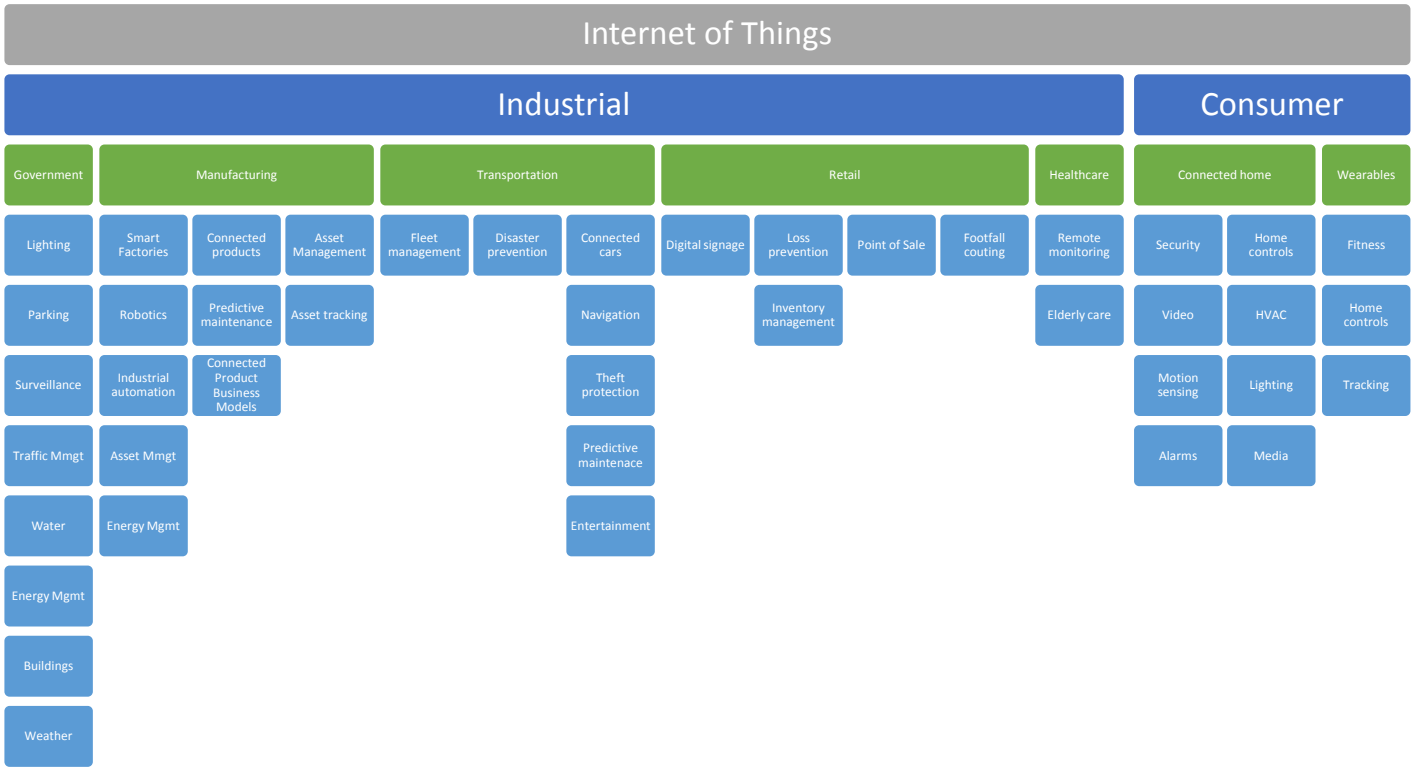
Explaining the Internet of Things Ecosystem and Taxonomy

Overview

451 Research defines the Internet of Things as the apps and systems enabling the virtualization of the physical world. This industry-wide movement is enabled and realized through the use of standalone or embedded, networked sensors and microprocessors deployed in physical objects or environments that are then connected to back-end systems and applications via a wide variety of network protocols and architectures. IoT systems create value by combining sensor capabilities with back-end and front-end systems that turn raw data into information services of value. IoT also can imply ability to control physical systems remotely or autonomously. Once connected, IoT systems capture and store data and data analytics to turn that data into actionable insight or enable value-added services not possible without Internet or equivalent connectivity.

The potential applications of IoT are vast and include a combination of IoT silos and IoT systems of systems. For example, let's use hospitality, and specifically a hotel operation. Today, many hotels have connected HVAC systems that allow them to remotely monitor and control heating. For this purpose let's call this the HVAC IoT silo. Others have connected lighting systems that enables monitoring and control of property lighting – the Lighting IoT silo. Lastly, there is a video surveillance system of remote IP cameras deployed around the property – the Surveillance silo. Today, these systems provide useful features on their own merits. When these systems are integrated together, completely new value is possible, with the potential to drive even more bottom-line savings or guest value. For instance, if video surveillance shows no movement in a room for a specific period of time, the system can turn down the heat and turn off the lights; it can reverse those steps when surveillance records the opposite underway.

The potential applications of IoT have appeal to a wide range of vertical markets. Some IoT applications have wide horizontal appeal while others will fit squarely into a specific vertical industry, as shown in the chart below.



IoT Taxonomy

With such broad opportunity for the IoT ecosystem, a taxonomy, or system of classification, is a useful tool to understand the scope of impact IoT is having across organizations and the technology stack. For IoT, a useful place to start is at the 'edge,' or where the value potential of IoT both starts and ends. We believe this value at the edge is driven by what we call the virtualization of the physical world – the deployment of IP connectivity into previously static or 'dumb' objects. These objects may include sensors, but can also be deployed with basic circuitry to send and receive data to/from a central point (cloud, datacenter) for further operations and analysis. Of course there are myriad technologies between these objects and the central data store that help create value from IoT. Starting at the edge and ending at the datacenter and cloud, we break IoT into 10 distinct categories, which we fully expect to evolve over time as the market matures. These categories represent the technologies and market trends that are at the backbone of the IoT ecosystem and are expected to produce the most value for organizations and technology suppliers. These coverage areas include edge computing, operating systems, gateways and aggregation, wearables, modules and connectivity, bandwidth providers, middleware (platforms) and applications, big data, cloud, and professional services.

Our ongoing analysis of these IoT categories focuses on:

- Providing a hype-free perspective on the progression of IoT in terms of market adoption and IT impacts
- Helping navigate the vast ecosystem of IoT enabling technologies spanning edge, networks, IT infrastructure, applications and services
- Delivering a compelling series of consumer and industrial survey products to help drive better decision-making for those with P&L responsibilities in IoT

Edge Computing

All IoT applications start with one or more of the following sensing categories:

Bio Sensing	Machine Sensing/Controls	Environmental Sensing
Where: Wearable or implantable into living organisms **What:** Location, velocity, heart rate, blood pressure, internal temp, glucose, brain activity	**Where:** Embedded or attached combinations of sensors and microcontrollers for data and control of powered machinery and/or passive tagging **What:** Location, temperature, power consumption, battery usage, device-specific information, velocity, subsystem health **Controls:** Off/on, if this then that commands	**Where:** Deployed into the physical environment - can be fixed or with mobility **What:** Video surveillance, motion detection, temperature, location, humidity, pressure, light, wind speed, seismic activity

The sensing and control activities described connect to or are integrated with the 'things' of IoT. These devices range from relatively simple temperature and pressure sensors to highly sophisticated and complex multi-input sensors on industrial equipment capable of preliminary data capture and analysis.

Modules and Connectivity

The modules and connectivity category includes the networking technologies used to deliver data from the sensing edge and the back-end and front-end systems and applications that are used to collect, store and analyze IoT data and make it either consumable for humans or allow them to communicate with other machines and systems autonomously. Different IoT applications will bring different application requirements such as bandwidth and latency.

IoT Gateways and Aggregation

Sensors and other edge devices will either incorporate or connect through external gateway devices that aggregate multiple sensors for local or remote data storage (databases) and data analysis. The myriad use cases inherent in IoT means that there will be both inexpensive sensors and gateways that tunnel traffic back to private or public cloud services for ex-post-facto analysis, and also more mission-critical latency-sensitive applications that require localized database and analysis. Edge intelligence and analysis could become more important to reduce the backhaul bandwidth to remote cloud datacenters and the latency inherent in the round-trip time over wide area networks.

IoT Wearables

Wearables represent an area of ongoing fast-paced consumer innovation, a driver of overall sensor manufacturing and an avenue for bandwidth/networking-infrastructure buildout. As we have seen in enterprise and BYOD, the consumerization of IT is a key driver and will ultimately extend into IoT as more users instrument themselves and the spaces they occupy (offices, homes, cars) with sensors and analytics.

IoT Operating Systems

The sensors and systems they are integrated within, or provide data through, require embedded operating systems, which have already developed into a distinct standalone segment within IoT. The operating systems provide a much-needed interface between hardware sensing devices, and leverage the application programming interfaces exposed by middleware and applications (below). There are multiple industry efforts underway to standardize the northbound and southbound interfaces out of these operating systems to accelerate the development of an ecology.

Middleware and Applications

The connective tissue of IoT are the middleware platforms that mediate between edge systems and gateways and centralized data stores and clouds. IoT middleware and application platforms have emerged to take on higher-order IoT device management, application development, data handling and management, data visualization and middleware-driven integration to enterprise IT systems and API management. This category includes horizontal platforms such as SIM management and operations, middleware, API management, device management and data management. This category also includes vertical-specific IoT platforms such as those sold into the connected car ecosystem, e.g., BlackBerry/QNX. 451 Research covers companies with IoT middleware and applications as well as pre-standard and industry consortia attempting to standardize on common data formats.

IoT Bandwidth Providers

A number of specific startups and service offerings from incumbent network connectivity providers have already emerged surrounding the Internet of Things. Bandwidth providers play a critical role in enabling IoT due to the often distributed nature of the sensors and data along with the expected explosion of the volume of traffic as more things come online. We expect this segment to grow considerably as the market matures and the types of IoT applications (and their unique traffic requirements) are better understood, and new services and tools are created to address these application-specific needs.

Big Data

Databases and analytics are where the key value of IoT is realized, in the actionable insights provided by the large quantities of data being aggregated. IoT's many use cases and applications eschew a single database model, and the market is already awash with multiple distributed and centralized database and analytics models. In addition, many mission-critical IoT applications require rapid analysis closer to the data 'surface,' and will require a combination of both distributed and centralized approaches to address. 451 Research covers both innovative database approaches to the IoT market as well as the various approaches vendors are taking to analyze the unprecedented amount of data that the IoT creates.

IoT Professional Services

This segment includes professional consulting and integration services related to IoT strategy, business process design, application design, systems integration and security. Despite the hype, IoT is still nascent and rapidly developing. Embracing IoT for any enterprise will introduce untold complexity and disruption to both existing IT systems and business processes. Global and regional SIs and consultants will be called on to play their normal roles from beginning to end of any IoT strategy lifecycle as well, either on their own or as part of even larger enterprise digitization efforts. As IoT develops and matures, 451 Research will cover the large population of professional services firms that will assist enterprises in developing and deploying their own IoT strategies.

IoT Cloud

The cloud has a critical enabling role as the execution venue of choice for many IoT applications and the tools that will drive the insights to deliver ROI. The availability of high-quality, virtualized, on-demand compute, storage and network resources in public, private or hybrid configurations has forever altered the enterprise IT infrastructure model for deploying and supporting enterprise application workloads. The game-changing economic and scale advantages of the cloud model, whether in a private datacenter or at a public cloud provider, align perfectly with the requirements of IoT, and they could be argued as the most critical enabler for its long-term viability as the execution venue of choice. 451 Research covers the many companies that have staked out IoT as the next growth market for new or existing cloud offerings and big data services.

M2M vs IoT

The terms 'machine to machine' (M2M) and 'IoT' are often used interchangeably, as they both include the capture of data from machines. IoT is slightly different and more ambitious than its predecessor M2M in that M2M systems are not connected to the Internet, nor are they typically integrated with existing IT systems such as CRM and ERP. M2M systems were siloes, fit for purpose, and often proprietary in nature. They were typically industrial in nature and were controlled by the OT/LOB, not IT. M2M systems today thrive in a number of industrial deployment scenarios such as asset tracking, fleet management and meter reading. The vision of IoT includes heavy use of Internet for connectivity, standards-based connection technologies at the edge, new business models, and direct interface into existing IT systems.

The 451 Research Internet of Things Market Map

The 451 Research Internet of Things Market Map™ outlines each of the sub-systems and integration services required to bring data from sensing and control systems into IT infrastructure and ultimately into the hands of enterprise decision-makers and consumers of IoT applications. These include sensors, microcontrollers, RF units, network aggregation equipment, IoT WAN/LAN bandwidth, middleware, applications, compute/storage/networks, data analytics, and professional services.

451 Research's IoT Research Agenda

The 451 Research Internet of Things research channel integrates both qualitative and quantitative research to triangulate on the early development of the IoT market. Qualitatively, the research team works with early adopter customers, IoT technology vendors, ecosystem players (funding sources, professional services) and the broader market to uncover where the real value is being realized in IoT, ROI of early deployments, nascent standardization efforts and future indicators of market development.

We bring unique quantitative insight to the IoT market, from both the supply side and the demand side. Through market sizing and forecasting of the myriad device types and radios driving the IoT revolution, we can monitor the growth and volume of endpoints producing data. Additionally, through thousands of quarterly IT decision-maker and consumer demand surveys, 451 Research keeps the pulse of the reality of enterprise adoption of IoT and the real value it is generating today, as well as expectations for the future.

To read the full Research Agenda, **click here**.