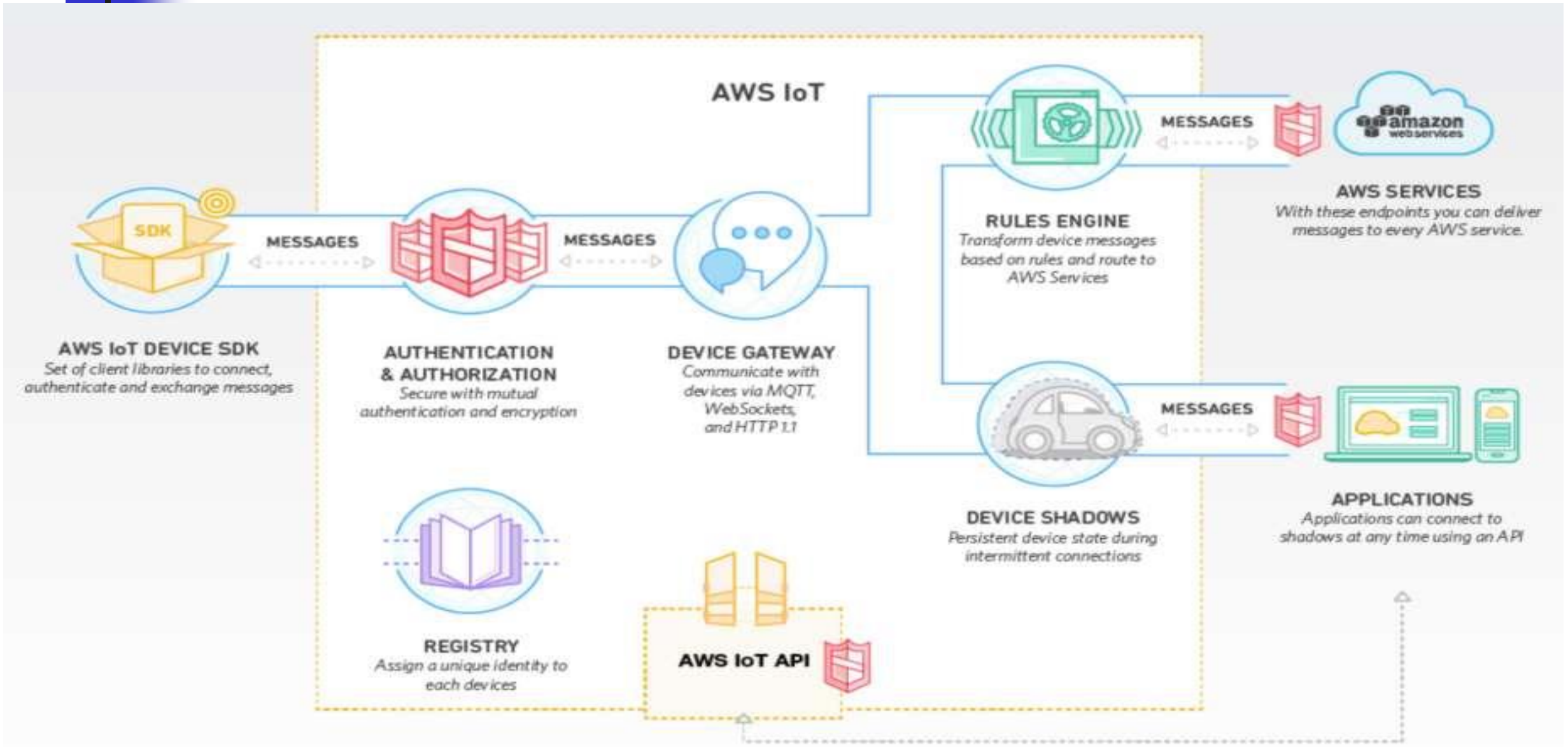
React immediately to conditions or situations. Turn device data into actions. Enable increasing levels of automation for more efficient, reliable, sustainable operations.



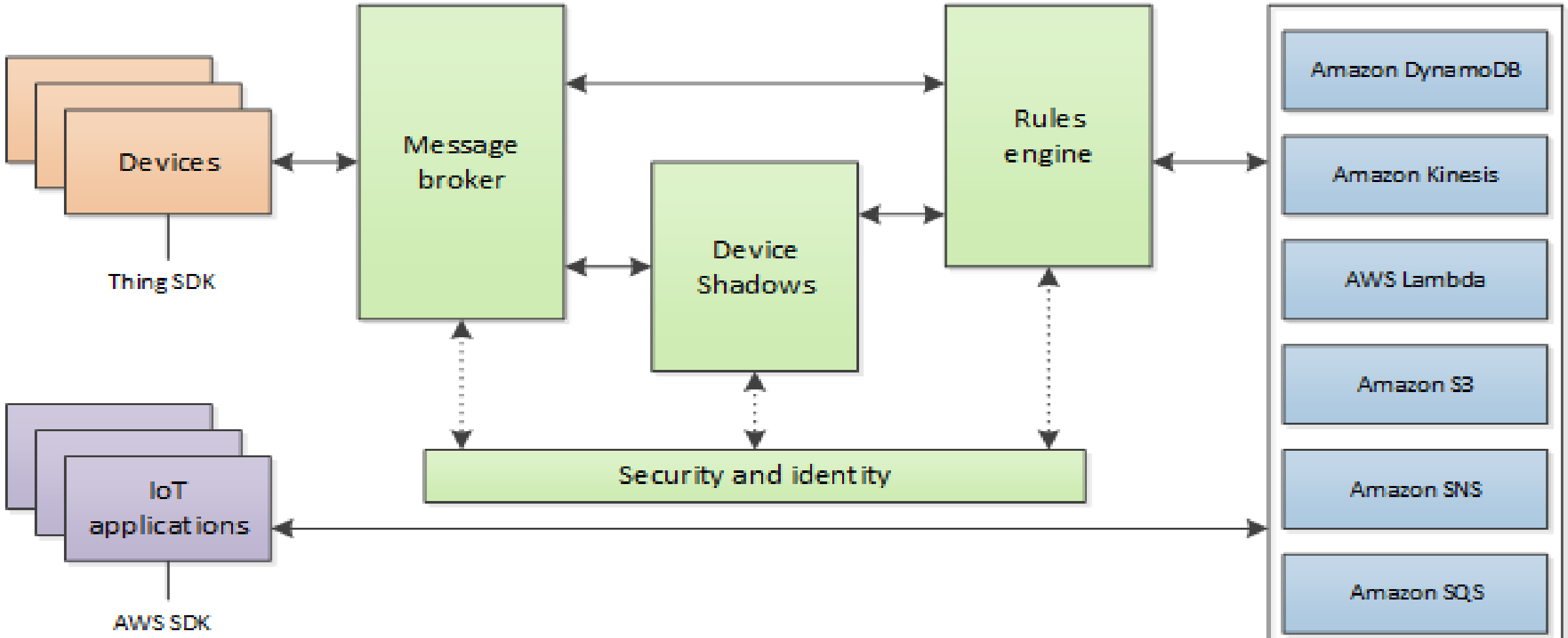
Several IoT Platforms

- We go a bit deeper into a selection of the many available ones:
  - Amazon Web Services (AWS) IoT
  - Microsoft Azure IoT Hub
  - Mindsphere by Siemens
  - EdgeXFoundry
- And several others:
  - Google Cloud Platform
  - ThingWorx IoT Platform
  - IBM Watson
  - Carriots
  - Kaa
  - …

Amazon Web Services (AWS) IoT

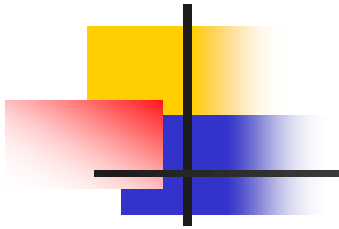


AWS IoT: Architecture

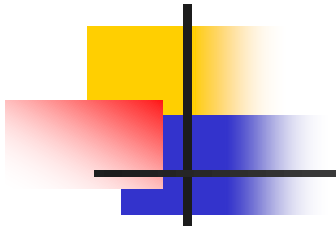


AWS IoT: Main Components (1)

- **AWS IoT Device SDK** connects devices to AWS IoT by using the MQTT, HTTP, or WebSockets protocols
  - the Device SDK supports C, Java, JavaScript, Arduino, iOS, Android,…
- **Device Gateway** supports (secure) communication with devices, by using a (1:1 or 1:n) **publish/subscribe** model
  - supports MQTT, WebSockets, and HTTP 1.1 protocols
- **Authentication and Authorization** with mutual authentication and encryption
  - authentication with native AWS (called ‘SigV4’) as well as X.509 certificate based authentication
  - AWS facilitates the whole certificate process management



- **Registry** assigns a **unique identity** to each device
  - also supports **metadata** describing capabilities of devices, e.g., whether a sensor reports temperature and if data in Fahrenheit or Celsius
- **Device Shadows**, i.e., persistent, virtual version of devices
  - applications or other devices exchange messages and **interact through the Shadow Device**
  - Device Shadows **persist** the last reported state and desired future state of each device even when the device is offline
  - exploit it to **retrieve the last reported state** of a device or **set a desired future state** through the API or using the rules engine



- **Rules Engine**, supporting to build IoT applications that gather, process, analyse, and act on data generated by connected devices
  - evaluates inbound messages published into AWS IoT and **transforms and delivers** them to another device or a cloud service, based on business rules you define
  - a rule can apply to data from one or many devices, and it can take one or many actions in parallel

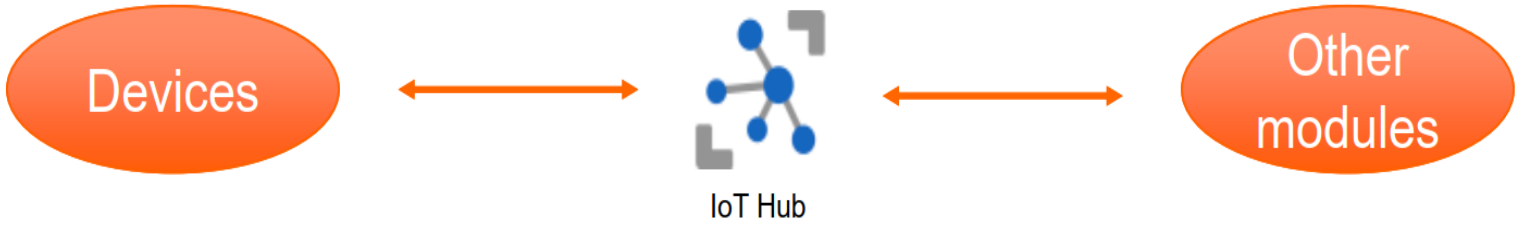
Azure IoT Platform

- Azure IoT Platform is a flexible architecture to solve industrial IoT problems that consists of many different services and modules that can be combined together, according to specific requirements.
  Azure IoT is internally organized in **3 levels of abstraction / layers**
  - **Things**: data is generated from **devices**, has a brief processing through **edge applications** and is sent trough some **connectivity service** to the next layer.
  - **Insights**: here data really get some manipulation. Can be stored in different kinds of storage, aggregated and analyzed through **stream analytics** and **machine learning tools** to derive some insights.
  - **Actions**: Finally those insights are visualized into graphs and **dashboards** that can help companies to take some actions on their plants

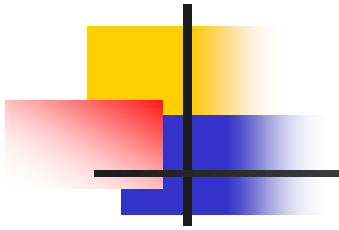
Azure IoT Architecture

Azure IoT Main Components

- **IoT Hub**: **manages the communication** among Azure services and in particular with IoT devices
- **IoT Edge**: service to deploy and manage applications over remote devices in their locations
- **Stream analytics**: one of the many analytics tools offered by Azure, focused on real-time data and complex event processing from IoT devices
- **Machine Learning (ML)**: cloud-based tool to train, deploy, and manage different ML models with support for different languages and popular ML libraries
- **Blob storage**: object storage solution for non-structured data, optimized for big data



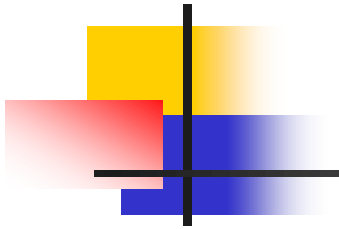
- Azure IoT Hub
  - Service hosted in the cloud that acts as a message hub for bidirectional communication between IoT devices and other modules of the application.
    It allows sending both the **telemetry data from devices to cloud** and **commands to change devices' behaviour from the cloud**.
- Different features:
  - Secure communications: complete control through a specific authentication for each device, different types (SAS, X.509)
  - Built-in Routing functionality with rules to automatically dispatch messages
  - Complete integration with other Azure services to build complete industrial solutions using among the others: Azure analytics, ML and Data Lake storage
  - Configuration of devices using metadata and state information which are stored in the hub and can be queried from the up-stream



- Azure IoT Connectivity

  The connection between devices and the hub is made possible trough **Azure IoT devices SDK**, which are libraries that provides the methods to connect to the platform. Many different languages and transport protocol are supported Languages

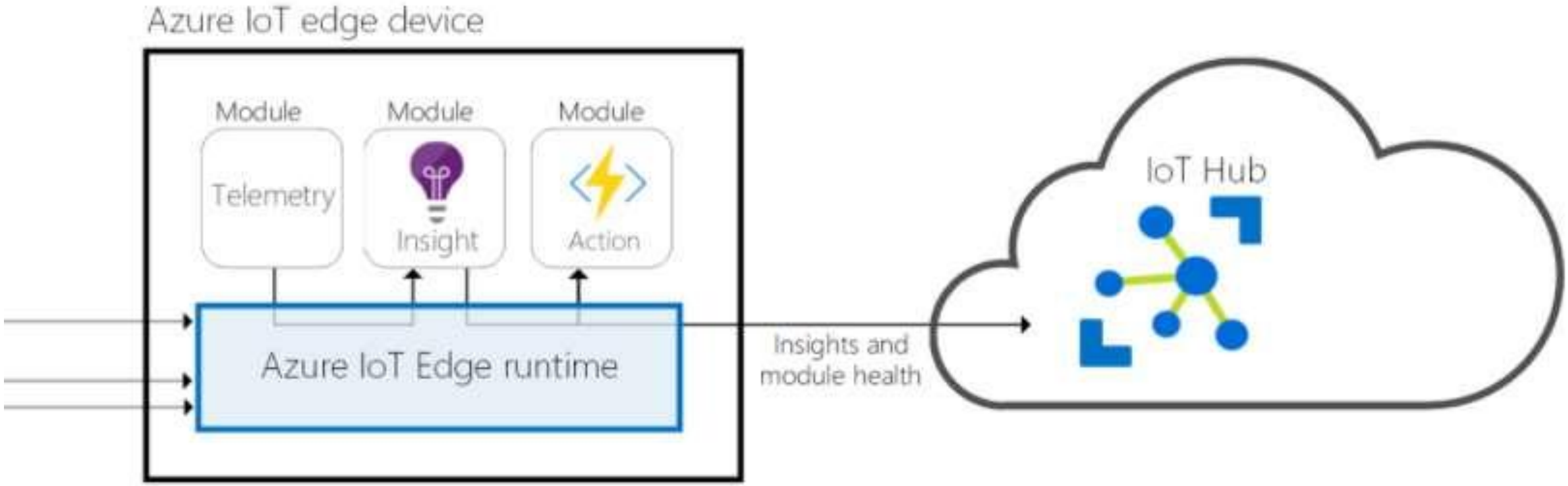
  - C
  - Java
  - Python
- Protocols
  - HTTPS
  - **AMQP**
  - **MQTT**

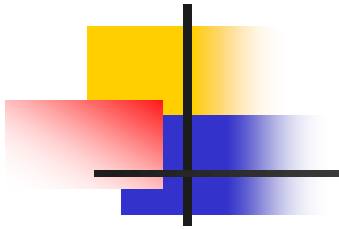


- Azure IoT Edge
  - **Services can run at the edge** of the architecture in order to enable fast data aggregation and analytics, running it closer to the devices and making it possible to respond quicker to anomalies and avoid sending terabytes of data up to the cloud Three main components:
  - **Edge Modules**: **containers** that run Azure services and apps executed at the edge in the device locality.
  - **Edge Runtime**: environment that runs on each device and **manages deployed modules**.
  - **Cloud interface**: to remotely monitor the devices

- Edge modules
  - Smallest unit of computation in Azure IoT Edge, **implemented as Docker compatible containers**. They can contain other Azure services or specific code written and containerized for the edge. Multiple modules can be deployed over the same device in order to communicate and create a more complex data pipeline
- Every module is made of 4 conceptual elements:
  - Image: package containing **the software of the module**
  - Instance: **unit of computation** that runs the image on the device; it is started by IoT Runtime.
  - Identity: information about **credentials and permissions** associated with each module.
  - Twin: **JSON document** that stores metadata regarding the **status of a module and configuration**

- Edge runtime

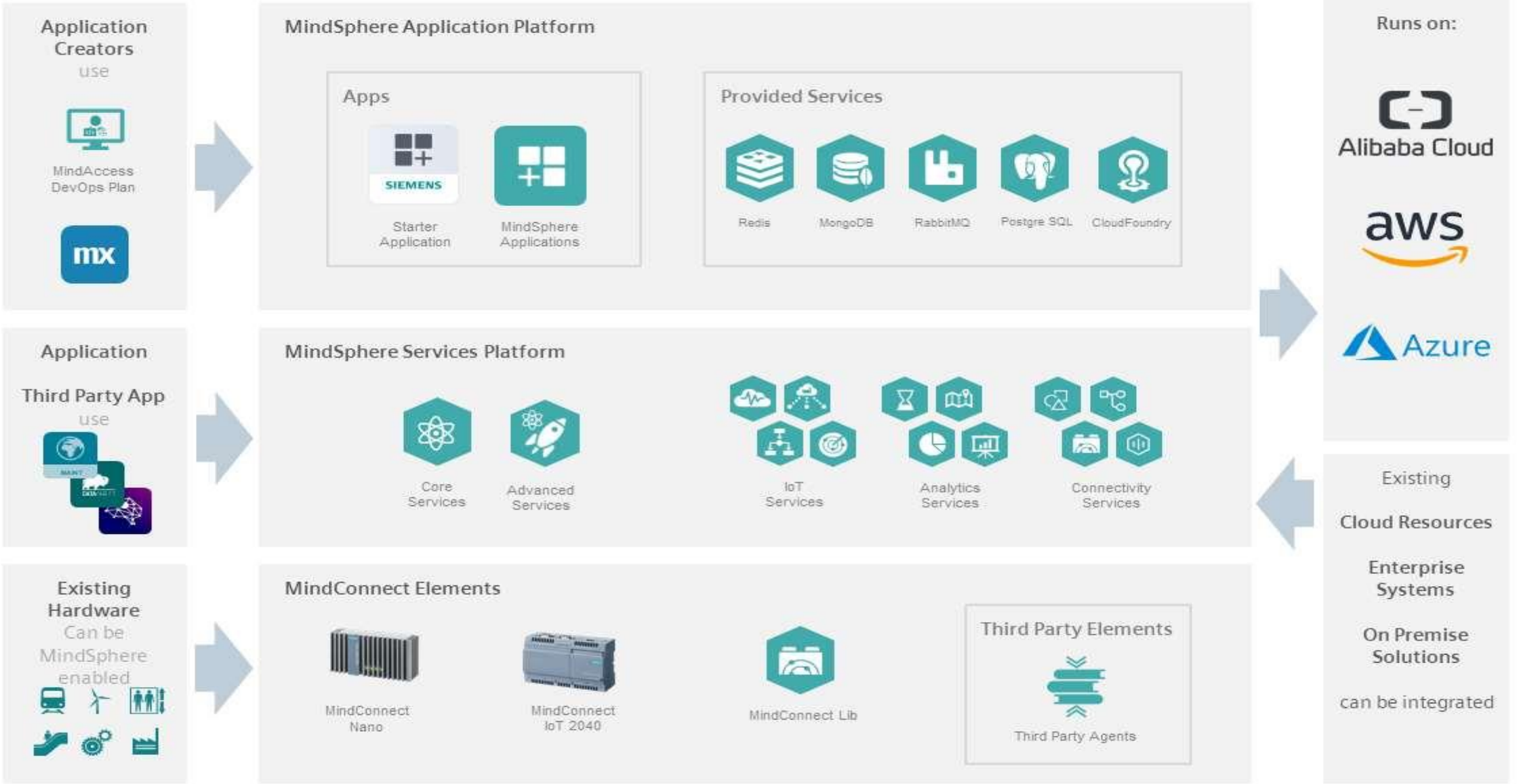




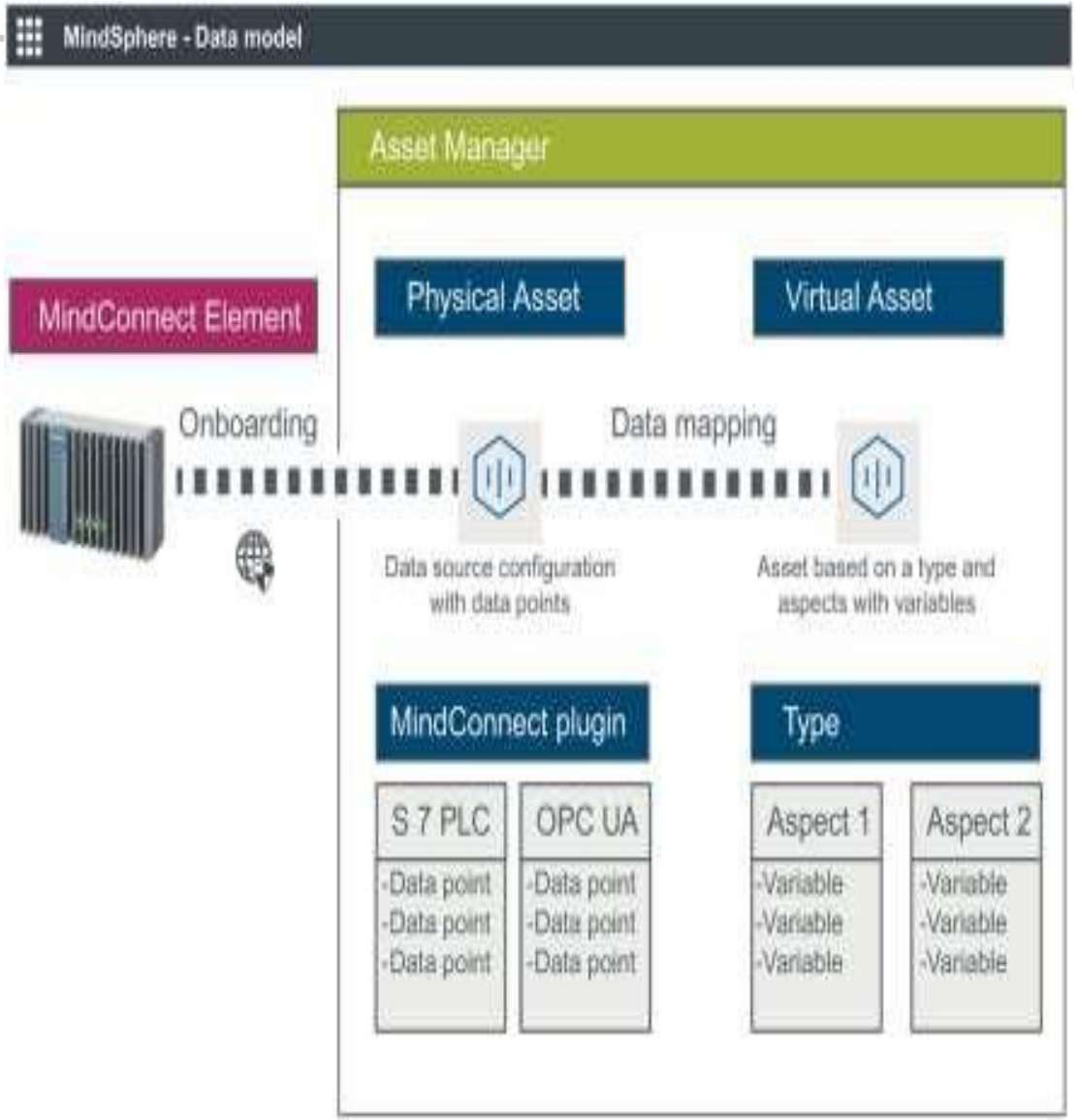
- Edge runtime is made by two modules: **Edge Agent that deploys and monitors other modules** and **EdgeHub** that is responsible for **communication**. The runtime once installed turns a device into an
- Edge device and gives them many features:
  - Ensures that modules are running and report module health to the cloud for monitoring
  - Manages communications between edge devices and normal devices, upstream with the cloud, and downstream with machines

- Siemens MindSphere Platform
- MindSphere is **a complex PaaS** to help developers build industrial IoT solution trough their services and apps.
- MindSphere consists of three distinct layers:
  - **Application system**: environment powered by CloudFoundry, deeply integrated with MindSphere ecosystem and services. Deployment, scaling, and monitoring are some of the features provided.
  - **Services**: support services exposed trough REST API to make development easier.
  - **MindConnect Elements**: different communication possibilities to connect machines and plants to MindSphere regardless of the manufacturer

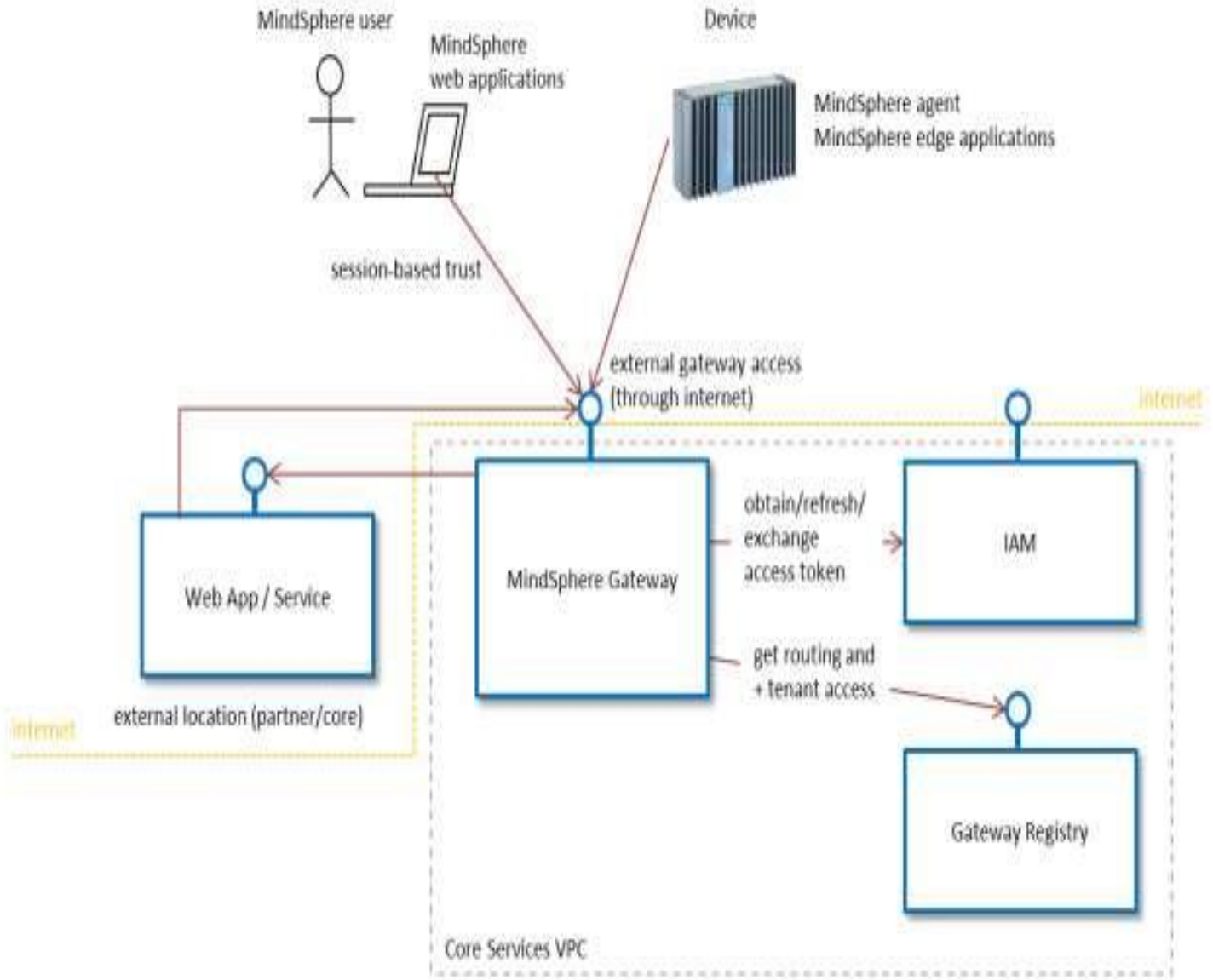
MindSphere Architecture

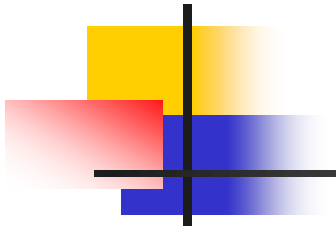


- MindConnect Elements
- **MindConnect** is the layer that **provides connectivity** to/from Mindsphere platform. There are both hardware and software ways to connect:
- MindConnect series and Simatic edge devices are meant to provide secure, reliable and fast connection.
- **They can interact with popular industrial protocols such as OPCUA**, and **MQTT** or use **S7** proprietary protocol. There is always the possibility to build your own connector using specific SDK library for a certain protocol



- MindSphere Gateway
- MindSphere provides **a gateway service** between web application clients, agents and edge applications, and backend services. **Routing has to be defined in the gateway registry** from the provider of services as well as the identity to grant the authorization.





- Mindsphere IoT Services
- **File Service**: provides a basic file management tools with an interface to manage, search and download data. Each file is linked to an asset, has some properties that describe it and can be retrieved after a connection to the IoT gateway. APIs provide CRUD operations on files.
- **Time Series service**: a service similar to File service, but **only for the data type time series**. Time series records are linked to an asset and an aspect and consist of a timestamp, one or more values and a quality indicator for variables.
- **Aggregation service**: creates aggregated **summaries of time series data and interfaces to read them**. It is particularly useful to reduce the amount of data sent to cloud for analysis. Once chosen a time interval to aggregate provides standard aggregate information such as min, max, average, tot number of points

- Mindsphere Connectivity Services
- **Agent management** service: provides API to create, update, delete and manage the **rights of agents**. **Agents are the primary actors that perfom actions on data in Mindsphere**, when created they are assigned an access token which is the key to get authenticated and autorized to communicate
- **MindConnect API**: **API to send data securely** from the shop floor devices to Mindsphere. Only agents that supports HTTP processing, TLS and JSON parsing have the requirements to communicate. It allows also to set the configuration for both the data source from which retrieve the data and the data model to be shared
- OPC UA PubSub Service: specific module that provides **MQTTbased API to agents** to upload data according to OPC UA specification