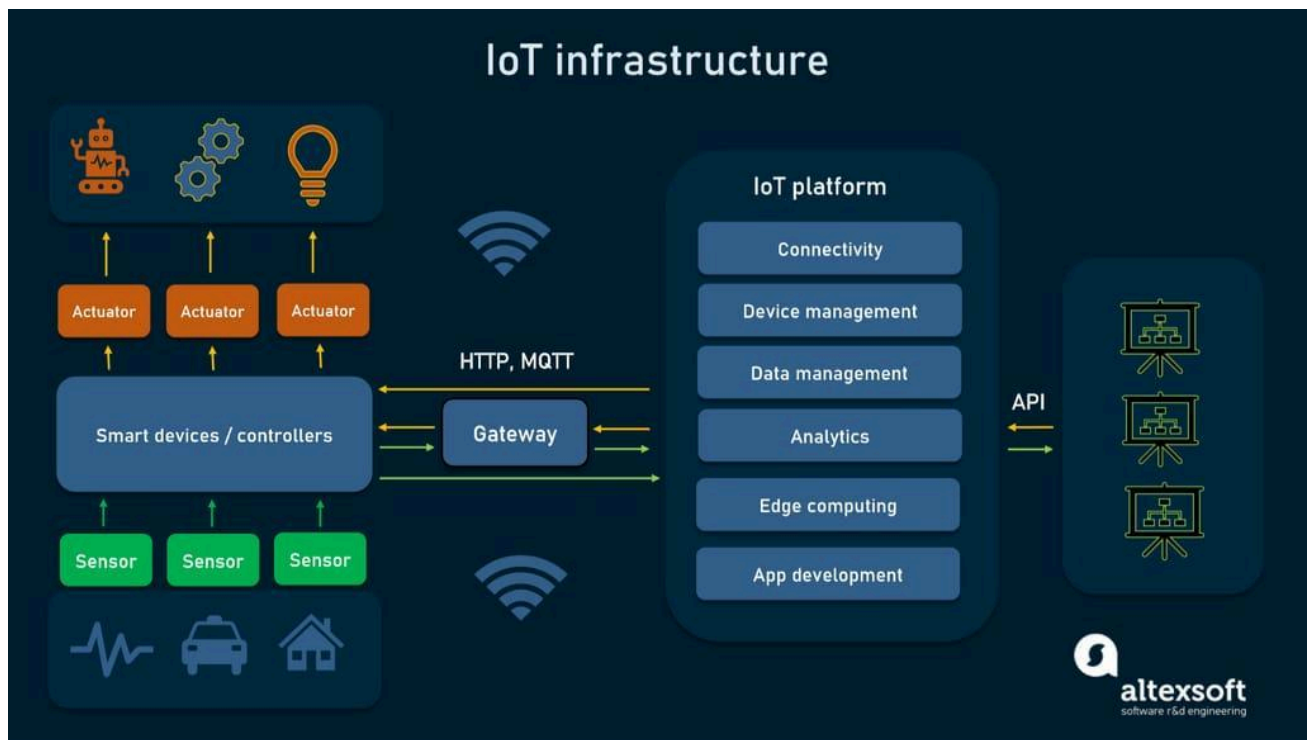# IoT Cloud/Analytics Platforms

IoT architecture layers

- perception layer (hardware components such as sensors, actuators, and devices),
- transport layer (networks and gateway),
- processing layer (middleware or IoT platforms), and
- application layer (software solutions for end users).

How an IoT system works.

Perception layer: IoT hardware

The hardware or "things" layer includes the following gears that work with signals from the physical world.

Transport layer: networks and gateways

The transport layer is responsible for smooth and secure data transmission from perception layer to processing layer.

Application layer: software solutions for users

- IoT software solutions allow end users to gain data insights, monitor and control devices, and, generally, manipulate the physical world through the IoT platform from computers and / or smartphones.

- Applications can be built on top of the IoT platform or integrate with it through APIs

Processing layer: cloud middleware or IoT platforms

IoT platform or middleware that actually drives IoT, enabling you to get all components and data streams connected. On the **one side, it links to gateways or devices,** and on the **other side integrates with third-party applications and systems via APIs**.

- **connectivity** or ensuring smooth data streaming and interactions between all IoT components;

- **device management**, which enables you to control and configure each piece of hardware in the IoT network as well as update software running on devices and gateways;

- **data management**, including data collection, processing, and storage;

- **data analysis** for extracting valuable patterns with machine learning, predictive analytics, and other methods;

- **visualization** or displaying data findings in the form of charts, graphs, 2D or 3D models; digital twin or creating the virtual representation of a device;

- **IoT app development** — platforms provide a workspace with a set of tools and templates to speed up app designing; and

- **edge / fog computing** — the practice of processing and storing data on devices, microcontrollers, gateways, and other IoT nodes to reduce burden for cloud servers.

The list of the top five, fully-fledged solutions are as follows:

- Amazon Web Service (AWS) IoT platform,

- Cisco IoT,

- Google Cloud IoT,

- IBM Watson IoT platform, and

- Microsoft Azure IoT.

Key IoT middleware at a glance

	Communication protocols	Key offering and its main functions	Edge computing solutions	Top-3 use cases
amazon web services	HTTP MQTT WebSockets	**AWS IoT Core:** ✓ Connectivity ✓ Authentication ✓ Rules engine ✓ Development environment	**FreeRTOS** edge operating system **IoT GreenGrass** edge computing platform	✓ Smart city ✓ Connected home ✓ Agriculture
CISCO	MQTT	**Cisco IoT Control Center** ✓ Mobile connectivity ✓ eSIM as a service ✓ Machine learning to improve security	**Cisco iOX** edge development platform **Cisco Edge Intelligence**	✓ Connected vehicles ✓ Manufacturing ✓ Smart city
Google Cloud	HTTP MQTT	**Google Cloud IoT Core** ✓ Connectivity ✓ Device management	**Edge TPU chip** enabling deployment AI at the edge	✓ Energy ✓ Smart parking ✓ Transportation and logistics
IBM Watson	HTTP MQTT	**IBM Watson IoT Platform** ✓ Connectivity ✓ Device management ✓ Real-time analytics ✓ Blockchain	**IBM Edge Application Manager** platform	✓ Manufacturing ✓ Agriculture ✓ Smart buildings
Microsoft Azure	HTTP MQTT AMQP over WebSockets	**Azure IoT Hub** ✓ Connectivity ✓ Authentication ✓ Device monitoring ✓ Device management ✓ IoT Edge	**IoT Edge** as an integral part of IoT Hub	✓ Healthcare ✓ Retail ✓ Manufacturing

altexsoft
software r&d engineering

AWS IoT Platform: the best place to build smart cities

Key use cases: smart city, connected home, agriculture, healthcare.
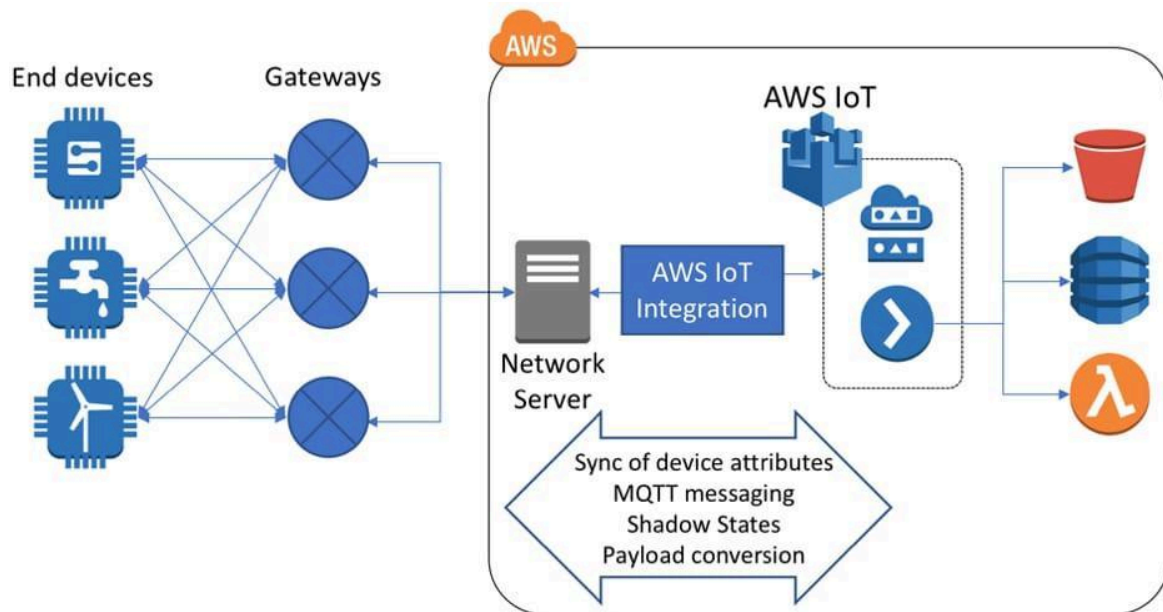
AWS IoT infrastructure. Source: AWS

AWS IoT Core is the IoT product suite from Amazon.

✔ AWS IoT Core is a managed cloud service that lets connected devices easily and securely interact with cloud applications and other devices.

✔ With AWS IoT Core, your applications can keep track of and communicate with all your devices, all the time, even when they aren't connected.

✔ AWS IoT Core also makes it easy to use AWS and Amazon services like AWS Lambda, Amazon Kinesis, Amazon S3, Amazon SageMaker, Amazon DynamoDB, Amazon CloudWatch, AWS CloudTrail, Amazon QuickSight, and Alexa Voice Service to build IoT applications that gather, process, analyze and act on data generated by connected devices, without having to manage any infrastructure

✔ A feature of IoT Core is **Device Shadow,** which stores the current or desired state of every device. So if the IoT device is offline or busy, cloud applications can still change its configuration or send

commands to it. As soon as the device is back online, it synchronizes its final state with updates.

✔ Support of Embedded C, C++, JavaScript, and Python. A visual drag-and-drop tool called **IoT Things Graph** that simplifies building workflows across IoT components.

Additional AWS IoT control services

- AWS IoT Device Management allows you to remotely organize, track, control, update, and scale large and diverse devices.
- AWS IoT Device Defender continuously checks IoT configurations against security requirements and sends alerts when spotting any gaps.
- AWS IoT Events is designed to identify complicated changes in equipment behaviour across thousands of devices and react to them based on predefined rules.
- AWS Site Wise comes in handy when you need to collect and organize data at an industrial level. The service connects to a manufacturer's equipment through a gateway, gathers and pre-processes data, and then sends it to the AWS Cloud.
- AWS IoT 1-Click is used to make a group of devices perform specific actions (like sending alert messages) at a button click.

AWS IoT Analytics

AWS IoT Analytics, automatically collects and cleans data before transmitting it to a time-series storage for further analysis. IoT Analytics has templates to build predictive maintenance models. It easily integrates with

- Amazon QuickSight, a business intelligence service to visualize data
- Jupyter Notebook that provides powerful tools for machine learning and advanced statistical analysis, and

AWS main advantage is its Edge software that is **FreeRTOS** and **Greengrass**. FreeRTOS is an open-source microcontroller operating system that makes it easy to program, deploy, back up, connect, and manage small, low power edge devices. FreeRTOS is compatible with all major microcontrollers and many IoT devices.

Features:

- **AWS IoT Device SDK** — quickly and easily connect your hardware device or mobile application to the AWS IoT Core.

- **Device Gateway —** manages all active device connections and applies semantics to multiple protocols to ensure devices can communicate securely and efficiently with the AWS IoT core.

- **Message Broker** is a high-throughput pub/sub message broker that securely transmits low-latency messages from all your IoT devices and applications.

- **Authentication and Authorization** so there will be no exchange of data between the data and AWS IoT Core without a proven identity.

- **Rule Engine** can be used to create IoT applications that can collect, process, analyze, and process data from globally connected devices without having to manage infrastructure.

  ****

Cisco IoT: the edge computing leader with the largest fleet of connected cars

Key use cases: *connected vehicles, manufacturing, smart cities, utilities.*

Best known for its networking equipment, Cisco is currently leading the IoT market in terms of edge infrastructure development. The very term *fog computing* or processing data on edge devices (controllers, gateways, routers, and so on) was coined by Cisco experts. The company is heavily investing in software and hardware to distribute workloads across multiple nodes and minimize latency of the growing IoT-systems.

Over 67,000 customers take advantage of two Cisco IoT platforms: **IoT Control Center (ex-Jasper)** for enterprise-grade companies, with the focus on cellular connectivity, and **Kinetic Operations Platform** for both cellular and non-cellular devices.

Cisco IoT Control Center

This platform supports various of RTOS/IoT OS that work with Debian Linux OS, providing immediate turnkey support for leading device manufacturers such as Intel and Microchip. Cloud features also trigger automated changes based on real-time events through workflows.

Features:

- **Predictive maintenance** — make the prediction automatically when the equipment needs servicing.

- **Real-time tracking** — assets tracks valuable assets in real-time and performs complex analysis and machine learning of captured data.

- Logistics and Supply Chain Management Fleet management, inventory tracking, cargo integrity monitoring.

- Provides integration with other Google services.

The connectivity capabilities such as:

- **machine learning.** The Control Center analyzes <u>3 billion events</u> a day to improve connectivity management, identify anomalies, and proactively address issues, increasing security.

- **eSIM as a service.** This tool simplifies SIM portability between different operators worldwide. The eSIM service allows for creating the local profile of a SIM card embedded in an IoT device

- **5G readiness.** The platform already supports 5G non-standalone (NSA) resting upon the existing 4G infrastructure.

- **Cisco Kinetic IoT operations platform**

It works with some third-party products recommended by Cisco.
**The Gateway Management Module** monitors industrial gateways and enables their remote configuration.
The Edge and Fog Processing Module pushes selected data management processes from the cloud to nodes and devices closer to data sources.
The Data Control Module performs the opposite function and moves data from devices to cloud-based applications, ensuring that the right information will reach the right place.

Edge computing stack

Cisco IOx is a Linux-based environment to manage fog applications over the network.
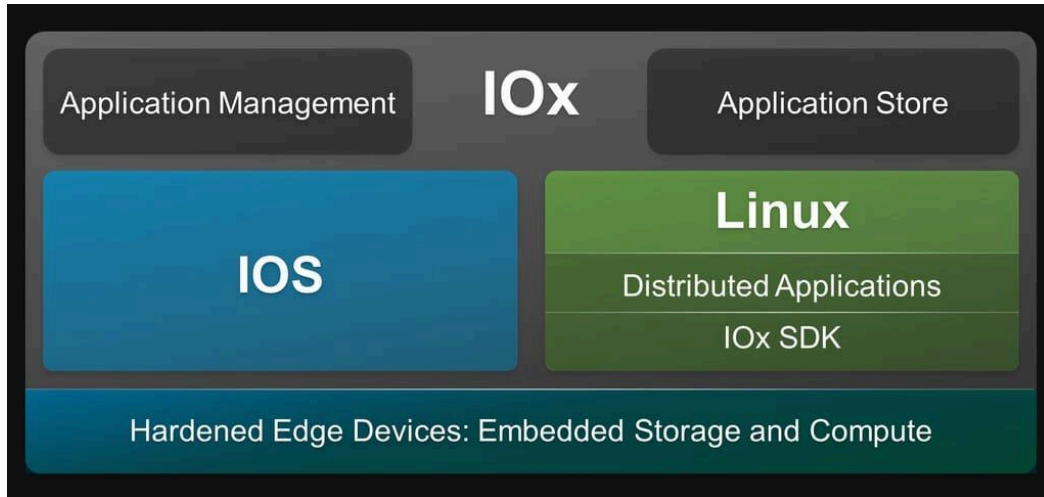
Cisco Edge Intelligence is designed to extract data from nodes, analyze and then send it to the right applications for further processing and getting insights. Cisco is collaborating with Microsoft to combine Edge Intelligence with Azure IoT Hub for smooth data transferring from IoT devices to apps in the Azure cloud.

****

Google Cloud IoT: driving transportation with Google Maps

Key use cases: energy, manufacturing, logistics and transportation, smart cities.

The Google Cloud IoT platform is a complete set of tools to connect, process, store, and analyze data both at the edge and in the cloud.

The platform consists of scalable, fully-managed cloud services; an integrated software stack for edge/on-premises computing with machine learning capabilities for all your IoT needs.

It is powerful enough to manage data from millions of devices. Teamed up with other Google Cloud services, it is already optimizing operations in manufacturing, building, energy, and other sectors.

Google Cloud IoT Core

Google IoT Core contains two modules. **Device Manager** enables you to set up, authenticate, configure, and control individual devices remotely. While **Protocol Bridge** working with MQTT and HTTP formats is responsible for connectivity.

From Cloud Pub/Sub data is forwarded to other Google cloud services. You may use

- Cloud Functions to create independent functions and instruct devices how to react on specific events,

- Cloud Dataflow to pre-process data in real time,

- Cloud Bigtable to ingest and store large volumes of data,

- BigQuery to analyse data in real time, create and train machine learning models,

- Data Studio to visualize insights extracted from BigQuery, using pre-built templates, and

- Cloud Datalab to develop custom analytics practices and visualizations.
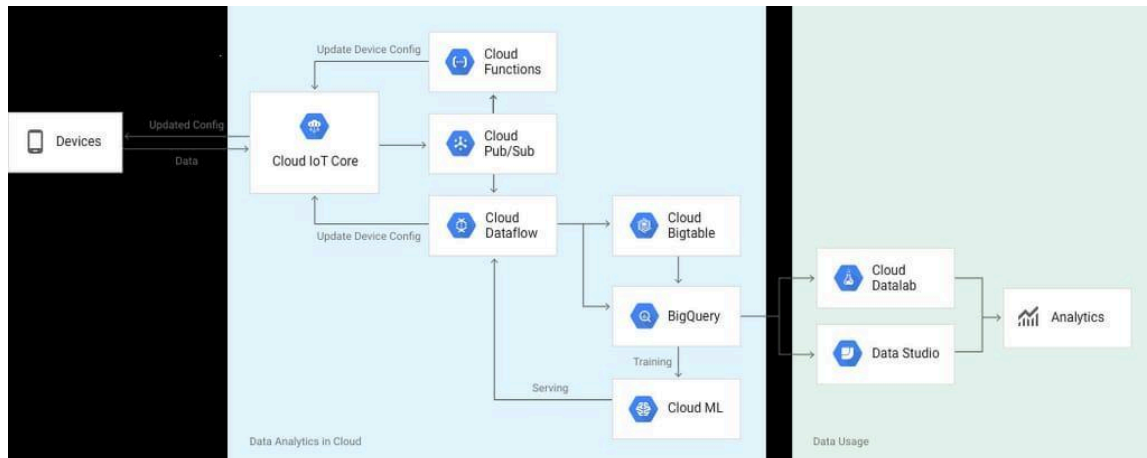
Cloud IoT Core integrations. Source: Google Cloud

Edge computing stack

Two giants are working together on a portfolio of edge computing solutions that will use Google's AI/ML capabilities and support 5G connectivity. For now, edge computing and AI in the Google IoT ecosystem is performed via its branded Edge TPU chip.

****

IBM IoT suite: **bringing intelligence to fields and factories**

Key use cases: *manufacturing, agriculture, smart buildings, logistics and transportation.*

IBM Watson IoT Platform (Connection Service and Analytics Service) is a ready-to-run, pre-integrated SaaS managed service **IoT** platform with capabilities in connectivity, data management and advanced analytics.

This is lead by IBM the pack of industrial solutions supporting <u>predictive maintenance</u>.

Built on the highest security standards, it serves as a hub to set up and control connected things that use MQTT messaging. The basic offering includes:

- **device management service** to add and remove devices individually or in bulk, perform rebooting, update firmware, receive metadata, and so on,

- **safe connectivity** and communication between devices based on MQTT protocol messaging; and

- **data lifecycle management**, which enables you to store data from devices and access real-time and historical data whenever you need it.

But you can expand these basic capabilities with advanced AI-driven analytics for gaining real-time insights and block chain service to add selected IoT data to the ledger and share it with specific clients and partners.

Digital Twins

IBM' s <u>Digital Twins</u> is a separate offering that by far outreaches virtual replicas of devices delivered by AWS and Microsoft Azure.

This approach enables you to run simulations and perform what-if analyses of physical objects and make decisions on how to improve their efficiency.
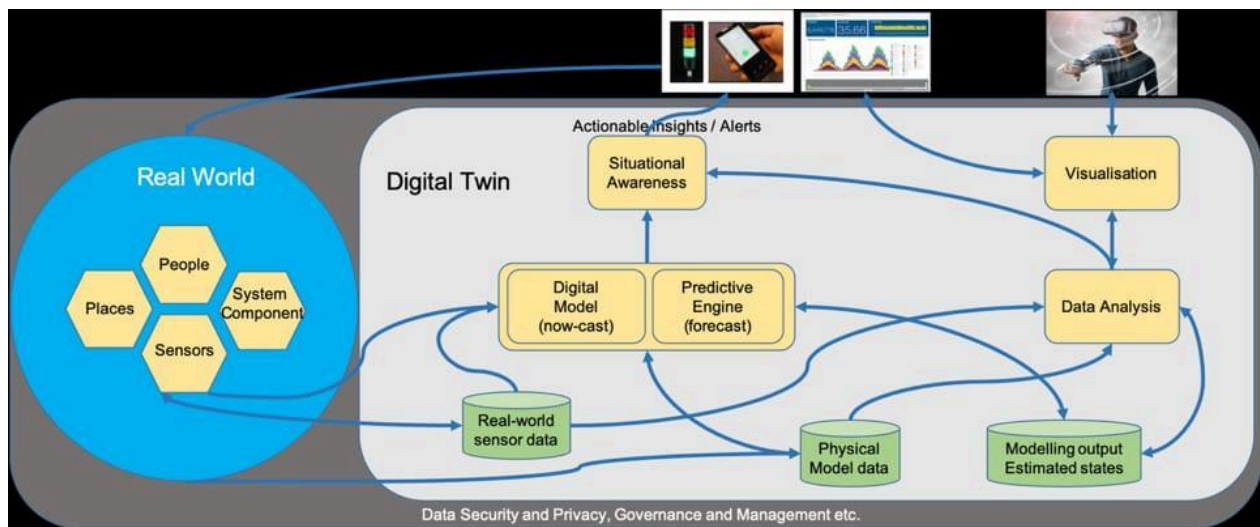
Digital Twin components. Source: IBM Developer

IBM Edge Application Manager

IBM has a separate platform to build analytics applications and then deploy, monitor, maintain, and scale them across thousands of devices, gateways, servers, and other edge nodes. IBM expects that edge computing capabilities will be revealed in full with the transition to 5G.

****

Microsoft Azure IoT: ahead of the pack in healthcare and security

Key use cases: *healthcare, retail, manufacturing, logistics and transportation.*

The Azure Internet of Things (IoT) is a collection of Microsoft-managed cloud services that connect, monitor, and control billions of IoT assets.

In simpler terms, an IoT solution is made up of one or more IoT devices and one or more back-end services running in the cloud that communicate with each other.

Whatever your industry or the size of your business or whether you're working with a partner or alone, Azure IoT has all the tools, devices, data analytics, and security you need to meet your IoT goals.

Features:

- Extensive integration with SAP, Salesforce, Oracle, WebSphere, etc.
- **Condition Monitoring** — Monitor key device parameters to detect anomalies.
- **Facility Management** — Optimizes energy use, space utilization and employee productivity in your factory.
- **Asset Tracking** identifies your assets, tools, and devices used in multiple locations with the Azure IoT Remote Monitoring Solution Accelerator.
- Optimize device performance for your Azure IoT Solution Accelerator operation to increase the efficiency of factory-connected devices.

Azure IoT Hub

IoT Hub is the foundational PaaS (platform-as-a-service) product, enabling device connectivity, management and communication. It comes in two tiers, basic and standard, with a different number of features supported. The basic tier provides services like:

- device-to-cloud messaging;
- device authentication;
- support for HTTP, MQTT, and AMQP protocols; and
- device monitoring and diagnostics.

If you need to control IoT devices remotely and distribute workloads across network, then you should consider the standard tier that adds

- cloud-to-device messaging,
- device management,
- device and module twins or storing information about the current and desired properties of devices and their components (modules), and
- IoT Edge to create program modules and deploy them across the network nodes.

Azure IoT Central

IoT Central is a scalable SaaS (software-as-a-service) offering rapid design of IoT software with built-in security features.

The platform comes with the integrated device monitoring and management functions to connect, reconfigure, and update devices.

The module includes numerous application templates for different industries to accelerate development speed. If combined with Azure IoT

Hub, it enables building more complex apps, capable of supporting millions of devices.

Additional IoT services

The collection of IoT-related solutions complement core platforms, extending their capabilities.

Azure Digital Twins lets you create virtual models of a physical environment based on insights extracted from IoT data- better efficiency.

Azure Sphere is a security solution to protect IoT devices, operating systems, and cloud services. It adds multiple layers of defense, provides continuous device monitoring, and enables returning compromised hardware components to their safe states.

Time Series Insights extracts data directly from IoT Hub to explore it, spot trends, identify anomalies, and present findings in the form of comprehensive visualizations. The solution easily integrates with other analytics services by Microsoft like Azure Machine Learning and Azure Databricks.

****

ThingWorx 8 IoT Platform

The ThingWorx low-code IoT development environment provides you with the flexibility to rapidly connect, create, and deploy comprehensive industrial IoT applications.

With pre-built extensions and widgets as well as a large ecosystem of partners, ThingWorx addresses the fundamental IoT development challenges, freeing you up to create solutions that accommodate constantly changing business needs.

It provides **Vuforia** for augmented reality development and the implementation of Kepware for industrial connectivity.

User can work with basic pogramming knowledge. Thingworx provides many tools for creating applications:- composer, mashup builder, memory, a search engine, collaboration, and connectivity.

Features:

- **Composer** provides a modeling environment for design testing.
- **Mashup** Builder delivers easy dashboard building through common components.

- **Search engine** SQUEAL in analyzing and filtering data, and searching records.

- It provides **Pre-built widgets** for the dashboard.

- It enables Easy connectivity with electronic devices, like sensors and RFIDs.

****

ThingSpeak IoT Platform

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud.

You can send data to ThingSpeak™ from your devices, create instant visualizations of live data, and send alerts using web services like Twitter® and Twilio®.

With MATLAB® analytics inside ThingSpeak, you can write and execute MATLAB code to perform preprocessing, visualizations, and analyses.

It enables engineers and scientists to prototype and build IoT systems without setting up servers or developing web software.

Features:

- Real-time sensor data visualization

- Data agregation from 3rd parties providers

- Schedule IoT analytics tasks to analyze data

- Event scheduling

- Run actions according to data acquired

ThingSpeak is available as a free service for non-commercial small projects (~ 8,200 messages/day). For large projects or commercial applications, You can use annual lic

****

How to choose the best IoT platform?

Along with a rich functionality, all of them offer

- high scalability, fitting the needs of any business, from startups to enterprises with millions of devices;
- built-in security for every layer of an IoT system; and
- tech support and detailed documentation on their products.

The question is, how do you choose the best option among five equal worth leaders? There are several things to consider before making the final decision.

Pricing and free tier

All platforms stick to a pay-as-you-go model, so the total price will depend on volume of use — or the number of messages or megabytes exchanged, devices connected, actions executed, and so on. Besides, the pricing may vary across regions.

IoT platform pricing and free tier comparison

Platform	Pricing plan	Free tier	Free tier across additional IoT services
Amazon IoT Core	Connectivity: $0.08 per million minutes of connection Messaging: $0.7–1 per million messages (the more messages the cheaper) Device shadow and registry: $1.25 per million operations Rules engine: $0.15 per million rules triggered/actions executed	Available for 12 months ✓ 2, 250,000 minutes of connection ✓ 500,000 messages ✓ 225,000 registry or Device shadow operations ✓ 225,000 rules triggered and 225, 000 actions executed	Available for 12 months ✓ Device Management: 50 remote actions per month ✓ AWS Greengrass: 3 devices ✓ AWS IoT Events: 250,000 message evaluations per month ✓ AWS IoT Analytics: 100 MB of data processes and 10 GB of data storage
Cisco IoT Control Center	Details are available at request	No free tier	No free tier
Google Cloud IoT Core	$0.00045–0,0045 per MB of data exchanged (the more data the cheaper)	First 250 MB	✓ 12-month free trial with $300 credit to spend on any Google Cloud Services ✓ The large suite of always free resources
IBM Watson IoT Platform	Starts at $500 per unit/ per month	No free tier	No free tier
Azure IoT Hub	Basic tier: $10 to 500 per unit/per month Standard tier: $25 to 2500 per unit/per month The price within the tier depends on the number of messages exchanged per day (up to 400,000, 6 million or 300 million)	Up to 8,000 messages per day and up to 500 registered devices	✓ 12-month free trial of popular Azure services ✓ $200 credit to explore Azure for 30 days ✓ 25+ always free services

altexsoft
software r&d engineering

What will it cost to run IoT?

To address the pricing model complexity, Amazon, Google, and Microsoft offer their customers a pricing calculator located on their

official website. But often the only way to estimate your IoT project cost is to run it for a month and pay the bill. Multiple reviews show that AWS tends to be the most expensive option, followed by Google and Microsoft Azure as the cheapest of the trio. As for IBM and Cisco, their pricing details are available on request.

Amazon, Google, and Microsoft also enable potential clients to make a proof of concept using their free tier plans. So, you can test whether the platform meets your requirements before starting to invest into particular services.

Hardware compatibility

IoT infrastructure involves numerous devices. If you already use certain equipment, network nodes, and other components, you must check whether your existing hardware is compatible with a particular platform. For example, Cisco IoT software is designed to work smoothly with Cisco IoT hardware.On the other hand, Amazon and Microsoft Azure view themselves as hardware agnostic and support mist of IoT devices. Anyway, to be on the safe side, look through the lists of hardware approved by a software provider you are interested in:

ense.