



Internet of Things and Services

Service-oriented architectures

IoT cloud platforms and services

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Internet of Things and Services
Computing and informatics

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IoT system architecture

☼ Cloud-centric

- ☒ Data from IoT devices such as sensors are streamed to a data center where all the applications that do the analytics and decision making are executed, using real-time and past data from one or more sources.
- ☒ Servers in the cloud control the edge devices too.

☼ Device-centric

- ☒ All the data is processed in the device (sensor nodes, mobile devices, edge gateways), with only some minimal interactions with the cloud for firmware updates or provisioning (*Edge* and *Fog Computing*).

☼ Distributed (*computing continuum*)

- ☒ Stretch the analytics and data processing across Cloud and Devices, leveraging the resources at each end seamlessly, **today IoT cloud platforms**



IoT cloud platforms

- IoT cloud platforms bring together capabilities of IoT devices and Cloud Computing delivered as a service over an end-to-end to platform.
- In this age, where billions of devices are connected to the Internet, we see increasing potential of tapping Big data acquired from these devices and processing them efficiently through various applications.
 - IoT devices are devices with multiple sensors connected to the cloud, typically via gateways.
 - There are several IoT Cloud Platforms in the market today provided by different service providers that host wide ranging applications.
 - These can also be extended to services that use advanced machine learning algorithms for predictive analysis especially in disaster prevention and recovering planning.



IoT cloud platform

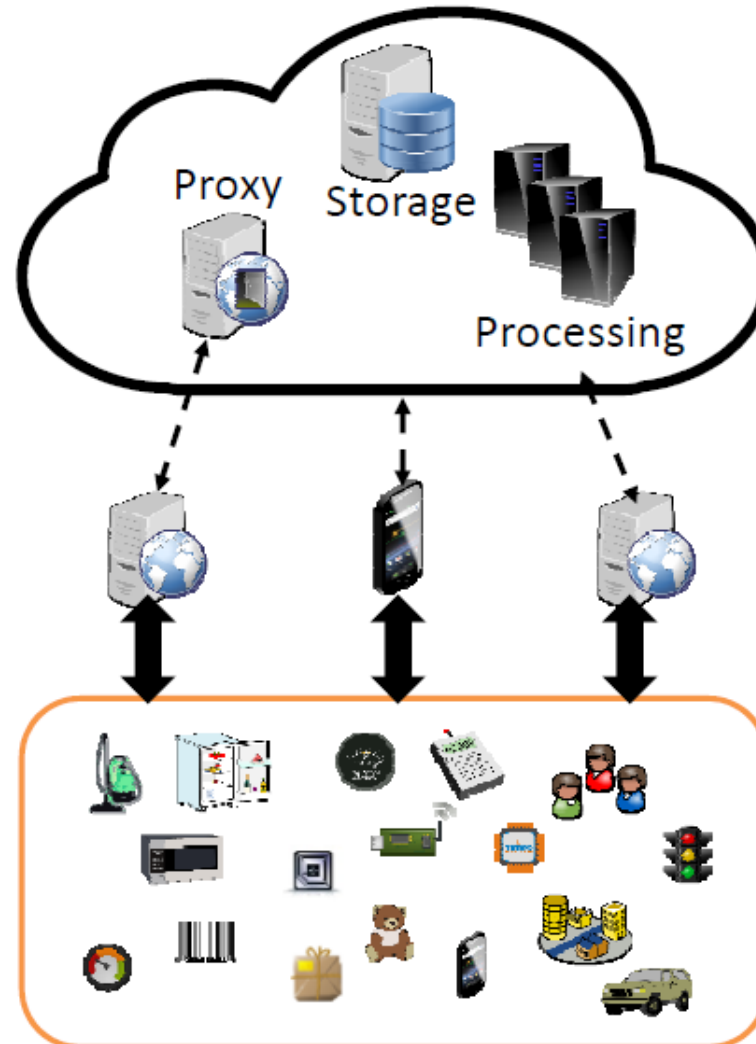
- ✿ An IoT cloud platform may be built on top of generic clouds such as those from Microsoft, Amazon, Google, or IBM.
- ✿ Network operators such as AT&T, Vodafone and Verizon may offer their own IoT platforms with stronger focus on network connectivity.
- ✿ Platforms could be vertically integrated for specific industries such as oil/gas, logistics and transportation, etc.
- ✿ Device manufacturers such as Samsung (ARTIK Cloud) and SAP (Leonardo) offer their own IoT cloud platforms.
- ✿ In most cases, typical features include connectivity and network management, device management, data acquisition, processing, analysis and visualization, application enablement, integration and storage.

IoT cloud platform - Features

- ✚ Middleware and the infrastructure that enables end-users to interact with smart objects
- ✚ Based on different architectures
 - ✚ Mostly cloud-based and centralized
 - ✚ Decentralized with edge/fog computing nodes and infrastructure
- ✚ Features
 - ✚ Data storage
 - ✚ Data processing/Analytics
 - ✚ Visualization of data
 - ✚ Device management and Discovery
 - ✚ Support different communication protocols
 - ✚ Support heterogeneity
 - ✚ Security and privacy



Remote Cloud-based processing



Connectivity nodes & Embedded processing

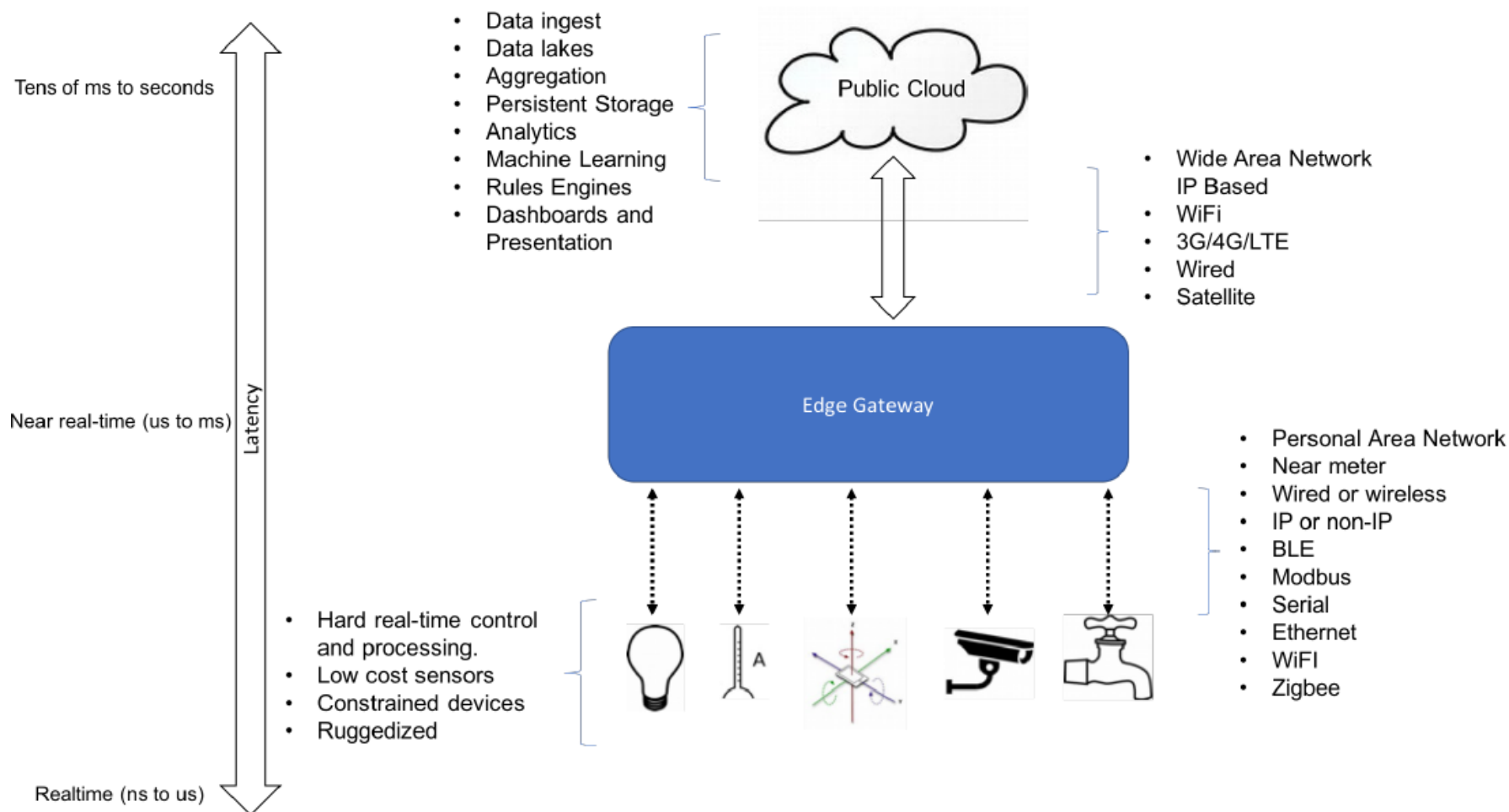
Sensing and smart devices

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Cloud architecture for IoT - Constraints

☀ Latency over edge-fog-cloud infrastructure



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IoT & Big Data processing

- ❁ Enormous amounts of unstructured data
 - ❁ In Zetabytes (10^{21} bytes) by 2020
 - ❁ Has to be properly stored, analyzed and interpreted and presented
- ❁ Big data acquisition and analytics e.g. with Apache MapReduce/Hadoop and Spark
- ❁ In addition to Big data, IoT mostly deals with Big streaming data
 - ❁ Message queues such as Apache Kafka to buffer and feed the data into stream processing systems such as Apache Storm
 - ❁ Apache Spark Streaming, Flink, Heron,...
- ❁ IoT platforms should have the ability to massively scale to handle real-time event processing of large volumes of data generated by various devices and applications.

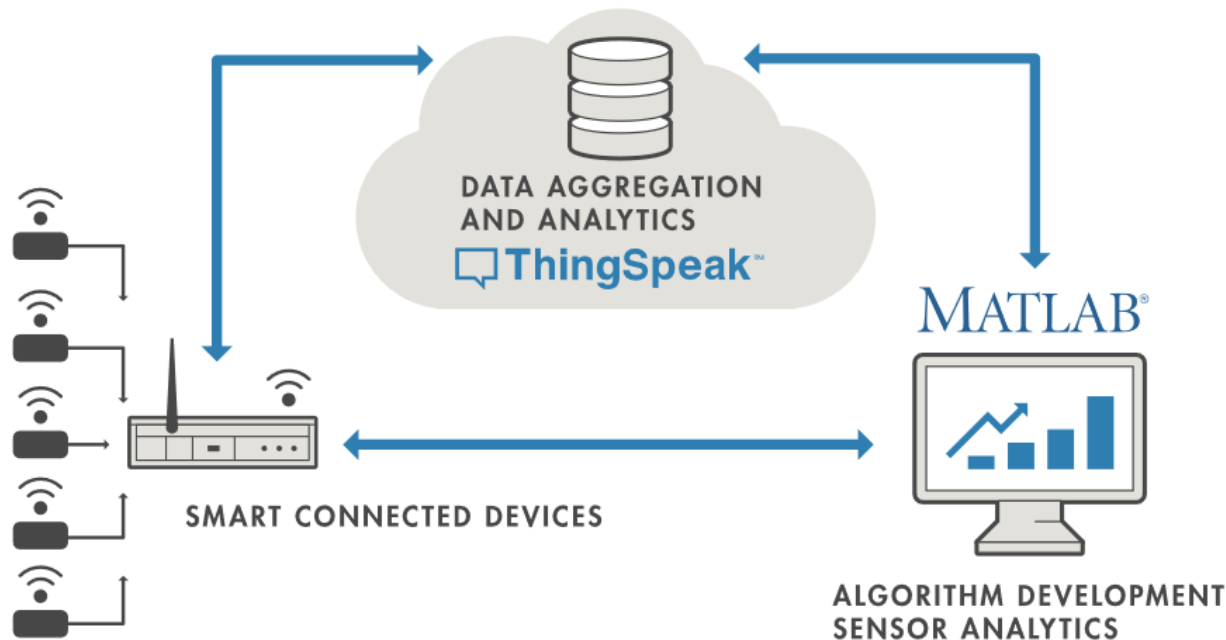


IoT Platforms – Open source

- ⊗ ThingSpeak
 - ⊠ <https://thingspeak.com/>
- ⊗ Thinger.io
 - ⊠ <https://thinger.io/>
- ⊗ Mainflux
 - ⊠ <https://www.mainflux.com/>
- ⊗ FIWARE
 - ⊠ <https://www.fiware.org/>
- ⊗ ThingsBoard
 - ⊠ <https://thingsboard.io/>
- ⊗ SiteWhere
 - ⊠ <https://sitewhere.io>
- ⊗ Kaa IoT
 - ⊠ <https://www.kaaproject.org/>
- ⊗ ...

ThingSpeak

- IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud
- ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak



https://thingspeak.com/pages/learn_more?Education



ThingSpeak - Features

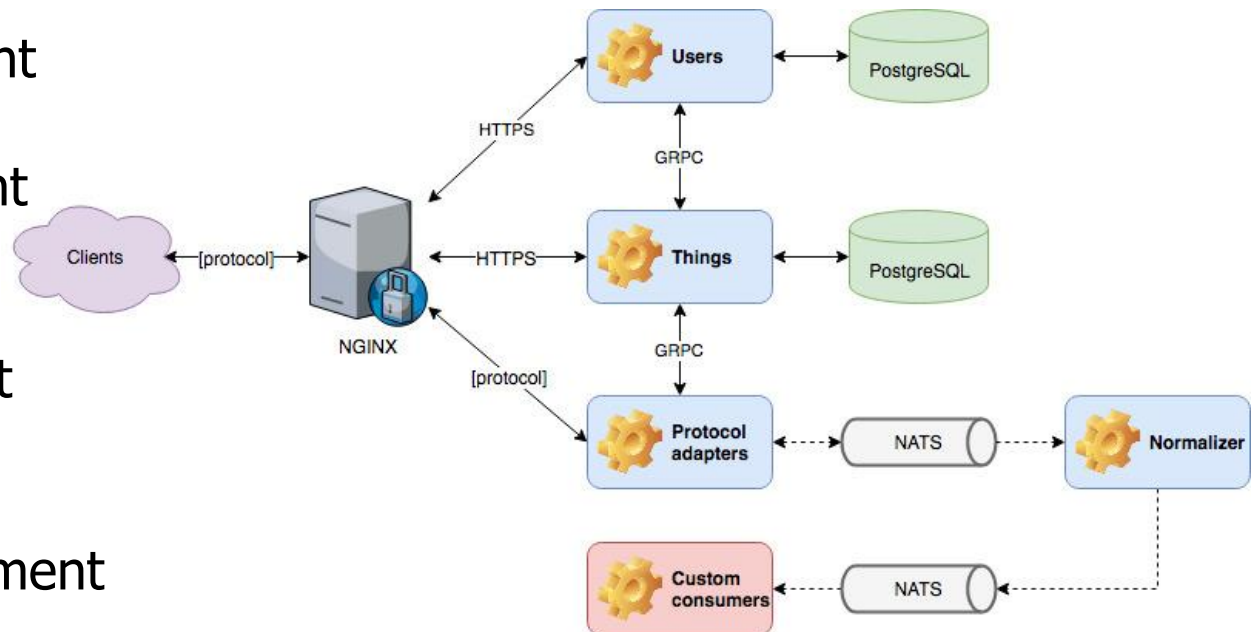
- ✿ Prototyping and building IoT systems without setting up servers or developing web software
- ✿ Can easily configure devices to send data to ThingSpeak using popular IoT protocols
 - ✦ Updates of channel feed via the REST and MQTT APIs
- ✿ Visualization of sensor data in real-time
- ✿ Live data stream aggregation and analytics
- ✿ Aggregate data on-demand from third-party sources
- ✿ Use the power of MATLAB to make sense of the IoT data
- ✿ IoT analytics automatically based on schedules or events
 - ✦ TimeControl function that enables event-triggered alerts

Mainflux

- Mainflux is modern, scalable, secure open source and patent-free IoT cloud platform written in Go
- Built as a set of microservices containerized by Docker and orchestrated with Kubernetes, Mainflux IoT platform serves as a software infrastructure and middleware

- Provides:

- Device management
- Data aggregation and data management
- Connectivity and message routing
- Event management
- Core analytics
- User Interface
- Application enablement

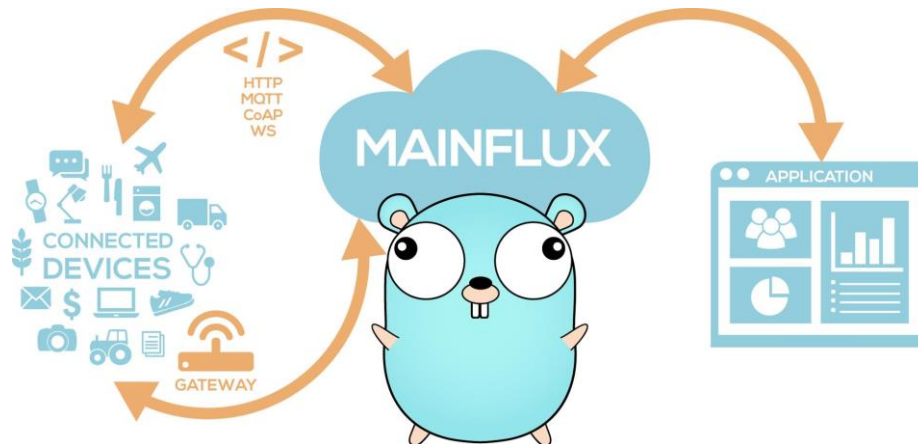


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Mainflux - Features

- ✿ Protocol bridging (i.e. HTTP, MQTT, WebSocket, CoAP)
- ✿ Device management and provisioning
- ✿ Fine-grained access control
- ✿ Platform logging and instrumentation support
- ✿ Container-based deployment using Docker
- ✿ <https://mainflux.readthedocs.io/en/latest/>





IoT cloud platforms and services - - Commercial

- ✚ Amazon Web Services IoT
- ✚ IBM Watson IoT Platform
- ✚ Microsoft Azure IoT Hub
- ✚ Google Cloud IoT
- ✚ Oracle Integrated Cloud for IoT
- ✚ SAP Cloud Platform for the Internet of Things
- ✚ Cisco Jasper Control Center
- ✚ GE Predix IoT
- ✚ Salesforce IoT
- ✚ HPE Universal IoT platform
- ✚ PTC ThingWorx Industrial IoT Platform
- ✚ Xively
- ✚ Carriots
- ✚ ...

IoT cloud platforms - Review

- Amazon Web Services (AWS), Microsoft Azure and Google Cloud Platform (GCP) are generic cloud platforms that have IoT-specific components.

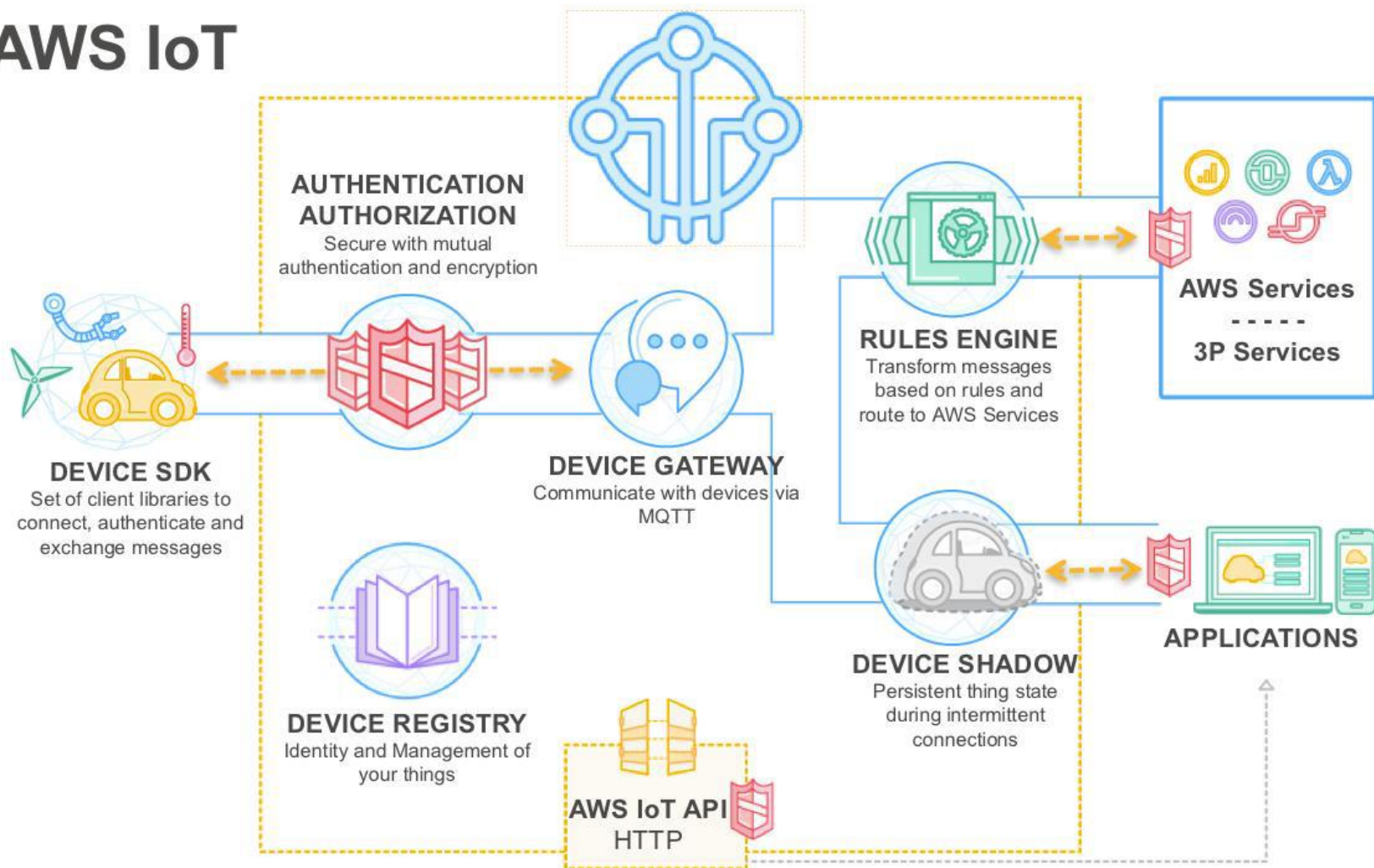
	Amazon Web Services	Microsoft Azure	Google Cloud Platform
IoT SaaS		Azure IoT Central	Android Things Console
IoT PaaS	AWS IoT Core	Azure IoT Solution Accelerators (formerly Azure IoT Suite)	Cloud IoT Core
Key IoT Services	AWS IoT Core Greengrass Core	Azure IoT Hub Azure IoT Edge	Cloud IoT Core
SDKs	AWS IoT Device SDK	Device SDKs Service SDKs	Weave SDK ¹ Android Things SDK
Messaging Support	HTTPS MQTT, WebSocket	HTTPS MQTT, WebSocket AMQP CoAP (via Azure IoT Protocol Gateway Framework)	HTTPS MQTT gRPC (via Cloud Pub/Sub)
Embedded OS	Amazon FreeRTOS	Windows 10 IoT	Android Things

0. Updated in June 2018. At Devopedia.org.

1. No update to Weave SDK since 2016.

Amazon IoT platform

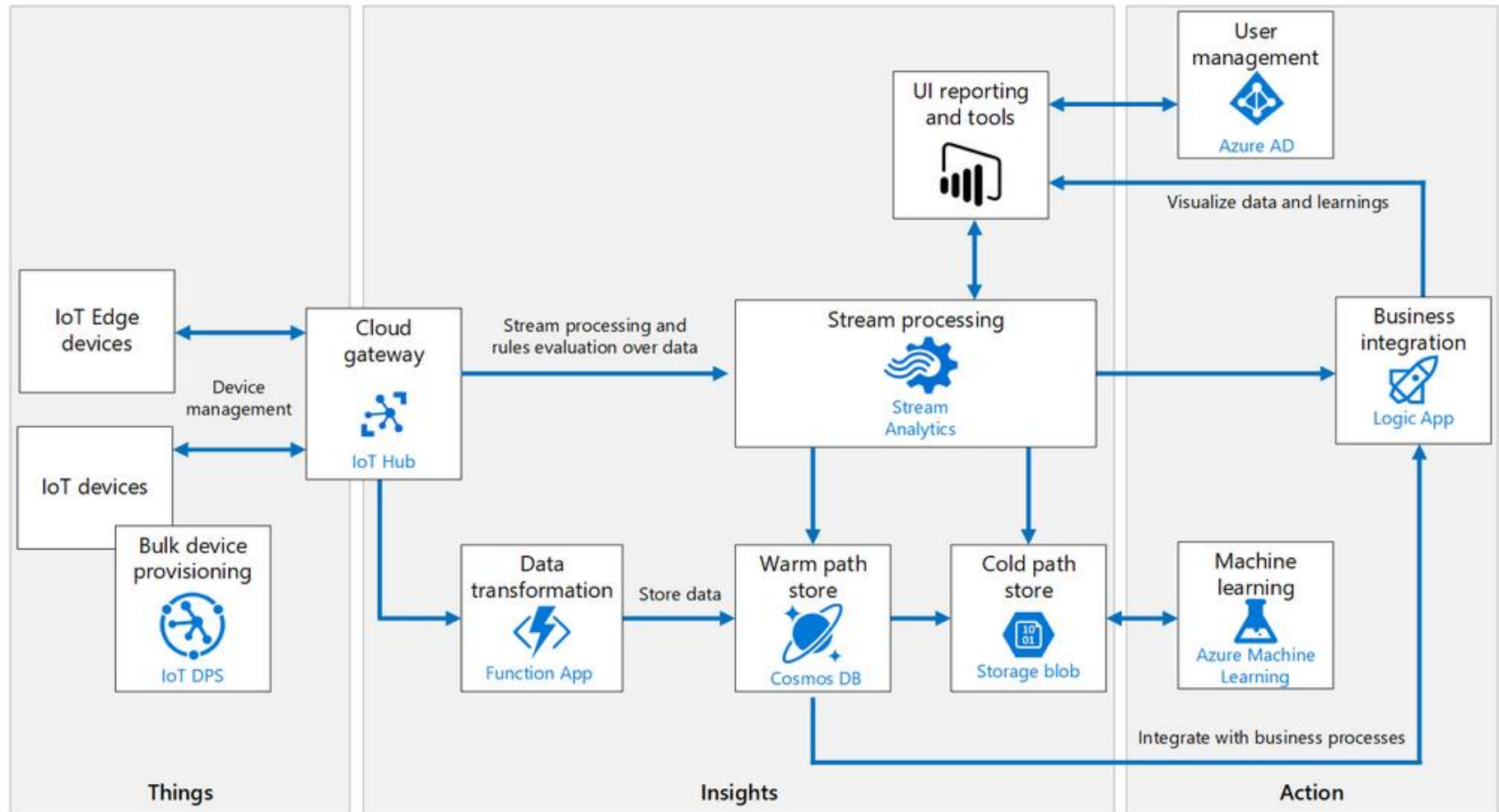
AWS IoT



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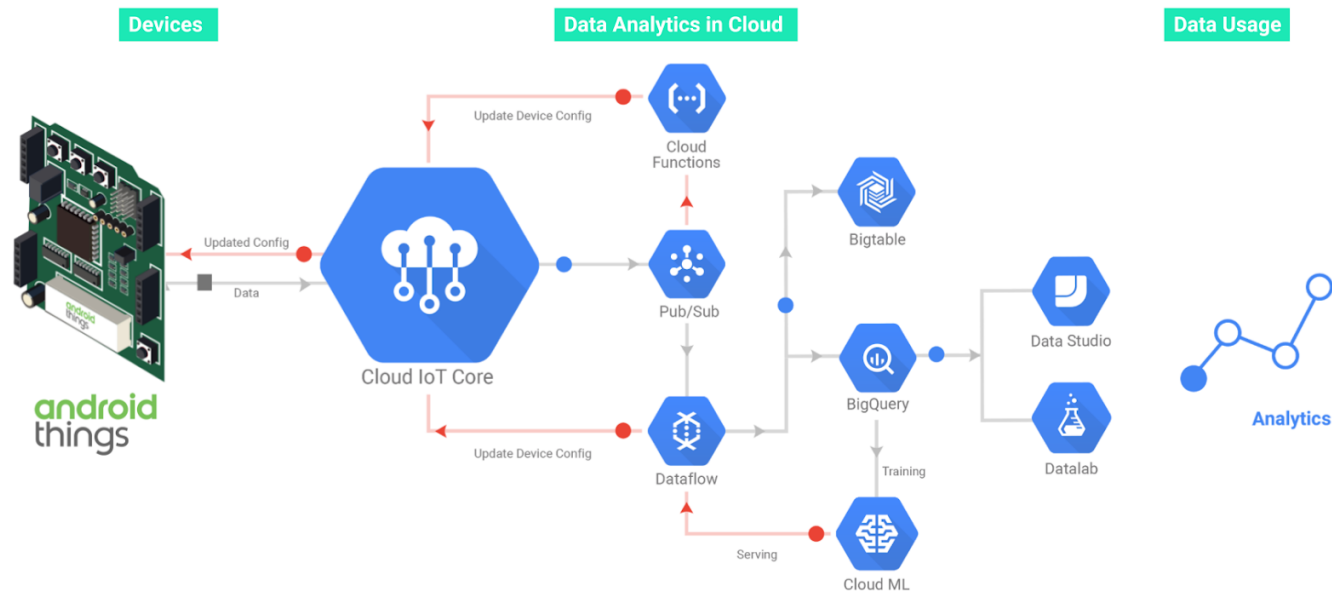
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Azure IoT architecture

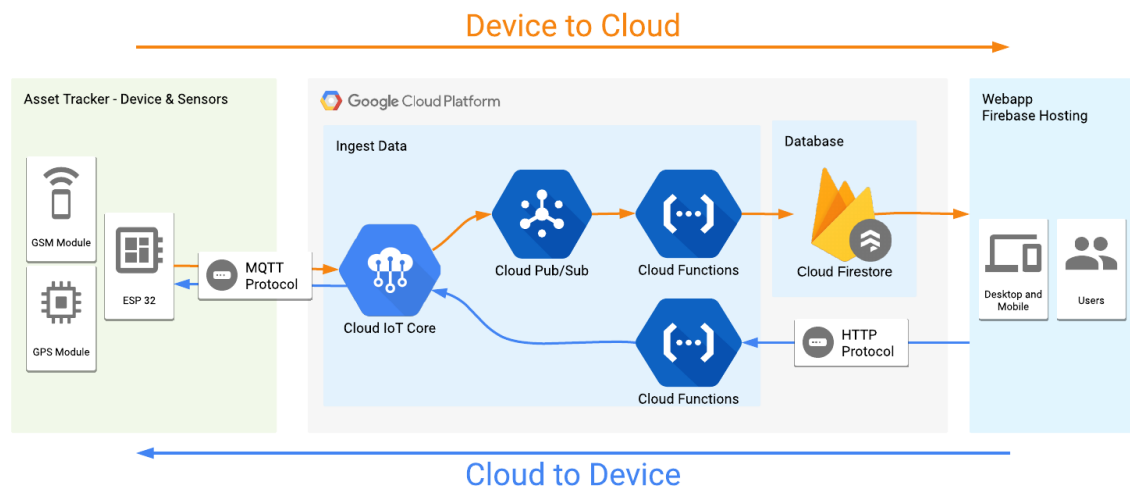


Google Cloud IoT

Services



Data & control flow





Everything as a Service - XaaS

Types of backend architecture

❁ Monolith

- ❁ The entire backend is deployed in one place so it's very heavy and difficult to scale for big apps.

❁ Microservices

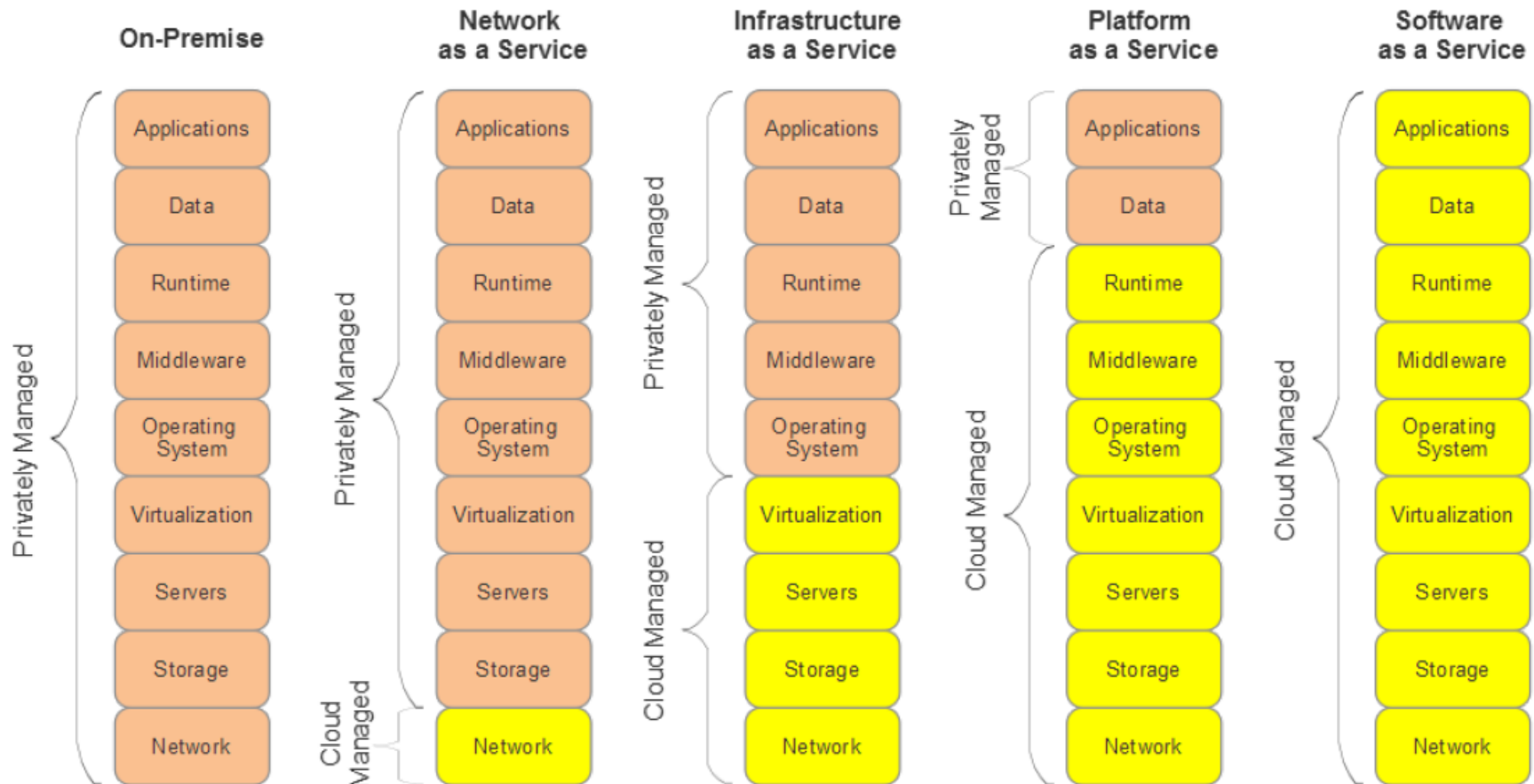
- ❁ The backend is divided into many (it depends mostly on the app size but usually it's from 10 to 80) microservices that can be deployed on different physical servers, each microservice should reflect a business feature e.g., authentication, payments, auctions, emails or inventory.

❁ Functions

- ❁ In contrary to monolith and microservices they are not daemons (running all the time) but only executed within max a few seconds when there is a need; an example is AWS Lambda

Cloud service model

✿ NaaS, IaaS, PaaS, SaaS,...



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Everything as a Service (XaaS)

- ✿ **DaaS** - Data as a Service
- ✿ **DBaaS** - Database as a service
- ✿ **FaaS** - Function as a Service
- ✿ **MLaaS** - Machine Learning as a Service
- ✿ **AaaS** - Analytics as a Service
- ✿ **SECaaS** or **SaaS** - Security as a service (Cloudblic, CloduFlare)
- ✿ **RaaS** - Robot as a service (AWS RoboMaker, Google Cloud Robotics Platform)
- ✿ **BaaS** - Business as a Service
- ✿ ...



Data as a Service (DaaS)

✿ DaaS

- ✿ Data as a Service is similar to SaaS, it can be even considered as a subset of SaaS. More specifically, it's an **(usually HTTP) API, which returns some data** e.g., currency exchange rates, sports results or weather forecasts.
- ✿ Examples: Facebook APIs and Google APIs, such as Google Maps, Google Translate API or AccuWeather.
- ✿ Free APIs: **RapidAPI** – <https://rapidapi.com/>, **ProgrammableWeb** - <https://www.programmableweb.com/>, <https://public-apis.xyz/>, <https://public-apis.io/>, <https://any-api.com/> and an API gateway - **Kong** - <https://konghq.com/>

✿ DBaaS

- ✿ Database as a service – it's a platform which **hosts our database providing backups, clustering, and high availability**. The most popular DBaaS are Amazon Aurora, Amazon DynamicDB, mLab, IBM Cloudant and MongoDB Atlas.



Function as a Service (FaaS)

- Function as a Service is even simpler than PaaS.
- As the name suggests, it's based on the functions which can be triggered by a given event, so it's an **event-based architecture**.
- The level of simplicity is so high that it's called a **serverless architecture**.
- The developer just writes a function and doesn't have to ponder about topics such as deployment, server resources, scalability,...
- Examples: AWS Lambda, Google Cloud Functions, Microsoft Azure Functions, OpenFaaS, OpenWhisk,...

Machine Learning as a Service

- ➊ MLaaS is a set of services that offer ready-made, slightly generic machine learning tools that can be adapted by any organization as a part of their working needs.
- ➋ These services range from facial recognition, natural language processing, predictive analytics and deep learning, data visualisation, through a slew of application programming interfaces, among others.
- ➌ The MLaaS algorithms are used to find pattern in data; mathematical models are built using these patterns and the models are used to make predictions using new data.
- ➍ Amazon's Amazon ML, Microsoft's Azure ML, IBM's Watson and Google Cloud ML are some of the leading providers of MLaaS services.

MLaaS services

Machine learning

- AWS Machine Learning (SageMaker), Azure Machine Learning Studio, IBM Watson Machine Learning, Google Cloud AI & AutoML, BigML (<https://bigml.com/>), Dataiku Data Science Studio (<https://www.dataiku.com>)
- Open source: [Apache PredictionIO](https://predictionio.apache.org/) <https://predictionio.apache.org/>

Natural language processing

- Amazon Comprehend, Azure Language API, Google Cloud Natural Language API, IBM Watson Natural language understanding

Speech recognition

- Amazon Transcribe, Azure Cognitive Services (Speech), Google Dialogflow, IBM Watson (Speech to Text, Text to Speech)

Computer vision

- Amazon Rekognition, Azure Cognitive Services (Vision), Google Cloud Vision API, IBM Watson Visual Recognition API



Service integration, orchestration and workflow automation

✿ IFTTT (If This Then That)

- ✿ Service platform that connects apps, devices and services from different developers in order to trigger one or more automations involving those apps, devices and services, creating chains of simple conditional statements, called applets.
- ✿ An applet is triggered by changes that occur within other web services such as Gmail, Facebook, Telegram, Instagram, or Pinterest
- ✿ <https://ifttt.com/>

✿ Zapier - <https://zapier.com>

✿ Microsoft Flow - <https://flow.microsoft.com>

✿ Camunda - <https://camunda.com/>

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 - ❁ <https://www.devteam.space/blog/10-best-internet-of-things-iot-cloud-platforms/>