Satellite Tron
Smart Things

Executive Order Spy System

Satellite Tron IoT Telematics System

IoT Telematics Design Architecture

Cloud and Edge Computing / Pi IoT Tron / Arduino Tron - MQTT Telemetry IoT Transport

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Custom Software Development – Executive Order Corporation

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Executive Order Corporation - We make Things Smart

Executive Order Corp. is a leading provider of technology that helps global companies design, develop, deploy, and integrate software applications

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Satellite Tron - Internet of Things Drools – IoT Telematics Design

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1.02	9/03/2018	Steven Woodward	Cloud and Edge Computing Satellite Tron IoT MQTT Telemetry Transport (M2M) Machine-to-Machine.
1.10	01/21/2022	Steven Woodward	Cloud and Edge Computing / Pi IoT Tron / Arduino Tron - MQTT Telemetry IoT Transport AI-Satellite Tron Applications using Drools-jBPM Expert System.

SUPPORTING DOCUMENTS

Document Number	Document Name Description
1	Business Requirements Document – Executive Order Document
2	SRS (System Requirements & Use-Cases) Document – EO Document
3	High-level Design Document – Executive Order Document
4	IF-SPECS Documents – Executive Order Document
5	Low Level Design – Application Development – Executive Order Document

About Executive Order Corporation

We make Things Smart

Executive Order Corp. provides custom software built by software professionals. We specialize in Satellite Tron (Internet of Things), desktop and web-enabled IT solutions for small and large business enterprises. Our professional offerings span business and technology consulting, business application development, mobile messaging solutions, custom web design, E-commerce development, web maintenance, website re-engineering, website optimization for search engine submission, internet marketing hosting solutions for enterprises, GPS, IoT (Internet of Things),remote sensing services and development program architecture of AI-Drools and jBPM (Business Process Management).

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1.1 Satellite Tron IoT Telematics Systems

1.1.1 Satellite Tron Telematics Definition

- Satellite Tron Telematics is a Cloud and Edge Computing / MQTT Telemetry IoT Transport Business Process Management Engine for Automotive and other IoT Device Orchestration.

1.1.2 Telematics Streaming Data Used in Transportation

Industries operating vehicle fleets with installed telematics systems generate huge streams of data. Vehicles that have Internet access to transmit and receive data in real-time and a telematics device, are called connected vehicles. An average connected vehicle can send approximately 25 gigabytes of data to the cloud every hour. Satellite Tron also provides in-vehicle device control of IoT devices remotely.

There are thousands of such vehicles. Together they create large amounts of data daily. With the right telematics system in place, this data can become a deep pool of valuable business insights for companies engaged in transportation and logistics.

We will dive into the data aspects of telematics systems. We'll explain how these systems work, what data they generate, and give guidance on implementing our telematics solution for you to become a data-driven company.

1.1.3 Telematics in Modern Vehicles

Telematics is the merging of two tech fields – *telecommunications* (a branch of technology dealing with long distance transmission of information by satellites, cell towers, internet, etc.) and *informatics* (the study of computational systems).

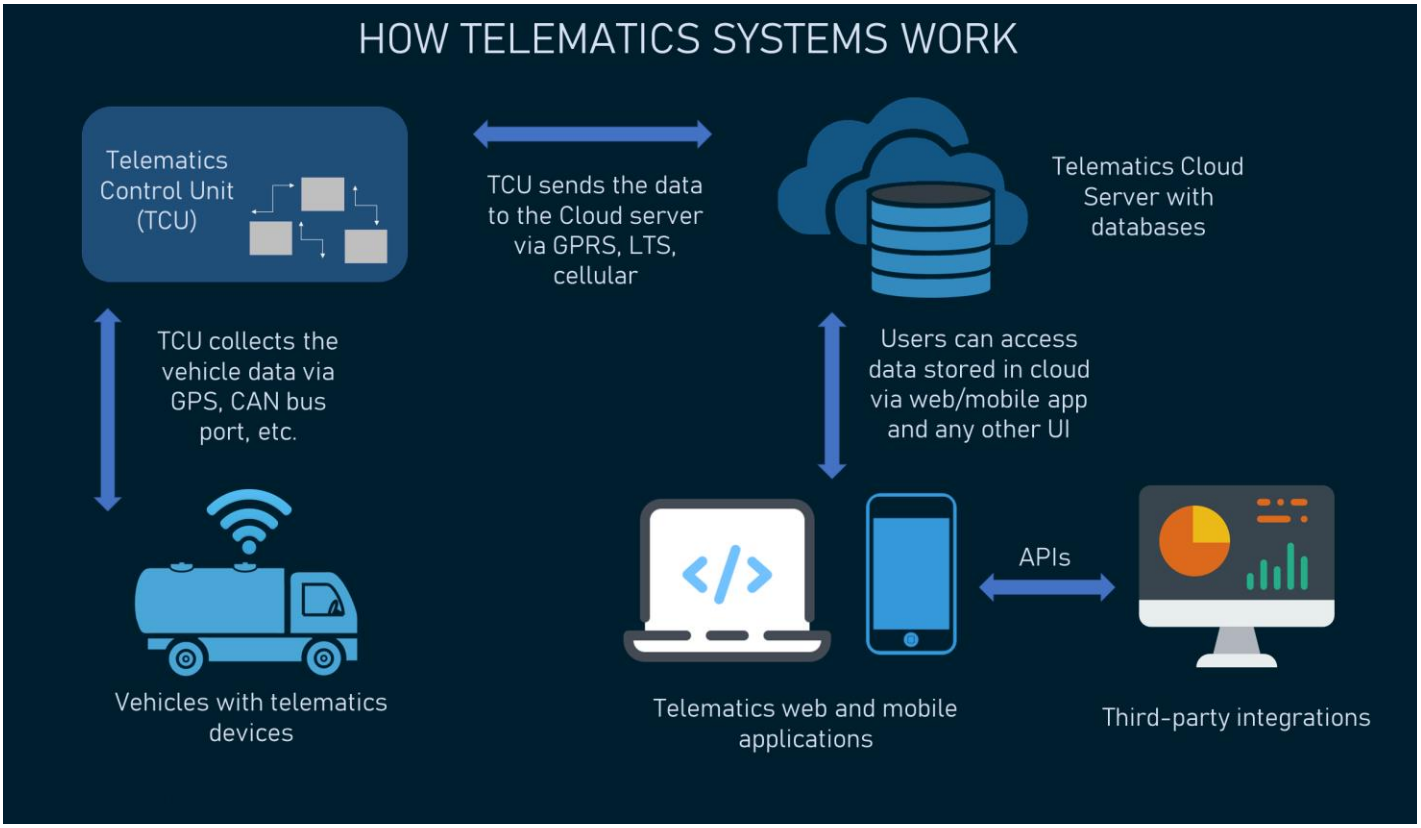
At the basis of **modern vehicle telematics**, there are systems – hardware and software – allowing for collecting, storing, and exchanging data points between fleet vehicles and central locations. Telematics deals with building a network of vehicles and telecommunication devices, and as such it falls under the IoT (Internet of Things).

1.1.4 Telematics in Modern Vehicles

Benefits of telematics systems are enormous. Companies involved in transportation and logistics make use of such solutions to:

- reduce fuel and operating costs
- optimize fleet management and driving standards
- perform remote diagnostics
- improve driver and vehicle safety
- make more informed decisions
- provide efficient customer support
- remote control of in-vehicle IoT devices
- remote telemetry of custom IoT devices

To understand how these benefits are achieved, let's have a closer look at components of telematics systems and the data that makes them work as a single unit.



The working principle of telematics systems.

The TCU (Telematics Control Unit) is an embedded, onboard device that tracks and examines a vehicle's performance, position, speed, etc. The device collects the vehicle data via GPS, CAN (Controller Area Network) bus port, and onboard diagnostics. Once collected over various interfaces, the data is then sent to the cloud server via the GPRS module, a cellular network, LTE (Long-Term Evolution) communication, or other channels.

Telematics Cloud Server is the cloud infrastructure, consisting of a web server, an application server, and a database that hosts collected data. Before information reaches the cloud telematics server, it is converted into MQTT messages. MQTT is the Message Queuing Telemetry Transport, and it's a simple lightweight messaging protocol commonly utilized within IoT platforms. Data stored in the cloud is available to the end users via a web/mobile app.

Telematics web and mobile applications or other software allow end users to access the data stored in the databases of the telematics server and extract insights from it. Apart from monitoring and controlling fleet vehicles, users can apply more advanced analytics to the collected data by feeding information into external software through APIs.

Telematics data connects vehicles and management teams by turning every car into a sort of data gateway. Not only does telematics data come in all shapes, but it also derives from different sources as a never-ending flow at high speed. That's why it's referred to as **streaming data** and used in the context of Big Data. Telematics data can be classified into these main categories.

- *Basic data records* - provide general information from a travel log of a certain vehicle. The records include such items as GPS data, the status/purpose of a trip, driver, time and date, etc.
- *Telemetry data* - refers to the vehicles environment data. This data is key metrics considered are speeding, harsh acceleration, and/or braking, and idling time. Also, temperature and humidity, light sensors, door lock sensors, movement and even radiation sensors.

- *Diagnostics data* - comes in the form of reports on vehicle condition. This sort of data encompasses metrics like tire pressure, vehicle malfunction, fuel consumption, and more.
- *Remote IoT device control* – in addition to general information from the vehicle. Our TCU can receive remote commands to the vehicle. This provides remote control for generators, security, environment/thermostats, lighting, locks or control of any IoT Edge Computing device connected to the vehicle or within BLE range.

All this sensor data combined with the GNSS (Global Navigation Satellite System) that provides PNT (positioning, navigation, and timing) services globally, and transmitted to the Telematics cloud server.

With all of these telematics components, let's discuss how to track these remote data streams and use them in the cloud.

1.2 Telematics Software Modules

The different types of data mentioned above can be mixed and matched to build feature-rich telematics solutions. Let's explore the key software modules systems and the data they can use.

1.2.1 Advanced alerting functionality

Telematics data used: all types

Both transportation logistics and security deal with events that require timely actions to be taken. Comprehensive alerting functionality contributes to the effectiveness of fleet management, and provides both operators/drivers and security with live data and notifications.

If an engine is idling for longer than it should, or some vehicles parts are due for checkups, you want to be sure that a system will alert to those issues. Real-time notifications on vehicle condition and driver behavior help you sort out problems right away, and also reduce possible risks in general.

Also, advanced notifications alert features allow you to set up mileage alerts to get notified when a vehicle exceeds the mileage threshold or adjust geofence monitoring to be aware of entry/exit times.

1.2.2 GPS vehicle, cargo, and delivery tracking

Telematics data used: GPS data

While the GPS component is the heart of such systems, it's a misconception to think that the only thing telematics does is pinpoint a vehicle's GPS location.

Once installed in the fleet, devices allow you to get accurate information about the location and movement of each of your vehicles in real-time. You will be able to track the journey from the moment of departure to the destination with all the stops and idle times along the way.

Transporters can take GPS tracking to a whole new level. By integrating a telematics system with weather forecasting services and injecting map-based algorithms that show real-time traffic patterns, drivers can get up-to-date information about dangerous areas and pick a safe route.

Since systems can generate maps showing the exact position of all vehicles in the fleet here and now as well as routes made over a certain period of time, logistics and transportation companies can manage fleets more effectively and inform customers about delivery times.

1.2.3 IoT control, measurement and monitoring

Telematics data used: informational, diagnostics data (IoT device control)

Our Satellite Tron telematics systems is equipped with features that enable monitoring and measuring of the vehicle and environment information. Along with remote IoT device control.

Vehicles are equipped with the Engine Control Module (ECM), Satellite Tron send miles per gallon information to the vehicle cloud dashboard, along with vehicle performance and signal engine error codes. By monitoring ECM data along with vehicle error code timely service can be performed, avoiding costly vehicle maintenance and breakdowns.

Satellite Tron API integrations and build-in custom connections between telematics and enterprise cloud systems provide easy integration into other software systems. The Satellite Tron TI-SensorTag module supports the most common types of low-power sensors in your vehicle.

Available sensors we offer include the following:

- Ambient temperature
- IR Object temperature
- Humidity sensor
- Pressure sensor
- Ambient light
- Accelerometer
- Gyroscope
- Magnetometer
- Digital microphone
- Magnetic sensor
- Simple button press
- SOS panic button press

We can provide complete control and monitoring of your equipment. Using our custom Satellite Tron TI-SensorTag IoT software solution is easy, fast, and the least expensive way to maintain your business equipment including the following:

- Add text, images, and links to your business assets
- No bandwidth or tracking limit
- Location traffic reporting
- Inventory tracking and reporting
- 128-bit SSL Security, if required
- Real-time UPS, FedEx, USPS, and worldwide shipping tracking
- Asset item reporting
- Completely configure any fields in product, order, and user databases
- RFID tag tracking
- Securely access order history
- FREE GPS Tracking
- Easily create product site billing
- Powerful eCommerce asset billing
- Powerful and configurable catalog for asset search
- Complete real-time payment processing
- Easily include extra sensors weight, quantity, sound, or temperature
- Easy to use checkout process
- Accept automatic bill on location
- Return customer tracking
- Employee login

Addition remote commands can be sent to the vehicle. This provides remote control for generators, security, environment/thermostats, lighting, locks or control of any IoT Edge Computing device connected to the vehicle or within BLE range.

1.3 Vehicle Maintenance and Monitoring

Telematics data used: basic data records and diagnostics data

Vehicle sensor data can be used for predictive machinery maintenance and analytics. It can help figure out if and when a particular vehicle component will fail.

The system monitors service records and provides automatic alerts for diagnostics checks. By analyzing a vehicle's maintenance history, managers can track the tendencies for parts to wear out or break and make more informed decisions regarding routine fleet maintenance. A customized module can even indicate repair centers so that a driver can access the nearest one when needed.

Remote diagnostics is the telematics-allows for collecting data such as fault codes to conduct timely diagnostics and preventive maintenance remotely, which helps to sort out the issue of unplanned vehicle downtime and cost.

1.3.1 Fleet Management, Functions, Solutions, and Innovations

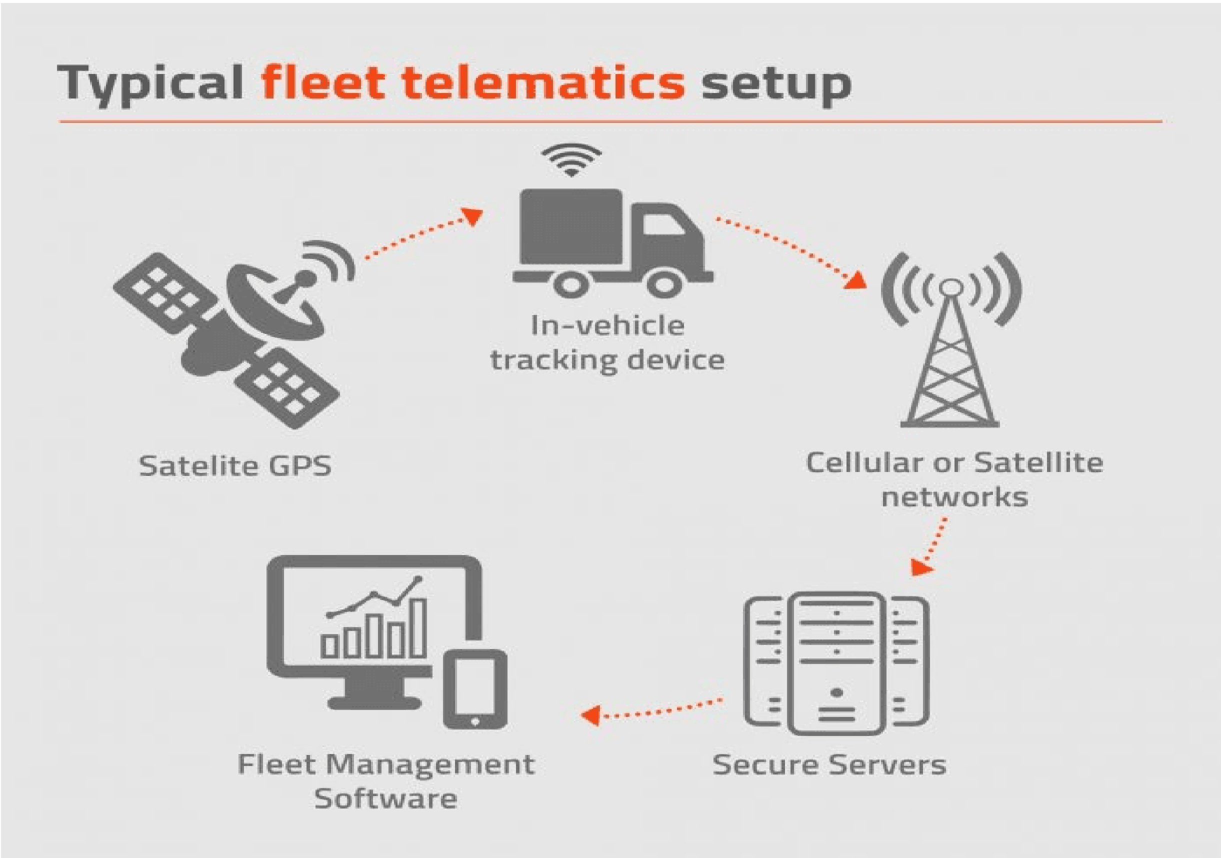
Shippers and carriers need to know more than simply a truck's location and vehicle characteristics. Businesses involved in transporting cargo require more complex solutions: maintenance scheduling, registration, tracking, driver management, and operation costs are only the tip of the iceberg.

Thousands of carriers take steps to become more efficient every day by embracing fleet management technologies. We will describe fleet management software (FMS), overview of its core modules and functions, and explore the innovations that Satellite Tron provides.

1.3.2 Fleet management software

Fleet management software is a standalone app or a cloud product that helps businesses maintain optimal use of their work vehicles from a central platform. Besides the software, the in vehicle fleet management involves the use of a Telematics Control Unit (TCU), Microcontrollers (MCU), Domain Control Unit (DCU), Electronic Control Units (ECU), with a Human-Machine Interface (HMI) devices.

FMS allows for tracking a large number of a vehicle's data: speed, temperature, engine block, fuel level, door opening, geographical location, route direction, etc. Received from a vehicle's sensors, this data is displayed to the manager who can track all their vehicles in real time, determine when they'll get to the destination, and how well the vehicles are handled by the drivers.



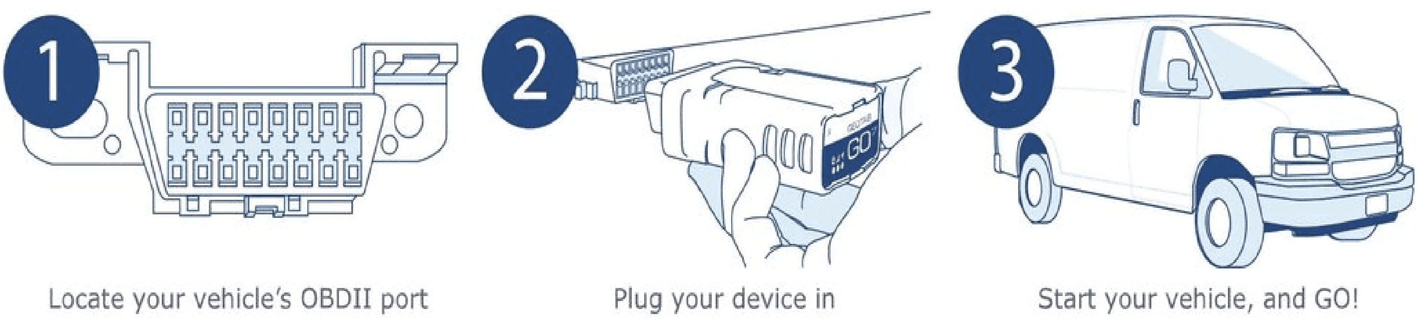
Fleet management information workflow.

Using dedicated software for managing fleet brings multiple benefits to the table:

- automates tasks (e.g. proper routing)
- streamlines associated processes (e.g. Vehicle maintenance)
- provides real-time insights for better management of both drivers and vehicles
- connects vehicles
- ensures smart transportation
- enhances driver safety
- guarantees consistent fleet performance
- reduces costs
- maintains compliance with major regulations for commercial drivers

1.3.3 Telematics remote communications

Telematics is a term that describes the use of information technology in remote communications. *Fleet telematics* is the system that supports the exchange of information between vehicles in the fleet and central locations. It's a small black box installed under the dash and connected to the diagnostics port or the CAN (Controller Area Network) bus port. A telematics device records the information from the vehicle using GPS and onboard diagnostics.



An installation instruction of a telematics device.

1.4 Modules of Fleet Management Software

A telematics unit can freely integrate with other hardware (Electronic Logging Device, driver cameras etc.), software, and mobile apps to provide insight into different freight-related business operations.

The combination of hardware and software delivers different types of functionality:

Routing – helps make logistics decisions based on vehicle GPS position, duration of stops, speed, etc.

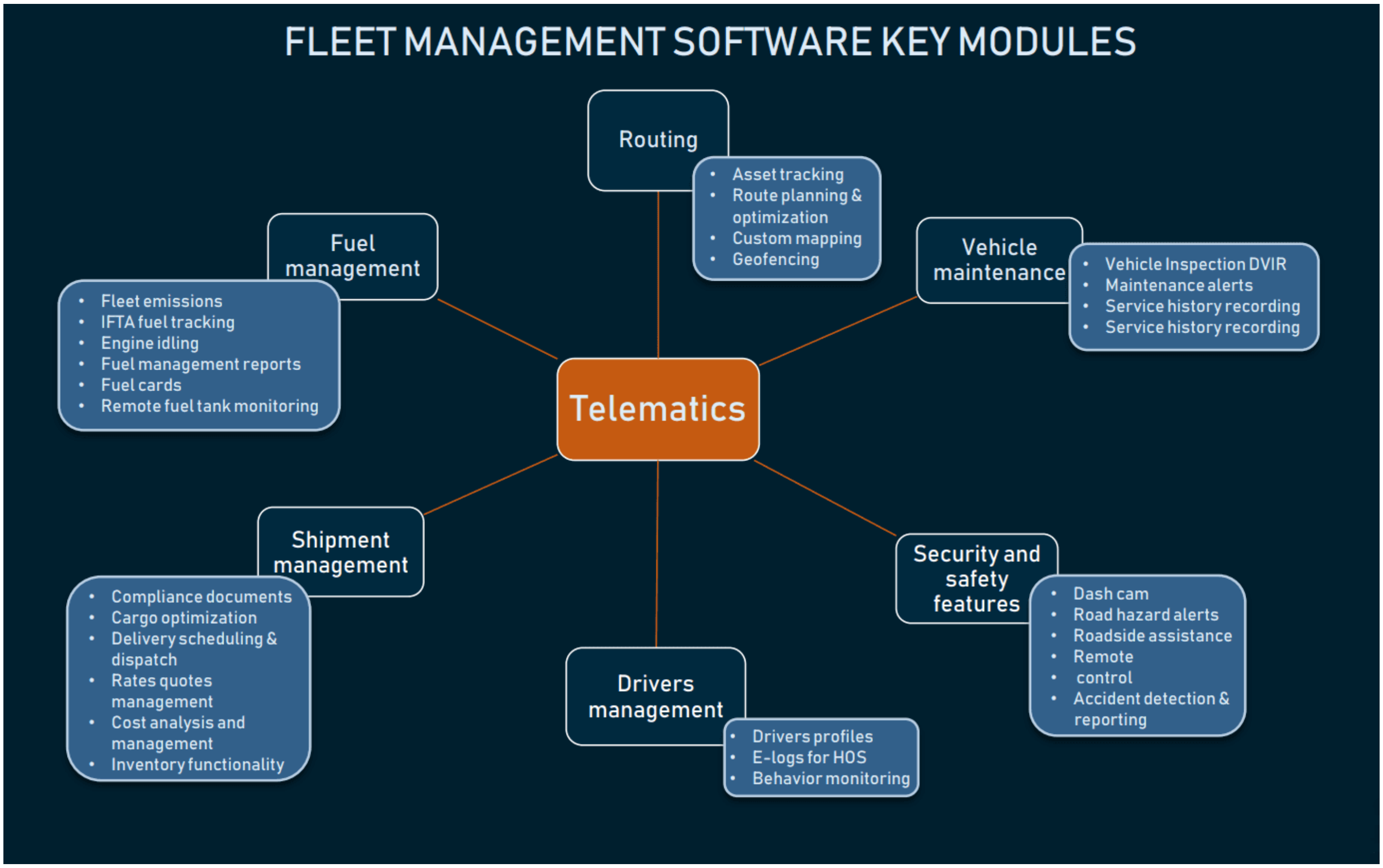
Fuel management – tracks fuel consumption tendencies to minimize idling time, emissions, and more.

Vehicle maintenance – streamlines the process of diagnosing and inspecting, reminds of routine checkups.

Drivers management – stores personal profiles and hours of service to analyze productivity and behavior.

Shipment management – analyzes expenses, quotes, licenses and more to optimize delivery, dispatch, and cargo placement.

Security and safety features – assist drivers with any safety issues on the road.



Main modules of fleet management software and their key features

1.4.1 Routing

The FMS routing module uses the data collected via a telematics device to provide a fleet manager with real-time updates on vehicle location, miles traveled, with status updates from anywhere.

Asset tracking. Installed in the dashboard, a GPS locator beacon allows fleet managers to track and study the vehicles in the fleet. A radio frequency identification system steps up to maintain tracking in poor signal areas, for example, underground or in a tunnel.

Tracking can be active, pinpointing a live vehicle's whereabouts, and passive, capturing the ride data for further analysis – such as route optimization, driving speed, idling tendencies, etc.

Geofencing. This feature provides various notifications on the vehicle's whereabouts: when the vehicles depart, when it leaves pre-defined boundaries or operates during off-duty hours, etc.

Route planning and optimization. While optimizing the route, basic factors to consider are time windows, stop durations, vehicle capacities, and lunch breaks. In addition, the system should timely alert on any road disruptions. Route optimization functionality plans efficient routes by determining the shortest and most fuel-efficient paths between each stop. Pairing route optimization with the fuel management module will save both time and fuel costs.

Custom mapping. Route planning capacity can be further expanded with the ability to design your own business-relevant maps. Being highly customizable in terms of views, legends, zone shapes, and sizes makes your maps so convenient in use.

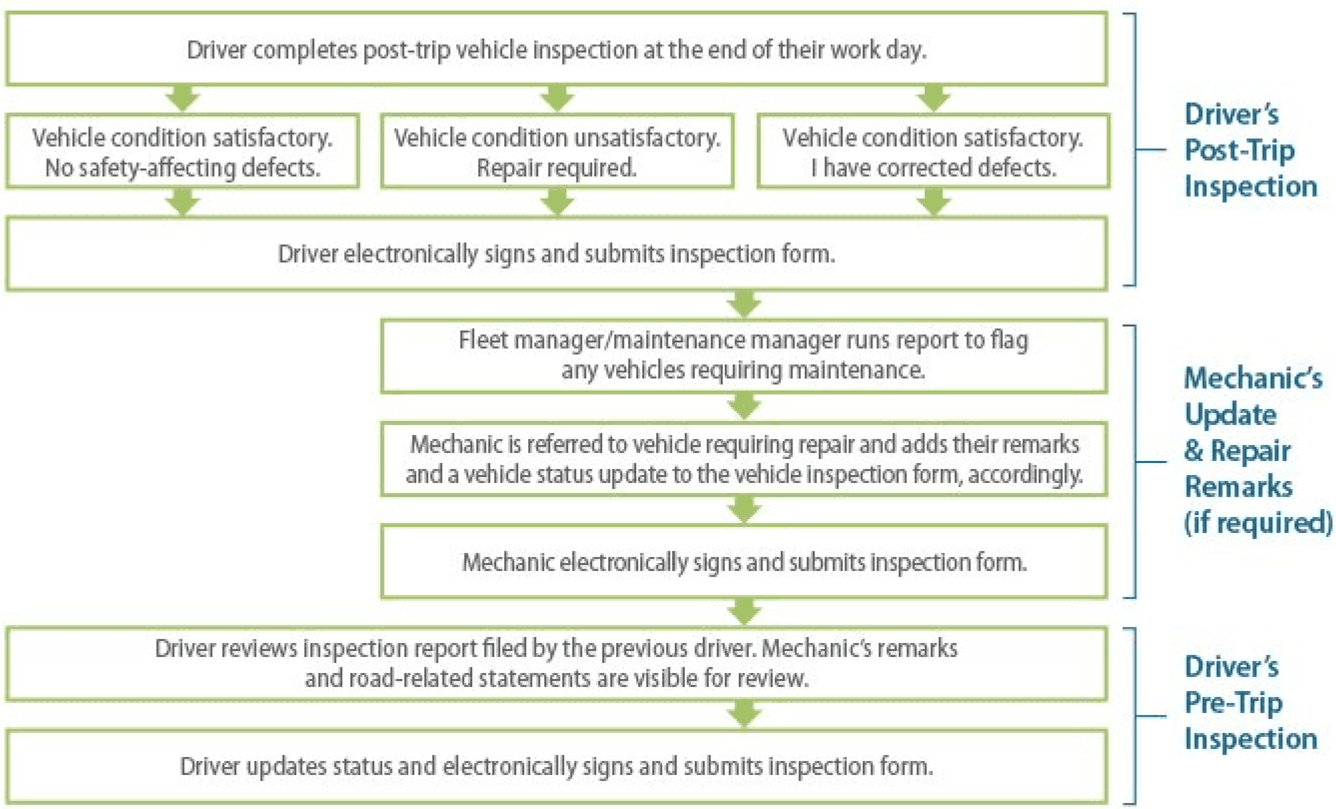
1.4.2 Vehicle Maintenance

A vehicle maintenance module plans routine checkups and alerts about the needed diagnostics.

Remote diagnostics. The utilization analysis feature gains insight into how your vehicles perform and which ones need replacement, helping with annual planning. FMS gives users such business insights as the top 10 vehicles due for scheduled maintenance.

Vehicle inspection DVIR. According to FMCSA regulations, Driver Vehicle Inspection Reports (DVIR) are logs with detailed vehicle operations and safety issues that must be filled out via a telematics-supported tablet during vehicle inspections.

Once a report is submitted, fleet managers can easily identify, group, and monitor vehicles that require routine or urgent maintenance. If a report does indicate the need for maintenance, DVIRs incorporate a mechanic's notes and updates. Sorting out DVIRs – reports on the defective vehicles, on the repaired ones, and on those certified as repaired — offers great visibility into the fleet conditions.



Workflow of an inspection report.

Service history recording. FMS automatically logs a detailed history of the vehicle's maintenance. This data can then serve for analyzing costs, tendencies in wear, neglect, and abuse, to further make effective fleet decisions.

Maintenance alerts. FMS provides automatic engine diagnostic alerts, tracks service records and sets reminders for oil changes, tune-ups, and other routine maintenance. Should there be an engine fault, the system will be there so that the driver has access to a network of repair centers.

1.4.3 Shipment Management

The shipment management module manages a fleet's workflow, orders/deliveries, and expenses to reduce rework and increase income.

Delivery scheduling and dispatch. Fleet companies need an FMS with strong scheduling and dispatch capabilities that make dispatching operations easier and more efficient. By maximizing dispatching and increasing schedule productivity, FMS helps the fleet get more jobs done on time.

Compliance documents. Licenses, tax reports, fleet insurance (including restrictions and due dates), and fuel transactions are carefully stored in FMS.

Cost analysis. FMS conducts a comprehensive cost analysis providing a clear picture of what your budget is spent on. It'll track the defined key metrics with the cost triggers, comparing them against the benchmarks.

Inventory functionality. Inventory control capabilities handle recording, tracking, costing, cycle counting, and automatic reordering to ensure availability and the right number of parts on hand, thereby reducing vehicle downtime.

1.4.4 Security and Safety Features

Safety management tools protect your vehicles and drivers by providing emergency roadside assistance, vehicle theft alerts, and remote monitoring. Being able to monitor a driver's time of arrival, speed and more, fleet companies can secure themselves from false claims.

Road hazard alert. Alerting services keep drivers informed in real time of the state of the road, the weather, or last-minute changes on the route. Such services automatically notify drivers when they're approaching potential roadway weather hazards.

Remote control. Vehicular control mechanisms enable tracking and gradually reducing the speed of an asset. This can be particularly beneficial in retrieving stolen vehicles.

Accident detection and reporting. If drivers happen to get into an accident, fleet accident management software allows for capturing necessary data live from the field to further support claims, repairs, and risk management.

Roadside assistance. Should fleet drivers experience any roadside issue, they can request help via their telematics device with integrated roadside assistance solution. The latter dispatches a service request to the closest provider, ensuring a fast response.

Dash cam. Automatically making photos, videos, and panorama thumbnail views, a dash cam can playback the entire event. Integrated with telematics, a dash cam provides visibility into any incidents.

1.5 Fleet Management Solutions Overview

Implementing an FMS fleet management solution that can help your business handle its transportation needs. The players included in this section are among the top 20 most popular options. We will give a brief overview of the leading fleet management solutions highlighting their stand-out features.

Advanced Driver-Assistance Systems (ADAS) are the systems that leverage AI, deep learning, and machine vision technologies. It's anticipated that ADAS will keep getting smarter, which will result in safer road use. Our Satellite Tron AI-IoT Artificial Intelligent Internet of Things provides advance AI.

One of the latest innovations here is predictive maintenance. It uses onboard sensors to predict when the vehicle may need repair. It can be paired with preventative maintenance systems that track maintenance tasks by date, mileage, kilometers, hours, or fuel consumption, and provides automated maintenance-due to notifications.

Business intelligence. Based on internal/external data and the company's historical trends, intelligent analytics allows for identifying areas in fleet operations where money can be saved.

Autonomous vehicles will enhance efficiency with self-driving capabilities. Further, the vehicles will improve road safety with integrated car technologies like forward collision avoidance.

Environmentally friendly logistics. As environmental consciousness is taking new turns, more fuel-saving measures are added. It's so important to have routing software to prevent fuel loss.

More mobile apps for fleet operations. Allowing drivers to stay in constant communication, mobile devices are certain to become the primary tools for handling fleet tasks.

To find out more about how technology drives change in transportation (trucking, air freight, and maritime shipments), check out our infographic.

FLEET MANAGEMENT SOLUTIONS

	Geotab	Verizon Connect	Teletrac Navman Director	Fleetio
Stand-out features	• in-vehicle driver feedback • security features • custom mapping	• route replay • proactive alerting • driver ID feature	• non-verbal check-in • dynamic dashboard with custom KPIs • driving safety alerts • vehicle inspection reports	• detailed maintenance management • inventory tracking • comprehensive fuel tracking
Provides hardware	✓	✓	✓	–
Per-month pricing	contact for pricing	$40/vehicle	$45/vehicle	$5/vehicle
Usability	easy	moderate	moderate	easy
Mobile app(s)	Geotab Drive	Spotlight Reveal Field Navigation	DriveApp	Fleetio Manage Fleetio Go Fleetio Parts
Help & Support	moderate	poor	moderate	good
ELD-compliant	✓	✓	✓	– (needs integration with compliant telemetrics)
Best for	any fleet size	midsize fleet	cost-efficient product for mixed fleets	simple solutions

Leading fleet management solutions compared: Geotab, Verizon, Teletrac Navman, and Fleetio

Geotab: highly customizable solution for small and large fleets

Geotab provides time-tested, comprehensive fleet management solutions. Geotab collects info and transforms it into high-value fleet management data a business can then act upon.

Geotab's rich functionality includes customizable mapping, GPS vehicle tracking, route optimization, engine health and maintenance, and open data integration. With the Geotab Drive mobile app that tracks Hours of Service, you can meet FMCSA regulations including DVIR and ELD compliance.

Security features. Given its *security first* principle, Geotab FMS is backed up with a variety of corresponding features:

- end-to-end security using authentication
- encryption
- message integrity verification
- unique IDs for individual devices
- non-static security keys
- digitally-signed firmware
- independent third-party expert validation

Proactive vehicle maintenance. Geotab maintains engine health by detecting issues early on and setting up vehicle maintenance reminders.

In-vehicle driver feedback and coaching tools. These functions foster safe driving behavior.

Verizon Connect: a full-featured product with international coverage

The world's largest telematics software supplier, Verizon Connect FMS combines a central dashboard software with in-vehicle tracking hardware. Verizon Connect has a variety of fleet tracking and management apps. Some popular ones are:

- Spotlight for optimizing vehicles, staff, and work
- Reveal Field for drivers to assign vehicles, tasks, and check their individual performance
- Navigation for accurate turn-by-turn directions.

Verizon Connect has rich features cover distribution, fleet maintenance, fuel, and transportation management, GPS tracking, logbook, logistics, service, and transportation dispatch.

Route replay. By caching historical journey data, Verizon lets you review where and when your drivers were, what routes they took, how long their stops lasted and whether they broke the speed limit.

Proactive alerting. While monitoring unwanted driver behavior, the system notifies accordingly upon identifying any violations.

Driver ID feature. Logging in your drivers allows for keeping an eye on individual drivers even if they use several vehicles within the company. Accompanied by driver scorecards, Verizon tracks the driver's performance.

Teletrac Navman DIRECTOR: affordable feature-rich solution for various needs

Director is a cloud-based GPS fleet tracking software product of Teletrac Navman, one of the largest FMS vendors in the world.

Fleet visibility. Paired with hardware units inside the fleet's vehicles, Director's central dashboard displays each vehicle's location and status in real time. Managers can track the fleet via a satellite view, a clickable list of vehicles, a GPS map, or an in-vehicle street-level camera.

Dispatching. Director allows drivers to message dispatchers and vice versa, even offering canned responses to further streamline communication.

Non-verbal check-ins. With the touch of a button or even automatically, a driver can check in the destination, proof of delivery, and HOS.

Dynamic dashboard. Director enables fleet managers to create a personalized dashboard for summarizing their KPIs.

Vehicle diagnostics. Providing the insight into the condition of the fleet vehicles, Director informs you of the amount of fuel used, idling time, whether the drive goals are met, and whether any vehicles are in use without proper authorization.

While Director is suited for fleet managers, drivers use an in-cab solution – the DriveApp and software suite. Using a tablet device, drivers can auto-record their HOS and vehicle diagnostic data, generate the E-logs and DVIRs for a roadside inspection.

FleetIO: software-only provider with a user-friendly interface

Unlike other FMS on this list, Fleetio doesn't provide a hardware component to collect vehicle data, which is why it's not ELD compliant. However, this problem can be solved with our Satellite Tron third-party telemetrics integrations.

Keeping it simple, this solution offers a robust proprietary FMS – Fleetio Manage, and free mobile apps – Fleetio Go and Fleetio Parts for drivers to report their start times, fuel use, daily vehicle inspections, and in the case of Parts, vehicle parts for replacement.

Maintenance management. Tracking fleet maintenance needs, the FMS reminds of an upcoming vehicle inspection, registration or an emissions test. Emergency notifications allow managers to respond quickly to instances.

Fuel tracking. Besides keeping a record of fuel usage, Fleetio Manage automatically calculates the fuel economy providing managers with the preliminary data to determine an efficient fuel economizing strategy. In addition, the software enables fuel card integrations.

Driver scheduling. Via the Fleetio Go app, drivers get assigned routes or inspections, while managers track each assignment by vehicle.

Parts and inventory. Using Fleetio Manage, operators can track the number of spare parts available, getting notifications to restock them when needed.

1.6 Fleet Management Industry Trends

The fleet management industry is marching into the era of IoT, adopting more effective ways of driver-vehicle communications and vehicle-to-infrastructure connectivity. Soon, telematics is going to become a very advanced factory-installed equipment. As the data keeps multiplying, it's going to demand a more sophisticated approach: from predictive to prescriptive analytics.

Behavior monitoring solutions. More apps with driver scorecards are expected to be developed. Tracking and measuring driver behavior will promote better decision making, and decrease safety and productivity costs.

A trend for video analytics is going to hit the industry this year. Requiring onboard computers with 5G and GPS, G-sensors, and IP cameras, this technology can be a great help in reducing accidents and cutting down on wasteful activities such as unnecessary fuel consumption.

Cloud computing offers a range of benefits for FMS, as it can enable:

- higher degrees of data and system integration
- highly customized solutions for fleet managers
- increased data download speeds
- more mobile-centric operations
- enhanced remote processing of fleet-related data and transactions

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2 IoT Architecture - Physical Signals to Business Decisions

2.1 IoT Internet of Things Solution Architecture

2.1.1 Satellite Tron Telemetric Design Methodology

IoT Architecture – is Physical Signals to Business Decisions. At Satellite Tron, our IoT Definition is, "IoT is the integration of computer-based systems into our physical world." quote by Steven Woodward. The following key design methodologies are utilized in the AI-Satellite Tron Telemetric Design architecture.

IoT solutions have become a regular part of our lives. From the smartwatch on your wrist to industrial enterprises, connected devices are everywhere. Having *things* work for us is no longer sci-fi fantasy.

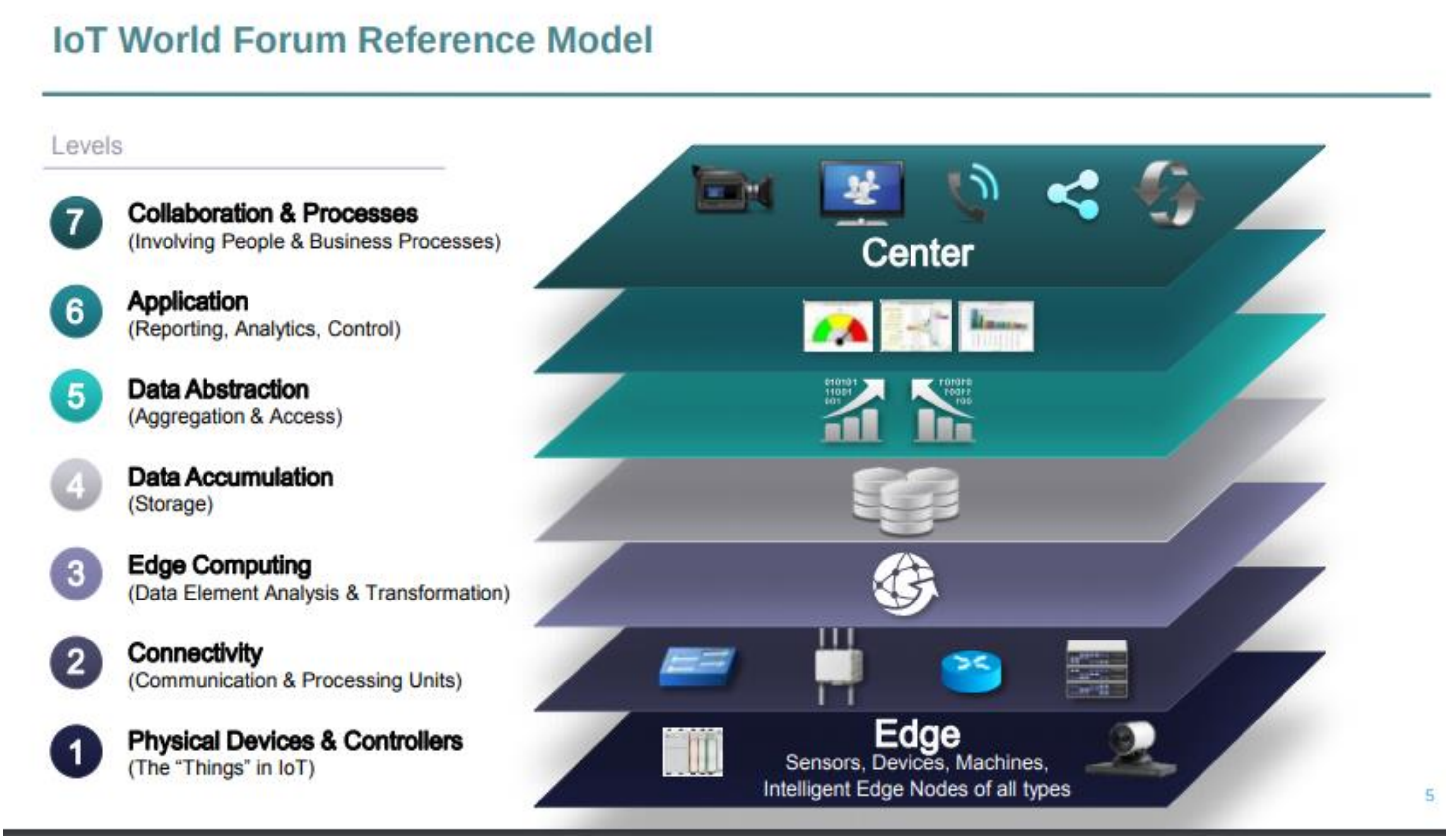
You tap the screen of your smartphone or say a word, and get immediate results. A door automatically opens, a coffee machine starts grinding beans to make a perfect cup of espresso while you receive analytical reports based on fresh data from sensors miles away.

But between your command and tasks fulfilled, there lies a large and mostly invisible infrastructure that involves multiple elements and interactions. Let's describe IoT — the Internet of Things — through its architecture, layer to layer. Let's look at Satellite Tron to see how this everyday magic works.

2.2 Major IoT Building Blocks and Layers

Before we go any further, it's worth pointing out that there is no single, agreed-upon IoT architecture. It varies in complexity and number of architectural layers depending on a particular business task.

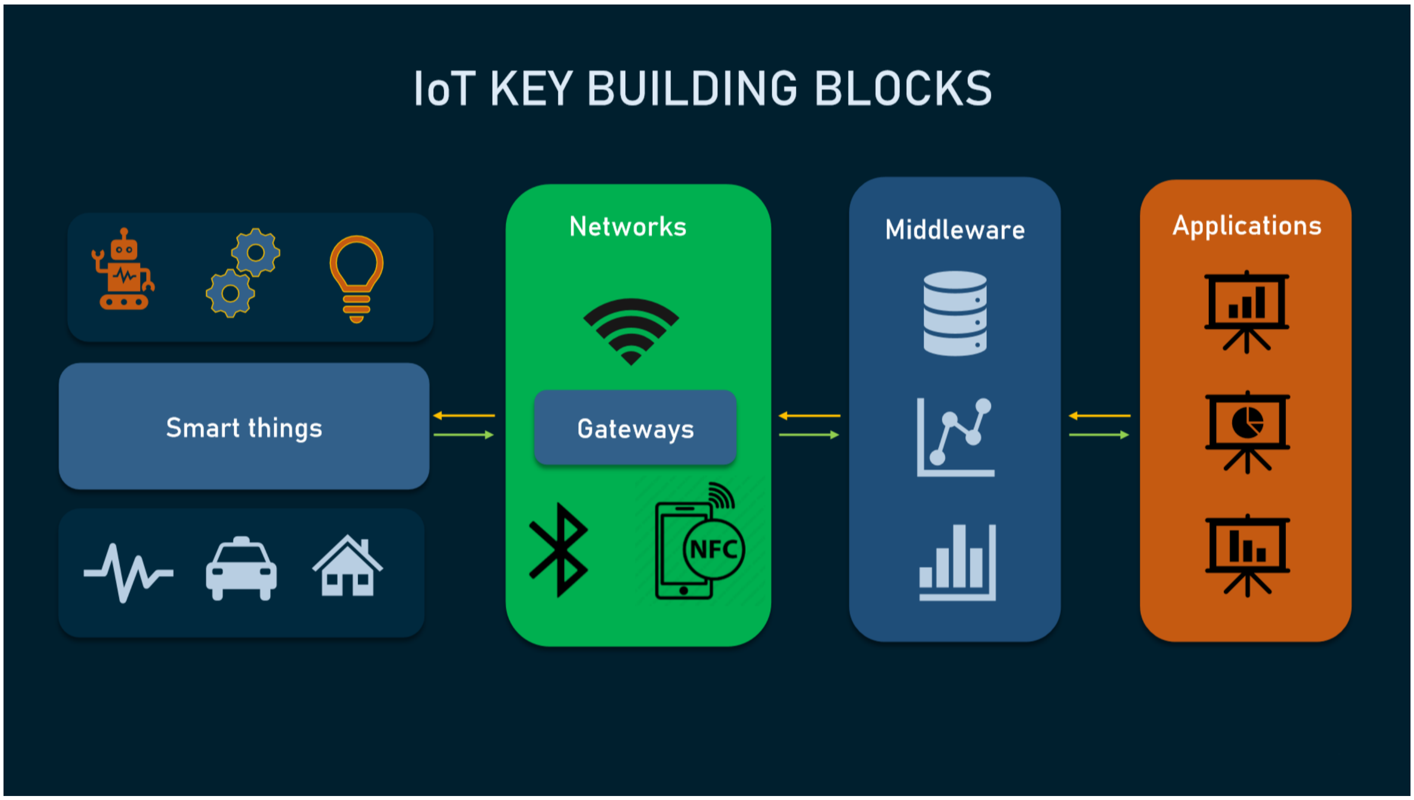
For example, the Reference Model introduced in 2014 by Cisco, IBM, and Intel at the 2014 IoT World Forum has as many as seven layers. According to an official press release by Cisco forum host, the architecture aims to *"help educate CIOs, IT departments, and developers on deployment of IoT projects, and accelerate the adoption of IoT."*



The standardized architectural model proposed by IoT industry leaders.

But no matter the use case and number of layers, the key building blocks of any IoT structure are always the same, namely:

- **smart things** the integration of computer-based systems into our physical world devices
- **networks** and **gateways** enabling low-power devices (which is often the case in IoT) to enter the big Internet
- the **middleware** or IoT platforms providing data storage spaces and advanced computing engines along with analytical capabilities
- **applications,** allowing end users to benefit from IoT and manipulate the physical world



The skeleton of an IoT system.

These elements make up the backbone of any IoT system upon which effective, multi-layered architecture can be developed. Most commonly, these layers are:

- **perception layer** hosting smart things
- **connectivity or transport layer** transferring data from the physical layer to the cloud and vice versa via networks and gateways;
- **processing layer** employing IoT platforms to accumulate and manage all data streams
- **application layer** delivering solutions like analytics, reporting, device control to end users

Besides the most essential components, we will also describes three additional layers:

- **edge or fog computing layer** performing data preprocessing close to the edge, where IoT things collect new information - Typically, edgy computing occurs on gateways
- **business layer** where businesses make decisions based on the data
- **security layer** encompassing all other layers

Often viewed as optional, these extra components none the less make an IoT project neatly fit modern business needs.

2.2.1 Perception Layer: Converting Analog Signals Into Digital Data and Vice Versa

The initial stage of any IoT system embraces a wide range of "things" or endpoint devices that act as a bridge between the real and digital worlds. They vary in form and size, from tiny silicon chips to large vehicles. By their functions, IoT things can be divided into the following large groups.

Sensors such as probes, gauges, meters, and others. They collect physical parameters like temperature or humidity, turn them into electrical signals, and send them to the IoT system. IoT sensors are typically small and consume little power.

Actuators, translating electrical signals from the IoT system into physical actions. Actuators are used in motor controllers, lasers, robotic arms.

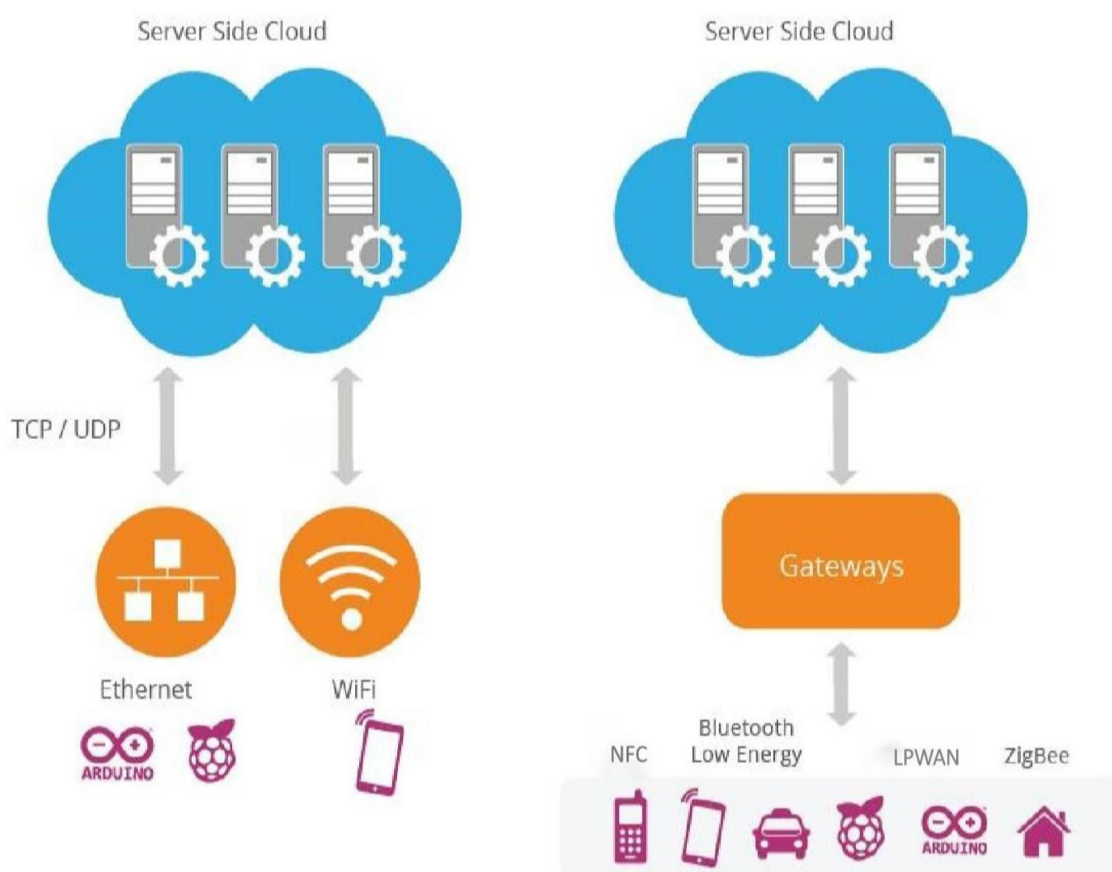
Machines and devices connected to sensors and actuators or having them as integral parts.

It's important to note that the architecture puts no restriction on the scope of its components or their location. The edge-side layer can include just a few "things" physically placed in one room or myriads of sensors and devices distributed across the world.

2.2.2 Connectivity Layer: Enabling Data Transmission

The second level is in charge of all communications across devices, networks, and cloud services that make up the IoT infrastructure. The connectivity between the physical layer and the cloud is achieved in two ways:

- directly, using TCP or UDP/IP stack;
- via gateways — hardware or software modules performing translation between different protocols as well as encryption and decryption of IoT data.



Two key models of connectivity between physical and cloud levels in IoT.

The communications between devices and cloud services or gateways involve different networking technologies.

Ethernet connects stationary or fixed IoT devices like security and video cameras, permanently installed industrial equipment, and gaming consoles.

WiFi, the most popular technology of wireless networking, is a great fit for data-intensive IoT solutions that are easy to recharge and operate within a small area. A good example of use is smart home devices connected to the electrical grid.

NFC (Near Field Communication) enables simple and safe data sharing between two devices over a distance of 4 inches (10 cm) or less.

Bluetooth is widely used by wearables for short-range communications. To meet the needs of low-power IoT devices, the Bluetooth Low-Energy (BLE) standard was designed. It transfers only small portions of data and doesn't work for large files.

LPWAN (Low-power Wide-area Network) was created specifically for IoT devices. It provides long-range wireless connectivity on low power consumption with a battery life of 10+ years. Sending data periodically in small portions, the technology meets the requirements of smart cities, smart buildings, and smart agriculture (field monitoring).

ZigBee is a low-power wireless network for carrying small data packages over short distances. The outstanding thing about ZigBee is that it can handle up to 65,000 nodes. Created specifically for IoT automation, it also works for low-power devices in industrial, scientific, and medical sites.

Cellular networks offer reliable data transfer and nearly global coverage. There are two cellular standards developed specifically for IoT things. LTE-M (Long Term Evolution for Machines) enables devices to communicate directly with the cloud and exchange high volumes of data. Also, NB-IoT or Narrowband IoT uses low-frequency channels to send small data packages.

Once parts of the IoT solution are networked, they still need messaging protocols to share data across devices and with the cloud. The most popular protocols used in the IoT ecosystems are:

- **DDS (the Data Distribution Service)** which directly connects IoT things to each other and to applications addressing the requirements of real-time systems;
- **AMQP (the Advanced Message Queuing Protocol)** aiming at peer-to-peer data exchange between servers;
- **CoAP (the Constrained Application Protocol),** a software protocol designed for *constrained devices* — end nodes limited in memory and power (for example, wireless sensors). It feels much like HTTP but uses fewer resources;
- **MQTT (the Message Queue Telemetry Transport)**, a lightweight messaging protocol built on top of TCP/IP stack for centralized data collection from low-powered devices.

In this protocol layer the IoTBPM server is fault tolerant and scales seamlessly to handle growing transaction volumes, ensuring that the ask goal can be carried out.

- **The IoTBPM Server Orchestration**

A company's end-to-end IoT BPM workflow will almost always span more than one IoT device or enterprise servers. These IoT device and enterprise services integration can be mission critical to the business and is rarely modeled and monitored. These cross-microservices workflows can be a company's core operation drivers, often they are rarely modeled and monitored, and the flow of events through different IoT devices is usually expressed only in low-level Interface flow specifications and rarely depict business enterprise goals and workflow diagrams.

In the context of IoT devices, when we say BPM, all we mean is "a sequence of tasks that allows us to achieve a goal." In IoT BPM orchestrated each task-goal can be carried out by a different IoT device, enterprise RESTful server, human task, or any other integrated service.

NETWORKING TECHNOLOGIES USED in IoT

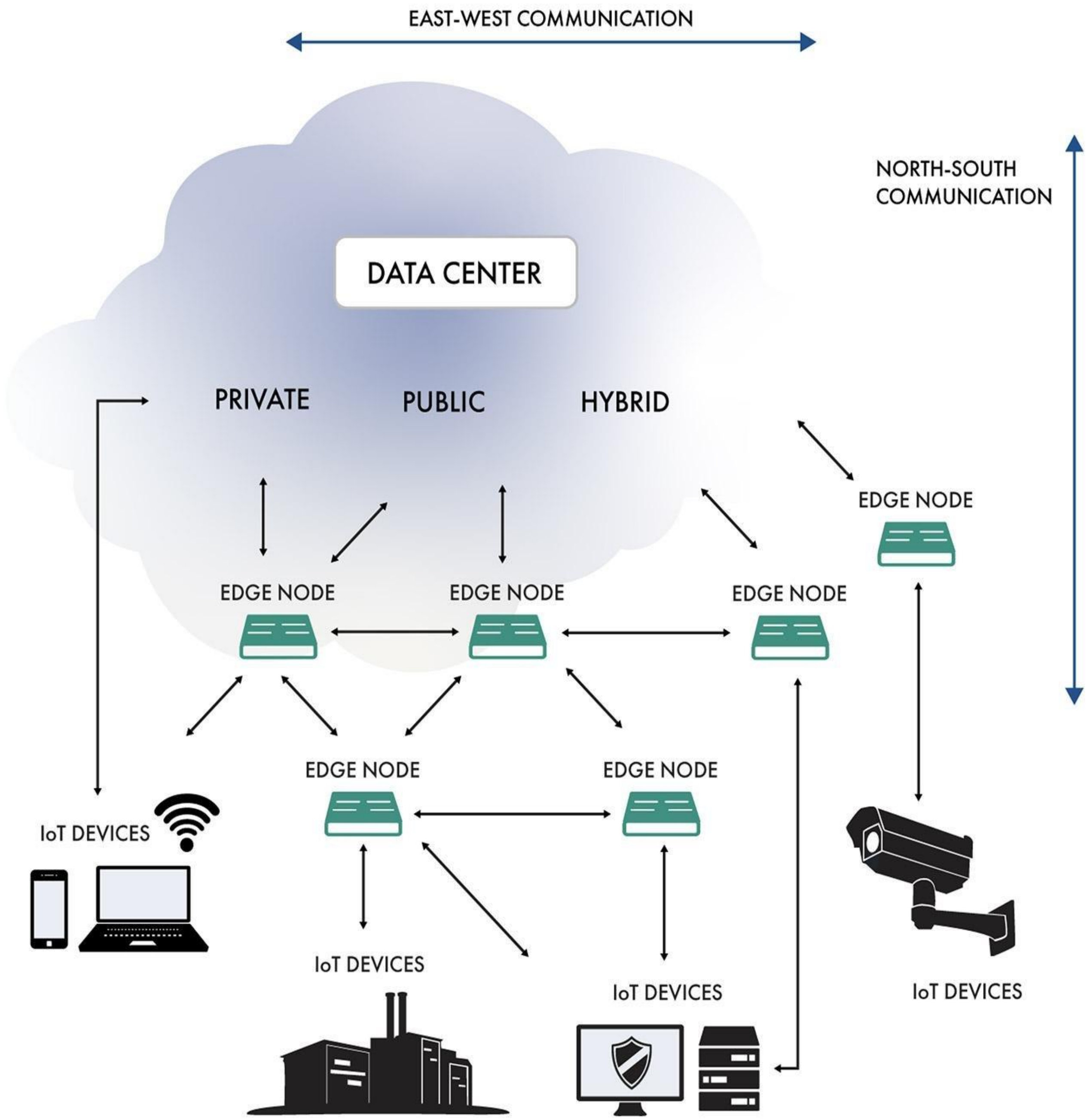
Network	Connectivity	Pros and Cons	Popular use cases
Ethernet	Wired, short-range	High speed Security Range limited to wire length Limited mobility	Stationary IoT: video cameras, game consoles, fixed equipment
WiFi	Wireless, short-range	High speed Great compatibility Limited range High power consumption	Smart home, devices that can be easily recharged
NFC	Wireless, ultra-short-range	Reliability Low power consumption Limited range Lack of availability	Payment systems, smart home
Bluetooth Low-Energy	Wireless, short-range	High speed Low power consumption Limited range Low bandwidth	Small home devices, wearables, beacons
LPWAN	Wireless, long-range	Long range Low power consumption Low bandwidth High latency	Smart home, smart city, smart agriculture (field monitoring)
ZigBee	Wireless, short-range	Low power consumption Scalability Limited range Compliance issues	Home automation, healthcare and industrial sites
Cellular networks	Wireless, long-range	Nearly global coverage High speed Reliability High cost High power consumption	Drones sending video and images

Major networking technologies used in the IoT projects.

2.2.3 Edge Computing or Fog Computing Layer: Reducing System Latency

This level is essential for enabling IoT systems to meet the speed, security, and scale requirements of the 5th generation mobile network or 5G. The new wireless standard promises faster speeds, lower latency, and the ability to handle many more connected devices, than the current 4G standard.

The idea behind edge or fog computing is to process and store information as early and as close to its sources as possible. This approach allows for analyzing and transforming high volumes of real-time data locally, at the edge of the networks. Thus, you save the time and other resources that otherwise would be needed to send all data to cloud services. The result is reduced system latency that leads to real-time responses and enhanced performance.



The scheme of communications between IoT devices, edge nodes, and cloud data centers.

Edge Computing occurs on gateways, local servers, or other edge nodes scattered across the network. At this level, data can be:

- evaluated to determine if it needs further processing at higher levels,
- formatted for further processing,
- decoded,
- filtered
- redirected to an additional destination

To sum up, the first three layers see data in motion, as it is constantly moving and altering. Only on hitting the next level, is data finally at rest and available for use by consumer applications.

2.2.4 Processing Layer: Making Raw Data Useful

The processing layer accumulates, stores, and processes data that comes from the previous layer. All these tasks are commonly handled via IoT platforms and include two major stages.

- **Data accumulation stage**

The real-time data is captured via an API and put at rest to meet the requirements of non-real-time applications. The data accumulation component stage works as a transit hub between event-based data generation and query-based data consumption.

Among other things, the stage defines whether data is relevant to the business requirements and where it should be placed. It saves data to a wide range of storage solutions, from data lakes capable of holding unstructured data like images and video streams to event stores and telemetry databases. The total goal is to sort out a large amount of diverse data and store it in the most efficient way.

- **Data abstraction stage**

Here, data preparation is finalized so that consumer applications can use it to generate insights. The entire process involves the following steps:

- combining data from different sources, both IoT and non-IoT, including ERM, ERP, and CRM systems
- reconciling multiple data formats
- aggregating data in one place or making it accessible regardless of location through data virtualization

Similarly, data collected at the application layer is reformatted here for sending to the physical level so that devices can "understand" it.

Together, the data accumulation and abstraction stages veil details of the hardware, enhancing the interoperability of smart devices. What's more, they let software developers focus on solving particular business tasks — rather than on delving into the specifications of devices from different vendors.

The power of the IoT (Internet of Things) device increases greatly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT devices action.

2.2.5 Application Layer: Addressing Business Requirements

At this layer, information is analyzed by software to give answers to key business questions. There are hundreds of IoT applications that vary in complexity and function, using different technology stacks and operating systems. Some examples are:

- device monitoring and control software
- mobile apps for simple interactions
- business intelligence services
- analytic solutions using machine learning

Currently, applications can be built right on top of IoT platforms that offer software development infrastructure with ready-to-use instruments for data mining, advanced analytics, and data visualization. Otherwise, IoT applications use APIs to integrate with middleware.

2.2.6 Business Layer: Implementing Data-Driven Solutions

The information generated at the previous layers brings value if only it results in problem-solving solution and achieving business goals. New data must initiate collaboration between stakeholders who in turn introduce new processes to enhance productivity.

The decision-making usually involves more than one person working with more than one software solution. For this reason, the business layer is defined as a separate stage, higher than a single application layer.

2.3 Satellite Tron AI-IoT jBPM (BPMN) Drools (BRMS)

The business layer is greatly enhances with the Satellite Tron AI-IoTBPM server for BRMS.

The power of the IoT (Internet of Things) device increases greatly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT devices action as part of our business process. The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one (BPM) diagram. With AI-IoTBPM adding Drools and jBPM to IoT, we make the IoT devices "Smart." Moving beyond just collecting IoT data and transitioning, to leveraging the new wealth of IoT data, to improving the SMART decision making is the key. The Executive Order Corp AI-IoTBPM will help these IoT devices, environments, and products to self-monitor, self-diagnose and eventually, self-direct. At Executive Order making "Things Smart" is our application of AI to IoT platform via Drools-Rules Inference Reasoning, jBPM, and ES-Expert Systems.

With the use of AI Drools-jBPM analysis and reasoning in IoT devices, we can orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based systems into the physical world that has never been available before. This results in greatly improved efficiency, accuracy, and economic benefits by increased automation – reduced intervention. This IoT orchestration of IoT devices gives us the ability for action after our AI decision.

2.3.1 Security Layer: Preventing Data Breaches

It goes without saying that there should be a security layer covering all the above-mentioned layers. IoT security is a broad topic worthy of a separate article. Here we'll only point out the basic features of the safe architecture across different levels.

Device security. Modern manufacturers of IoT devices typically integrate security features both in the hardware and firmware installed on it. This includes

- embedded TPM (Trusted Platform Module) chips with cryptographic keys for authentication and protection of endpoint devices
- a secure boot process that prevents unauthorized code from running on a powered-up device
- updating security patches on a regular basis
- physical protection like metal shields to block physical access to the device

Connection security. Whether data is being sent over devices, networks, or applications, it should be encrypted. Otherwise, sensitive information can be read by anybody who intercepts information in transit. IoT-centric messaging protocols like MQTT, AMQP, and DDS may use standard Transport Layer Security (TSL) cryptographic protocol to ensure end-to-end data protection.

Cloud security. Data at rest stored in the cloud must be encrypted as well to mitigate risks of exposing sensitive information to intruders. Cloud security also involves authentication and authorization mechanisms to limit access to the IoT applications. Another important security method is device identity management to verify the device's credibility before allowing it to connect to the cloud.

The good news is that IoT solutions from large providers like Microsoft, AWS, or Cisco come with pre-built protection measures including end-to-end data encryption, device authentication, and access control. However, it always pays to ensure that security is tight at all levels, from the tiniest devices to complex analytical systems.

3 Edge Computing IoT Internet of Things Architecture

3.1 Edge Computing IoT Solution Design

3.1.1 Edge Computing Implementation Methodology

Smart technologies — like autonomous vehicles, intelligent buildings, and the Industrial Internet of Things (IIoT) or Industry 4.0 manufacturing — generate so much data that it causes traffic jams enroute to the servers. The elegant solution to this challenge is shifting some tasks from powerful, but remote, data centers to smaller processors at the edge, or in direct proximity to IoT devices.

While the idea is not new, its realization has become more feasible with the arrival of high-speed 5G networks. It is expected that before long, 50 percent of edge-generated data will be stored and processed locally, without the need to travel to a centralized repository.

3.1.2 Edge Computing Distributed IT Infrastructure

Edge computing is a distributed IT infrastructure that brings processing of raw data close to its sources, primarily — IoT sensors. This allows for assigning workloads to multiple machines, rather than relying on a single computer to deal with never-ending traffic from myriads of devices. Only actionable results are eventually transmitted to the main server, often located far away or in the cloud.

Moving a certain portion of jobs to the periphery results in higher bandwidth and lower latency compared to frameworks built around remote centralized servers.

If translated to business terms, this means

- better performance
- shorter response times
- real-time insights
- unlimited scalability

Besides that, edge computing allows you to occupy less cloud storage space owing to the fact that you save only the data you really need and will use.

The idea of edge computing, can be compare it with closely associated concepts.

3.1.3 Fog Computing vs Edge Computing vs Cloud Computing

Terms "fog computing," coined by Cisco, and "edge computing" are often used interchangeably as they both involve allocating processing and analytics resources closer to the points where data is generated.

Fog computing or fogging happens within the local area network (LAN), somewhere between the edge and large servers.

Edge computing, data is processed on the devices physically attached to the sensors.

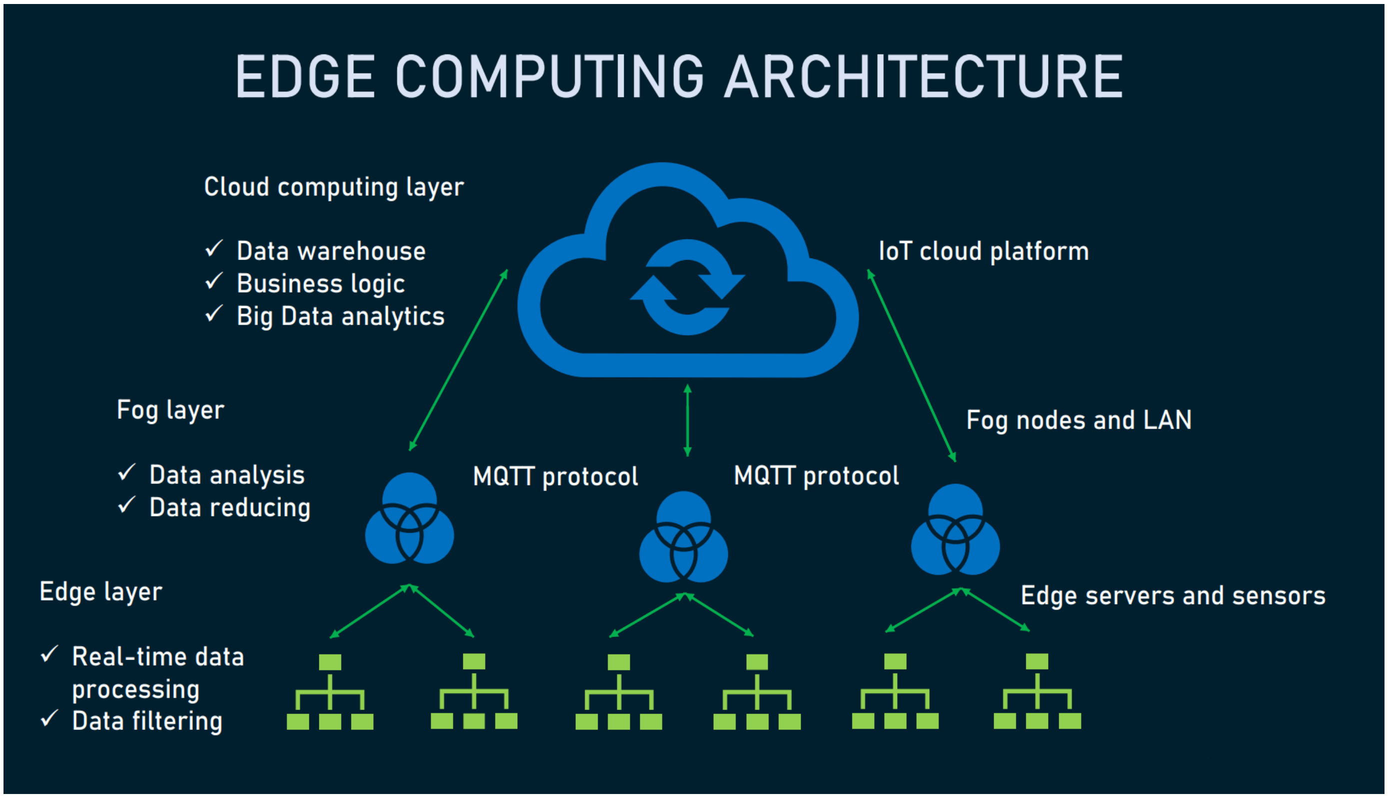
Similar to edge and fog computing, **cloud computing** supports the idea of distributed data storage and processing. It replaces or complements traditional data centers, enabling scalable deployment of resources across multiple locations and providing powerful tools for analytics. Yet, cloud facilities can be hundreds or even thousands of miles away from where data is produced.

In practice, three types of computing are just different layers of a system for processing IoT data. In most cases, the layers exchange information via MQTT (message queue telemetry transport) — a lightweight IoT protocol for pub/sub communications.

3.1.4 Edge Computing Architecture

IoT system architectures that outsource some processing jobs to the periphery can be presented as a pyramid with an edge computing layer at the bottom.

The Executive Order Corp AI-IoTBPM will help these IoT devices, environments, and products to self-monitor, self-diagnose and eventually, self-direct. At Executive Order making **"Things Smart"** is our application of AI to IoT platform via Drools-Rules Inference Reasoning, jBPM, and ES-Expert Systems.



How systems supporting edge computing work.

At an **edge computing layer,** the processing is performed on edge servers that directly interface with dozens to thousands to even millions of sensors and controllers. These servers have analytics capabilities and even run ML models to make decisions on the site in real-time. For example, they can coordinate movements of robotic arms or predict equipment breakdowns.

The edge layer also filters raw data according to predefined parameters eliminating traffic congestion on the way to the cloud. A popular instance is video recognition. Instead of moving full streams to the cloud, local devices pre-process everything that cameras "see," cut off inapplicable parts and send to the server only relevant video data.

A **fog computing layer** bridges the edge and the cloud. Here, fog nodes or IoT gateways execute additional filtering and analysis. The layer is capable of processing more data than edge servers. Yet, many systems do without the mediation of this kind. In other words, edge computing doesn't need fogging while fog computing can't substitute for edge computing.

A **cloud computing layer** accumulates valuable data from all edge devices and fog nodes and stores it in data warehouses. That's where the business logic resides and Big Data analytics can be run owing to huge processing power.

The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one (BPM) diagram. With AI-IoTBPM adding Drools and jBPM to IoT, we make the IoT devices "**Smart**." Moving beyond just collecting IoT data and transitioning, to leveraging the new wealth of IoT data, to improving the SMART decision making is the key.

3.1.5 Edge Computing Examples and Use Cases

Edge computing impacts all key industries, including manufacturing, healthcare, farming, transportation, security, and more. In particular, it drives the Internet of Medical Things (IoMT), autonomous vehicles and telematics technologies, and predictive maintenance, a proactive approach to servicing industrial machines.

Roughly, edge computing can be considered as an important extension of cloud computing.

3.1.6 Key Edge Computing Providers

In response to a growing demand, many tech giants have launched their edge computing platforms.

- large cloud providers who have the core IoT software infrastructure, wide range related services
- hardware manufacturers who produce sensors, micro-processing units (MPUs), networking

As a rule, the latter partner with the former to take advantage of their storage and processing capabilities. Below, we'll look at edge offerings from four popular vendors — two from each group.

TOP PLATFORMS FOR EDGE COMPUTING

	Supported devices	Services and capabilities	Real-life use cases
FREE RTOS / AWS Greengrass	Amazon partner hardware	✓ Operating system for microcontrollers ✓ Software development for edge devices ✓ Local data processing and management ✓ Edge AI	✓ Solar energy sharing ✓ Equipment monitoring and maintenance
Azure IoT Edge	Azure appliances	✓ Hardware-as-a-service ✓ Local data processing and management ✓ Edge AI ✓ Edge storage ✓ Support for disconnected scenarios	✓ Computer vision for ship navigation ✓ Innovation of operating rooms infrastructure
NVIDIA	NVIDIA-certified servers by Cisco, Dell, Lenovo, etc.	✓ Edge AI ✓ Integration with OpenShift to orchestrate edge deployments ✓ Integrations with AWS Greengrass and Azure IoT Edge	✓ Intelligent retail ✓ Analyzing video data to improve traffic flow
CISCO	Cisco networking hardware	✓ Edge AI ✓ Code deployments orchestration ✓ Integration with Microsoft Visual Studio ✓ Integrations with Microsoft Azure IoT, Software AG, and Quantela clouds.	✓ Reducing emergency response times of patrol vessels ✓ Preventing leaks in water distribution facilities ✓ Predictive maintenance for oil & gas well equipment

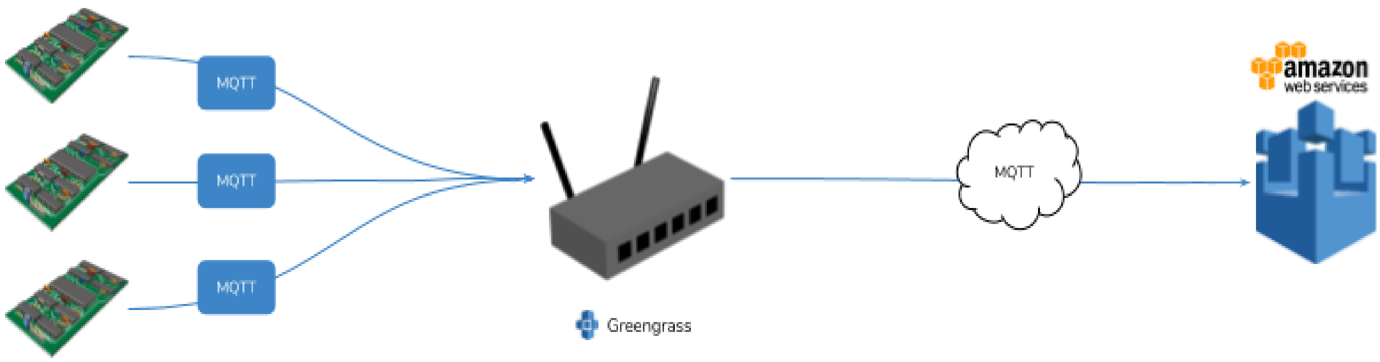
Hardware and software offerings from main edge computing providers.

3.1.7 Amazon FreeRTOS and Greengrass: Reduce Spending on Equipment Maintenance

FreeRTOS and Greengrass extend the AWS IoT platform, enabling third-party developers to program and manage edge devices qualified to work with Amazon cloud. You can get familiar with the list of Amazon partner hardware here.

A free operating system for microcontroller units (MCUs), FreeRTOS links MCU-based sensors and actuators directly to the cloud or more powerful edge devices running Greengrass.

The latter, in turn, allows you to write code and train machine learning models with AWS services and then deploy them on qualified physical platforms and IoT gateways. All communications are performed via MQTT protocol.



Amazon edge computing offering.

Customers and use cases

FreeRTOS facilitates building a peer-to-peer platform called SOLshare. It interconnects home solar electric systems across Bangladesh allowing them to monetize excess energy. Another application is monitoring hydraulic lifts on commercial trucks, run by Shimadzu, a manufacturer of precision instruments. This helps reduce equipment downtime and maintenance spendings.

Eco Fit, an early adopter of Greengrass, uses edge computing to analyze data from gym equipment to provide better maintenance.

3.1.8 Microsoft Azure Stack Edge: Ensures Safe Ship Navigation

Azure Stack Edge uses a hardware-as-a-service model to provide their customers with edge processing devices compatible with other Azure products.

Appliances ordered from the Azure portal take advantage of Microsoft's AI and IoT services, computing, and storage capabilities. They enable you to run containerized applications and machine learning models built and trained in the Azure cloud. Devices have a local storage space and support disconnected scenarios in harsh environments.

Customers and use cases

Azure AI and edge appliances are used by JRCS, a Japanese maritime equipment manufacturer, to implement computer vision and ensure safe navigation. One more example is Olympus Medical Systems utilizing Azure equipment and AI to analyze and interpret data in real time from video cameras installed in operating rooms.

3.1.9 NVIDIA EGX: Number One Choice for Smart Cities

The global provider of graphic processing units (GPUs) and system-on-a-chip units (SoCs) launched its edge computing stack EGX in 2019. It is compatible with NVIDIA AI Enterprise software and integrated with OpenShift, a Kubernetes platform by RedHat. This enables companies to develop and train models in the cloud and then run and orchestrate AI deployments across NVIDIA-certified servers, produced by Dell, Cisco, Lenovo, Hewlett-Packard and other industry leaders.

EGX is also pre-connected to major IoT platforms, enabling users to manage edge computing operations via AWS Greengrass or Azure IoT Edge.

Customers and use cases

The world's top retailer Walmart chose EGX to analyze 1.6 terabytes of data generated per second by its shops. Edge AI apps perform a large number of tasks — for example, they send alerts when you need to restock shelves or open a new checkout lane.

NVIDIA is also a popular choice for smart city solutions — like analyzing data from video cameras to optimize traffic lines, improve traffic flow, and enhance safety of pedestrians.

3.1.10 Cisco Edge Intelligence: Prevents Leaks of Water, Oil, and Gas

US-based global leader in networking, Cisco is one of the edge computing pioneers. The company offers Edge Intelligence orchestration software that runs on its industrial gateways and services routers. It simplifies data extraction from IoT sensors, using built-in industry standard connectors. Then, the software performs real-time microprocessing of this information.

The pre-processed data can be sent to multiple cloud destinations as Cisco is pre-connected with Microsoft Azure IoT, Software AG, and Quantela, a smart city automation platform.

How Cisco Edge Intelligence works.

Edge Intelligence is integrated with Microsoft Visual Studio, a popular code editor most developers are familiar with. So, engineers write, test, and deploy their edge software using the convenient environment.

Customers and use cases

The Port of Rotterdam uses Cisco Edge Intelligence to analyze and visualize data from their patrol vessels. Real-time insights enable predictive maintenance and improve emergency response times. Other customers are oil and gas wells and water distribution facilities that use Cisco software to remotely control their equipment and prevent leaks and breakdowns.

3.2 IoT Edge Computing Implementation

Companies that consider utilizing edge computing have a choice: to do everything themselves or to rely on vendors like above-mentioned Cisco or NVIDIA with their end-to-end solutions.

Each option comes with its own pros and cons, and the final decision will largely depend on the company's budget, in-house tech expertise, project scale, and other factors. Answers to the following questions can help you head for the right conclusion.

3.2.1 How critical is it for Your Business to Have Full Control over the Edge?

The DIY approach allows you to keep ownership of the edge on your side. This is a significant advantage for businesses dealing with private data that is subject to strict regulations. Healthcare organizations are among them. Companies who worry about their trade secrets and know-hows will probably also be uncomfortable putting their local processing units in the hands of third-party vendors.

However, edge infrastructure from a single provider can be quite safe in terms of data leaks. Say, Cisco edge equipment and software don't interfere with operational data. Specific information about machines stays within the internal networks of a manufacturer. If you seek support from a vendor, discuss this point from the get-go.

3.2.2 Do you Have Sufficient Internal Expertise in IoT and Networking?

The lack of common standards in edge computing is the main obstacle in the way of its adoption. Various devices, physical platforms, and servers may require different processing power and support different communication protocols. Companies without internal expertise in IoT and networking often can't handle edge deployments and maintenance on their own.

3.2.3 How Many Locations and Endpoints do you have?

Orchestration and automation is another key challenge of edge computing. The more locations and endpoints you have, the more difficult it becomes to manage their day-to-day work. When it comes to large factories with millions of sensors, you need to automate as many repetitive tasks related to the edge as possible.

Again, everything comes down to experts able to set up the automation across networks. Edge computing vendors, especially those specialized in networking equipment, have specialists who can get these processes up and running.

3.2.4 Who Will Take Care of Data Security?

Irrespective of data protection laws, two-thirds of IT companies have serious concerns about edge computing security. A larger network of devices by its nature creates a wider surface for malicious attacks.

Data breaches can happen during communication between edge computing servers, or when sensitive information is processed and stored locally.

Large tech providers typically take security concerns seriously, perform regular vulnerability assessments, update firmware and software, and quickly address issues, should they occur. If you implement the edge architecture on your own, contemplate safety precautions in advance.

The vital countermeasures to edge-related cyber threats are

- prioritizing regular **software updates** to all devices to ensure that you run the bug-free version with all the most current patches
- performing **side-channel analysis** to detect unusual system behaviors (like increased power consumption) or timing delays) and thus identify installation of malicious hardware or software at the edge

Companies rowing their own boat have to invest heavily in strategies and workforce to minimize security risks and conform to compliance requirements.

4 IoT Platforms and Architecture Layers

4.1 Growth in Connected IoT Devices

4.1.1 Cloud, Edge Computing and Fog Computing

Hundreds of new devices will be connected to the web at a breathtaking pace. For the most part, they belong to the Internet of Things (IoT) / Edge or Fog Computers, or gadgets capable of communicating and sharing data without human interaction.

The technology will shift into an even higher gear with the arrival of fifth-generation or 5G networks supporting a million gadgets per square kilometer — ten times as many as in the 4G era. The number of active IoT connections is expected to double by 2024.

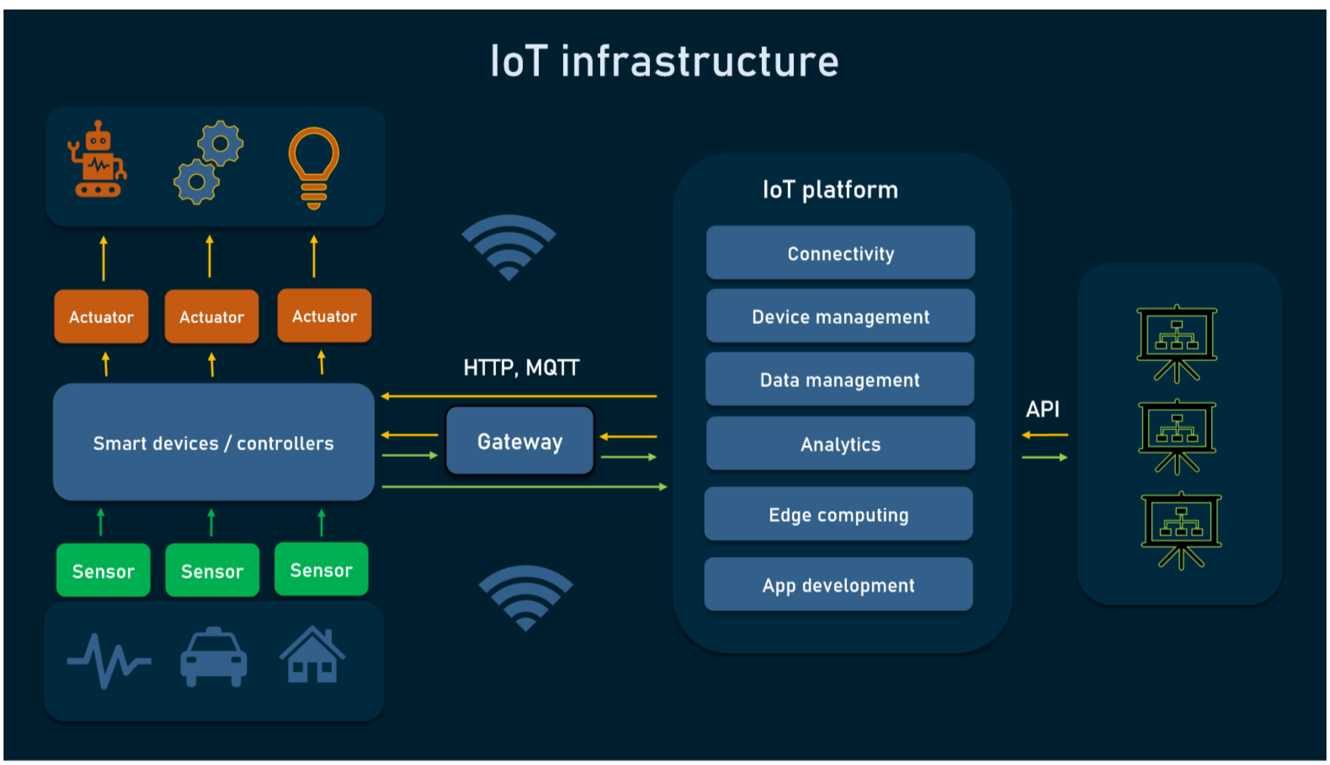
Day by day, the IoT sees wider adoption, opening new opportunities and driving more value to both businesses and their clients. For companies, incorporating the consistent IoT strategy into daily routine means continuous access to valuable data about products and processes that can be translated into reduced expenses, improved efficiency in logistics and maintenance, better products, and enhanced customer experience.

But to build and run a robust infrastructure, a manufacturer or service provider needs a solid foundation — in other words, an IoT platform that connects devices, collects data, and creates insights. We will explain the IoT ecosystem, outline the core IoT platform functionality, and compare major players.

4.1.2 IoT Architecture Layers

With an IoT platform acting as a bridge between the physical world and business processes, the IoT infrastructure contains several key layers

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



How an IoT system works.

4.1.3 Perception Layer: IoT Hardware

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

Sensors capture signals from the physical world, convert them into digital form, and feed them to the IoT system. You can monitor and manage sensors remotely, using our Satellite Tron and IoTBPM BRMS applications.

Actuators receive signals from the IoT system and translate them into physical actions manipulating equipment. Similar to sensors, actuators can be configured from remote computers.

Devices are connected to sensors or even have them embedded as an integral part. On the other side, devices link to a gateway or directly to an IoT platform. These hardware components cache and preprocess real-time data, reducing the burden on central storages and main processors.

4.1.4 Transport Layer: Networks and Gateways

The transport layer is responsible for smooth and secure data transmission from perception layer to processing layer. It encompasses wired or wireless networks and a gateway — a hardware or software module that consolidates data from devices, analyzes it, performs translation between different protocols, and forwards information to the cloud. As a rule, the gateway converts all information into MQTT messages — the lightweight protocol most widely used in the IoT.

4.1.5 Processing Layer: Cloud Middleware or IoT Platforms

Here we come to an 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.

Typically, fully-fledged platforms take care of such important tasks:

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

4.1.6 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.

With the place of IoT platforms in the connected ecosystem more clearly defined, let's concentrate on their functions, options available on the market, and how to differences between them.

4.2 IoT Platform Landscape and Key Players

The total number of known IoT platforms reached today is staggering, with half of them focusing on manufacturing and industrial use (IIoT). Other popular activity areas are energy, mobility, smart cities, and healthcare.

Fragmented and unconsolidated, the IoT platform market nonetheless has several major players enjoying the largest market share. 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
- 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

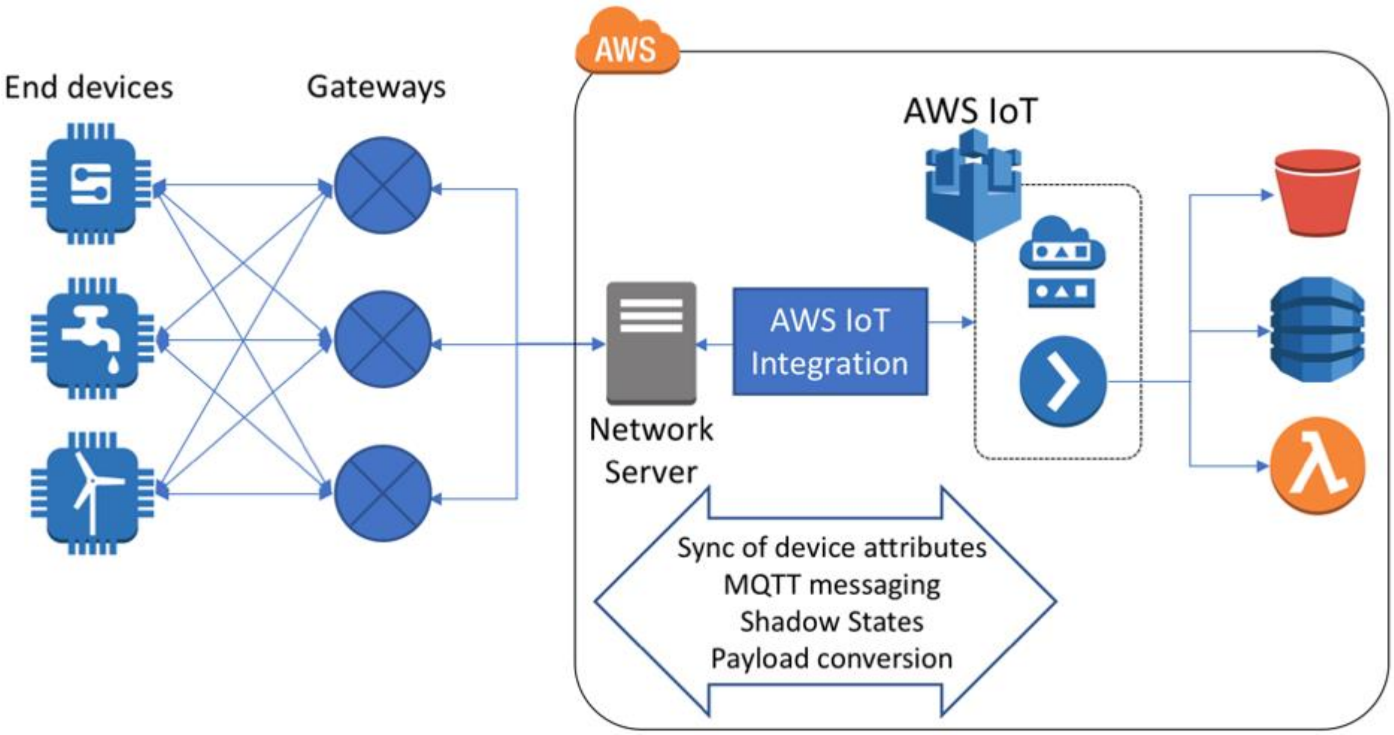
4.2.1 AWS IoT Platform: The Best Place to Build Smart Cities

Key use cases: *smart city, connected home, agriculture, healthcare.*

Key strengths: *large variety of available services, rich development environment to simplify and accelerate IoT app designing.*

Backed by the public cloud leader, this IoT platform has users across 190 countries. In addition to a broad sets of tools, it offers easy integrations with other popular AWS services taking advantage of Amazon's scalable storage, computing power, and advanced AI capabilities.

In 2020, AWS was recognized as a leading IoT applications platform empowering smart cities. It is also in the forefront of building connected home products, powered by Alexa Voice. Among successful use cases in other domains are projects for Philips HealthCare, Rio Tinto (the world's second largest metals and mining corporation), and Bayer Crops Science (agriculture).



AWS IoT infrastructure. Source: AWS

4.2.2 AWS IoT Core

IoT Core is the heart of the AWS IoT suite, which manages device authentication, connection, and communication with AWS services and each other. Its entry point — **Device Gateway** — supports MQTT, HTTP, and WebSocket protocols. Amazon claims that the module is scalable enough to handle over a billion devices, with each of them being assigned a unique identity. Due to authentication and encryption provided at all points of connection, IoT Core and devices never exchange unverified data.

Vetted messages are processed by the **Rules Engine** that routes them either to a device or cloud AWS service — like AWS Lambda (a serverless computing platform), Amazon Kinesis (a solution for processing big data in real time), Amazon S3 (a storage service), to name a few.

Another useful 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.

Of five platforms, AWS IoT Core is the most popular choice among programmers, and for a reason. It offers SDKs for Android and iOS applications as well as for Embedded C, C++, Java, and Python. Amazon speeds up development by providing a large collection of templates along with a visual drag-and-drop tool called **IoT Things Graph** that simplifies building workflows across IoT components.

4.2.3 Additional AWS IoT Control Services

You can complete IoT Core functionality with the following optional services.

AWS IoT Device Management allows you to remotely organize, track, control, update, and scale large and diverse device fleets. Agnostic to a device type, the service supports any IoT thing, from microcontrollers to connected fridges.

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 behavior across thousands of devices and react to them based on predefined rules.

AWS SiteWise 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.

4.2.4 AWS IoT Analytics

The core intelligent solution, AWS IoT Analytics, automatically collects and cleans data before transmitting it to a time-series storage for further analysis. The service enables you to enrich information streamed by devices with data from external sources.

IoT Analytics has templates to build predictive maintenance models. It easily integrates with:

- Amazon QuickSight, a business intelligence service to visualize data insights
- Jupyter Notebook that provides powerful tools for machine learning and advanced statistical analysis
- Amazon SageMaker, an environment for building, training, and deployment of machine learning models

4.2.5 Edge Computing Stack

Amazon facilitates edge computing by providing a real-time operating system for microcontrollers called FreeRTOS. The freely distributed technology allows you to easily program low-power devices and securely connect them to IoT Core, other AWS services, and hardware components.

Also, you can extend analytical, management, and other Amazon capabilities to more powerful equipment by using AWS IoT GreenGrass. The service enables you to write code in the cloud and then deploy it on devices to be executed locally.

4.2.6 Cisco IoT: the Edge Computing leader with the Largest Fleet of Connected Cars

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

Key strengths: *mobile connectivity, environment for edge computing, 5G readiness.*

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.

4.2.7 Cisco IoT Control Center

IoT Control Center is the largest cellular connectivity platform servicing over 160 million mobile devices and 29,000 enterprise-grade customers worldwide. The middleware is also known as the number one service provider for connected cars.

More than 4 million devices are added to the middleware every month to take advantage of the connectivity capabilities such as:

- **machine learning.** The Control Center analyzes 3 billion events 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 — instead of building complex integrations between different service providers.
- **5G readiness.** The platform already supports 5G non-standalone (NSA) resting upon the existing 4G infrastructure. By the end of 2020, the company is going to add 5G standalone (SA) indicationg the creation of a new separate network.

4.2.8 Cisco Kinetic IoT Operations Platform

Cisco Kinetic comprises three components teamed up to connect devices of any type and manage data both at the edge of the network and in the cloud. The platform is compatible with Cisco networking hardware, however, it works with some third-party products recommended by Cisco.

The Gateway Management Module monitors industrial gateways and enables remote configuration.

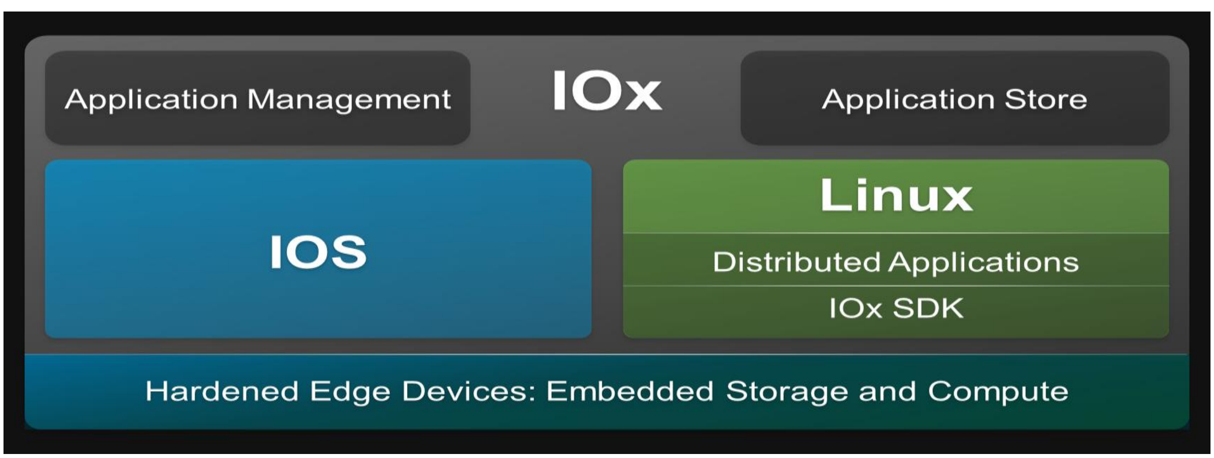
The Edge and Fog Processing Module pushes selected data management processes from the cloud to nodes and devices closer to data sources.

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. You can create rules for different apps depending on the data type. The module is cloud-neutral, so you are free to use any cloud provider for data storage and management.

4.2.9 Edge Computing Stack

The software part of Cisco's edge computing offering includes two major solutions.

Cisco IOx is a Linux-based environment to manage fog applications over the network. Cisco provides development tools and guidelines for app building within the IOx ecosystem. But you can also use out-of-the-box solutions by Cisco and its partners.



IOx environment structure. Source: Cisco Blogs

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. The solution also comes pre-integrated with Software AG Cloud and Quantela, a smart city automation and AI platform.

4.2.10 Google Cloud IoT: Driving Transportation with Google Maps

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

Key strengths: *data analytics and visualization, wide range of available cloud services.*

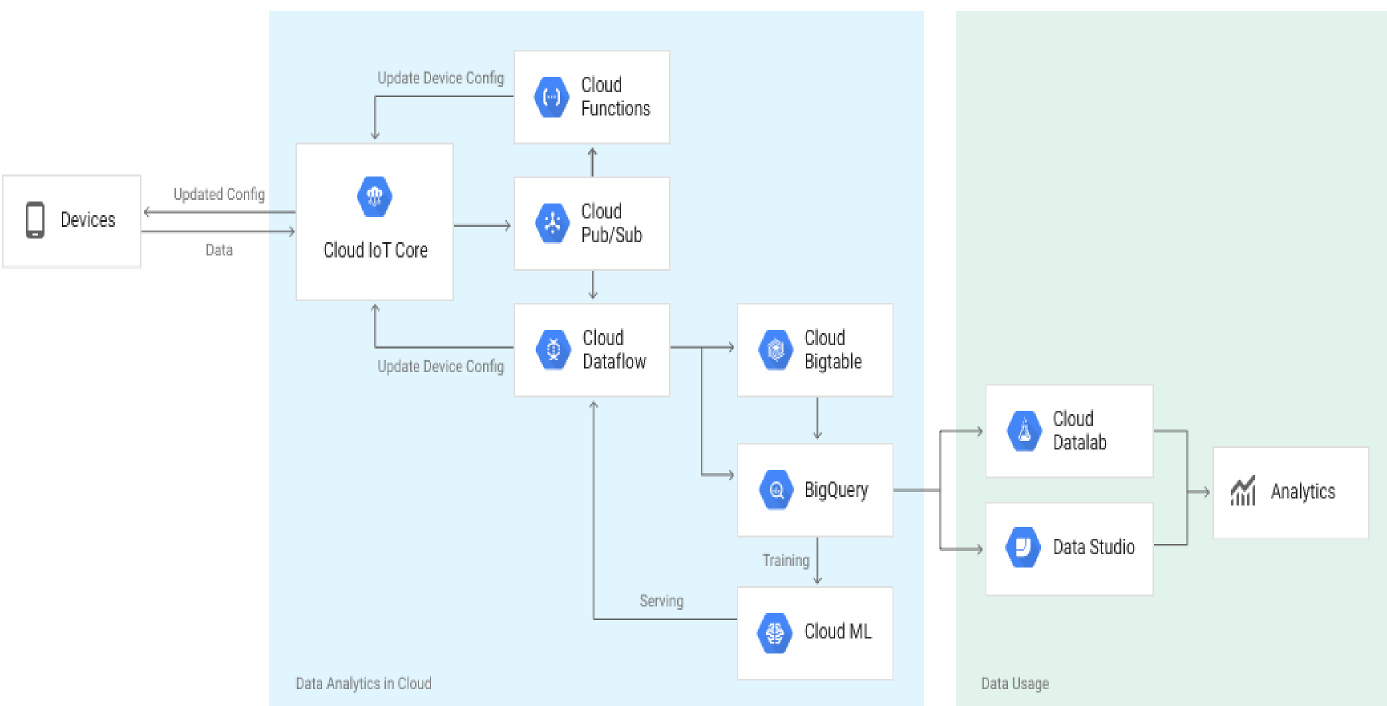
The IoT suite from the most popular search engine is centered on its flagship product **Cloud IoT Core**, powerful enough to manage data from millions of devices. Teamed up with other Google Cloud services, it is already optimizing operations in manufacturing, building, energy, and other sectors. Its transportation and smart city solutions take advantage of Google Maps Platform allowing for visualization of geographical data.

4.2.11 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. It publishes data streams to Cloud Pub/Sub service that make possible merging messages from different sources into a single system.

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 preprocess data in real time
- Cloud Bigtable to ingest and store large volumes of data
- BigQuery to analyze data in real time, create and train machine learning models
- Data Studio to visualize insights extracted from BigQuery, using pre-built templates
- Cloud Datalab to develop custom analytics practices and visualizations



Cloud IoT Core integrations. Source: Google Cloud

4.2.12 Edge Computing Stack

In March 2020, Google announced a partnership with AT&T, the world's largest telecommunication company by revenue. 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.

4.2.13 IBM IoT Suite: Bringing Intelligence to Fields and Factories

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

Key strengths: *real-time insights and predictive analytics with machine learning and AI.*

IBM combines IoT with powerful cognitive capabilities of Watson platform — an industry leader in AI and machine learning. Its assortment of AI-driven IoT products includes Watson Decision Platform for agriculture, Watson Supply Chain Insights for connected logistics and transportation, Watson Building Insights for analyzing energy and asset usage, and a set of industrial equipment solutions.

4.2.14 IBM Watson IoT Platform

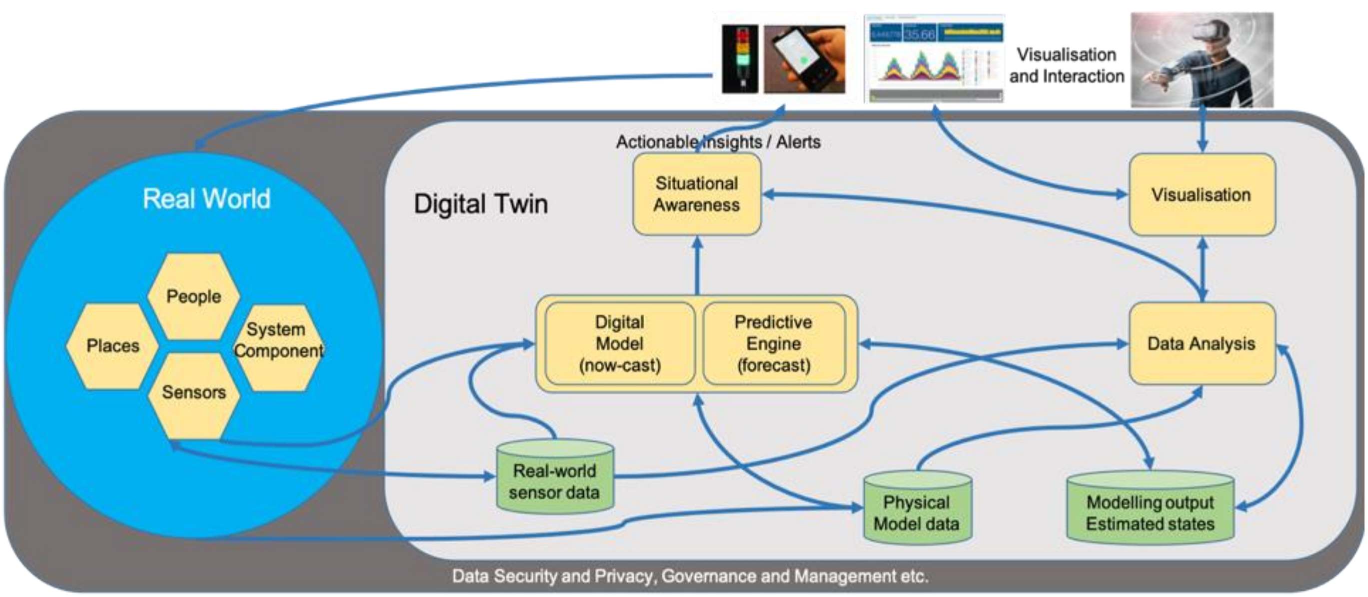
The IoT platform by IBM leads the pack of industrial solutions supporting predictive maintenance. Built on the highest security standards, it serves as a hub to set up and control connected things that use MQTT messaging. The basic offering includes:

- **device management service** to add and remove devices individually or in bulk, perform rebooting, update firmware, and receive metadata
- **safe connectivity** and communication between devices based on MQTT protocol messaging
- **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 augment these basic capabilities with advanced AI-driven analytics for gaining real-time insights and blockchain service to add selected IoT data to the ledger and share it with specific clients and partners.

4.2.15 Digital Twins

IBM' s Digital Twins is a separate offering that by far outreaches virtual replicas of devices delivered by AWS and Microsoft Azure. Having worked with the concept since the Apollo space program, IBM creates complex digital twins of huge systems and products. 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

4.2.16 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.

4.2.17 Microsoft Azure IoT: Ahead of the Pack in Healthcare and Security

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

Key strengths: *robust core middleware, enhanced security, Windows for IoT.*

In 2018, Microsoft declared their intentions to pour $5 billion into IoT technologies within four years. Now, at the halfway mark, its Azure IoT suite features a wide range of tools for all sorts of devices, with more additions to come in the next two years.

Azure has a strong footprint in healthcare, retail, manufacturing, energy, logistics and transportation. All the solutions come with the highest level of safety as Microsoft spends over $1 billion annually on cybersecurity technologies.

The presence of Microsoft in the IoT ecosystem is expanded by Windows 10 IoT. The Enterprise version is meant for ATMs, point-of-sale terminals, medical equipment, kiosks, Windows 10 IoT Core runs on small devices and wearables, with or without display.

4.2.18 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
- 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)
- IoT Edge to create program modules and deploy them across the network nodes.

4.2.19 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.

4.2.20 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. These models can be used to reorganize the infrastructure for 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.

4.2.21 Choosing an IoT Platform

IoT platforms features basically overlap, though they are packaged differently. Along with a rich functionality, all of them offer

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

4.2.22 IoT Pricing Tier

IoT costs are often hard to predict, as the core solution typically includes only a limited set of functions. Every single service you use on top of basic features involves additional expenses.

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, and actions executed.

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.

4.2.23 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:

Amazon Device Qualification Partners

Azure certified IoT hardware

Google Cloud Platform partners

IBM Business Partners

4.2.24 Domain Expertise

Though all platforms work across several industries, each of them can outperform others in a particular domain. For example, if you run a big enterprise with complex infrastructure and millions of sensors, your natural choice will be IBM, boasting exclusive expertise in managing industrial equipment.

AWS is a good fit to implement a smart home scenario, while Cisco will bring most value to businesses dealing with connected vehicles. Cisco can also provide a good start for companies that build their IoT infrastructure from the ground up, offering all necessary hardware, software, and connectivity services. Microsoft proved its efficiency in the Internet of Medical Things (IoMT), and Google has convincing use cases in energy, transportation, and building smart parks.

Remember, that your choice is not limited to the five leading platforms. There are still over 600 other options waiting in the queue, and chances are high that one of them will meet your needs even better than tech leaders.

5 Digital Twins – Components and Implementation

5.1 Digital Twins System Architecture

5.1.1 Digital Twins Virtual Replica of Physical Objects

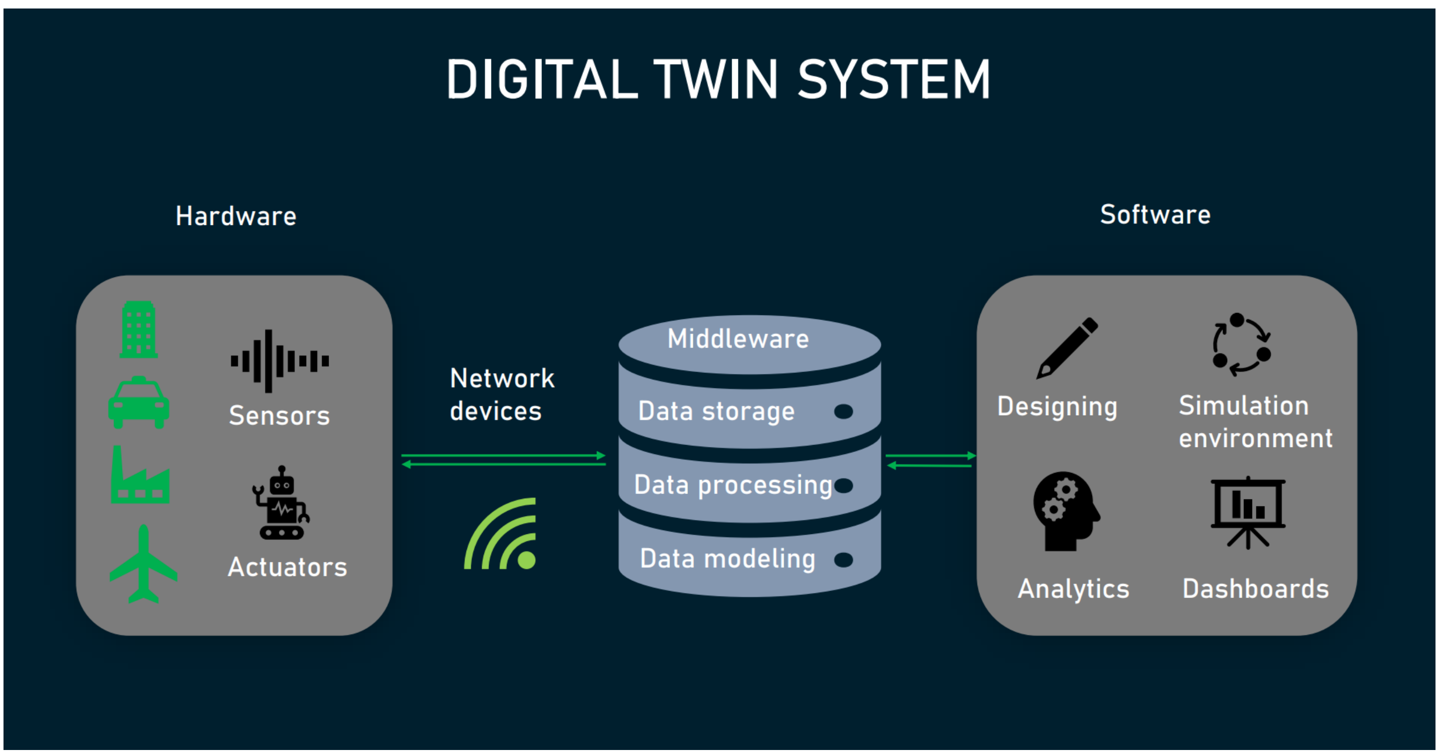
Digital twins play the same role for complex machines and processes, they prevent harm that otherwise could be done to precious assets. Having made their way to the virtual world, duplicates save time, money, and effort for numerous businesses — protecting the health and safety of high value resources.

A **digital twin (DT)** is a detailed and dynamically updated virtual replica of physical objects and/or processes, made to monitor performance, test different scenarios, predict issues, and find optimization opportunities. Unlike traditional computer-aided design and engineering (CAD/CAE) models, a DT always has a unique, real-world counterpart, receives live data from it, and changes accordingly to mimic the origin through its lifecycle.

The twinning, however, doesn't happen out of thin air. This process involves numerous pieces working as a uniform system.

5.1.2 Digital Twins System Architecture

A digital twin system contains hardware and software components with middleware for data management in between.



Components of the digital twin system.

Hardware components. The key technology driving DTs is the Internet of Things (IoT) sensors that initiate the exchange of information between assets and their software representation. The hardware part also includes actuators, converting digital signals into mechanical movements, network devices like routers, edge servers, and IoT gateways.

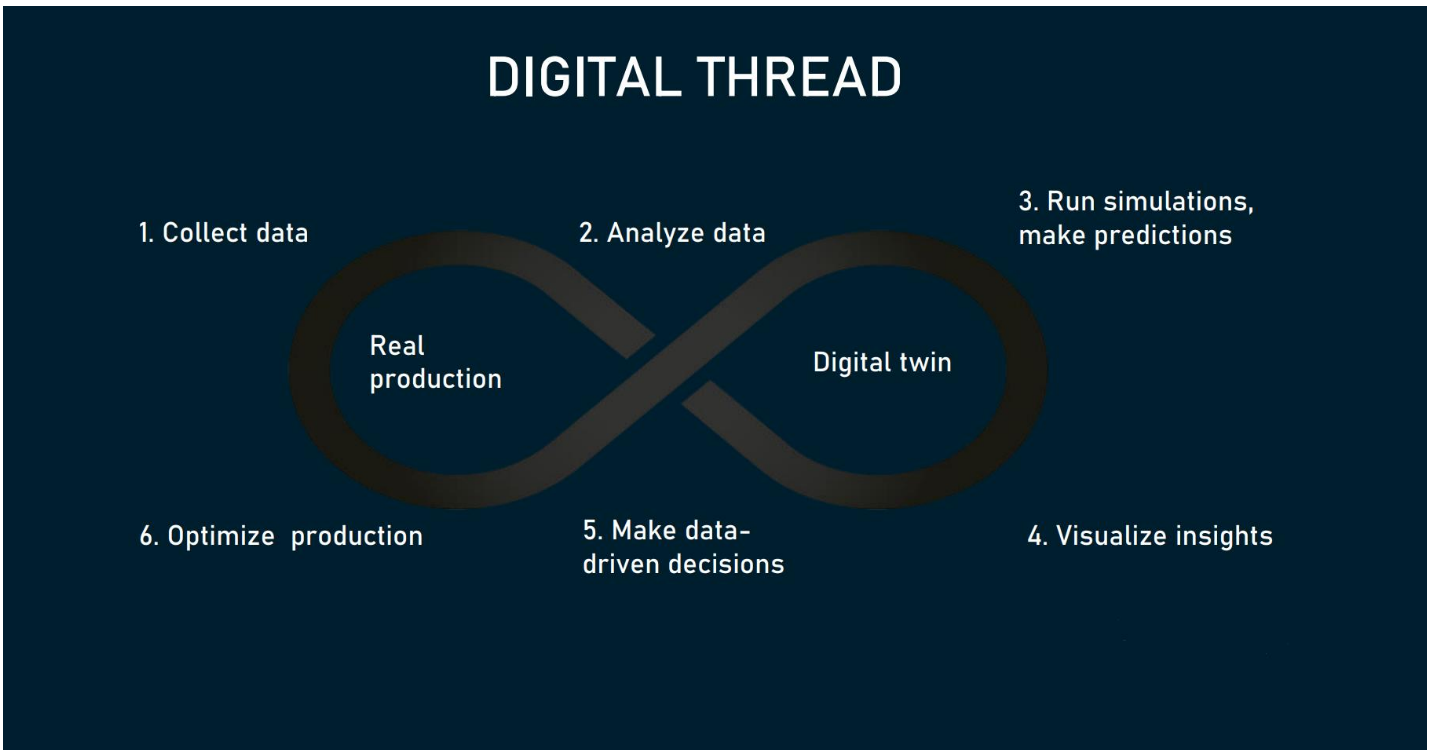
Data management middleware. Its bare-bones element is a centralized repository to accumulate data from different sources.

Ideally, the middleware platform also takes care of such tasks as connectivity, data integration, data processing, data quality control, data visualization, data modeling and governance, and more. Examples of such solutions are common IoT platforms and industrial (IIoT) platforms that often come with pre-built tools for digital twinning.

Software components. The crucial part of digital twinning is the analytics engine that turns raw observations into valuable business insights. In many cases, it is powered by machine learning models. Other must-have pieces of a DT puzzle are dashboards for real-time monitoring, design tools for modeling, and simulation software.

5.1.3 Digital Thread: A Bridge between Physical and Virtual Worlds

Having all the required components in hand, you can interconnect physical systems and their virtual representations into a closed loop known as a *digital thread*. Within it, the following iterative operations are performed.



Steps within a digital thread.

1. Data is collected from a physical object and its environment and sent to the centralized repository.
2. Data is analyzed and prepared to be fed to the DT.
3. The digital twin uses fresh data to mirror the object's work in real time, test what will happen if the environment changes, and find bottlenecks. At this step, AI algorithms can be applied to tweak the product design or spot unhealthy trends and prevent costly downtimes.
4. Insights from analytics are visualized and presented via the dashboard.
5. Stakeholders make actionable, data-driven decisions.
6. The physical object parameters, processes, or maintenance schedules are adjusted accordingly.

Then the process is repeated based on the new data.

Digital twins reduce the complexity of the real world to the information necessary for decision-making. This makes the technology welcome across many industries.

5.2 Digital Twins Main Applications

This new approach to managing product life cycle, the concept of digital twins gained traction in many areas including supply chain management, remote equipment diagnostics, predictive maintenance, and more. They can serve any phase of product development, from designing to post-production monitoring and servicing.

Of course, virtual modeling doesn't work as well for every business. Its implementation comes with a hefty price tag and may make little to no economic sense for simple products. Virtual models suit complex and large-scale projects and multi-component mechanisms, finding the most successful applications in:

- construction of buildings, bridges, drilling platforms, and other large objects
- industrial environments
- designing and manufacturing of complex products like cars, jet turbines, airplanes, or new drugs
- urban planning
- the energy sector with its huge equipment for power generation and transmission

Within these industries, twinning can be performed at different levels — from a separate component to the entire product to production to system of systems.

Component Twinning

The basic level of twinning allows engineers to evaluate the durability, resilience, energy efficiency, and other characteristics of the separate parts that constitute a product. They can use simulation software to analyze how the component in question will behave under static or thermal stress and in other real-life scenarios.

Product or Asset Twinning

The replica of the entire product reveals how individual components work together under various conditions and what can be done to achieve better performance and reliability. Digital twinning also can be used to design new technical solutions — instead of creating multiple prototypes. This shortens development time and allows for faster iterations.

Process and Production Twinning

Digital twinning is applicable not only to physical assets but to processes as well. In this case, you create complete virtual models of the production steps.

This approach helps answer important questions like: How long will it take to produce a particular product? How much will it cost? Which machine should do what? Which steps can be automated? Is the production of a particular item feasible at all? Additionally, visualizing the entire production process makes it easier to prevent costly downtimes.

System Twinning

A digital twin of the system brings visibility to complex interconnections and interdependencies of products and processes. The twinned system can be as large as a multistory building, electrical grid, or even a whole city, which can be viewed as "a system of systems." However, investment to build such a replica in many cases may not equal to the hoped-for return. That's why system twinning is not as widespread as other DT types.

Below, we'll give real-life examples of how digital twins work in different industries across all levels.

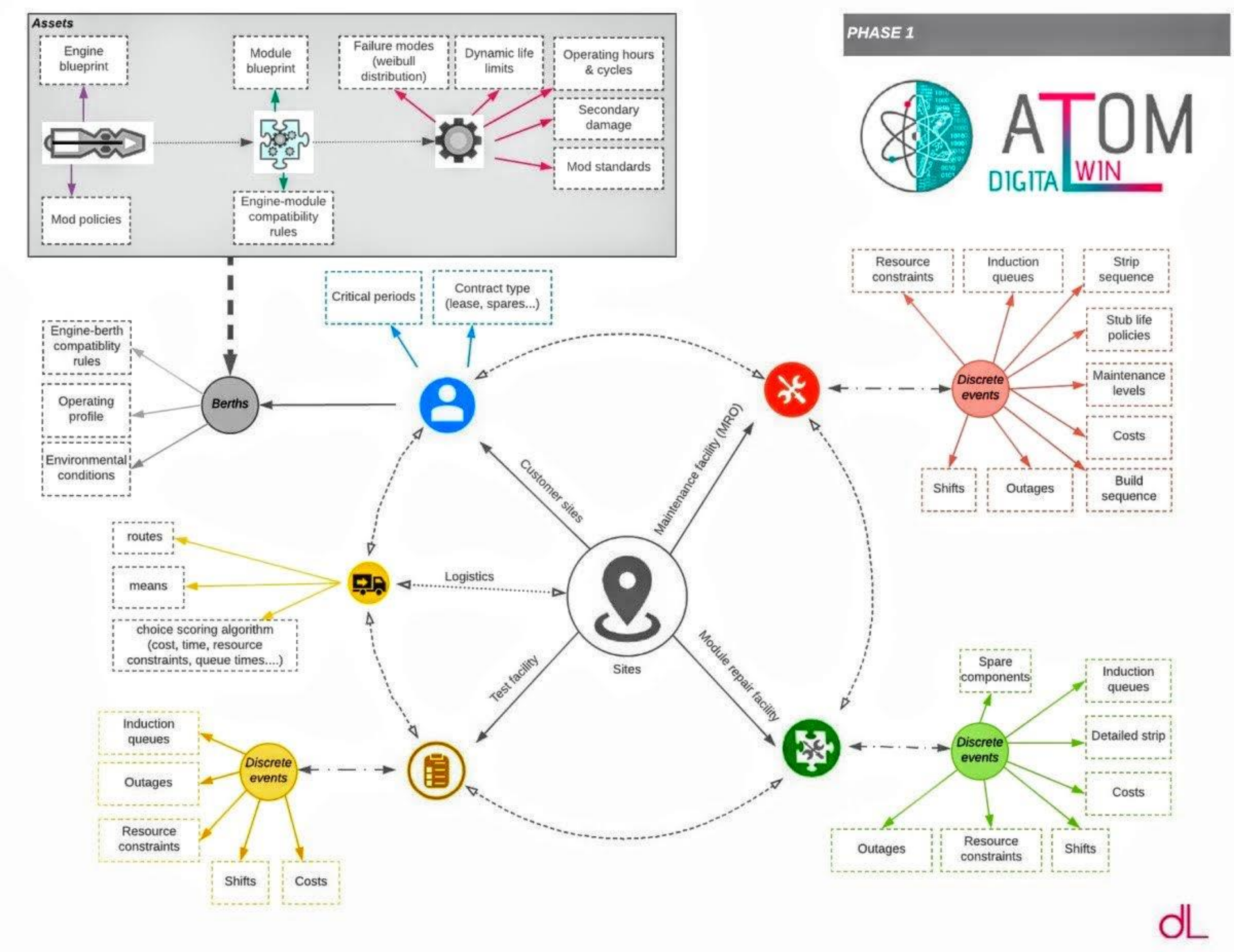
5.2.1 Automotive Industry: Running Tesla Car Replicas for Remote Diagnostics

Each new car produced by Tesla has its own digital twin. Sensors embedded in a vehicle constantly stream data about the environment and performance to the virtual copy that lives in the cloud. AI algorithms analyze these feeds to identify whether the car works as expected. If not, the problems are fixed by sending **OTA - Over-The-Air** software updates.

In this way, Tesla adapts the vehicle's configurations to different climate conditions, virtually improves its performance, and provides remote diagnostics, minimizing the need for visiting service centers.

5.2.2 Power Generation: Predicting the Performance of Gas Turbines

The Europe's largest industrial manufacturing company and a digital twinning pioneer, Siemens developed a virtual avatar of its gas turbine and compressor business purchased from Rolls-Royce. The digital twin called ATOM (Agent-Based Turbine Operations and Maintenance) represents the production and servicing of their turbine fleet, spanning the supply chain operations.



ATOM digital twin reflects complex interactions across the entire lifecycle of the gas turbine.

ATOM digests live data from multiple sources to thoroughly model cobwebs of engine parameters, performance metrics, maintenance operations, and logistics steps across the entire turbine lifecycle. By running different what-if scenarios and visualizing their results, it helps stakeholders make better investment decisions.

5.2.3 Supply Chain Simulation: Bringing Visibility to Logistics

Google presented a new service that enables companies to build digital twins of their physical supply chains. The solution focuses on organizations in the retail sector, healthcare, manufacturing, and automotive industry. It aggregates information from multiple sources into one place and helps customers get a complete and clear view of their logistics.

Google claims that the DT paves the way to much faster data analysis: tasks that previously took up to two hours now take just a few minutes. With its fresh offering, the company is snapping at the heels of IBM, Amazon, and Microsoft, all of which launched supply chain and other digital twin options earlier.

5.2.4 Urban Planning: Creating Profiles of Buildings to Reduce Energy Consumption

Automatic Building Energy Modeling or AutoBEM for short enables the generating of digital twins for any building in the US. The project took the developers

AutoBEM relies on public information like satellite imagery, street views, light detection and ranging (LIDAR), prototype buildings, and standard building codes to generate energy profiles of structures. A twin reflects all critical external and internal characteristics including a building's height, size, and type, a number of windows and floors, building envelope materials, roof type, heating, ventilation, and cooling.

Advanced algorithms behind the twin predict which technologies are to be implemented to save energy. This includes modern water heaters, smart thermostats, solar panels, and more. Additionally, AutoBEM will be widely used in urban planning and maintenance as there is much concern about energy consumption in cities across the US.

5.3 Approach to Digital Twinning

Theoretically, you can build a digital twin for almost everything. In practice, it's far from feasible to create a replica that covers every single aspect of a product or manufacturing process. If you've already jumped to the conclusion that your business will benefit from DTs or at least want to test the idea, choose a single component or operation that is most vulnerable or crucial for your business.

Once you understand what you are going to twin in the first place, the next steps may be the following.

5.3.1 Choose the Type of Digital Twin: Physics-Based vs Data-Driven vs Hybrid Models

Generally, there are two types of DTs — *physics-based* twins and *data-based* twins. The former rely on physical laws and expert knowledge. They can be built from CAD files and used to simulate the work of comparatively simple objects with predictable behavior - like a piece of machinery on production line.

The key downside is that updating such twins takes hours rather than minutes or seconds. So, the approach makes sense in areas where you don't need to make immediate decisions.

Contrasted with the physics-based type, data-based twins don't require deep engineering expertise. Instead of understanding the physical principles behind the system, they use machine learning algorithms (typically, neural networks) to find hidden relationships between input and output.

The data-based method offers more accurate and quicker results and is applicable to products or processes with complex interactions and a large number of impact factors involved. On the other hand, to produce valid results it needs a vast amount of information not limited to live streams from sensors.

Algorithms have to be trained on historical data generated by the asset itself, accumulated from enterprise systems like ERP, and extracted from CAD drawings, bills of material, Excel files, documents.

Today, various combinations of two methods — or so-called *hybrid twins* — are often used to take advantage of both worlds.

5.3.2 Narrow Down the Focus

Even if we're speaking of the same component or product, different models are to be created for different tasks. For example, the General Electric Digital department defines four categories of models that can be integrated into the DT designed for the needs of power plants.

Lifting models track equipment condition and forecast how it will age providing for its operations and exposure to damaging factors. This helps optimize maintenance outages and extends the asset's working lifespan.

Anomaly models are responsible for early fault detection to reduce unplanned downtimes.

Thermal models simulate parameters related to thermal efficiency to better manage degradations.

Transient models predict the plant's speed, reliability, and emissions under different conditions. The gained insights are used to achieve the best operational flexibility with consideration for equipment and site limitations.

At this step, you need to define what exactly your model will do: monitor conditions, prevent faults, simulate behavior under different parameters, and help in product design. Focus on one task, test results, and only then augment your digital twin with other capabilities.

5.3.3 Consider the Investments to be made

Let's presume that your company already has sensors and CAD or CAE software to create a basic representation of your assets. At the next phase, you will need to invest in:

- additional hardware — for example, edge computing devices to process data on the periphery, closer to IoT sensors
- services of a data management or IoT platform or other middleware to ingest and process data from disparate systems and store it in one place
- simulation software
- analytics solutions
- domain experts to run physics-based simulations
- data scientists if you opt for data-driven or hybrid methods

It's worth noting that large cloud providers and leaders in digital twinning offer services that cover many aspects of digital twinning.

5.3.4 Explore Ready-to-Use Solutions

Digital twins are a key piece of the digital transformation puzzle. They create an accurate virtual replica of physical objects, assets, and systems to boost productivity, streamline operations and increase profits. Digital Twin is most commonly defined as a software representation of a physical asset, system or process designed to detect, prevent, predict, and optimize through real time analytics to deliver business value.

DT tools, elements, and blueprints work well when bought from one vendor. Otherwise, compatibility and integration issues are possible. As with other emerging and evolving technologies, digital twinning lacks generally accepted standards, leading to poor interoperability between systems.

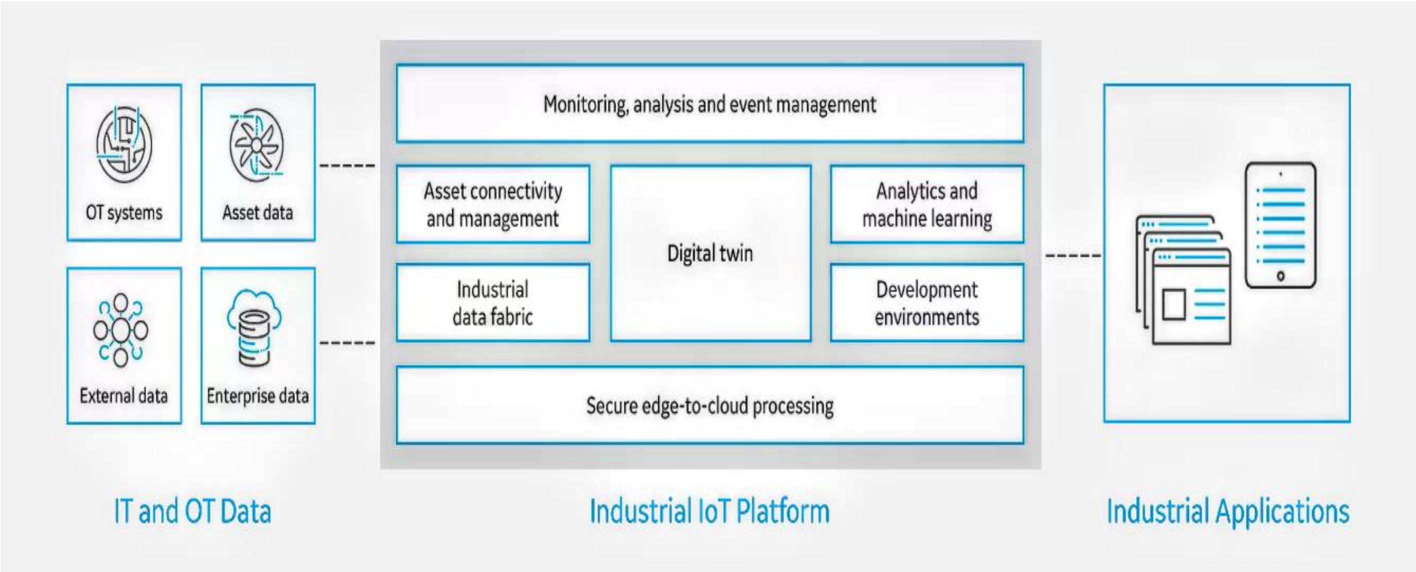
Here's a short overview of the DT products from industry leaders that will save you time and effort.

IBM Digital Twin Exchange works as a virtual shop where organizations may search, purchase, and download digital twins or data related to them from different manufacturers. The assortment includes 3D CAD models, bill of material (BOM) lists, engineering manuals, etc. They can be teamed with IBM Maximo asset management solution to predict asset performance and schedule maintenance operations based on fresh data.

Azure Digital Twins is a platform as a service (PaaS) for visualizing physical environments with all connected devices, locations, and occupants involved. The relationships between these objects are represented with spatial graphs. The service is paired with Azure IoT Hub that collects data from IoT sensors and other Azure services.

Oracle IoT Digital Twin Framework enables you to create both physics-based and data-driven or predictive digital twins. The former compares observed and desired parameters to detect existing problems. The latter run machine learning algorithms to forecast future issues and prevent or prepare for them.

GE Digital Twins software allows companies to rapidly create digital twins and get value from them, using "blueprints" from their catalog. The three core areas covered by GE are manufacturing assets, grid networks, and production processes. DT software is powered by machine learning and integrated with GE's IIoT platform called Predix.



Digital twins are at the core of GE's Predix platform.

5.3.5 Remember That DT is Not Off-The-Shelf Technology

Each DT is as unique as a product or process it represents. While ready-to-use infrastructures, platforms, and models can facilitate the development, but they won't do all the work. You will still need experts in data, machine learning, cloud technologies, and, of course, engineers, capable of integrating different parts of hardware and software puzzles.

5.3.6 What to Expect with DT

Despite all promises and even proven examples of success, digital twins still don't see wide adoption. To some extent, the complexity of their creation is to blame. Another reason that we already mentioned is a scarcity of industry standards that restrains communication and data exchange across platforms and apps from different vendors.

Hopefully, this will change soon: More and more tech leaders including Microsoft, GE Digital, and Dell have become part of the Digital Twin Consortium to facilitate the development, adoption, and interoperability of DTs. This goal is hard to achieve without clear technical guidance and agreed-upon frameworks.

5.4 Digital Twins with IoT

While Digital Twins are virtual replicas of physical devices that data scientists and IT pros can use to run simulations before actual devices are built and deployed. Digital Twins for IoT is more actual than predictive. Digital twin technology has moved beyond manufacturing and into the merging worlds of the Internet of Things, artificial intelligence and data analytics.

As more complex "things" become connected with the ability to produce data, having a digital equivalent of data gives us the ability to have a digital avatar of the physical world. This IoT digital twins, is a dynamic software model of a physical thing or system in the world.

In essence, an IoT digital twin is a cloud computer program that takes real-world data about a physical object or system as inputs and produces the physical object or system being mimicked and use that data to develop a model that simulates the real-world original in digital space.

The twin is constructed so that it can receive input from sensors gathering data from a real-world counterpart. This allows the twin to represent the physical object in real time, in the process offering insights into performance and potential problems.

Digital twins offer a real-time look at what's happening with physical assets, which can reduce network traffic and latency. The IoT digital twin is designed to represent its physical counterpart, in which case the twin can provide feedback as the product is refined, this can radically alleviate maintenance burdens.

Clearly, the explosion of IoT sensors are part of what makes digital twins possible. And as IoT devices are refined, digital-twin scenarios can include smaller and less complex objects, giving additional benefits to companies.

Digital twins can be used to predict different outcomes based on variable data. This is similar to the run-the-simulation scenario often seen in science-fiction films, where a possible scenario is proven within the digital environment. With additional software and data analytics, digital twins can often optimize an IoT deployment for maximum efficiency, as well as help designers figure out where things should go or how they operate before they are physically deployed.

The more that a digital twin can duplicate the physical object, the more likely that efficiencies and other benefits can be found. For instance, in manufacturing, where the more highly instrumented devices are, the more accurately digital twins might simulate how the devices have performed over time, which could help in predicting future performance and possible failure.

5.4.1 Digital Twins vs. Predictive Twins

In a November 2017 an article for Network World, outlined an example of an Oracle digital-twin tool that provides users with two options – a digital twin and a predictive twin.

The digital twin "can include a description of the devices, a 3D rendering and details on all the sensors in the device. It continuously generates sensor readings that simulate real life options."

5.4.2 Digital Twins for IoT More Actual than Predictive

The predictive twin "models the future state and behavior of the device," Puri writes. "This is based on historical data from other devices, which can simulate breakdowns and other situations that need attention."

As part of its digital-twin initiative Microsoft is taking the concept and applying it to processes in addition to physical products. In a whitepaper, Microsoft proposes the idea of the digital process twin:

"The Process Digital Twin is the next level of digital transformation, compounding Product Digital Twin benefits throughout the factory and supply chain," Microsoft states. The associated whitepaper highlights some advanced manufacturing scenarios that product digital twins don't support, but that process digital twins would.

5.4.3 Benefits of Digital Twins

Digital twins offer a real-time look at what's happening with physical assets, which can radically alleviate maintenance burdens. Chevron is rolling out digital twin tech for its oil fields and refineries and expects to save millions of dollars in maintenance costs. And Siemens as part of its pitch says that using digital twins to model and prototype objects that have not been manufactured yet can reduce product defects and shorten time to market. Keep in mind that that digital twins aren't always called for, and can unnecessarily increase complexity. "Digital twins could be technology overkill for a particular business problem. There are also concerns about cost, security, privacy, and integration."

Ultimately though, think of a digital twin as a bridge between the physical and digital worlds. These components are connected to a cloud-based system that receives and processes all the data that the sensors monitor. This entry is analyzed against business and other contextual data. Lessons are learned and opportunities are discovered within the virtual environment that can be applied to the physical world – ultimately, to transform your business.

It is a virtual prototype of a "living" and dynamic object, which means that it is updated whenever its physical twin undergoes changes. It is also capable of learning, absorbing the knowledge of people, machines, and the environment in which it exists.

6 Satellite Tron AI-IoT Artificial Intelligent

6.1 Internet of Things Artificial Intelligent Architecture

6.1.1 Internet of Things Artificial Intelligent Conclusion

- An inference model provides a conclusion reached on the basis of evidence and reasoning.

6.1.2 When IoT meets Telematics Artificial Intelligent

In the Internet of Things (IoT), as more and more devices and pieces of software interconnect, a great necessity arises for the systems that allow complex situations to be detected in a simple collaborative way by people and devices and be able to react quickly upon detection of these situations.

Internet of Things (IoT) provides lots of telemetry and sensor data; however, the data points by themselves do not provide value unless they can be annualized and turned into actionable, contextualized information. Big data and data visualization techniques allow us to gain new insights by batch-processing and off-line analysis. Real-time sensor data analysis and decision-making are often done manually but to make it scalable, it is preferably automated. Artificial Intelligence (AI) provides us with the framework and tools to go beyond trivial real-time decision and automation use cases for IoT.

With AI-Satellite Tron (Artificial Intelligence – Internet of Things), it is important to understand the difference and relationship between big data and real-time event reasoning, known as temporal reasoning. Big data analysis of sensor data retrieved from many Satellite Tron devices provides statistical information on particular components and data points. Decision making will allow deciding whether there is a need for maintenance of one particular component. With temporal reasoning, IoT sensors provide information that Drools AI is acted on immediately. For example; in Drools AI-IoT, judging impact avoidance of a vehicle and making course adjustments is an example of AI temporal reasoning or a rational agent.

The AI-Satellite Tron rational agent is a central concept in artificial intelligence. An agent is something that perceives its environment through sensors and acts upon that environment via actuators, servos or motors. For example, a robot may rely on cameras as sensors and act on its environment via motors.

A rational agent is an agent that acts, and that does 'the right thing.' The right thing depends on the performance criterion defined for an agent, but also on an agent's prior knowledge of the environment, the sequence of observations the agent has made in the past and the choice of actions that an agent can perform. The AI BRMS Drools itself is the heart of the agent that computes, and reasons based on the available data and its knowledge of the IoT sensors on the environment.

6.1.3 AI Patterns in STREAM or CLOUD Mode

Drools AI-Satellite Tron patterns behave differently in STREAM mode when compared to CLOUD mode. In CLOUD mode, the engine assumes that all facts and events are known in advance (there is no concept of the flow of time) therefore, AI patterns are evaluated immediately.

When running in STREAM mode, patterns with temporal constraints require the engine to wait for an event to occur before activating the rule. The time period is automatically calculated by the engine and events which are considered immutable state changes, the results of which will fire a rule.

Real-time sensor data analysis and decision-making are often done manually but to make it scalable, it is preferably automated. AI provides us with the framework and tools to go beyond trivial real-time decision and automation use cases for IoT.

Executive Order Corp. has developed both a CLOUD-based and a STREAM-based architecture that observes its environment via IoT defined sensors and acts on its environment through AI BRMS Drools-jBPM software, arriving at conclusions reached on the basis of evidence and reasoning. This platform that uses concepts of AI and applied those to the use case of smarter decision making in IoT.

"If a machine thinks, then a machine can do." – Steven Woodward

"It's not you interacting with the machine; it's the machine interacting with you." – Steven Woodward

6.2 AI-Satellite Tron Artificial Intelligent Reasoning

6.2.1 Satellite Tron AI-Artificial Intelligent Smart Things Automation

The Internet of Things (IoT) refers to a network of connected devices collecting and exchanging data and processing it over the internet. IoT promises to provide "smart" environments (homes, cities, hospitals, schools, stores, offices, etc.) and smart products (cars, trucks, airplanes, trains, buildings, devices, etc.). While this data is useful, there is still "a disconnect" in integrating these IoT devices with mission-critical business processes and corporate cloud data awareness.

The task of moving IoT devices beyond "connected" to "smart" is daunting. Moving beyond collecting IoT data and transitioning, to leveraging this new wealth of IoT data, to improving the smart decision-making process is the key to automation. Artificial Intelligence (**AI**) will help these IoT devices, environments and products to self-monitor, self-diagnose and eventually, self-direct. This is what we said in the opening of this book, "If a machine thinks, then a machine can do."

However, one of the key concepts in enabling this transition from connected to smart is the ability to perform **AI Analytics**. The traditional analytic models of pulling all data into a centralized source such as a data warehouse or analytic sandbox is going to be less useful. We are not trying just to analyze complex IoT data; we are trying to make "smart decisions" and take actions base IoT devices analytics.

***IoT Definition** – IoT is the integration of computer-based systems into our physical-world.*

Our world is increasingly linked through the number of already connected IoT devices. IoT components are equipped with sensors and actuators that enable sensing, acting, collecting and exchanging data via various communication networks including the internet. These IoT devices such as wearable, GPS, smartphones, connected cars, vending machines, smart homes, and automated offices are used in areas such as supply chain management, intelligent transport systems, robotics, and remote healthcare. Businesses can rapidly gain a competitive edge by using the information and functionalities of IoT devices (sensors and actuators). So, a business process uses IoT information to incorporate real-world data, to make informed decisions, optimize their execution, and adapt itself to context changes.

Also, the increase in processing power of IoT devices enables them to take part in the execution of the business logic. This way IoT devices can aggregate and filter data and make decisions locally by executing parts of the business logic whenever central control is not required, this is the heart of Edge Computing, reducing both the amount of exchanged data and of central processing involvement.

The power of the IoT device increases greatly when a business process (jBPM) can use them to provide information about our real-world as well as execute IoT device actions as part of our business process. The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one (BPM) diagram. With our applications, we are adding Drools-jBPM to IoT devices to the automobile. Making **"Things Smart"** is the application of AI to IoT platform via Drools Rules Inference Reasoning, jBPM, and Expert Systems (ES) Architecture for mobile devices.

With the use of AI Drools-jBPM analysis and reasoning in IoT devices, we can orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based into the physical-world that has never been available before. This results in improved efficiency, accuracy, and economic benefits by increased automation - reduced intervention. This IoT orchestration of IoT devices gives us the ability for action after our AI decision.

6.2.2 AI-IoT Drools-jBPM Artificial Intelligent Reasoning

AI-IoT is a mix of Business Processes (BPM) with Business Rules Drools (Reasoning), to define advanced and complex scenarios. Also, Drools Rules Engine adds the ability of temporal reasoning, allowing business processes to be monitored, improved, and cover business scenarios that require temporal inferences. Event stream processing focused on the capabilities of processing streams of events in (near) real time, while the main focus of CEP (Complex Event Processing) was on the correlation and composition of atomic events into complex (compound) events. Satellite Tron for CEP is primarily an event processing concept that deals with the task of processing multiple events with the goal of identifying the meaningful events within the IoT event cloud.

6.3 Satellite Tron IoTBPM Sensor Software Suite

6.3.1 Satellite Tron Sensor Sends MQTT Telemetry Transport

The power of the IoT (Internet of Things) device increases significantly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT devices as part of our business process. The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one diagram. With Satellite Tron adding Drools and jBPM to IoT, we make the IoT devices **"Smart."** Moving beyond just collecting IoT data and transitioning, to leveraging the new wealth of IoT data, to improving the **SMART** decision making is the key. The Executive Order AI-Satellite Tron will help these IoT devices, environments, and products to self-monitor, self-diagnose and eventually, self-direct.

The IoTBPM Tron allows you to send IoT sensor data and information directly to the AI-Satellite Tron Drools-jBPM Expert System from the IoT Edge device. This provides a very lite streamline IoT to Drools-jBPM (Business Process Management) application process with sensor and GPS positioning information.

The Satellite Tron MQTT sensor software allows you to interface and send MQTT Telemetry Transport Information from your external connected IoT Edge devices to the Satellite Tron AI-IoT Drools-jBPM Cloud Server. The AI-Satellite Tron Agent software uses a WiFi wireless transceiver interface to stream telemetry information to the Satellite Tron Agent for any control module sensors or remote control connected Edge Computer, Arduino or Raspberry Pi, through the IP Gateway of the TCU device.

6.4 IoTBPM Server Drools-jBPM GPS Application Examples

6.4.1 IoT Control AI-IoT Drools-jBPM Artificial Intelligent Smart Automation

In the IoT GPS Tracking Control jBPM example, we demonstrate how to invoke **business rules** from within our application and how to execute our jBPM processes and how to handle the interactions between **process** and **rules** using an IoT sensor device and GPS position sensor.

Business processes and rules are two core concepts which are defined as follows:

- **Business processes:** Represents what the business does.
- **Business rules:** Represents decisions that the business makes.

Although processes and rules are two different things, there is a clear advantage if your end users are allowed to combine processes and rules. This means for example:

- Rules can define which processes to invoke
- Rules can specify decisions in that process
- Rules can augment (or even override) the behavior specified in the process (for example to handle exception cases)
- Assignment rules can be used to assign actors to (human) tasks
- Rules can be used to dynamically alter the behavior of your process

6.4.2 GPS Position IoTBPM Server Drools-jBPM GPS Automation

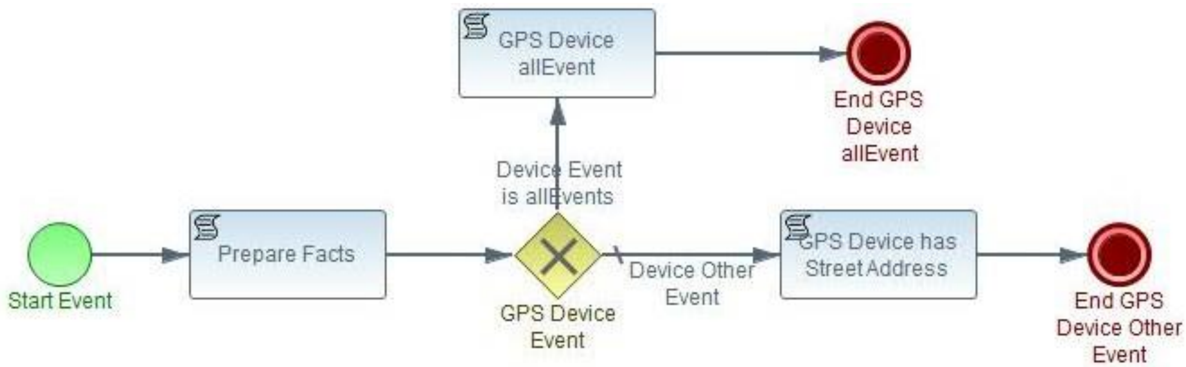
There are many IoT GPS options to choose from with EOSpy. First, you don't have to use a GPS module. If you have a fixed IoT device, consider hardcoding your GPS LAT/LON position. Then, if you have IoT device monitoring, for instance, a door open, you could pin that device location to a building map. This would give you a visual indicator of the location of which door was open on your building blueprint.

Look at the EOSPY AI-IoTBPM Arduino Tron Sensor sketch for an example of how you can find LAT/LON from an address and hardcoding a GPS LAT/LON position-location to the Arduino Tron application.

```
//Update these with LAT/LON GPS position values
//You can find LAT/LON from an address
https://www.latlong.net/convert-address-to-lat-long.html
String lat = "38.888160"; // position LAT
String lon = "-77.019868"; // position LON
```

The Satellite Tron device has many options for GPS modules. The Satellite Tron Edge Computer has methods to read information like date, time, location and satellites in view from the standard NMEA data streams. This NMEA data stream gives you the LAT/LON position to set in your LAT/LON data packet.

Example 5.6.4.1 GPS Position AI-IoTBPM Drools-jBPM



In the GPS position example, we can examine the IoT device event that transmitted the GPS position. This could be a significant IoT event reported from the device, such as motor started, airbags deployed, overheat, outside Geofence or over-speed.

Example 5.6.4.2.GPS Position Speed Over 60 Rule

```
//declare rule to fire when Device speed is over 60
rule "GPS Device Speed Alert"
      when
        $event : ServerEvent( $eventId : id, $lat : lat, $lon : lon,
        $altitude : altitude, $speed : speed, $speed > "60" )
      $device : Devices( $deviceId : id,  $eventId == id )
      then
            $device.action = "Alert";
            $device.status = $event.getEvent();
            com.arduinotron.ui.MainWindow.getInstance().log($event.getName()
+ " GPS Speed Alert lat:" + $lat + " lon:" + $lon + " speed:" + $speed);
            modify( $device )
end
```

This GPS position rule fires when the GPS device reported speed is greater than 60. The rule reports the position and speed that fired the rule. Depending on the GPS devices, the module can report additional information that is transmitted along with the LAT/LON data packet. This information may be different depending on the device type, environment, and conditions.

- **GPS Device Module Environment and Condition Rules**

There are additional rules that respond to the GPS device, if the IoT device sends text messages or if the device sent an alarm.

Example 5.6.4.3.GPS Device Send Alarm

```
//declare rule to fire when GPS Device sends Alarm message
rule "GPS Device Sent Alarm"
      when
        $event : ServerEvent( $eventId : id, $alarm : alarm, $alarm != null )
      $device : Devices( $deviceId : id,  $eventId == id )
      then
            com.arduinotron.ui.MainWindow.getInstance().log($event.getName()
+ " Sent Alarm: " + $alarm);
end
```

In addition, there are rules for processing a GPS device text message; the GPS device fixes information and GPS device address location. All of the information and messages are transmitted along in the LAT/LON data packet from the IoT device.

In the GPS position example, we can see the rules for GPS device distance, GPS device fix information, and GPS device address location being fired. If the GPS module transmitted additional information in these fields.

```
" Sent Alarm: " + $alarm); or " Sent Massage: " + $message);
```

Fields, then those rules would fire. Any alarm or message can be defined. An example of some values that can be sent in the alarm field.

```
// Values to send in &alarm= field
const String ALARM_GENERAL = "general";
const String ALARM_SOS = "sos";
const String ALARM_VIBRATION = "vibration";
const String ALARM_MOVEMENT = "movement";
const String ALARM_OVERSPEED = "overspeed";
const String ALARM_LOW_POWER = "lowPower";
const String ALARM_LOW_BATTERY = "lowBattery";
```

- **jBPM Script Task Node GPS Tracking Devices**

The jBPM Script Task Node; GPS Device has street address runs a conditional Java script task.

```
log("GPS Device " +  kcontext.getVariable("name") + " event TYPE KEYPRESS 2 (2.0)");
```

A script task is executed by our business process engine when a script task action is fired. The modeler or implementer defines a script in a language that the engine can interpret. When the task is ready to start, the engine will execute the script. When the script is completed, the task will also be completed. Script tasks can run action tasks and very complex evaluations and are convenient for combining data.

- **Additional GPS Tracking Devices**

Many companies make various off-the-shelf GPS Tracking devices that our EOSpy tracking system can use. Configuring these devices will vary a little from vendors. First, add the new device with a unique identifier into the EOSPY – Executive Order Sensor Processor System Server. Next, configure your device to use the appropriate EOSPY Server IP address and port number. If the device fails to report, check the IP Address and Device ID.

EOSPY supports more than 120 GPS communication protocols and more than 850 models of GPS tracking devices from popular GPS vendors. Review the list of supported devices for information about your GPS Tracking Device.

- **Additional GPS Tracking Sensor Data**

The EOSpy live map server and Satellite Tron application will display and allow you to process additional map sensors data. This will allow you to automate your processes and allow you to gain visibility into your business operations.

This additional data could be: ambient temperature, IR object temperature, humidity sensor, pressure sensor, ambient light, accelerometer, gyroscope, magnetometer, digital microphone, magnetic sensor, and magnetometer. Or any other sensor data that you could accumulate and act upon.

These IoT device components are equipped with sensors and actuators that enable sensing, acting, collecting and exchanging data via various communication networks including the internet. All of this sensor data can be analyzed and acted on. Along with the ability to send command and control messages to your IoT devices to perform any task.

7 IoTBPM Server Drools-jBPM IoT Automation

7.1 IoTBPM Server IoT Automation Project

In the previous sections we discussed the integration of Drools and BPM into our IoT projects. In the AI-IoTBPM Server Drools-jBPM application project examples, we demonstrated that the actions and behavior of our IoT devices could be controlled from our BPM engine and analytical reasoning can be achieved through Drools Rules. Also, with the use of AI Drools-jBPM analysis and reasoning in IoT devices, we can orchestrate dissimilar devices that normally have no awareness of each other.

We are going to expand on what we have learned in the previous sections and add some new IoT components and devices that will be a part of our AI-IoTBPM Server Drools-jBPM Automation project. These new additions will give us additional situational awareness and allow us to interact more naturally with our IoT components and devices.

7.1.1 IoT Automation Situational Awareness (SA)

IoT Situational Awareness (SA) is the perception of environmental elements by our IoT devices and events with respect to time or space, the comprehension of their meaning, and the projection of their change of status to us (humans) in a perceivable way. This might be as simple as turning on a light, displaying a message or sounding an alarm. However, we want to know more; we want to know our SA.

Additionally, as distributed IoT sensors and applications become larger and more complex, the simple processing of raw sensor and actuation data streams becomes impractical. Instead, data streams must be fused into tangible facts, information that is combined with knowledge to perform meaningful notifications. What we have accomplished with our AI-IoT Drools-BPM implementation, is our Satellite Tron IoT devices are judging and making decisions after cognitive situational reasoning.

7.2 Satellite Tron IoT Tiles Control Panel

The Satellite Tron IoT Tiles is a control panel (dashboard) for Satellite Tron IoT Things, which controls IoT smart automation and IoT monitoring from your tiles panel. IoT Tiles allows you to send IoT commands directly to your IoT devices and monitor all your IoT device sensors and alert messages.

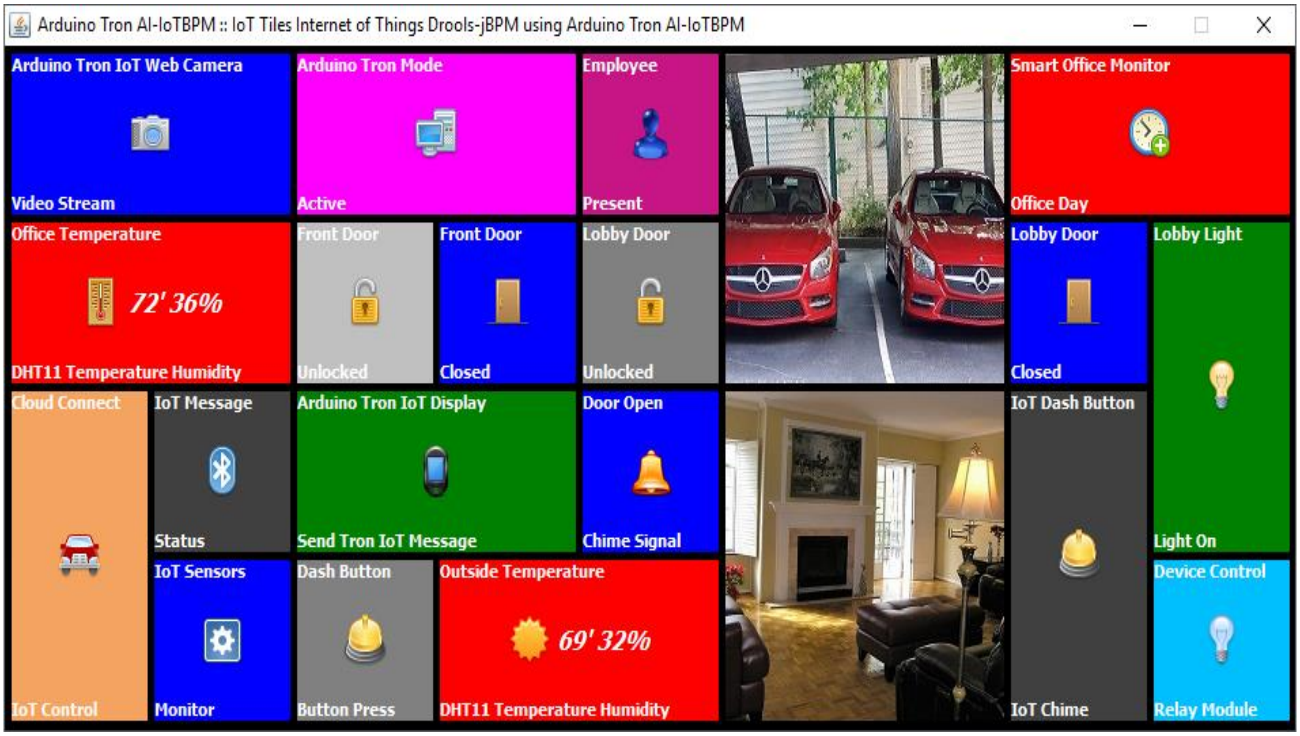


Figure 6.1.2: Satellite Tron IoT Tiles Control Panel (Dashboard)

This single dashboard gives you two-way communications with all your IoT devices and Satellite Tron IoT Things. Also, it provides situational awareness, alerts and notification messages from each of your IoT devices. Satellite Tron IoT Things events are updated "instantly" on the IoT Tiles panel. You can view the state of your Satellite Tron IoT Things: Presence Sensors, Contact Sensors, Motion Sensors, Temperature, Water Sensors, Battery Status, Vibration Sensors, Luminosity Sensors, GPS (Location), Weather (Office and Outside), or any equipment from one panel from IoT Tiles panel.

From Satellite Tron IoT Tiles you can fully control all IoT devices from one panel, use it to control: Switches, Dimmable Lights, Control lights, Momentary Switches, Theme Lights, Control Thermostats, Heating/ Cooling Thermostats, Control Things, Door Locks, Entrance Door Access, Music Players, Cameras (Image Capture), and more. Control all manufacturing floor equipment from one panel.

- **Satellite Tron IoT Tiles Automation for Controlling these IoT Devices**

1. SECURITY CAMERAS

Office security and monitoring are paramount for your property or rental space. Integrate surveillance systems with office automation audio today to take advantage of cutting edge security features like sound-activated recording and motion detection. See who's approaching and leaving your office front door--or other sensitive spaces, like your server room.

2. LIGHTING AUTOMATION

Complete control of your office automation lighting from brightness to color from your IoT office control panel. Lighting automation lets you regulate lighting options in your office remotely and conveniently.

3. OUTDOOR LIGHTING

Dim and control building lighting from your IoT device, or program the lights to turn off automatically at a designated time. If you are using a smart door sensor, you can activate the walkway lights when the office door opens or when motion is detected.

4. DOORBELL

See and talk to delivery drivers or other visitors at your loading dock or main entrance - even if you're not at the office.

5. LOCKS & SECURITY

Let smart office locks control access to your business. Locks office automation enables you to control your locks via IoT devices. Never lose another physical key or worry about whether you locked your business doors or not.

6. CLIMATE CONTROL

Use your thermostat in your office automation control system and control temperature from a tablet or computer anywhere you are. Program your office's thermostats for the nights and weekends, so you're not air-conditioning or heating empty rooms.

7. MOTION SENSORS

Wireless motion detectors for notification. Program your lights to turn on and off when people enter and leave and have the system alert you when someone's entered your office.

8. WINDOW SHADES

Reduce energy costs by programming your shades to move with the sun. Great energy savings for heating and cooling also, ambient lighting.

9. WATER LEAK ALARM

Check for water in your office and get notified of leaks and floods when you are not in the office. Water leak alarms are designed to help mitigate damage and avoid leak conditions so that they can be fixed before they become much costlier problems. These flood alerts can be crucial, and they make this sensor one of the most popular for office automation alerts.

10. PRESSURE-SENSITIVE MATS

Pressure-sensitive mats alert you to comings and goings of visitors, employees, and intruders. These wireless monitors send alerts to you when someone steps on the mat. Most are suitable for indoor or outdoor use.

11. CONFERENCE ROOM RESERVATIONS

Smart-office automates a conference room reservation. As soon as you walk into a meeting room, RFID software recognizes you and books the room on the spot.

12. HUBS & CONTROLLERS

Office automation has enabled central control devices from which you control all your automation mechanisms. Satellite Tron IoT Tiles is affordable office automation options for you, customized this hub controller for your office needs.

The beauty of the Satellite Tron IoT Tiles is that all your IoT device technology becomes interactive with humans through one simple IoT Tiles panel dashboard on your computer. With the Satellite Tron IoT Tiles getting your IoT project working with an excellent human interface is a fast-easy solution.

7.2.1 Satellite Tron Web Server Cloud Interface for IoT Device Control

IoT device management is the process of configuring, monitoring and maintaining the device software that provides its functional capabilities. Effective IoT device management is critical to establishing and maintaining the health, connectivity, and security of all of your IoT devices. The Satellite Tron Web Server provides device management to set IoT device parameters, activate and deactivate your devices, and grant access control of your IoT devices parameters from the Internet.

The beauty of the Satellite Tron Web Server is that the IoT device technology becomes interactive with humans through a simple Web Server browser interface. The integration between Satellite Tron Web Server and IoT devices presents a viable control and notification solution with a bright future – one that will connect people, things, and systems together as part of business-critical processes as never before.

The Satellite Tron lightweight Web Server provides an IoT dashboard, management, and control for remote management of your Internet-Enabled IoT devices. With the Satellite Tron Web Server getting your IoT project working in the cloud is a fast-easy solution.

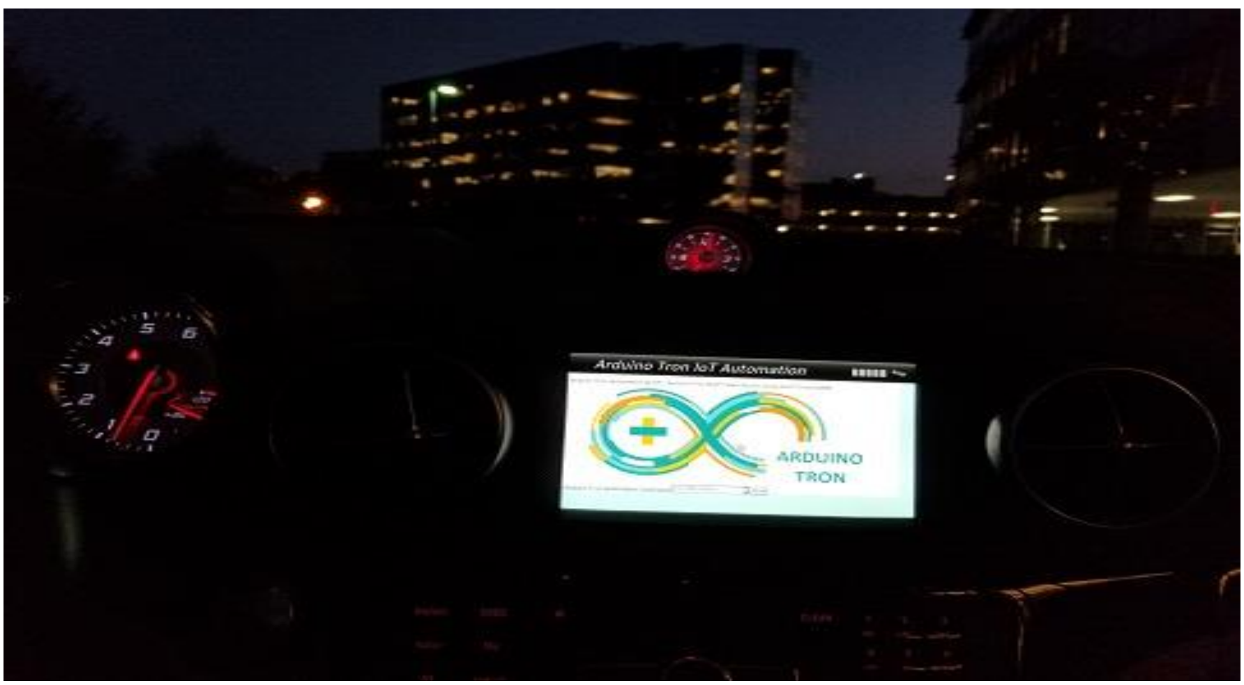


Figure 6.1.4: Satellite Tron Web Server Cloud Interface

The Satellite Tron Web Server Cloud Interface for IoT Device Control can be addressed from any web browser anywhere in the world. This connection is from a car's in-dash display using the automobile's web browser to connect to the Satellite Tron Web Server Cloud Interface.

Here are some applications for the Satellite Tron Web Server Cloud Interface:

- Support for MQTT IoT device control and managing
- Bidirectional IoT device communication and data storage
- Send and receive IoT data between sensor readers or triggering devices
- Cross-device platform and server messaging
- Monitor device sensors and stored metadata
- Monitor and track device status or consumption levels in real-time
- Automated code executes to trigger alerts or IoT device actions

7.3 Satellite Tron IoTBPM Server Architecture

The power of the IoT (Internet of Things) device increases significantly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT Agent (devices) as part of our business process. The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one diagram.

With Satellite Tron IoTBPM Server adding Drools and jBPM to IoT, we make the IoT devices "**smart.**" Moving beyond just collecting IoT device data and transitioning, to leveraging the new wealth of IoT data, to improving the **SMART** decision making is the key. The Executive Order Satellite Tron AI-IoTBPM Server will help these IoT devices, environments, and products to self-monitor, self-diagnose and eventually, self-direct.

The Satellite Tron allows you to send IoT sensor data and information directly to the AI-IoTBPM Drools-jBPM Expert System from the Satellite device. This provides a very lite streamline IoT to Drools-jBPM (Business Process Management) application process with sensor, measurement, telemetry and GPS positioning information. The Satellite Tron IoTBPM Server provides us the three-tiered architecture to provide a complete AI-IoT system.

- **AI (Drools-JBPM):** AI- Analysis Temporal Reasoning and CLOUD Database
- **Server (IoTBPM):** Big Data, Capture, Storage, Analysis IoTBPM Data
- **IoT (Satellite Tron):** Environment Sensors, IoT Data Collection, and MQTT

jBPM Business Process Management

jBPM is a flexible Business Process Management (BPMN 2.0) that allows you to model, execute, and monitor business processes throughout their life cycle. Business Process Management (jBPM) was established to analyze, discover, design, implement, execute, monitor and evolve collaborative business processes within and across organizations. BPM implements a strategic **Goal** of an organization.

A business process allows you to model business goals by describing the steps that need to be executed to achieve those goals, and the order of those goals are depicted using a (BPM) flow chart. Executable business processes bridge the gap between business, users, developers and IoT devices as they are higher-level and use domain-specific concepts that are understood by business users but can also be executed directly by developers and IoT devices.

Additionally, jBPM is an extremely time-sensitive and responsive technology that allows time-critical, dynamic business processes to be changed quickly and while processes are still in progress. This means that jBPM systems can take advantage of the real-time nature of data coming from and going to our IoT devices. This is an ideal fit for our IoT business needs. jBPM supports human-centric, system-centric and hybrid scenarios.

In a human-centric scenario, the jBPM system factors in the human element in the business process, putting the person in the center of decision-making and action. This makes it a great match for IoT medical and wearable technology advances.

In system-centric and hybrid scenarios, we have demonstrated how we can repurpose a legacy signaling device to operate with new or different behavior in IoT. This demonstrates opportunities for direct integration of computer-based systems into the physical-world that has never been available before by repurposing legacy systems or mechanical systems instead of replacing the hardware or physical machine. This also allows you to update legacy mechanical system with new safety features and device status notifications that were never built into the original systems.

Where is the human role in this increasingly systemized world? The beauty of IoT and jBPM is that technology becomes an important factor for its users. Systems can guide, advise and leave the most difficult decisions to the experts. Hand in hand, users and their system will be better equipped to provide easier, faster and more optimized service. The integration between IoT devices and jBPM presents a viable solution with a bright future – one that will connect people, things, and systems together as part of business-critical processes as never before.

- **The Internet of Things (IoT)**

At Executive Order Corp., we are uniquely positioned with the hardware and software experience to help your business capitalize on the **IoT** revolution. We help your company with **IoT.**

  - **Physical Engineering**: Electrical, Component, and Mechanical
  - **Design**: Prototyping, Industrial design, UI / UX
  - **Manufacturing**: Design for Manufacturing, Supply Chain Management (SCM)
  - **Security**: Device, Software, Cloud, and Protocol Specific such as BLE 4.2
  - **Software**: Networking and Infrastructure, Embedded-Systems Programming, Big Data, Machine Learning, Servers, Cloud Computing, Arduino, Raspberry Pi Apps and Web

"**Internet of Things**" is a set of technology that will gradually and sometimes almost imperceptibly begin to affect us in the coming years. Any specific device or application might be small, but the combination of sensors and devices creates significant long-term changes that can both make our lives easier and more informed. Executive Order Corp SBC WiFi Serial Transceiver Module with 4MB Flash, provides a very inexpensive **IoT MQTT** Telemetry Transport platform.

IoT promises to provide "**smart**" environments (homes, cities, hospitals, schools, stores, offices, etc.) and smart products (cars, trucks, airplanes, trains, buildings, devices, etc.). The task of moving beyond "connected" to "smart" IoT devices is the reason for the IoTBPM Server. The Executive Order Satellite Tron AI-IoTBPM Server helps these IoT devices, environments, and products to self-monitor, self-diagnose and eventually, self-direct.

I tell people the key with AI-IoTBPM is, "If a machine thinks, then a machine can do."
Also, "It's not you interacting with the machine; it's the machine interacting with you."

- **Satellite Tron WiFi MQTT Sensors and IoT Devices**

Sensors provide the data you need to automate processes and gain visibility into your business operations. At Executive Order Corp., we have extensive expertise in the Industrial Internet of Things (IIoT) and Machine to Machine (M2M) technology that can be what your company needs to increase efficiencies or distributive business models. Additionally, with IoTBPM Server you can add jBPM and Drools Rules AI-ES reasoning to your business models for "**Smart**" IoT device reasoning.

- **Custom Applications and Dedicated IoT Devices**

For many commercial business applications, the desire is to use a device for a specific function without the distraction and security threats of an open ecosystem. Custom applications allow your business to harness the powerful capabilities of the system and tailor it to your specific needs. These dedicated device solutions can be custom mounted products or off-the-shelf handheld devices.

Our Satellite Tron is an excellent, proven, pre-built, platform application that allows you to use a mobile MQTT telemetry transport device. The Satellite Tron enterprise application provides a solid and reliable platform that your company can build its own custom dedicated application on using an internet-connected or mobile network connected device.

AI-IoT Satellite Tron Sensor

The AI-IoTBPM Satellite Tron Sensor software allows you to interface and sends MQTT telemetry transport information from your external connected Edge devices to the IoTBPM Server. The AI-IoT Satellite Tron Agent software uses a WiFi wireless transceiver interface to stream telemetry information to the IoTBPM Server for any control module sensors or remote control connected Satellite Tron device.

AI-IoTBPM Satellite Tron Agent

The AI-IoTBPM Satellite Tron Agent software interface allows you to send commands with the AI-IoTBPM Server software to control external Edge Computer connected devices. The AI-IoTBPM Satellite Tron Agent software uses a WiFi wireless transceiver interface to control and interact with module sensors and remote control devices.

You can control any device from the AI-IoTBPM Satellite Tron Agent software or stream any interface over the WiFi or internet. With the AI-IoTBPM Satellite Tron Agent software, you can automatically turn on lights, appliances, cameras, and lock / unlock doors from the IoTBPM Server Drools-jBPM expert system processing model.

7.4 Satellite Tron IoT Telematics Design Summary

Internet of Things (IoT) devices opens an opportunity to create a new generation of business processes that can benefit from IoT integration, taking advantage of networking, sensing capabilities, remote awareness and the ability for rational agents to take automated actions. A rational agent is an IoT agent that acts and that does 'the right thing.' The right thing obviously depends on the performance criterion defined for an agent, but also on an agent's prior knowledge of the environment, the sequence of observations the agent has made in the past and the choice of actions that an agent can perform.

While this data is useful, there is still "a-disconnect" in integrating these IoT devices with mission-critical business processes and corporate cloud data awareness.

The task of moving IoT devices beyond "**connected**" to "**smart**" is daunting. Moving beyond collecting IoT data and transitioning, to leveraging this new wealth of IoT data, to improving the smart decision-making process is the key to automation. Artificial Intelligence (**AI**) will help these IoT devices, environments, and products to self-monitor, self-diagnose, and eventually, self-direct. This is what we said in the opening of this book, "If a machine thinks, then a machine can do."

However, one of the key concepts in enabling this transition from connected to smart is the ability to perform **AI Analytics**. The traditional analytic models of pulling all data into a centralized source such as a data warehouse or analytic sandbox is going to be less useful. We are not trying to just analyze complex IoT data; we are trying to make "smart decisions" and take actions base on our AI Analytics of IoT devices.

IoT Definition *– IoT is the integration of computer-based systems into our physical-world.*

With Satellite Tron (Artificial Intelligence – Internet of Things) AI-IoTBPM BPMN modular, this allows us to define both the business processes and IoT devices behavior at the same time using one diagram. The Satellite Tron AI-BRMS Drools itself is the heart of the agent that computes, and reasons based on the available data and its knowledge of the IoT sensors on the environment. With Satellite Tron adding Drools-jBPM to IoT is easy, we make the IoT devices "**smart**."

The power of the IoT device increases significantly when business process (jBPM) can use them to provide information about our real-world as well as execute IoT device actions as part of our business process. This increases the processing power of IoT devices, enabling them to take part in the execution of the business logic. The jBPM-BPMN modular allows us to define both the business processes and IoT devices behavior at the same time using one (BPM) diagram. In our examples, we demonstrated adding Drools-jBPM to IoT devices. Making **"Things Smart"** is the application of AI to IoT platform via Drools-Rules Inference Reasoning, jBPM, and ES-Expert Systems Architecture.

With the use of AI Drools-jBPM analysis and reasoning in IoT devices, we can orchestrate dissimilar devices that normally have no awareness of each other. This creates opportunities for direct integration of computer-based systems into the physical-world that has never been available before. This results in improved efficiency, accuracy, and economic benefits by increased automation - reduced intervention. This IoT orchestration of IoT devices gives us the ability for action after our AI decision.

Business Rules Management Systems builds additional value on top of a general-purpose Rules Engine by providing business user-focused systems for rule creation, management, deployment, collaboration, and analysis user tools. These further add to the value by making the Rules Engine easily implemented and ingrained into our existing Enterprise Systems.

The Satellite Tron AI-IoTBPM Drools-jBPM Expert System provides sophisticated jBPM and Drools processing. This allows us to define IoT behavior within business process and with the same level of abstraction of other atomic actions or events in our standard jBPMN.

AI-IoT Satellite Tron Vehicle Telematics Solution

Artificial Intelligence (**AI**) is a very broad research that focuses on "making computers think like humans." Expert Systems (**ES**) uses knowledge representation: a knowledge base for reasoning, (i.e., we can process data with this knowledge base to infer conclusions).

At the basis of modern vehicle telematics, there are systems – hardware and software – allowing for collecting, storing, and exchanging data points between vehicles and central locations. Telematics deals with building a network of vehicles and telecommunication devices.

With the Satellite Tron AI-IoTBPM Drools-jBPM Expert System that provides sophisticated jBPM and Drools processing, we now make the vehicle the IoT (Internet of Things) and Edge Computer. We make the vehicle the Expert Systems and Knowledge-Based Expert System that are considered to be "applied artificial intelligence." The vehicle can now reason to a conclusion (infer) beyond what we currently know, and take appropriate action.

AI-IoT Satellite Tron Applications in the Automotive Industry

Vehicle connectivity and applied the benefits of implementing Industrial IoT Solutions for Automotive

Improved Performance

- Effective human resources management
- Minimum equipment downtime
- Optimized route planning
- Transport infrastructure optimization

New Business Models

- Tele-operated vehicles
- Digital twins of the vehicle fleet
- Data collection for failure diagnostics
- Testing improvements for the next-gen products
- Studying driver’s behavior

Effective Asset Usage

- Remote monitoring and breakings detecting of vehicles
- Fuel consumption management and proper use control
- Decrease of the faulty equipment downtime
- Traffic management
- Availability planning accuracy

Increased Safety

- Fleet and shipment damage prevention
- Environment and vehicle monitoring for safe movement
- Railways signaling system and level crossing control

- Driving style monitoring
- ADAS and video recording onboard

Telematics combines telecommunications and vehicular technologies, with IoT enabling breakthroughs in telematics telemetry and device control. There are hundreds of other innovations in the field of telematics that are already altering the vehicular landscape.

Telematics applications include tracking of vehicles, trailers, and containers, fleet management, satellite navigation, emergency warning systems, car-sharing, and other intelligent vehicle technologies. Thanks to the Internet of Things (IoT), the telematics industry is seeing more breakthroughs than ever before.

- ***IoT and Telematics Definition*** *– IoT is the extension of internet connectivity to physical devices and everyday objects, like vehicles.*

When IoT and telematics come together, with Satellite Tron (Artificial Intelligence – Internet of Things) AI-IoTBPM BPMN modular, vehicles can be enhanced with electronics, connectivity, and hardware that allow them to communicate and interact with other devices, a vehicle that communicates with its world.

This technology is responsible for many of the innovations found in our vehicles today.

Telematics is a vast field that includes various aspects of telecommunications, wireless connectivity, electrical engineering, IT, and road transport. Connected cars and other automotive technologies are currently garnering the most attention in telematics innovations.

Telematics is revolutionizing consumer vehicle technology.

Other applications emerging in the market involve vehicle communications technology that allows a vehicle to connect to a variety of IoT devices. This technology means a car can exchange data with other connected vehicles, smart traffic lights, smart cities, toll road collection points, 3rd-party products, business applications and services.

This will result in exponential growth, in parallel with IoT advancements.