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BECK

Internet of things (IoT)

WP2 - TEACHING (LEARNING) MATERIALS: SMART CITY AND ANALYTICS (WITH COURSE PROJECT)

VGTU

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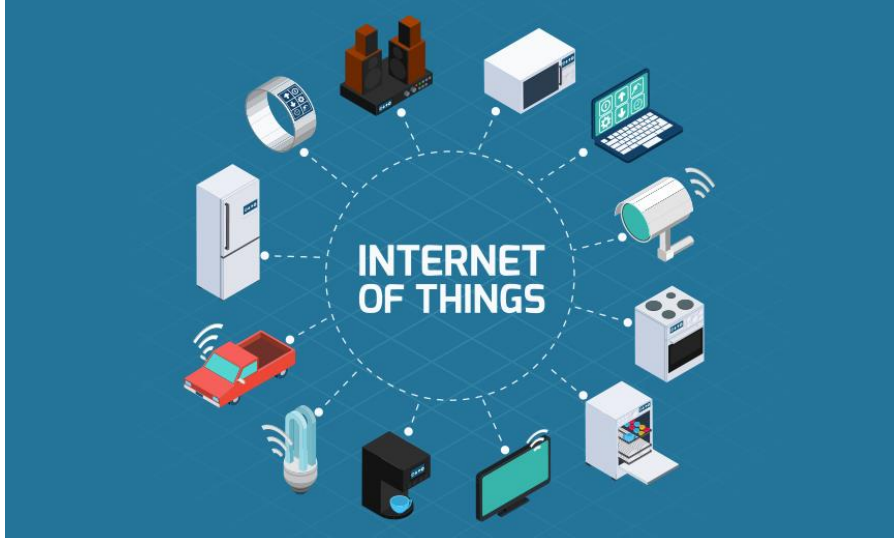
Definition of the Internet of things (IoT)



There is no commonly recognized definition of IoT; it can be defined in several ways:

1. The concept goal of the IoT is to enable things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network and any service. IoT is a new revolution of the Internet. Objects make themselves recognizable and they obtain intelligence thanks to the fact that they can communicate information about themselves and they can access information that has been aggregated by other things. For example, alarm clocks will go off early if there's traffic; plants will communicate to the sprinkler system when it's time for them to be watered; medicine containers tell your family members if you forget to take the medicine. All objects can play an active role thanks to their connection to the Internet [1].

IoT Definition

2. The IoT could be conceptually defined as a dynamic global network infrastructure with self-configuring capabilities where physical and virtual things have identities, physical attributes, and virtual personalities; use intelligent interfaces; and are seamlessly integrated into the information network [2].

3. International Telecommunication Union (ITU) defines the IoT as a “global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things, based on existing and evolving interoperable information and communication technologies.” Importantly, ITU points out that the IoT is a “vision,” not a single technology, and that it has “technological and societal implications” [3].

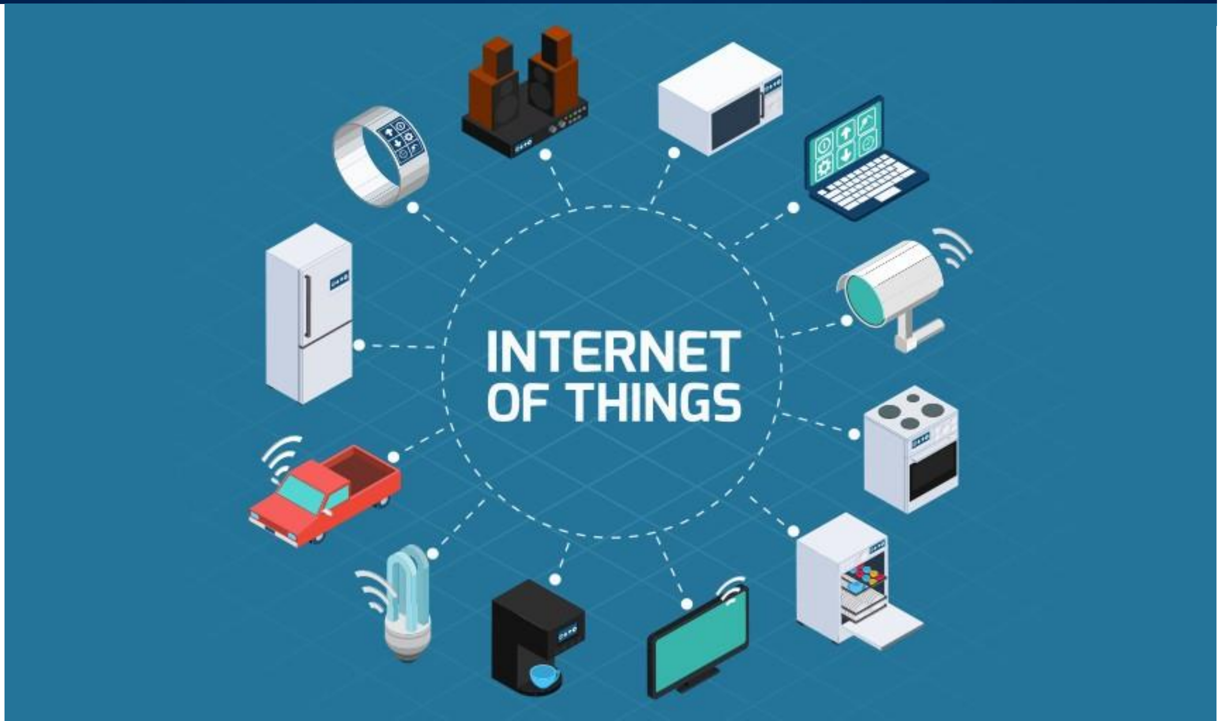
IoT Definition

4. The IoT is the network of physical objects that contain embedded technology to communicate and sense or interact with their internal states or the external environment (Gartner).

5. The Oxford Dictionary defines IoT as the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data.

6. The IoT enables the objects in our environment to become active participants; that is, they share information with other members of the network or with any other stakeholder and they are capable of recognizing events and changes in their surroundings and of acting and reacting autonomously in an appropriate manner. In this context the research and development challenges to create a smart world are enormous. A world where the real, digital, and virtual are converging to create smart environments that make energy, cities, and many other areas more intelligent [1].


IOT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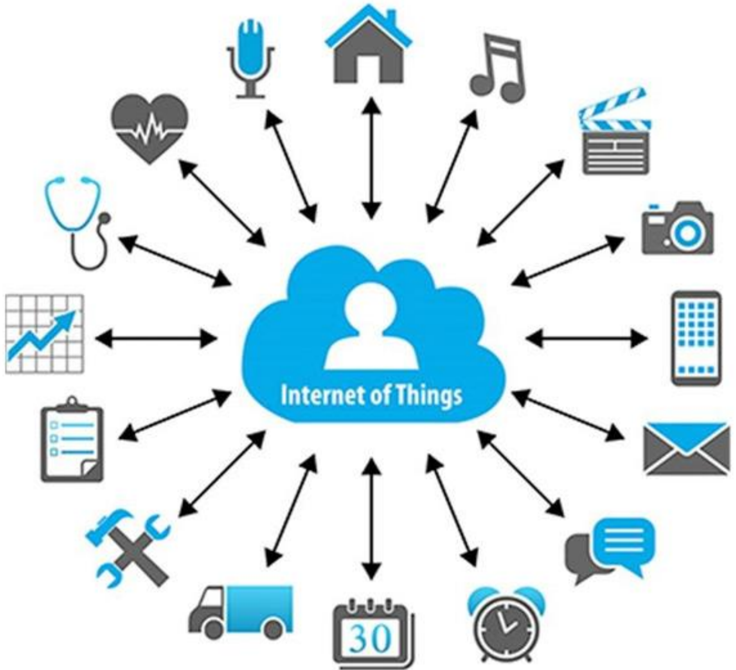
Internet of Things
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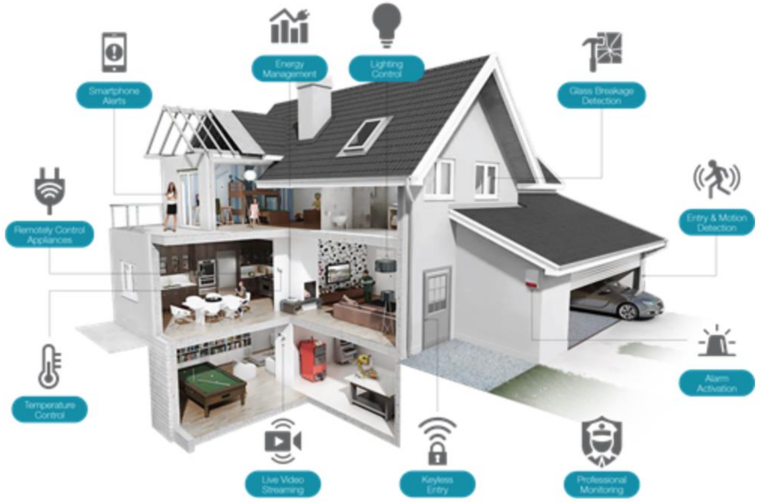
IoT Definition



Embedded with electronics, Internet connectivity, and other forms of hardware (such as sensors), these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled.

The definition of the Internet of things has evolved due to convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.[5] Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers.

The IoT concept

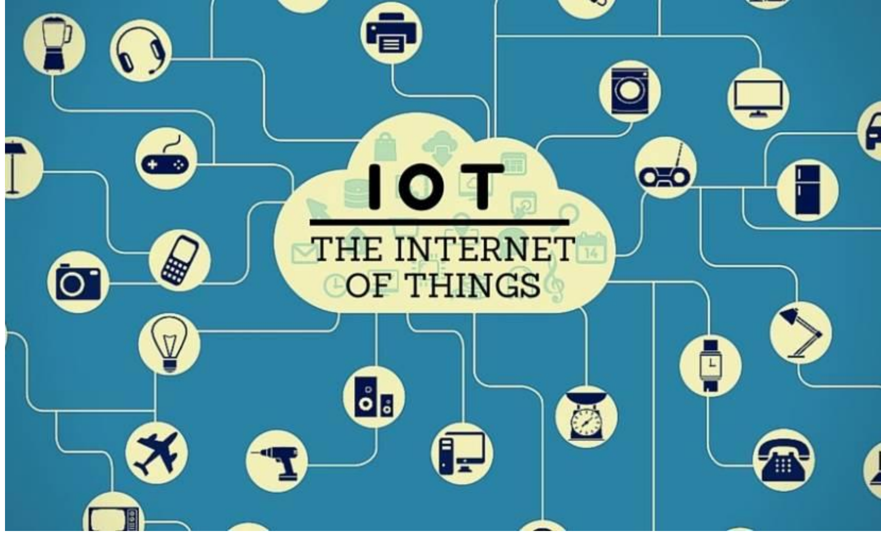
The IoT concept refers to uniquely identifiable things with their virtual representations in an Internet-like structure and IoT solutions comprising a number of components such as [1]:

1. Module for interaction with local IoT devices (for example embedded in a mobile phone or located in the immediate vicinity of the user and thus contactable via a short-range wireless interface).

2. Module for local analysis and processing of observations acquired by IoT devices.

3. Module for interaction with remote IoT devices, directly over the Internet or more likely via a proxy. This module is responsible for acquisition of observations and their forwarding to remote servers for analysis and permanent storage.

The IoT concept



4. Module for application-specific data analysis and processing. This module is running on an application server serving all clients. It is taking requests from mobile and web clients and relevant IoT observations as input, executes appropriate data processing algorithms, and generates output in terms of knowledge that is later presented to users.

5. Module for integration of IoT-generated information into the business processes of an enterprise. This module will be gaining importance with the increased use of IoT data by enterprises as one of the important factors in day-to-day business or business strategy definition.

6. User interface (web or mobile): visual representation of measurements in a given context (for example on a map) and interaction with the user (ie, definition of user queries).

The IoT Technological trends

Advances in wireless networking technology and the greater standardization of communications protocols make it possible to collect data from sensors and wireless identifiable devices almost anywhere at any time. Massive increases in storage and computing power, some of it available via cloud computing, make number crunching possible at a very large scale, at a high volume, and at a low cost. It is possible to identify, for the years to come, a number of distinct macrotrends that will shape the future of IoT [2]:

1. The explosion in the volumes of data collected, exchanged, and stored by IoT interconnected objects will require novel methods and mechanisms to find, fetch, and transmit data.

2. Research is looking for ultralow power autonomic devices and systems from the tiniest smart dust to the huge data centers that will self-harvest the energy they need.

3. Miniaturization of devices is also taking place at a lightning speed, and the objective of a single-electron transistor, which seems to be (depending on new discoveries in physics) the ultimate limit, is getting closer.

4. The trend is toward the autonomous and responsible behavior of resources. The ever-growing complexity of systems, possibly including mobile devices, will be unmanageable, and will hamper the creation of new services and applications, unless the systems will show “self” functionality, such as self-management, self-healing, and self-configuration.

The IoT Technological trends

Chamberlin [4] takes a look at two important enabling technologies that are helping to make the future of IoT a reality today:

1. Advances in connectivity and networks. To connect all the expected billions of devices to the Internet, more Internet addresses were needed than were available through the IPv4 protocol. Once connected, all these devices need networks to communicate with other devices and computer systems. There are many different types of networks that are available and each has different strengths for different applications. While all these different wireless communications standards and technologies result in a fragmented approach, each of these networks has strengths for certain applications.

2. Advances in sensor and microprocessor design. The following advancements are enabling new types of IoT systems and applications: smaller, more durable sensors, multiprocessor chips, increasing processor performance and efficiency, and lower costs.

IoT Applications

Consumer applications

A growing portion of IoT devices are created for consumer use, including connected vehicles, home automation, wearable technology (as part of Internet of Wearable Things (IoWT)[25]), connected health, and appliances with remote monitoring capabilities.

Smart home

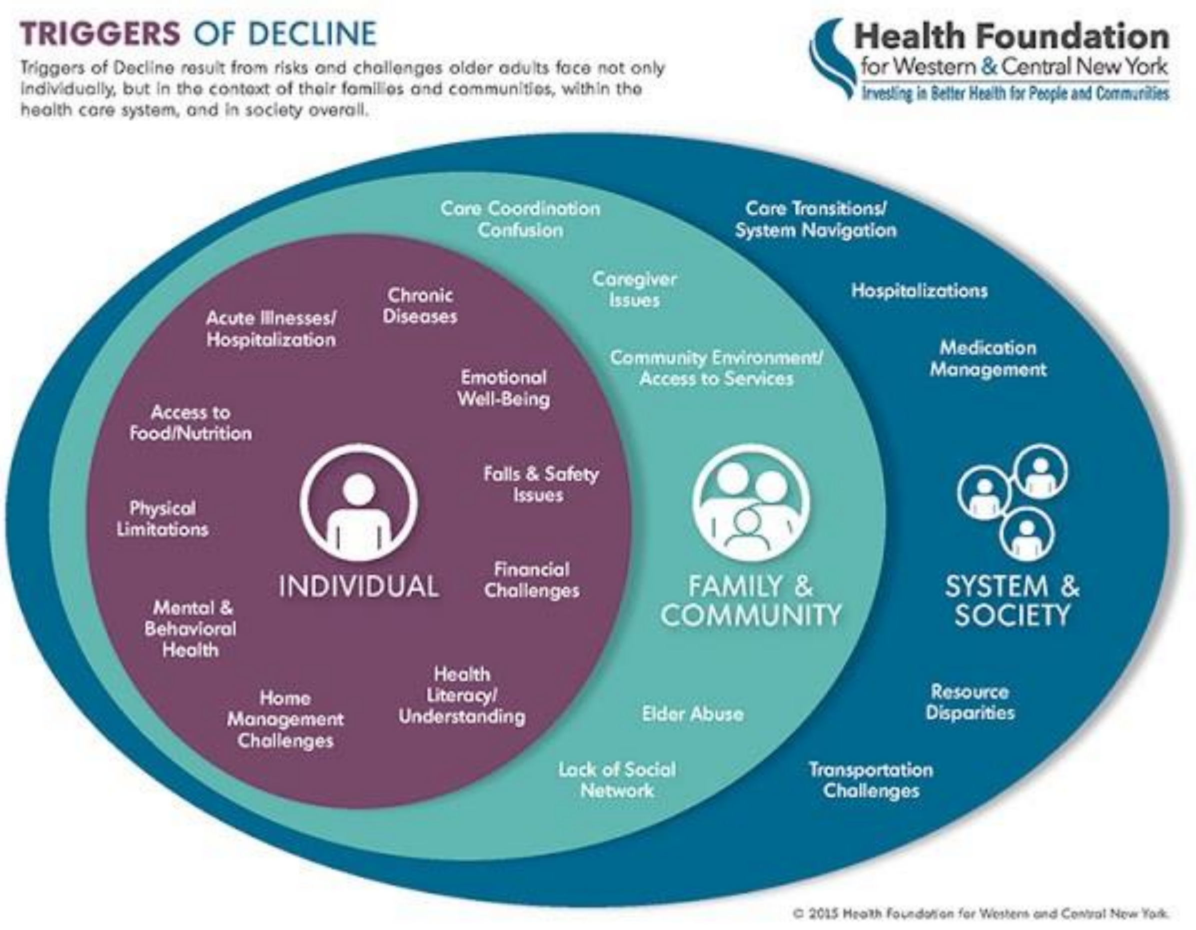
IoT devices are a part of the larger concept of home automation, which can include lighting, heating and air conditioning, media and security systems. Long term benefits could include energy savings by automatically ensuring lights and electronics are turned off.

A smart home or automated home could be based on a platform or hubs that control smart devices and appliances. For instance, using Apple's HomeKit, manufacturers can get their home products and accessories be controlled by an application in iOS devices such as the iPhone and the Apple Watch. This could be a dedicated app or iOS native applications such as Siri.[This can be demonstrated in the case of Lenovo's Smart Home Essentials, which is a line of smart home devices that are controlled through Apple's Home app or Siri without the need for a Wi-Fi bridge. There are also dedicated smart home hubs that are offered as standalone platforms to connect different smart home products and these include the Amazon Echo, Google Home, Apple's HomePod, and Samsung's SmartThings Hub.

Elder care

One key application of smart home is to provide assistance for those with disabilities and elderly individuals. These home systems use assistive technology to accommodate an owner's specific disabilitiesVoice control can assist users with sight and mobility limitations while alert systems can be connected directly to cochlear implants worn by hearing impaired users. They can also be equipped with additional safety features. These features can include sensors that monitor for medical emergencies such as falls or seizures.[36] Smart home technology applied in this way can provide users with more freedom and a higher quality of life.

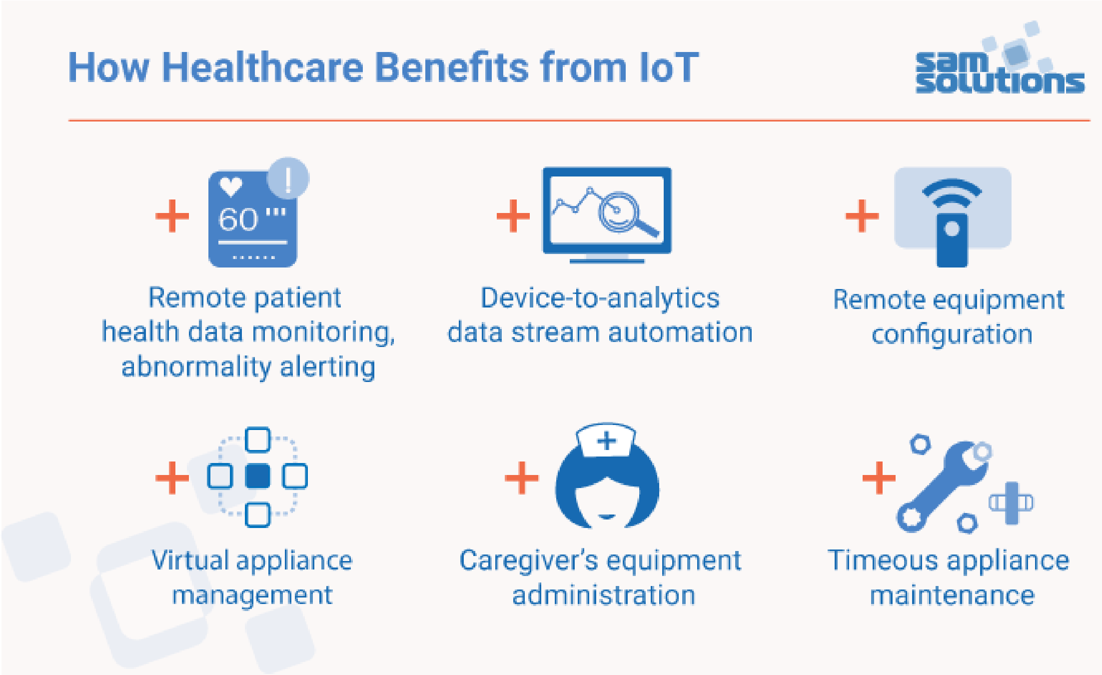
The term "Enterprise IoT" refers to devices used in business and corporate settings. By 2019, it is estimated that the EIoT will account for 9.1 billion devices.



Medical and healthcare

The Internet of Medical Things (also called the internet of health things) is an application of the IoT for medical and health related purposes, data collection and analysis for research, and monitoringThis 'Smart Healthcare', as it can also be called, led to the creation of a digitized healthcare system, connecting available medical resources and healthcare services.

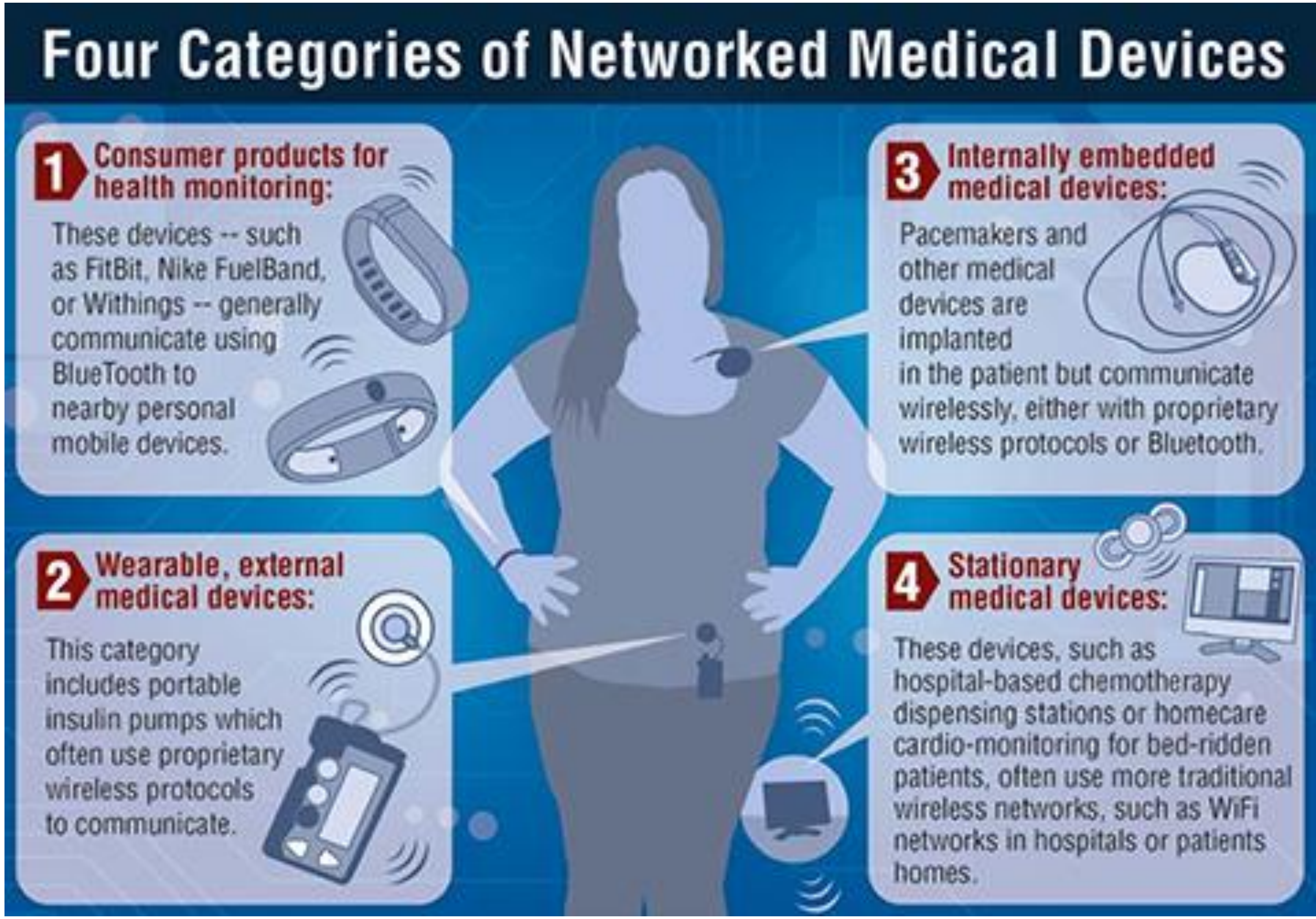
IoT devices can be used to enable remote health monitoring and emergency notification systems. These health monitoring devices can range from blood pressure and heart rate monitors to advanced devices capable of monitoring specialized implants, such as pacemakers, Fitbit electronic wristbands, or advanced hearing aids. Some hospitals have begun implementing "smart beds" that can detect when they are occupied and when a patient is attempting to get up. It can also adjust itself to ensure appropriate pressure and support is applied to the patient without the manual interaction of nurses. A Goldman Sachs report indicated that healthcare IoT devices "can save the United States more than $300 billion in annual healthcare expenditures by increasing revenue and decreasing cost." Moreover, the use of mobile devices to support medical follow-up led to the creation of 'm-health', used "to analyze, capture, transmit and store health statistics from multiple resources, including sensors and other biomedical acquisition systems".



Medical and healthcare

Specialized sensors can also be equipped within living spaces to monitor the health and general well-being of senior citizens, while also ensuring that proper treatment is being administered and assisting people regain lost mobility via therapy as well. These sensors create a network of intelligent sensors that are able to collect, process, transfer and analyse valuable information in different environments, such as connecting in-home monitoring devices to hospital-based systems. Other consumer devices to encourage healthy living, such as connected scales or wearable heart monitors, are also a possibility with the IoT. End-to-end health monitoring IoT platforms are also available for antenatal and chronic patients, helping one manage health vitals and recurring medication requirements.

Advances in plastic and fabric electronics fabrication methods have enabled ultra-low cost, use-and-throw IoMT sensors. These sensors, along with the required RFID electronics, can be fabricated on paper or e-textiles for wirelessly powered disposable sensing devices.[51] Applications have been established for point-of-care medical diagnostics, where portability and low system-complexity is essential.



Medical and healthcare

As of 2018 IoMT was not only being applied in the clinical laboratory industry, but also in the healthcare and health insurance industries. IoMT in the healthcare industry is now permitting doctors, patients and others involved (i.e. guardians of patients, nurses, families, etc.) to be part of a system, where patient records are saved in a database, allowing doctors and the rest of the medical staff to have access to the patient's information. Moreover, IoT-based systems are patient-centered, which involves being flexible to the patient's medical conditions. IoMT in the insurance industry provides access to better and new types of dynamic information. This includes sensor-based solutions such as biosensors, wearables, connected health devices and mobile apps to track customer behaviour. This can lead to more accurate underwriting and new pricing models.

The application of the IOT in healthcare plays a fundamental role in managing chronic diseases and in disease prevention and control. Remote monitoring is made possible through the connection of powerful wireless solutions. The connectivity enables health practitioners to capture patient’s data and applying complex algorithms in health data analysis.

Building and home automation

IoT devices can be used to monitor and control the mechanical, electrical and electronic systems used in various types of buildings (e.g., public and private, industrial, institutions, or residential) in home automation and building automation systems. In this context, three main areas are being covered in literature:

- The integration of the Internet with building energy management systems in order to create energy efficient and IOT-driven "smart buildings".

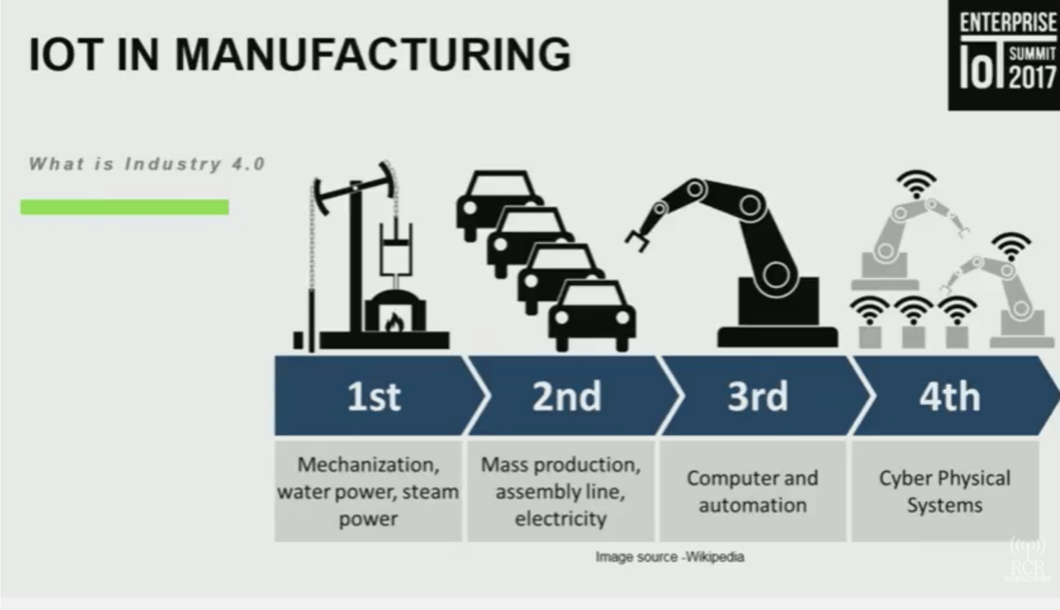
- The possible means of real-time monitoring for reducing energy consumption and monitoring occupant behaviors.

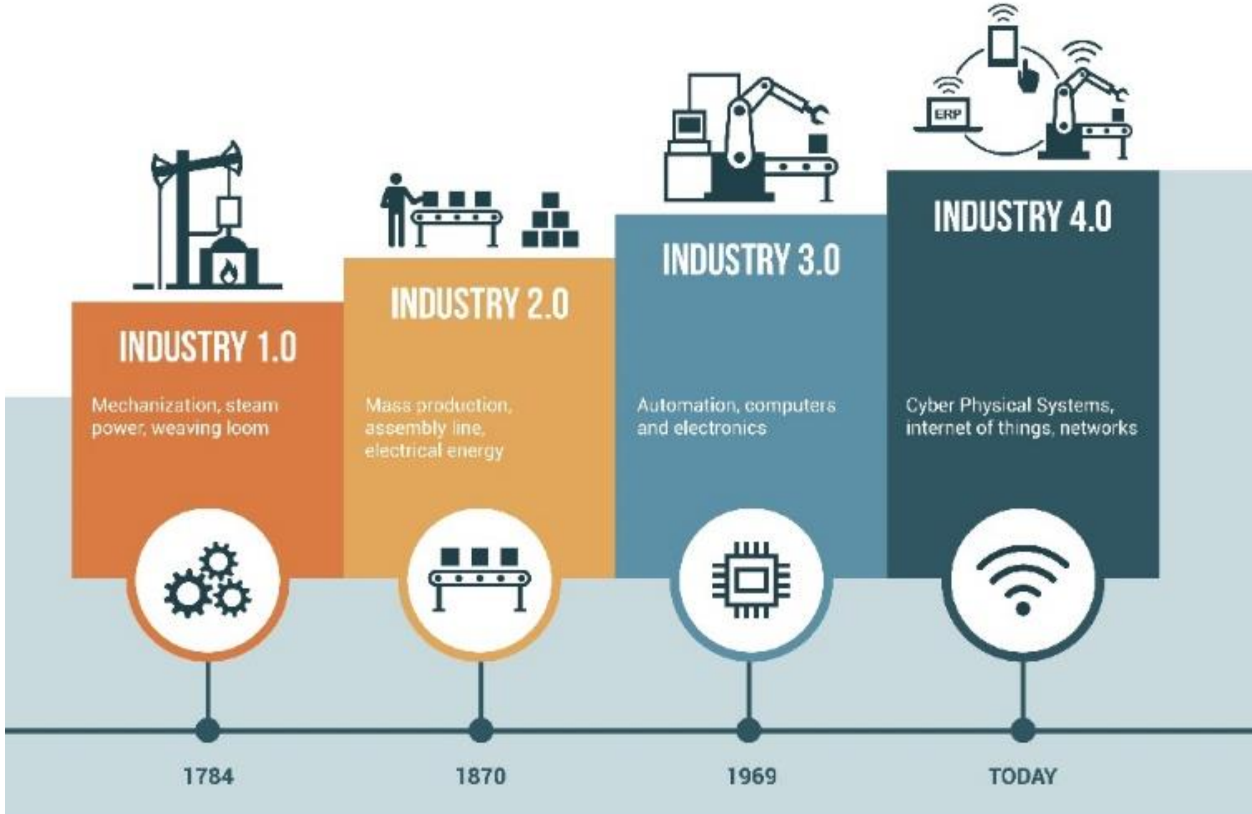
The integration of smart devices in the built environment and how they might to know how to be used in future applications.

Manufacturing

The IoT can realize the seamless integration of various manufacturing devices equipped with sensing, identification, processing, communication, actuation, and networking capabilities. Based on such a highly integrated smart cyberphysical space, it opens the door to create whole new business and market opportunities for manufacturing. Network control and management of manufacturing equipment, asset and situation management, or manufacturing process control bring the IoT within the realm of industrial applications and smart manufacturing as well. The IoT intelligent systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing production and supply chain networks, by networking machinery, sensors and control systems together.

Digital control systems to automate process controls, operator tools and service information systems to optimize plant safety and security are within the purview of the IoT. But it also extends itself to asset management via predictive maintenance, statistical evaluation, and measurements to maximize reliability. Smart industrial management systems can also be integrated with the Smart Grid, thereby enabling real-time energy optimization. Measurements, automated controls, plant optimization, health and safety management, and other functions are provided by a large number of networked sensors.

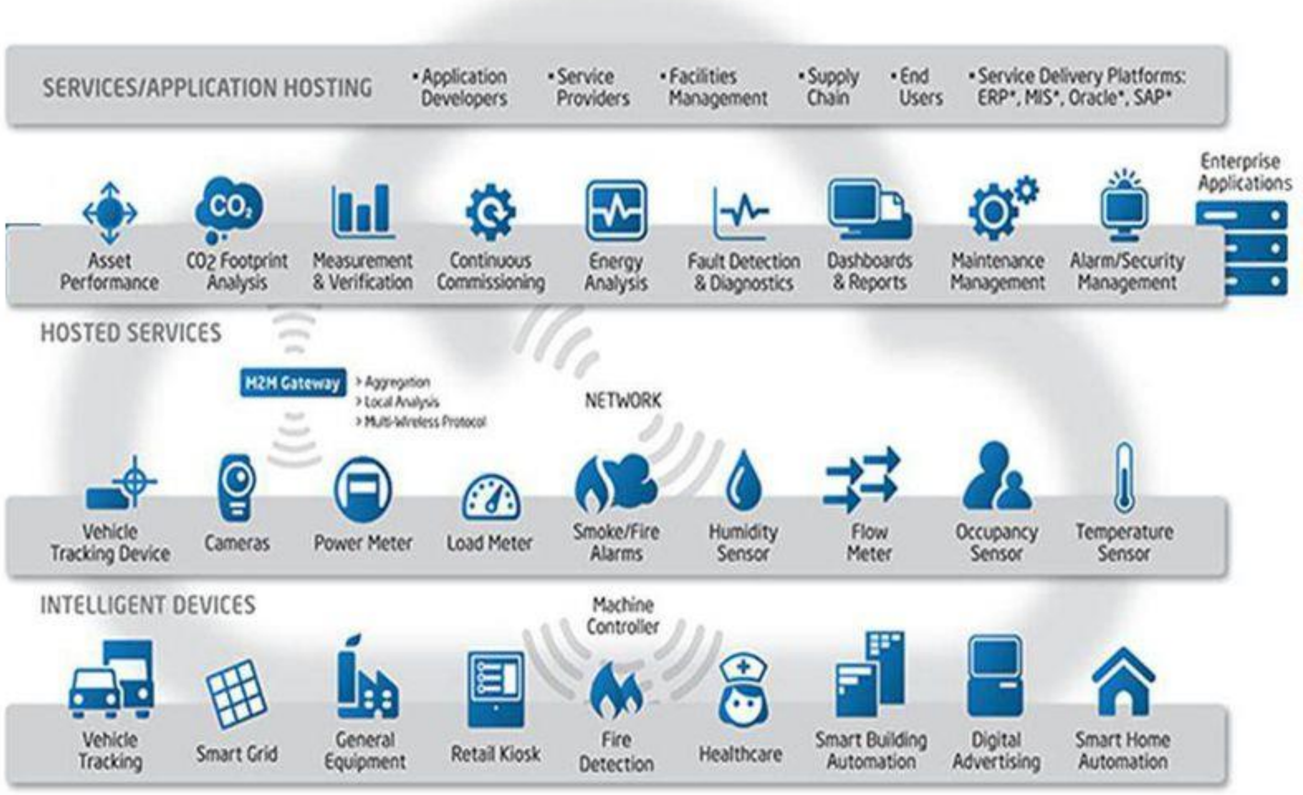


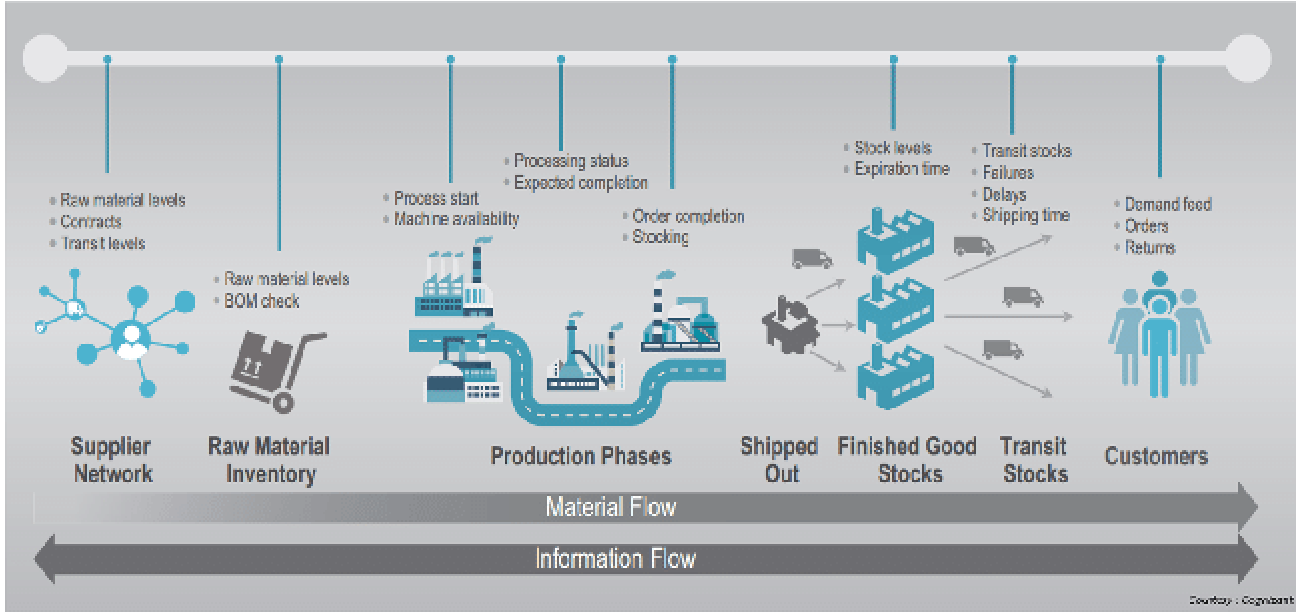


Manufacturing

The term industrial Internet of things (IIoT) is often encountered in the manufacturing industries, referring to the industrial subset of the IoT. IIoT in manufacturing could generate so much business value that it will eventually lead to the Fourth Industrial Revolution, so the so-called Industry 4.0. It is estimated that in the future, successful companies will be able to increase their revenue through Internet of things by creating new business models and improve productivity, exploit analytics for innovation, and transform workforce.[64] The potential of growth by implementing IIoT may generate $12 trillion of global GDP by 2030.

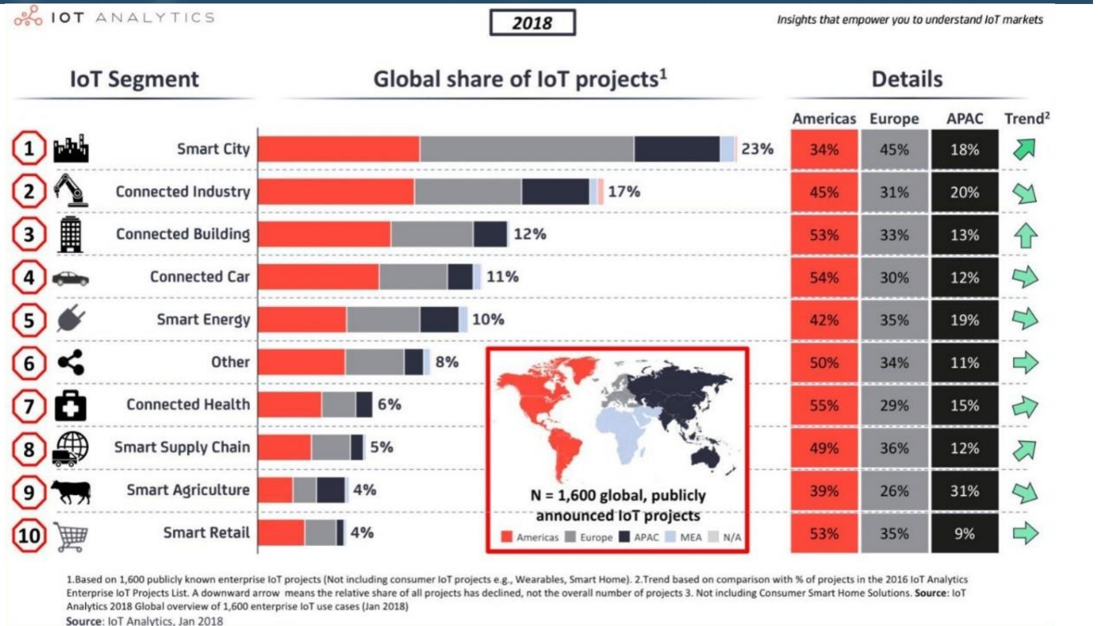
Design architecture of cyber-physical systems-enabled manufacturing system. Industrial big data analytics will play a vital role in manufacturing asset predictive maintenance, although that is not the only capability of industrial big data. Cyber-physical systems (CPS) is the core technology of industrial big data and it will be an interface between human and the cyber world. Cyber-physical systems can be designed by following the 5C (connection, conversion, cyber, cognition, configuration) architecture, and it will transform the collected data into actionable information, and eventually interfere with the physical assets to optimize processes.





Manufacturing

An IoT-enabled intelligent system of such cases was proposed in 2001 and later demonstrated in 2014 by the National Science Foundation Industry/University Collaborative Research Center for Intelligent Maintenance Systems (IMS) at the University of Cincinnati on a bandsaw machine in IMTS in Chicago. Bandsaw machines are not necessarily expensive, but the bandsaw belt expenses are enormous since they degrade much faster. However, without sensing and intelligent analytics, it can be only determined by experience when the band saw belt will actually break. The developed prognostics system will be able to recognize and monitor the degradation of band saw belts even if the condition is changing, advising users when is the best time to replace the belt. This will significantly improve user experience and operator safety and ultimately save on costs.



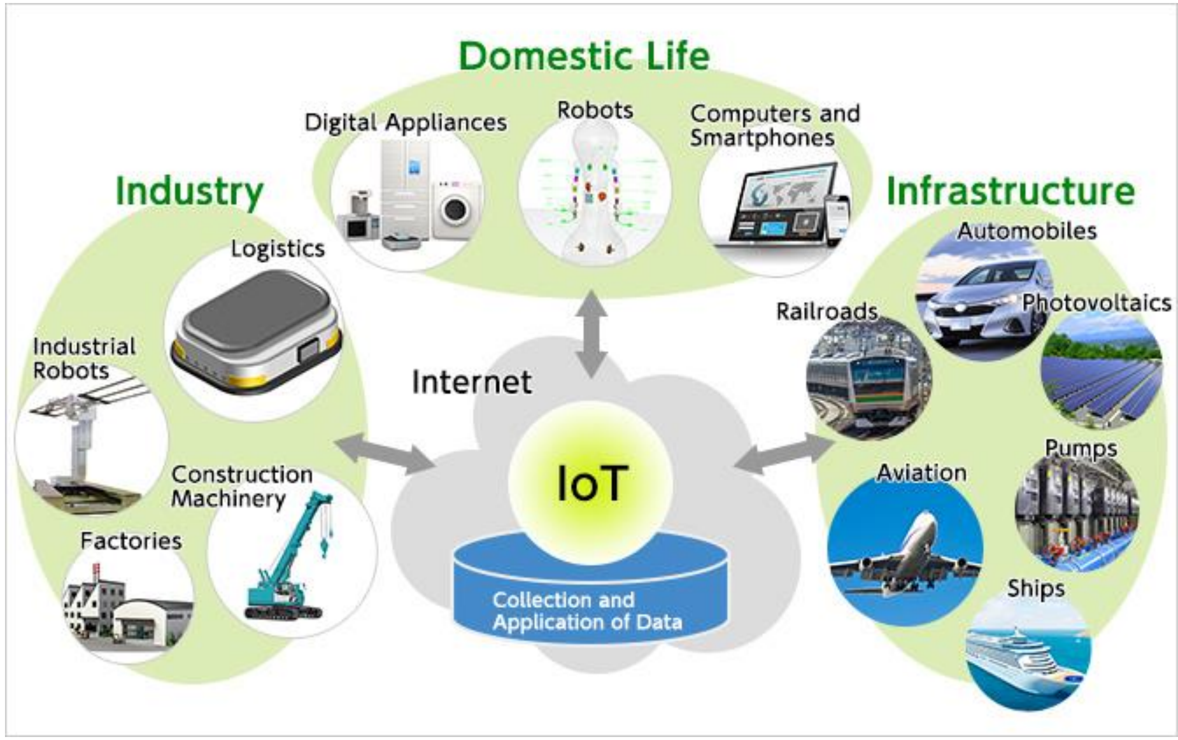
Agriculture

There are numerous IoT applications in farming such as collecting data on temperature, rainfall, humidity, wind speed, pest infestation, and soil content. This data can be used to automate farming techniques, take informed decisions to improve quality and quantity, minimize risk and waste, and reduce effort required to manage crops. For example, farmers can now monitor soil temperature and moisture from afar, and even apply IoT-acquired data to precision fertilization programs.

In August 2018, Toyota Tsusho began a partnership with Microsoft to create fish farming tools using the Microsoft Azure application suite for IoT technologies related to water management. Developed in part by researchers from Kindai University, the water pump mechanisms use artificial intelligence to count the number of fish on a conveyor belt, analyze the number of fish, and deduce the effectiveness of water flow from the data the fish provide. The specific computer programs used in the process fall under the Azure Machine Learning and the Azure IoT Hub platforms.

Infrastructure applications

Monitoring and controlling operations of sustainable urban and rural infrastructures like bridges, railway tracks and on- and offshore wind-farms is a key application of the IoT. The IoT infrastructure can be used for monitoring any events or changes in structural conditions that can compromise safety and increase risk. The IoT can benefit the construction industry by cost saving, time reduction, better quality workday, paperless workflow and increase in productivity. It can help in taking faster decisions and save money with Real-Time Data Analytics. It can also be used for scheduling repair and maintenance activities in an efficient manner, by coordinating tasks between different service providers and users of these facilities. IoT devices can also be used to control critical infrastructure like bridges to provide access to ships. Usage of IoT devices for monitoring and operating infrastructure is likely to improve incident management and emergency response coordination, and quality of service, up-times and reduce costs of operation in all infrastructure related areas. Even areas such as waste management can benefit from automation and optimization that could be brought in by the IoT.



Metropolitan scale deployments

There are several planned or ongoing large-scale deployments of the IoT, to enable better management of cities and systems. For example, Songdo, South Korea, the first of its kind fully equipped and wired smart city, is gradually being built, with approximately 70 percent of the business district completed as of June 2018. Much of the city is planned to be wired and automated, with little or no human intervention.

Another application is a currently undergoing project in Santander, Spain. For this deployment, two approaches have been adopted. This city of 180,000 inhabitants has already seen 18,000 downloads of its city smartphone app. The app is connected to 10,000 sensors that enable services like parking search, environmental monitoring, digital city agenda, and more. City context information is used in this deployment so as to benefit merchants through a spark deals mechanism based on city behavior that aims at maximizing the impact of each notification.

Metropolitan scale deployments

Other examples of large-scale deployments underway include the Sino-Singapore Guangzhou Knowledge City; work on improving air and water quality, reducing noise pollution, and increasing transportation efficiency in San Jose, California; and smart traffic management in western Singapore. French company, Sigfox, commenced building an Ultra Narrowband wireless data network in the San Francisco Bay Area, the first business to achieve such a deployment in the U.S. It subsequently announced it would set up a total of 4000 base stations to cover a total of 30 cities in the U.S. by the end of 2016, making it the largest IoT network coverage provider in the country thus far. Cisco also participates in smart cities projects. Cisco has started deploying technologies for Smart Wi-Fi, Smart Safety & Security, Smart Lighting, Smart Parking, Smart Transports, Smart Bus Stops, Smart Kiosks, Remote Expert for Government Services (REGS) and Smart Education in the five km area in the city of Vijaywada.

Another example of a large deployment is the one completed by New York Waterways in New York City to connect all the city's vessels and be able to monitor them live 24/7. The network was designed and engineered by Fluidmesh Networks, a Chicago-based company developing wireless networks for critical applications. The NYWW network is currently providing coverage on the Hudson River, East River, and Upper New York Bay. With the wireless network in place, NY Waterway is able to take control of its fleet and passengers in a way that was not previously possible. New applications can include security, energy and fleet management, digital signage, public Wi-Fi, paperless ticketing and others.

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Built environment can be defined in several ways:

• The term built environment refers to the human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighborhoods and cities that can often include their supporting infrastructure, such as water supply or energy networks. The built environment is a material, spatial, and cultural product of human labor that combines physical elements and energy in forms for living, working, and playing. It has been defined as “the human-made space in which people live, work, and recreate on a day-to-day basis”.

• The “built environment encompasses places and spaces created or modified by people including buildings, parks, and transportation systems.” In recent years, public health research has expanded the definition of built environment to include healthy food access, community gardens, walkability, and bikability (http://www.ieltsinternational.com/).

Built environment is developed in order to satisfy residents' requirements. Human needs can be physiological or social and are related to security, respect, and self-expression. People want their built environment to be aesthetically attractive and to be in an accessible place with a well-developed infrastructure, convenient communication access, and good roads, and the dwelling should also be comparatively cheap, comfortable, with low maintenance costs, and have sound and thermal insulation of walls. People are also interested in ecologically clean and almost noiseless environments, with sufficient options for relaxation, shopping, fast access to work or other destinations, and good relationships with neighbors.

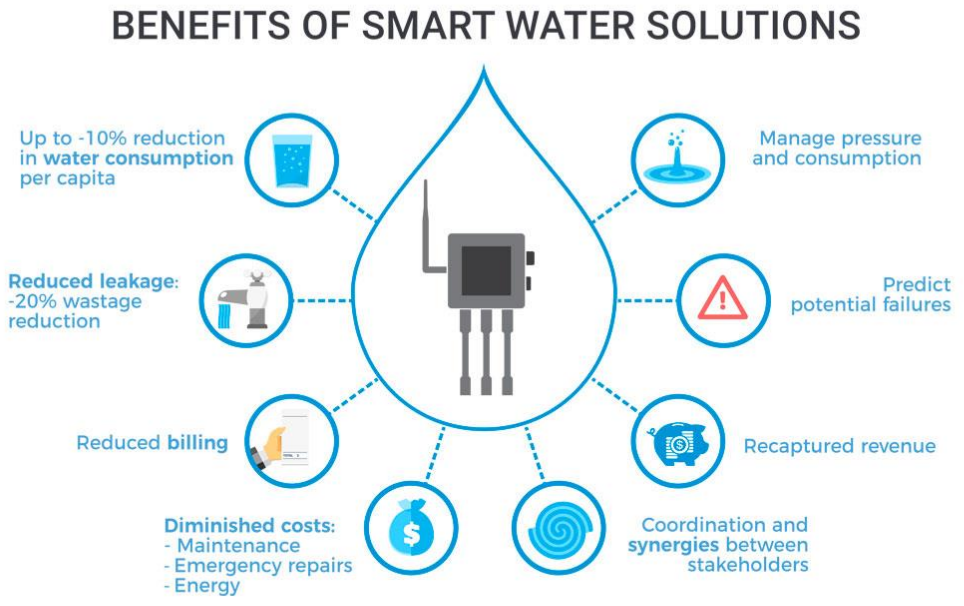
It must be admitted that the most serious problems of built environments (eg, unemployment, vandalism, lack of education, robberies) are not always related to the direct physical structure of housing. Increasing investment into the development of social and recreational centers, such as athletic clubs, physical fitness centers, and family entertainment centers, the infrastructure, a good neighborhood and better education of young people, can solve such problems. Investment, purchase and sale of a property, and its registration have related legal issues. The legal system of a country aims to reflect its existing social, economic, political, and technical state and the requirements of the market economy. As illustrated, the life cycle of the built environment can be assessed taking into account many quantitative and qualitative criteria.

Potential applications of the IoT for the built environment are many and various, fitting into almost all activities done by persons, organizations, and the community as a whole. Libelium [4] has released the document "Top 50 Internet of Things Applications". Based on Libelium [4], here is an overview of the applications used in the built environment:

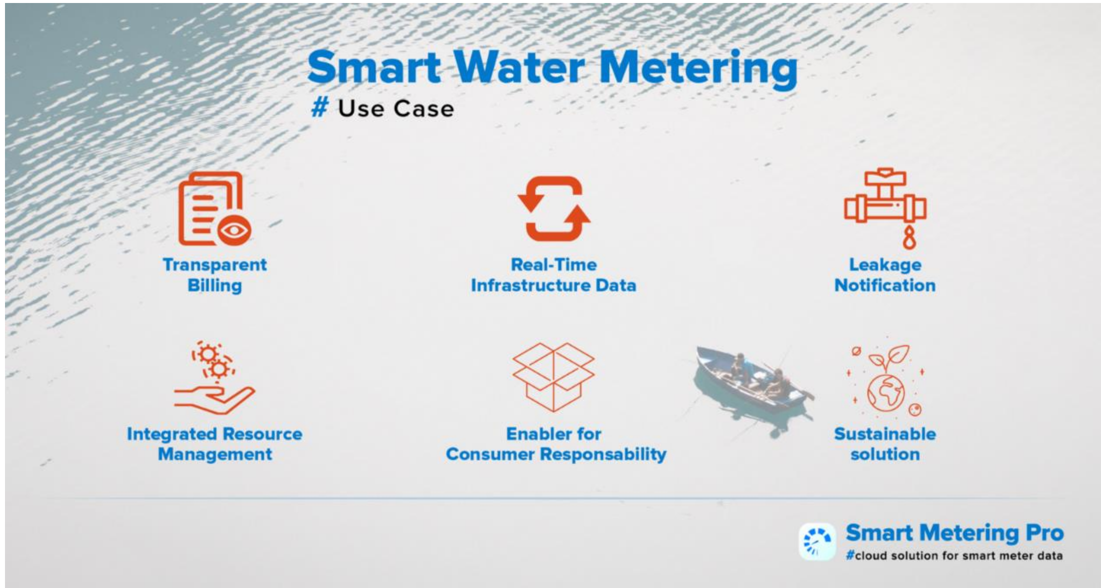
1. Domotic and home automation: Energy and water use (energy and water supply consumption monitoring to obtain advice on how to save cost and resources), remote control appliances (switching on and off appliances remotely to avoid accidents and save energy), intrusion detection systems (detection of window and door openings and violations to prevent intruders), art and goods preservation (monitoring of conditions inside museums and art warehouses).

2. Smart cities: Smart parking (monitoring of parking spaces availability in the city), structural health (monitoring of vibrations and material conditions in buildings, bridges, and historical monuments), noise urban maps (sound monitoring in bar areas and centric zones in real-time), electromagnetic field levels (measurement of the energy radiated by cell stations and WiFi routers), traffic congestion (monitoring of vehicles and pedestrian levels to optimize driving and walking routes), smart lighting (intelligent and weather-adaptive lighting in street lights), waste management (detection of rubbish levels in containers to optimize the trash collection routes), smart roads (intelligent highways with warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams).

3. Smart environment: Forest fire detection (monitoring of combustion gases and preemptive fire conditions to define alert zones), air pollution (control of CO2 emissions of factories, pollution emitted by cars), snow level monitoring (snow level measurement to know in real time the quality of ski tracks and allow security corps avalanche prevention), landslide and avalanche prevention (monitoring of soil moisture, vibrations, and earth density to detect dangerous patterns in land conditions), earthquake early detection (distributed control in specific places of tremors).



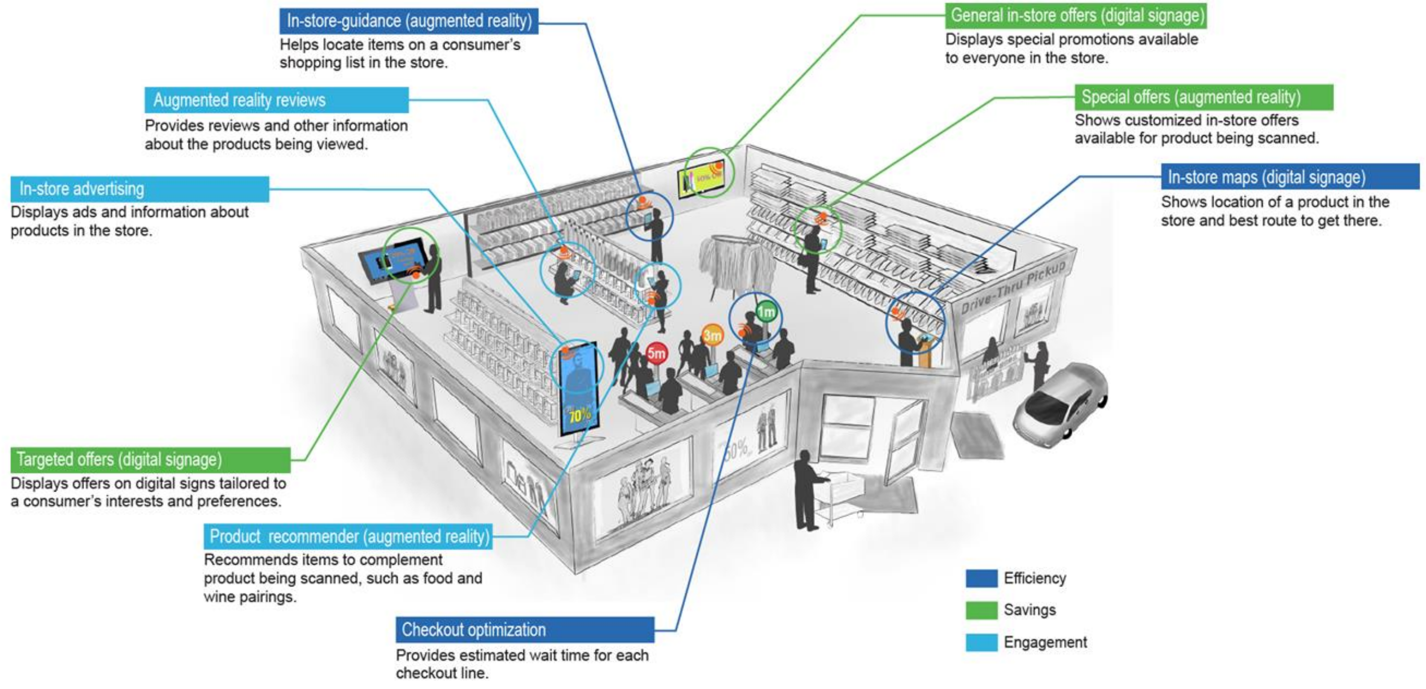
4. Smart water: Potable water monitoring (monitor the quality of tap water in cities), chemical leakage detection in rivers (detect leakages and wastes of factories in rivers), swimming pool remote measurement (control remotely the swimming pool conditions), pollution levels in the sea (control real-time leakages and wastes in the sea), water leakages (detection of liquid presence outside tanks and pressure variations along pipes), river floods (monitoring of water level variations in rivers, dams, and reservoirs).



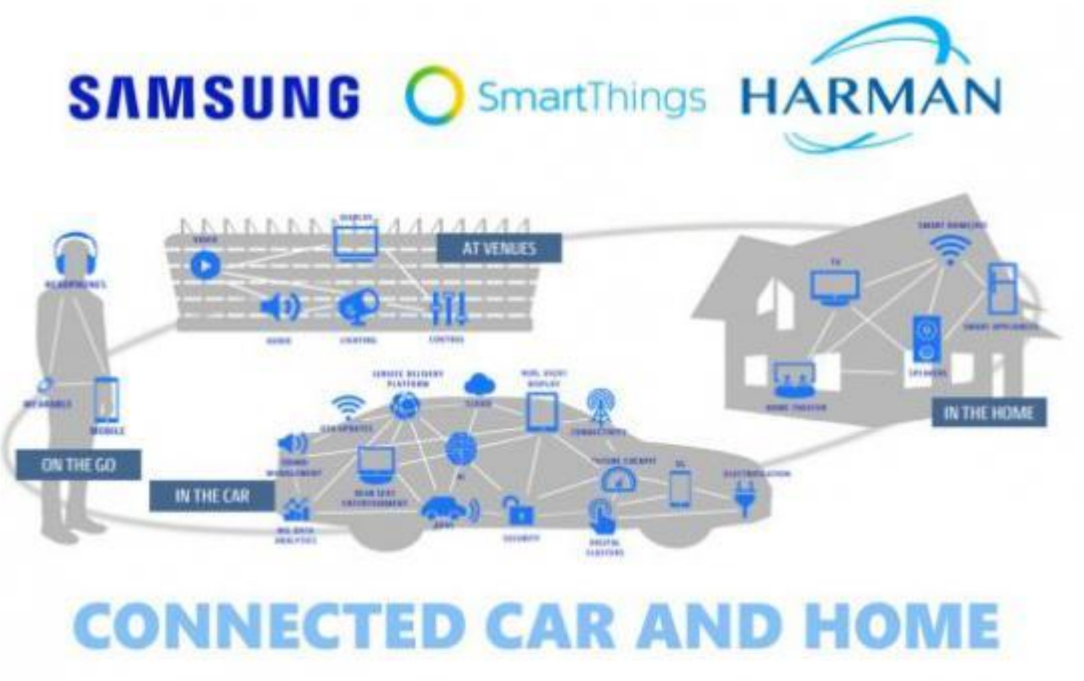
5. Smart metering: Smart grid (energy consumption monitoring and management), tank level (monitoring of water, oil, and gas levels in storage tanks and cisterns), photovoltaic installations (monitoring and optimization of performance in solar energy plants), water flow (measurement of water pressure in water transportation systems), silos stock calculation (measurement of emptiness level and weight of the goods).

6. Security and emergencies: Perimeter access control (access control to restricted areas and detection of people in nonauthorized areas), liquid presence (liquid detection in data centers, warehouses, and sensitive building grounds to prevent breakdowns and corrosion), radiation levels (distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts), explosive and hazardous gases (detection of gas levels and leakages in industrial environments, surroundings of chemical factories, and inside mines).

7. **Retail:** Supply-chain control (monitoring of storage conditions along the supply chain and product tracking for traceability purposes), NFC payment (payment processing based on location or activity duration for public transport, gyms, theme parks, etc.), intelligent shopping applications (getting advice in the point of sale according to customer habits, preferences, presence of allergic components for them, or expiring dates), smart product management (control of rotation of products in shelves and warehouses to automate restocking processes).



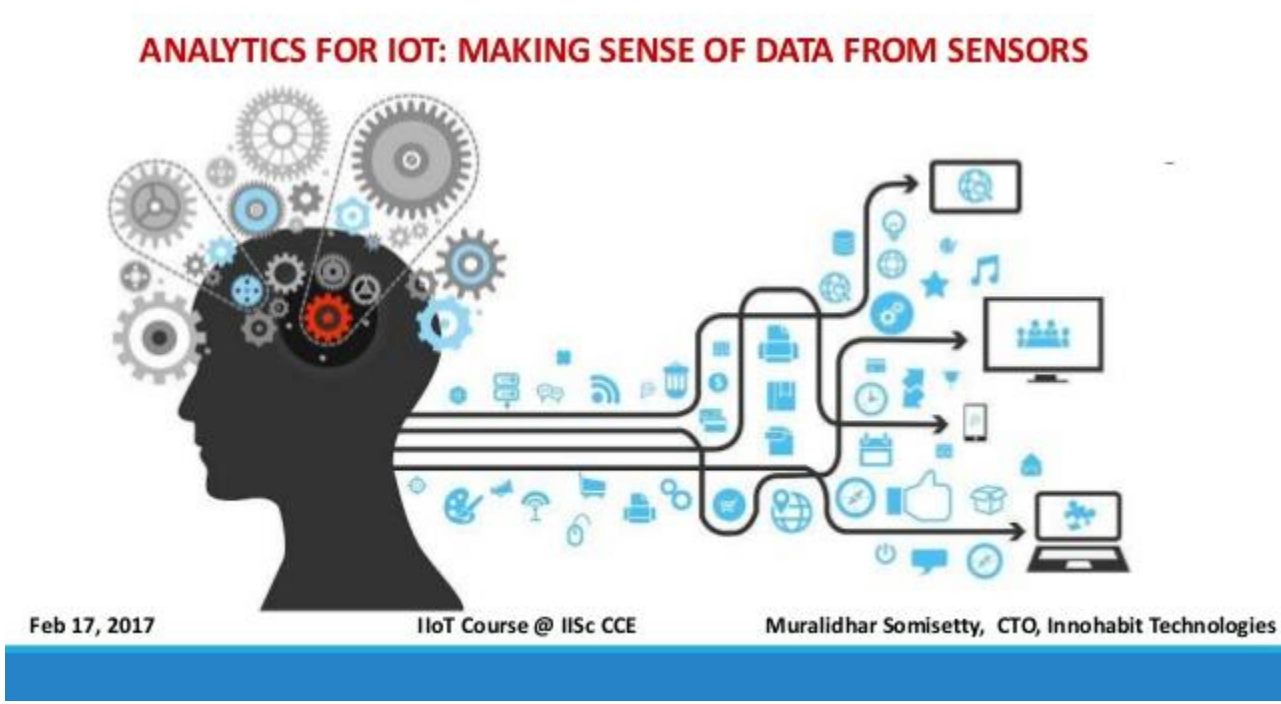
Potential applications of the IoT for the built environment are many and various, fitting into almost all activities done by persons, organizations, and the community as a whole. These (smart home, real-time information about the city's environment, Oxford Flood Network, waste collection for smart cities, wireless monitoring systems in the field of civil engineering, urban intelligence platform, emotional gateway to Minneapolis, waste management, cyber security challenges in smart cities, smart environment monitoring system for pollution, health e-research system, negotiation in cyber-physical systems, real-time safety early warning system for cross-passage construction, RFID-plants in the smart city) are provided in brief next.

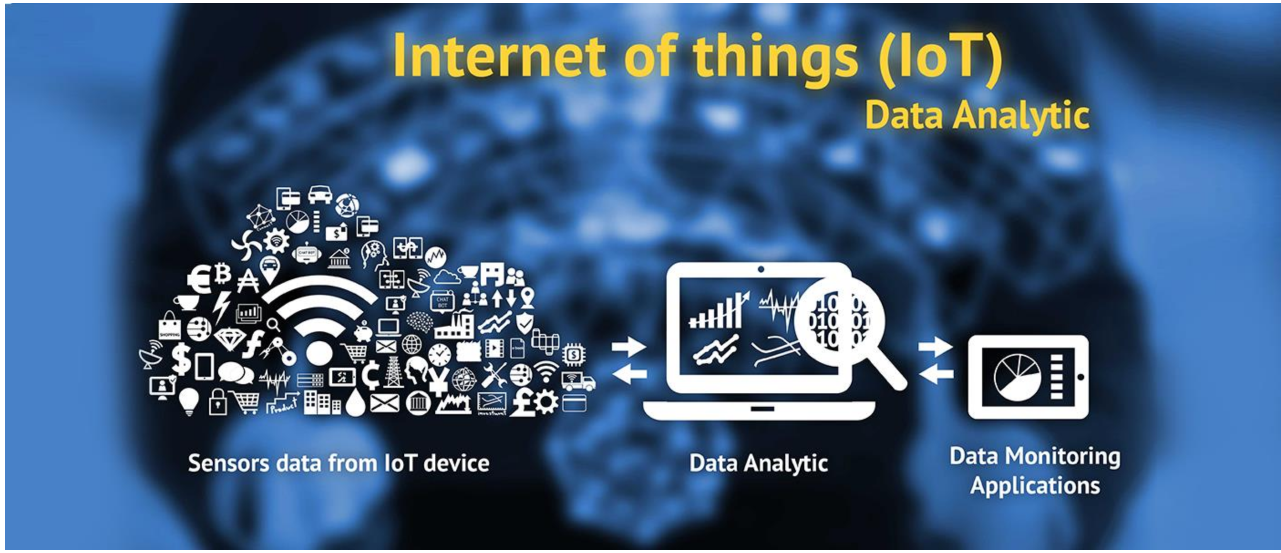


All of Samsung's products would be built on platforms that are open and compatible with other products and 90% of its products—which range from smartphones to refrigerators—would be able to connect to the Web by 2017. In 5 years, every product in the company's entire catalog is expected to be Internet-connected. In effect, Samsung is readying for the IoT, the term for the concept of using sensors and other technologies to hook just about anything you can think of into the Internet. Samsung introduced a new home-monitoring subscription service that will send immediate texts or calls to the smartphone of a user or designated contacts about problems or emergencies at their home, such as a flood, fire, plumbing leak, or a pet out in the yard when a storm is starting. The premium service also includes built-in DVR services for cameras (watch around your home for different issues), alert for different issues (for example, grandma did not get up this morning; my kid did not get home from school on time; my dog is out in the yard and there's a storm coming, etc.) (Tibken, 2015).

This summer, data scientists and architects in Chicago are working on a new form of civic infrastructure: highly visible, aesthetically pleasing, 1-foot-square boxes mounted on light poles that track environmental conditions around them. Those small boxes represent a big idea: Inside each one, about a dozen sensors measure heat, humidity, air quality, carbon monoxide, and carbon dioxide levels, and light and noise levels, and those data will be made publicly available so that they can be used by application developers and researchers as well as the city. About 50 will be installed this year in the Loop area of the city [7].

Right now, cities collect information in the form of permit applications, inspection results, and other service-related inputs. Analysis of these data can help cities know how the city is doing and assist it in targeting its efforts. But information about the well-being of a city—the quality of lives lived on its streets—is harder to come by. The Array of Things, as Chicago's Urban Center for Computation and Data calls this project, will start providing real-time information about the city's environment. For example, sensors will be able to detect mobile devices that have Bluetooth turned on, so the city will have information about the level of pedestrian density in a particular area. The city, as well as any researcher, will know about fine-grained pollution levels in different neighborhoods for the first time. Now it's moving to understand its weather, pollution, and noise in a transparent, public-friendly way. This means that the city will be able to investigate reams of these data, combine it with other information, and make predictions about its future that inform how the city allocates its resources and changes its policies. It's crowded? Change the traffic light patterns. Pollution is a problem in particular neighborhoods? Find out why and fix it. Gathering these data will not solve all of Chicago's challenges, such as a shooting rate that remains among the nation's highest. But making a better city also means improving the quality of daily life at street level. Investing time and money in data makes sense, and it's changing how local government works. Chicago, the quintessential American city, is quickly becoming the nation's leading city for data analytics [7].





Oxford Flood Network is installing sensors around Oxford. Network have several on the Thames and Castle Mill Stream area and some under floors to detect rising water when the time comes. The levels are very low at the moment, but we know how quickly that can change. Oxford Flood Network is collecting a list of people who are happy to host a sensor (50 × 50 × 100 mm) and/or gateway device (90 × 60 × 26 mm). There is no cost to the host for the device, but inhabitants will need to help keep it up and running by checking it periodically online and perhaps changing the battery once a year. Oxford Flood Network will use the sensors to create a detailed map of water levels around the city in higher detail than the Environment Agency's existing sensors. Oxford Flood Network involves communities and citizens, improving literacy in the IoT (Handsome, 2015).

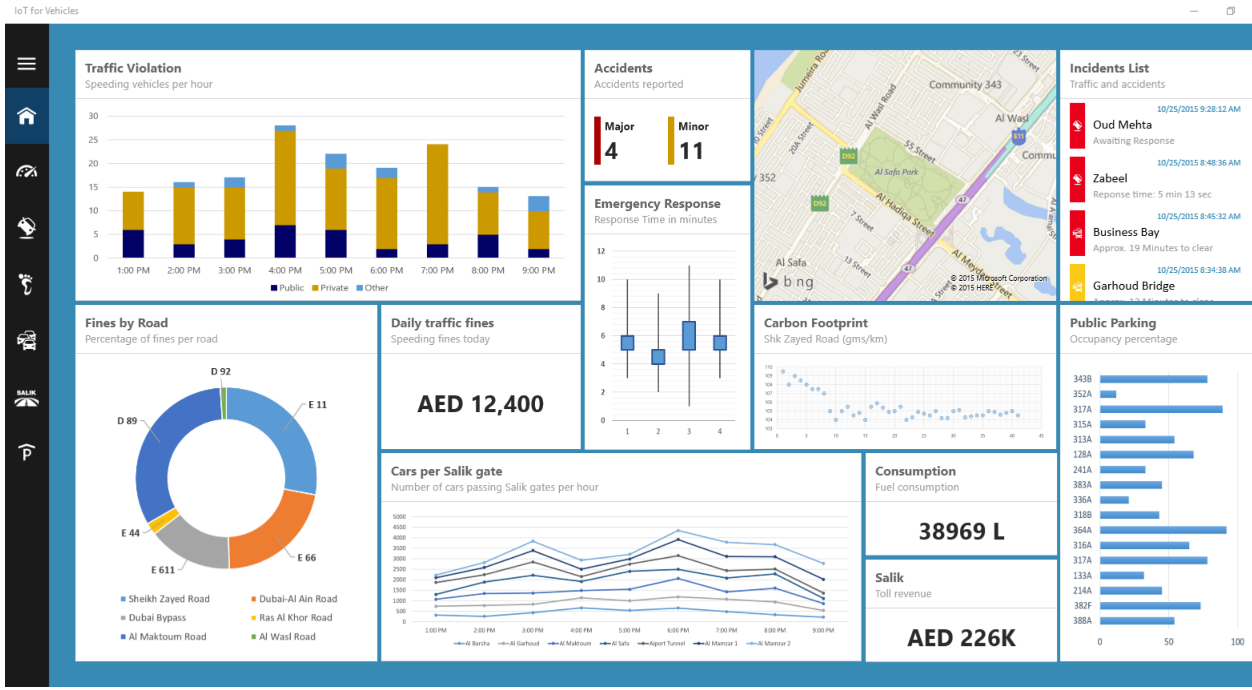
Until now collecting waste has been done with static routes and schedules. Containers are collected every day or every week regardless of whether they are full or not. This causes unnecessary costs, poor equipment utilization, and the constant nuisance of container overfill. Enevo ONe uses smart wireless sensors to gather fill-level data from waste containers and sends it to a cloud-based analytics platform. The platform then generates accurate forecasts for ideal container pick-up schedules and routes that can be can be accessed directly by the driver through any cellular-enabled tablet or smartphone. The Enevo ONe service provides not only monitoring, scheduling, and optimized routes, but truly smart waste collection plans, which are the result of millions of complex calculations regarding fill-level trends and projections, scheduling constraints, and routing options. Collection based on Enevo's smart plans significantly reduces costs, emissions, road wear, vehicle wear, noise pollution, and work hours. Enevo ONe provides up to 50% in direct cost savings in waste logistics. And that's not all. Reducing the amount of overfull containers means less litter and happier customers (Enevo, 2015).

A long-term deployment has been set up to demonstrate the capabilities and the ease of use of wireless monitoring systems in the field of civil engineering. In this application tensile forces of cable stays of a cable-stayed bridge are monitored by tracking natural frequencies of cable vibrations. Wireless sensors (accelerometer, air temperature, air humidity), running on a single set of batteries were installed on six stays to measure cable acceleration. Since energy resources are limited and data communication is an energy-consuming task, the amount of transmitted data has to be kept small in order to extend system lifetime. In this case, the acceleration time series is processed on the node and reduced to one frequency value, which has to be transmitted over the air. The concept of data reduction by means of processing raw data on the sensor node level is demonstrated in the deployment at the Stork Bridge in Winterthur. The installation has been running since 2006 and is one of the first long-term wireless monitoring applications worldwide (Decentlab, 2015).

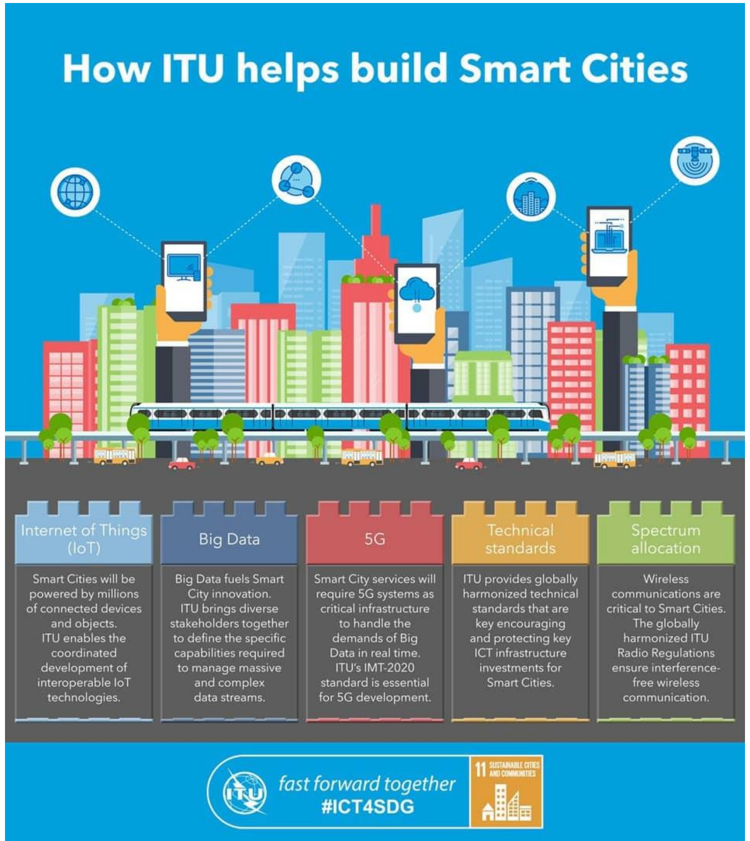
Founded in 2012 and based in New York City, Placemeter is an urban intelligence platform that quantifies the movement of modern cities, at scale. Placemeter ingests any kind of video to analyze pedestrian and vehicular movement, revealing hidden patterns and strategic opportunities. Placemeter (2015) platform leverages proprietary computer vision technology to gather data without identity detection from live streams and archival video. Placemeter is using feeds from hundreds of traffic video cameras to study 10 million pedestrian movements each day. It's using that data to help businesses learn how to market to pedestrian consumers. Placemeter also says it wants to use the data to help consumers with information such as when to visit your neighborhood coffee bar when the line is shorter. Placemeter says it does not store the video, nor does their analysis involve facial recognition (Patterson, 2014).

Placemeter is turning disused smartphones into big data. Measuring data about how the city moves in real time, being able to make predictions on that, is definitely a good way to help cities work better. That's the vision of Placemeter—to build a data platform where anyone at any time can know how busy the city is, and use that. City residents send Placemeter a little information about where they live and what they see from their window. In turn, Placemeter sends participants a kit to convert their unused smartphone into a street sensor, and agrees to pay cash as long as the device stays on and collects data. The more action outside—the more shops, pedestrians, traffic, and public space—the more the view is worth (Jaffe, 2014).

On the back end, Placemeter converts the smartphone images into statistical data using proprietary computer vision. The company first detects moving objects and classifies them either as people or as 11 types of vehicles or other common urban elements, such as food carts. A second layer of analysis connects this movement with behavioral patterns based on the location—how many cars are speeding down a street, for instance, or how many people are going into a store. Placemeter taking all measures to ensure anonymity. The smartphone sensors do not capture anything that goes on in a meter's home (such as conversations), and the street images themselves are analyzed by the computer, then deleted without being stored (Jaffe, 2014).

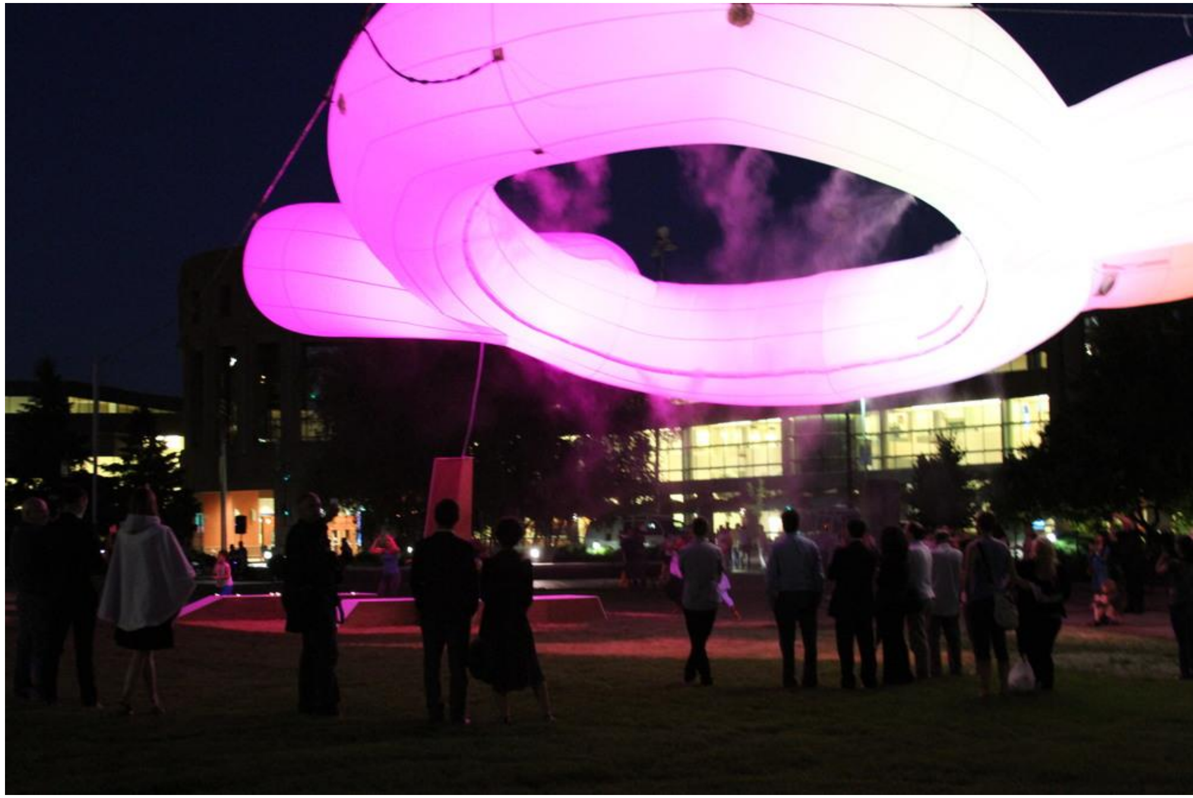


Efforts to quantify city life with big data are not new, but Placemeter's clear advance is its ability to count pedestrians. With its army smartphone eyes, Placemeter promises a much wider net of real-t data dynamic enough to recognize not only that a person exists but that person's behavior, from walking speed to retail interest to gen interaction with streets or public spaces. The benefits could exten both private and public entities alike. Investors might use Placem data to find the best location for a store, while retailers could lo things like their sidewalk-to-store conversion rate and how it comp to other stores on the block. Meanwhile, municipal agencies co detect the use of benches or near misses at intersections— generally evaluate (and perhaps improve) public projects more qu than they might otherwise. In the future people can use Placem data to know when a basketball court is free or when the grocery s will be least crowded. It's this grassroots approach to big data could make Placemeter a powerful platform for governn accountability (Jaffe, 2014).



It needs between 2500 and 2700 video feeds to properly cover the city. With high-resolution cameras Placemeter says it can detect the gender of pedestrians with between 75% and 80% accuracy. This opens the potential for advertisements to be targeted to a more appropriate audience. Better foot traffic data could let retailers know whether they're paying too much for a location. The location of a store can make a huge difference in its success. Placemeter wants to sell its foot traffic data to businesses to help them get a better opportunity. Placemeter is trying to find inefficiency in the market. Ultimately the price starts to increase to a level that accurately reflects how good or bad the area is. Placemeter is trying to effectively short circuit that (McFarland, 2014).

Minneapolis Interactive Macro Mood Installation (MIMMI) is an emotional gateway to Minneapolis, bringing residents and visitors together to experience and participate in the collective mood of the city. MIMMI is a large, air-pressurized sculpture suspended from a slender structure located at the Minneapolis Convention Center Plaza. Cloud-like in concept, the sculpture hovers 30 feet above the ground, gathering emotive information online from Minneapolis residents and visitors to the plaza. MIMMI analyzes this information in real time, creating abstracted light displays and triggering misting in response to this input, creating light shows at nighttime and cooling microclimates during the daytime. Whether the city is elated following a Minnesota Twins win or frustrated from the afternoon commute, MIMMI responds, changing behavior throughout the day and night. To understand the city's mood, MIMMI sources information from local Twitter feeds and uses textual analysis to detect the emotion of those tweets, a process developed by INVIVIA's technologists using open source technology. By aggregating the positivity and negativity of tweets in real time, MIMMI transmits the abstracted emotion of the city to a series of WiFi-enabled LED bulbs and an integrated water misting system. The low-energy lights, hung inside of the sculpture material and stretching throughout the entire shape, display the mood beginning at sunset. The color of the lights shifts from cool colors (negative) to warm and hot colors (positive) depending on the mood, with rate of the lights' change depending on the rate of tweets (Minneapolis, 2015).



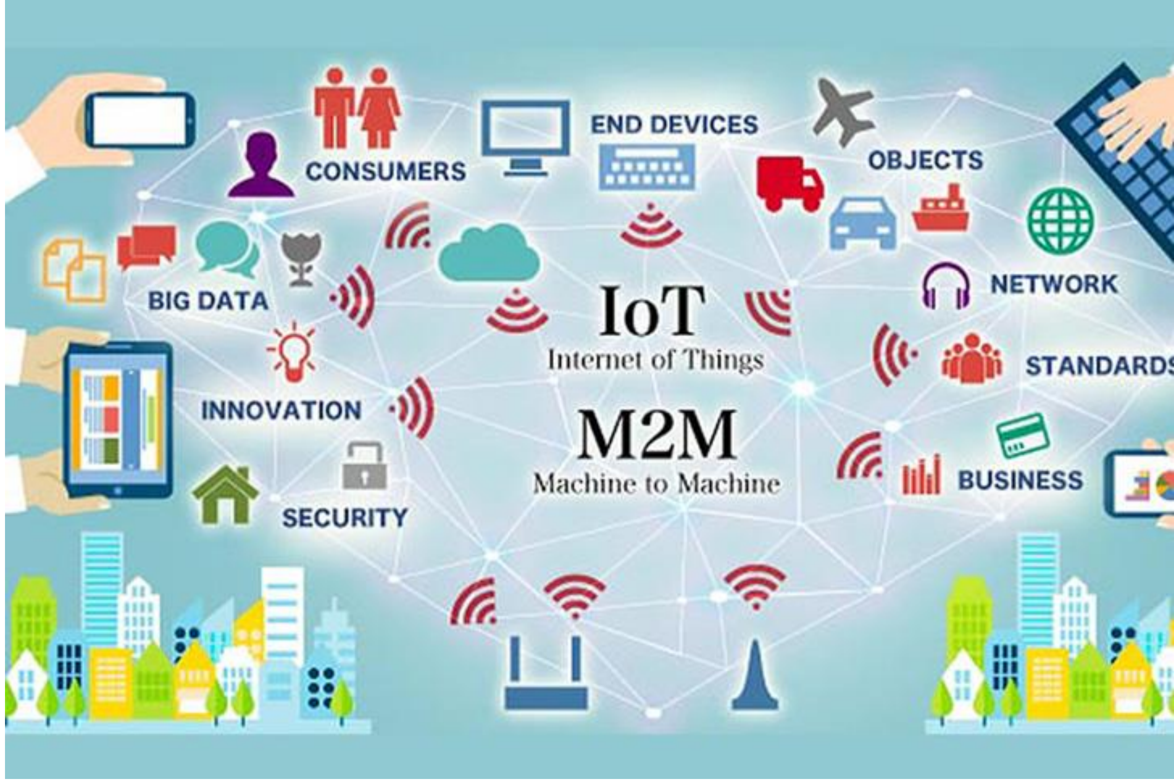
If the city mood is particularly “sad” or emotional for any particular reason, visitors to the plaza can come together to lift MIMMI's (and the city's collective) spirits, as MIMMI can detect movement at the plaza and include this information in its analytics. The more people present and moving around under the cloud, the more active MIMMI will become, responding either with increased lighting or misting depending on the time of day. Dance, high activity, and movement will positively affect MIMMI's mood displays. The website, www.minneapolis.org/mimmi, will catalog the mood of the city generated by MIMMI over the summer and fall, allowing visitors to see daily and weekly trends in the city's emotions. When visitors using iOS (iPhones) arrive at the plaza, the app will transform into an augmented reality view of MIMMI, providing a wholly new way of looking at the installation with additional animations emphasizing the city's current mood (Minneapolis, 2015).

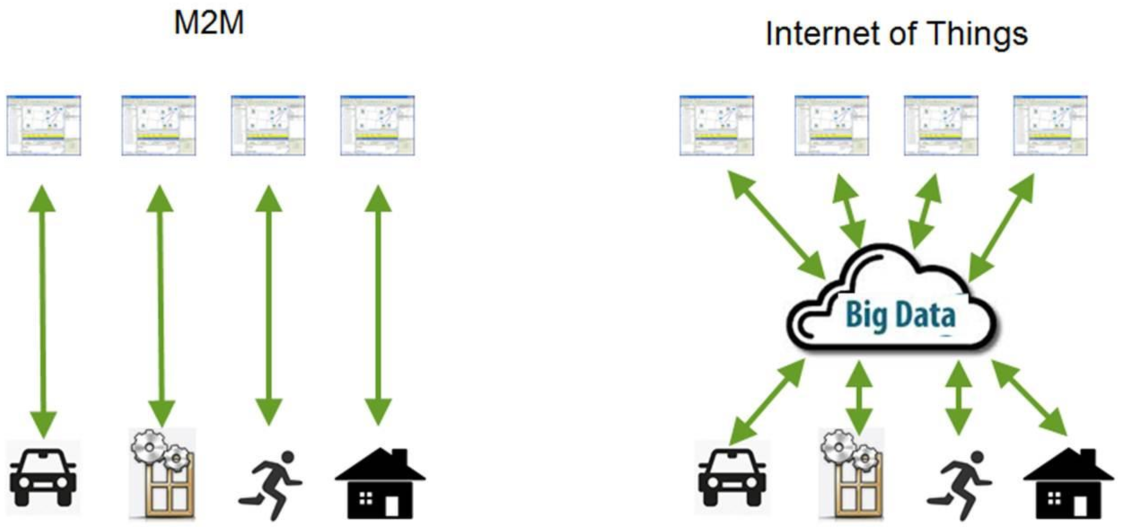
Homes, cars, public venues, and other social systems are now on their path to the full connectivity known as the IoT. Standards are evolving for all of these potentially connected systems. They will lead to unprecedented improvements in the quality of life. To benefit from them, city infrastructures and services are changing with new interconnected systems for monitoring, control, and automation. Intelligent transportation, public and private, will access a web of interconnected data from GPS locations to weather and traffic updates. Integrated systems will aid public safety, emergency responders, and in disaster recovery (Elmaghraby and Losavio, 2014). Elmaghraby and Losavio [4] examine two important and entangled challenges: security and privacy. Security includes illegal access to information and attacks causing physical disruptions in service availability. As digital citizens are more and more instrumented with data available about their location and activities, privacy seems to disappear (Elmaghraby and Losavio, 2014).

With the rapid development of urbanization in China, the number and size of underground space development projects are increasing quickly. At the same time, more and more accidents are causing underground construction to increasingly become a focus of social attention. Therefore, this research presents a real-time safety early warning system to prevent accidents and improve safety management in underground construction, based on IoT technology. The proposed system seamlessly integrates a fiber Bragg grating sensor system and a radio frequency identification (RFID)-based labor tracking system. This system has been validated and verified through a real-world application at the cross passage construction site in the Yangtze Riverbed Metro Tunnel project in Wuhan, China (Ding et al., 2013).

A city may become smart and green through strategic deployment of information and communication technology infrastructure and services to achieve sustainability policy objectives in which trees have to be involved. Plants not only constitute green space useful to contrast urban pollution effects or provide ecosystemic benefits to residents but they can also be used as bioindicators and their involvement in communication networks can represent a significant contribution to build a smart, green city. RFID tags can be easily associated with plants, externally or internally. This latter approach is particularly indicated if the identification of trees needs to be secured since its production, eliminating the risk of tag losses or removal. Interesting applications may be derived by implementing RFID tags in biomonitoring systems in order to guarantee a real-time data communication in which tags may act as antennas for multifunctional green spaces (Luvisi and Lorenzini, 2014).

Machine-to-machine (M2M) communication uses technologies to allow both wireless and wired systems to connect with devices of the same ability. It is also to enable applications that allow businesses to increase productivity and competitiveness through increased efficiencies, cost-savings, and improved levels of services. The machines use telemetry or telematics to connect to one another; this is accomplished over wireless networks. Wireless networks can transmit data to and from each machine. M2M technology is the means of communication of different types of mechanical devices for the exchange of data or information to one another. The M2M interface allows monitoring, control, and management of remote equipment or machines. Remote monitoring, control, and management of devices and machines allow businesses to address maintenance issues and restore functionality. The basic structure involves a central system that is able to connect with other systems at various locations via wireless networks.





The central computer system can collect or send data or information to each remote machine or headquarters. Key applications are (M2M, 2015):

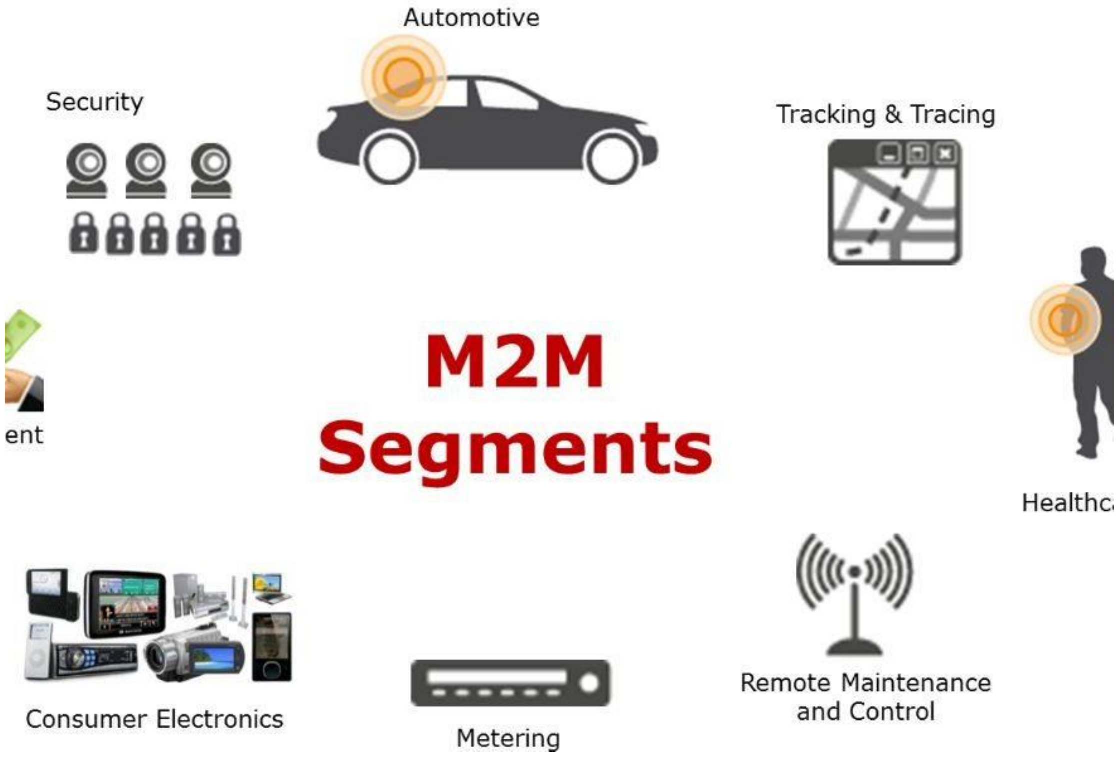
1. onnecting machines to other machines: remote production environments, for example

2. Connecting machines to services centers: cars notifying service centers of maintenance issues, for example

3. Connecting service centers to machines: vending machines reporting stock status to a central inventory system, for example

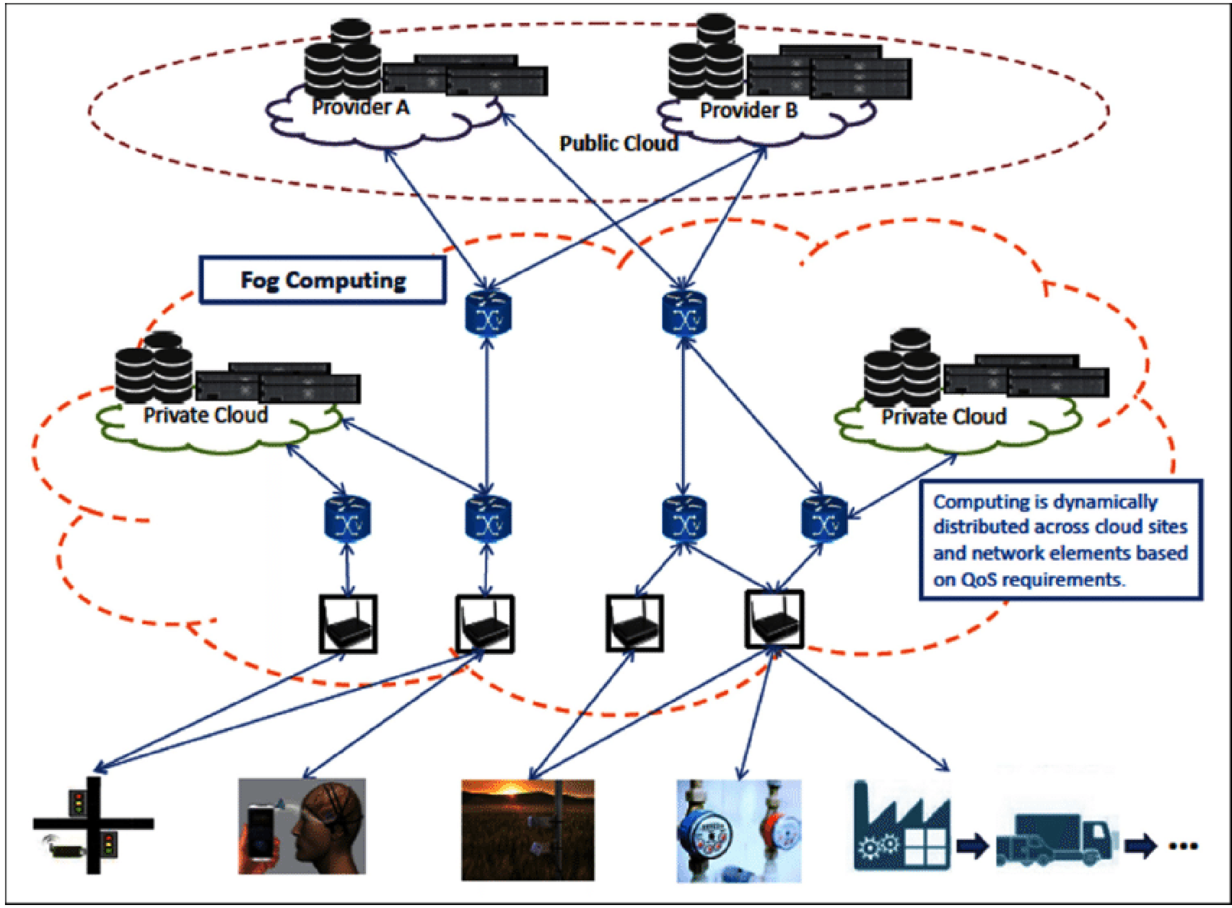
4. Connecting vehicles to machines: fleet management and location, for example

Not many M2M applications for the built environment are available in the world. These (M2M communications for smart cities, from M2M to the IoT in the built environment) are discussed briefly, next.



Vilajosana and Dohler (2015) have observed a steady increase in the deployment of M2M technologies in urban environments. It is the beginning of a paradigm referred to as the smart city, where smartness is added to city infrastructure through sensors, big data, and other capabilities. Vilajosana and Dohler (2015) review currently used smart city M2M technologies that are due to appear. It dwells in great detail on one of the most prominent deployment use cases, smart parking. The more holistic problem of handling data in advanced platforms, and how to offer it to the emerging ecosystem, is also discussed. Financial and governance issues are then outlined through 10 challenges that lie ahead for a successful explosion of the smart city market (Vilajosana and Dohler, 2015).

Digital technologies are often suggested as the panacea through the development of smart cities—cities that in some form integrate a digital infrastructure with the physical city in order to reduce environmental impact while improving quality of life and economic prospects. While these sorts of concepts have been around for several decades, the advent of smartphones and cheaper sensor technology means that digitally enabled, or smart, cities are fast becoming a real-world possibility (Höller et al., 2014).



Participatory sensing (PS), also known as urban, citizen, or people-centric sensing, is a form of citizen engagement for the purpose of capturing the surrounding environment in a city as a first step for contributing to the solution of specific issues such as public health and well-being. Either citizens on their own initiative, or citizens organized through a specific campaign initiated by city authorities, collect sounds, pictures, videos, and other sensor data using their mobile phones as the main tool to monitor the environment and transfer the collected data to a storage space. The collected data are analyzed by citizens or city authorities, conclusions and action plans are drawn, and actions are taken. Although this form of engagement was typical a few years ago, nowadays the PS concept has been enriched to include active citizen journalists or passive social media sensing in the sense that citizen engagement to social media such as Twitter can also be used as additional input to PS campaigns (Höller et al., 2014).

WSNs as a central part of cyber-physical systems are gaining commercial momentum in many areas, including building monitoring and intelligent home automation. Users wish to successively deploy hardware from different vendors. Interoperability is taken for granted by the customers who want to avoid the need for exhaustive configuration and set up. Therefore, the need for an interoperable and efficient application layer protocol for M2M communication in and across the boundaries of WSNs arises (Schmitt et al., 2014).

A building automation system (BAS) is a computerized, intelligent system that controls and measures lighting, climate, security, and other mechanical and electrical systems in a building. The purpose of a BAS is typically to reduce energy and maintenance costs, as well as to increase control, comfort, reliability, and ease of use for maintenance staff and tenants (Höller et al., 2014).

Smart Cities

Definition of the Smart City

A smart city uses information and communication technology (ICT) to improve operational efficiency, share information with the public and provide a better quality of government service and citizen welfare. The main goal of a smart city is to optimise city functions and promote economic growth while also improving the quality of life for citizens by using smart technologies and data analysis. The value lies in how this technology is used rather than simply how much technology is available. The success of a smart city relies on the relationship between the public and private sectors as much of the work to create and maintain a data-driven environment falls outside the local government remit. For example, smart surveillance cameras may need input and technology from several companies. Aside from the technology used by a smart city, there is also the need for data analysts to assess the information provided by the smart city systems so that any problems can be addressed and improvements found. A city's smartness is determined using a set of characteristics, including (TWI-Global):

- An infrastructure based around technology
- Environmental initiatives
- Effective and highly functional public transportation
- Confident and progressive city plans
- People able to live and work within the city, using its resources

Definition of the Smart City

A smart city is a framework, predominantly composed of Information and Communication Technologies (ICT), to develop, deploy, and promote sustainable development practices to address growing urbanization challenges. A big part of this ICT framework is essentially an intelligent network of connected objects and machines that transmit data using wireless technology and the cloud. Cloud-based IoT applications receive, analyze, and manage data in real-time to help municipalities, enterprises, and citizens make better decisions that improve quality of life. Citizens engage with smart city ecosystems in various ways using smartphones and mobile devices and connected cars and homes. Pairing devices and data with a city's physical infrastructure and services can cut costs and improve sustainability. Communities can improve energy distribution, streamline trash collection, decrease traffic congestion, and even improve air quality with help from the IoT. Together, these smart city technologies are optimizing infrastructure, mobility, public services, and utilities. For instance (THALES):

- Connected traffic lights receive data from sensors and cars adjusting light cadence and timing to respond to real-time traffic, reducing road congestion.
- Connected cars can communicate with parking meters and electric vehicle (EV)charging docks and direct drivers to the nearest available spot.
- Smart garbage cans automatically send data to waste management companies and schedule pick-up as needed versus on a pre-planned schedule.
- And citizens' smartphone becomes their mobile driver's license and ID card with digital credentials, which speeds and simplifies local government services.

Definition of the Smart City

Smart Cities use connected technology and data to (1) improve the efficiency of city service delivery (2) enhance quality of life for all (3) increase equity and prosperity for residents and businesses. A Smart City is an urban development that unites the needs of the citizens in a sustainable and secure way. All buildings, cars and machines are connected, constantly transmitting data to improve and develop the city. Road monitors can report real-time traffic to cars, easing traffic and reducing the risk of road collisions, for example, and Smart Cities have also developed e-learning education and 24/7 healthcare, providing modern services to all inhabitants. Alongside this, Smart City technology can monitor the pollution and chemical levels in the air and water supply, reducing the risk of both air and water contamination. Smart energy sources are also implemented, to ensure the city is developing and continuing its sustainability. These innovations, alongside countless others, mean Smart Cities can enormously improve the standard of living for the citizens and sustain the environment long term (Digi.City).

Other definitions of the Smart City

- A smart city is a developed urban area that creates sustainable economic development and high quality of life by excelling in multiple key areas; economy, mobility, environment, people, living, and government (Business Di
- A smart city is a municipality that uses information and communication technologies to increase operational efficiency, share information with the public and improve both the quality of government services and citizen welfare (IoT World).
- A broad, integrated approach to improving the efficiency of city operations, the quality of life for its citizens, and growing the local economy (Boyd Cohen).
- Smart City technologies have two different features. One is optimization, such as using road infrastructure better, via self-driving cars, and efficiency. The other aspect is being more social. How can we come together to use the city better and waste less? (Carlo Ratti)
- Hundreds of aging cities have embraced digital technology, but few are moving as quickly as New York to link municipal computer networks, develop novel applications, make digital data public or install so many thousands of sensors to monitor urban life—from water quality, traffic and power use, to the sound of gunfire (Robert Lee Hotz).
- Until recently, smart city solutions often seemed more like “slideware” than real services to improve the quality of life of citizens and the productivity of urban businesses. But the falling cost of connectivity and computing power is finally enabling municipalities to deploy innovative solutions that promise to tackle some of the thorny challenges they face (Dave Pringle).


Smart government
Smart health
Mobility/ Wi-Fi
Open data
Smart farming/ agriculture
Smart grid/ energy/ utilities
Smart manufacturing
Smart/ digital citizens
Smart buildings
Smart transportation
H
SMART CITY COMPONENTS


Smart Society
Smart care
Big Data
Smart Working
Smart Energy
IOT
Smart Retail
End user driven innovation
Smart product management
Smart building
Smart Home
Smart Mobility

Smart City Dimensions

DIMENSIONS / PROJECT AREAS	Smart Governance					Smart Economy					Smart Mobility							Smart Environment							Smart People					Smart Living							
CHALLENGES	SGo1. Participation	SGo2. Transparency and information	SGo3. Public and Social Services	SGo4. Multi-level governance	SGo5. Efficiency in municipal	SEc1. Innovation	SEc2. Entrepreneurship	SEc3. Local & Global	SEc4. Productivity	SEc5. Flexibility of labor market	SMo1. Traffic management	SMo2. Public Transport	SMo3. ICT Infrastructure	SMo4. Logistics	SMo5. Accessibility	SMo6. Clean, non-motorised options	SMo7. Multimodality	SEn1. Network and environmental	SEn2. Energy efficiency	SEn3. Urban planning and urban	SEn4. Smart buildings and building	SEn5. Resources management	SEn6. Environmental protection	SEn7. Awareness rising and	SPe1. Digital education	SPe2. Creativity	SPe3. ICT - Enabled working	SPe4. Community building and	SPe5. Inclusive society	SLi1. Tourism	SLi2. Culture and leisure	SLi3. Healthcare	SLi4. Security	SLi5. Technology accessibility	SLi6. Welfare & Social inclusion	SLi7. Public spaces management	
Low urban institutional capacities																																					4
Deficit of social services																				X												X			X		4
Instability in governance																																			X		7
Gap government - governed																																X			X		12
Centralization & lack of coordination																																					6
Lack of awareness							X												X		X	X															12
Shortage in access to information																																					6
Lack of equity							X					X				X			X	X	X	X										X	X	X	X		24
Unbalanced geographical development												X				X	X			X		X	X														18
High infrastructures deficit												X				X	X			X		X	X									X					13
Shortage in access to technology						X																															6
Lack of competitiveness						X	X		X										X			X								X	X	X	X	X	X		19
Lack of economy diversification						X	X																							X							8
Excess of informal economy							X																												X		5
Lack of public transport												X				X	X			X															X		8
Increase of private car												X				X	X			X		X															11
Pollution												X				X	X		X	X	X	X	X														15
Very rapid urbanization																X				X	X	X	X												X		15
Lack of quality on neighbourhoods												X				X	X			X	X		X												X		16
Inefficient resources cycle												X				X	X		X		X	X	X														10
Climate change effects												X				X	X		X	X	X	X	X														12
Urban poverty and inequality							X					X				X	X			X	X	X								X	X	X	X	X	X		24
Threats to cultural identity							X													X			X							X							15
Low educational level and digital skills																																					4
High obstacles to social mobility							X													X	X											X	X	X	X		16
Lack of accessible leisure facilities												X				X	X			X	X														X		12
Urban violence and insecurity																				X															X		7
	8	8	8	6	6	3	8	10	1	7	7	11	7	5	12	12	10	6	6	15	10	11	8	12	12	3	9	11	14	4	8	7	7	13	13	11	

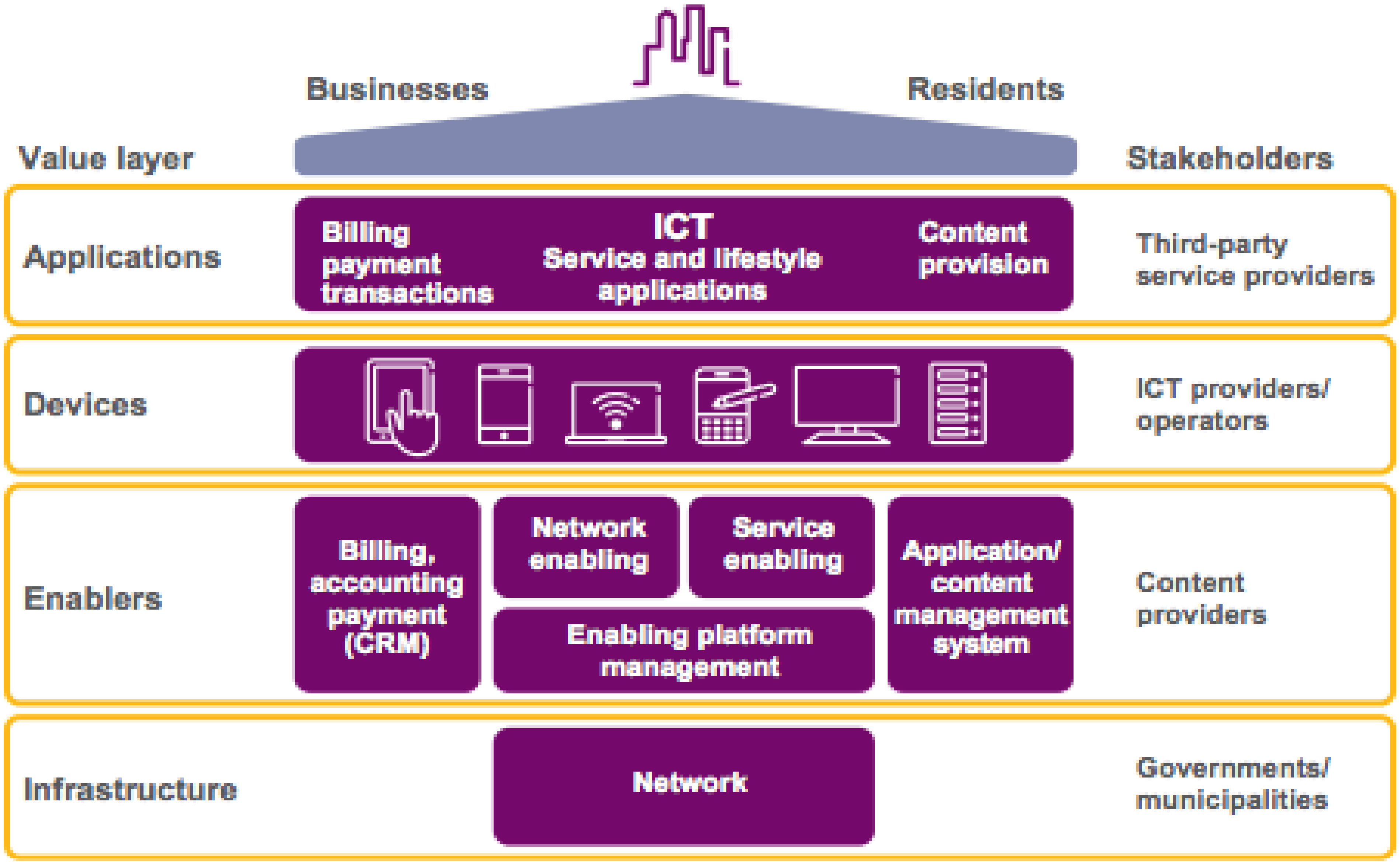
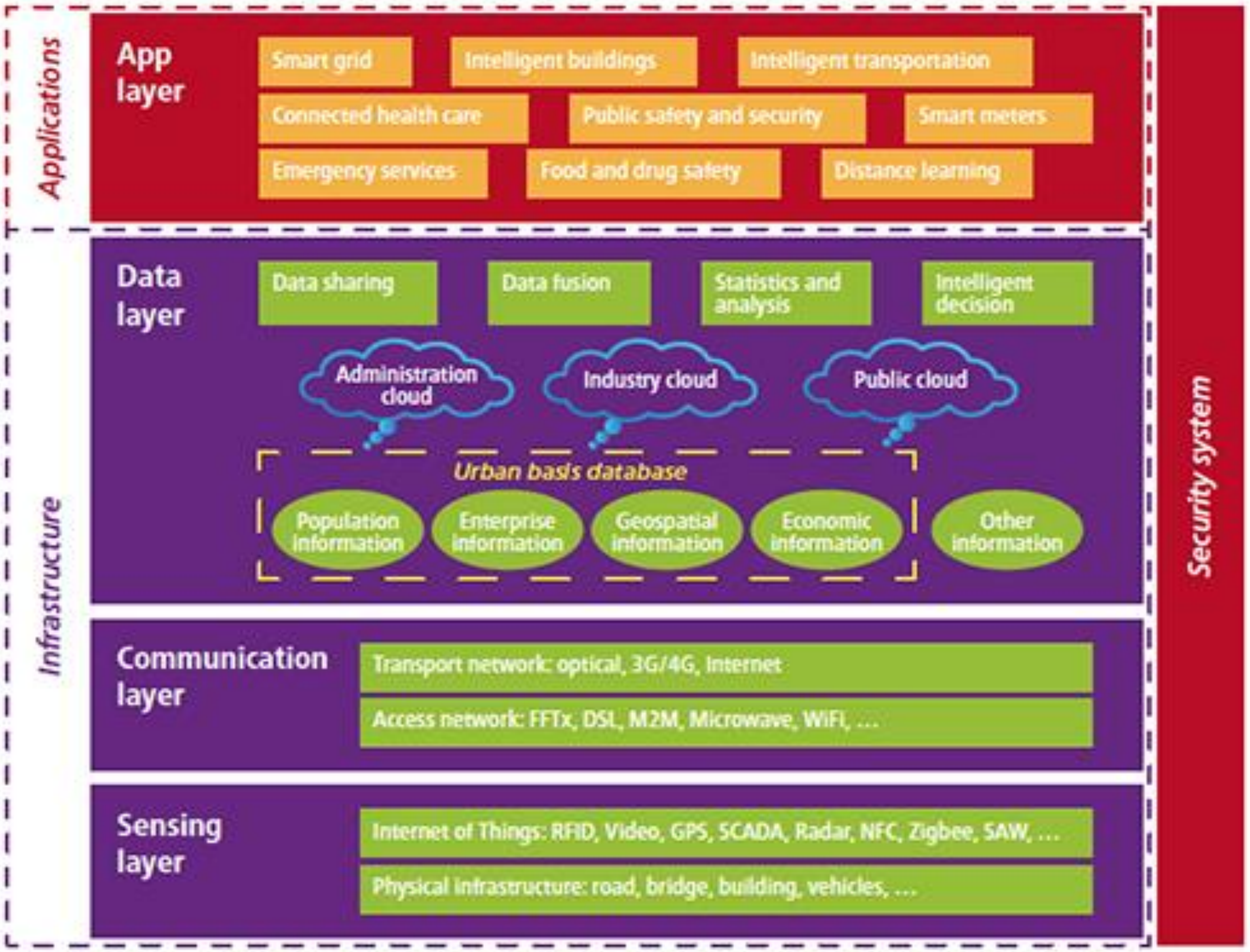


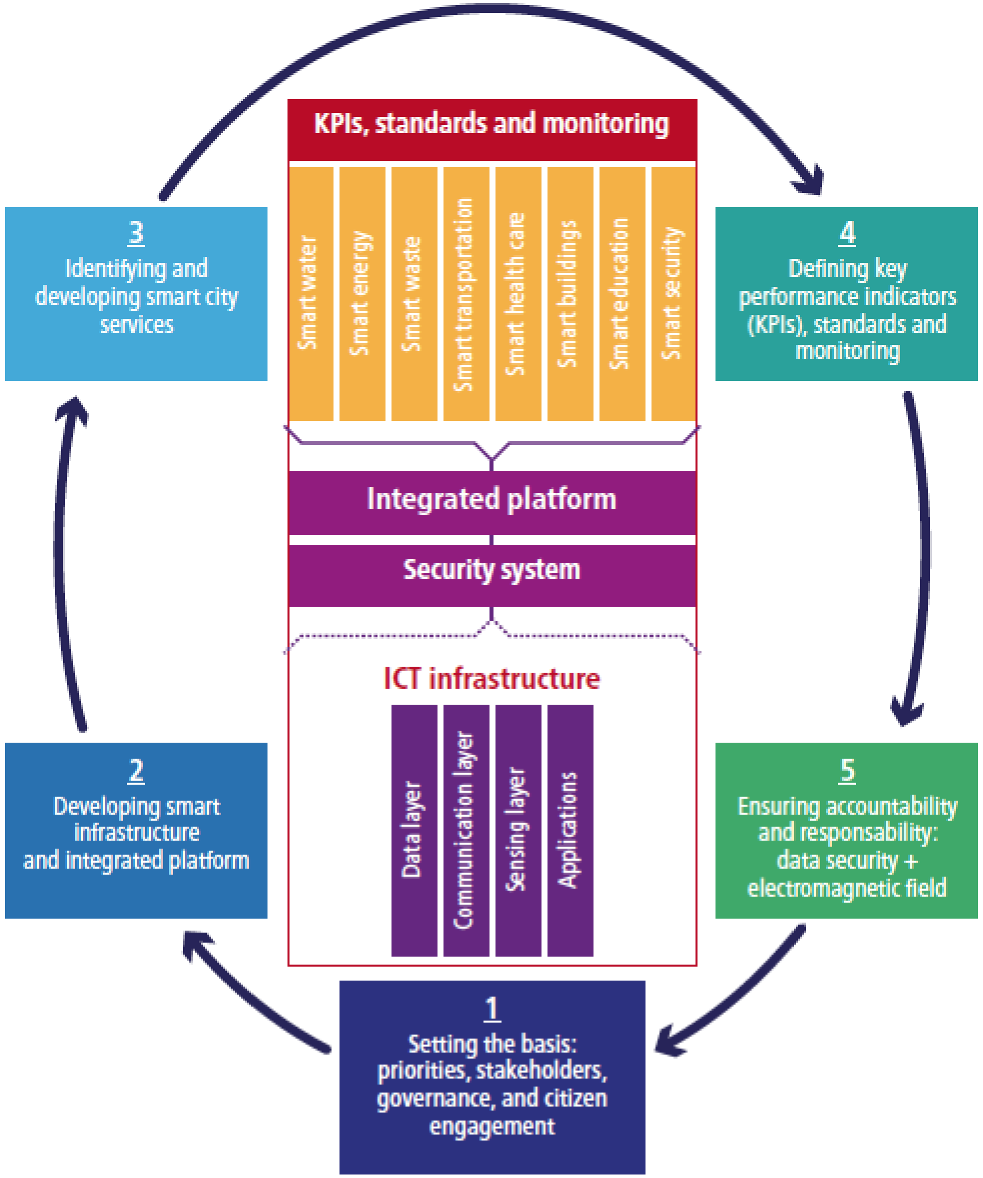
Figure 2: Value layers, technology layers and stakeholders in a smart, sustainable city.

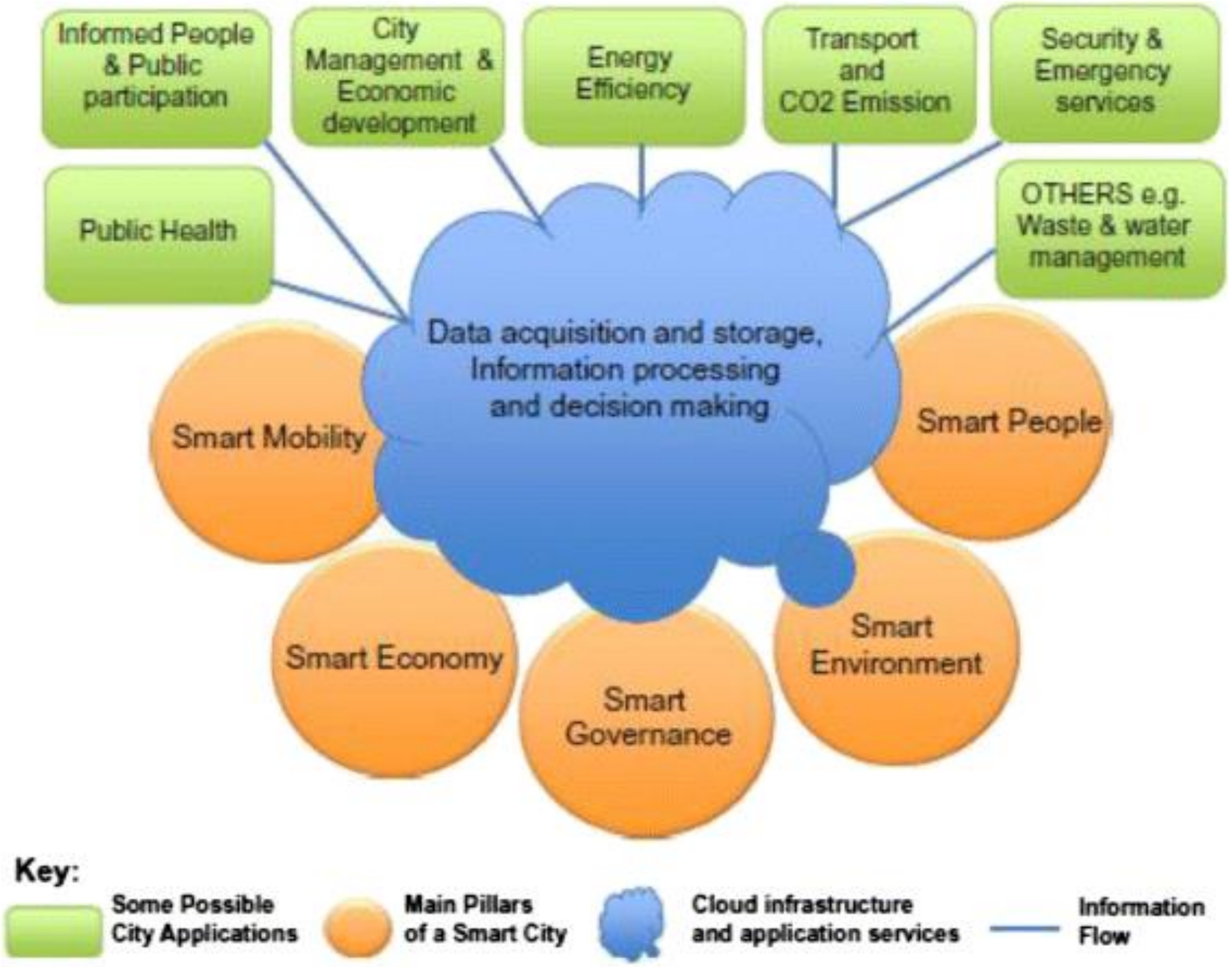
Figure 1 — Architecture of a smart sustainable city



Source: Technical Report on ICT Infrastructure for Cyber-Security, Data Protection & Resilience.

Figure 2 — Smart sustainable city — guiding framework




Informed People & Public participation
City Management & Economic development
Energy Efficiency
Transport and CO2 Emission
Security & Emergency services
Public Health
OTHERS e.g. Waste & water management
Data acquisition and storage, Information processing and decision making
Smart Mobility
Smart People
Smart Economy
Smart Governance
Smart Environment
Key:
Some Possible City Applications
Main Pillars of a Smart City
Cloud infrastructure and application services
Information Flow