Internet of Things (IoT) and Machine-to-Machine (M2M) communications

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Abstract: Internet of Things (IoT) and Machine-to-Machine (M2M) communications describes how the Internet will expand as sensors and intelligence are connected to physical things such as physical assets or consumer devices and these things in turn are connected to the Internet. The vision and model have existed for years, but there has been acceleration in the number and types of things being connected and in the technologies for collecting, processing, and sharing information. The paper explores some of the key applications for IoT and M2M communications, including consumer electronics, automotive and transportation, energy and utilities, industrial and commercial buildings, and others.

Introduction: The Internet of Things market allows different combinations of smart things/objects and sensor network technologies. People using diverse and interoperable communication protocols realize that a dynamic heterogeneous/multimodal network can be deployed in remote or unreachable (mines, oil platforms, forests, pipes, tunnels, etc.) spaces or in cases of emergencies such as earthquakes, floods, fire, radiation areas, and others. In IoT infrastructure, these “things or objects” will realize and explore each other and learn to take advantage of each other’s data by sharing resources and dramatically enhancing the scope and dependability of the resulting services. Machine-to-Machine communications will be focused more on the terminals and data centers (for example, cloud computing, home data centers, others) than the nodes, as in the current networks. Expansion of storage capacity at lower costs will result in the local accessibility of most information required by people or things/objects. This can be coupled with improved processing capabilities and always-on connectivity. This will make increase the role of terminals in communications. Internet of Things market and Machine-to-Machine communications will bring physical business benefits such as high-resolution management of resources and products, better collaboration between enterprises, and improved life-cycle management. Many of these benefits are achieved via exclusive identification for individual things/objects, which enable each other to cooperate independently by building up an individual life history of cooperation and activities over time. Among the industry verticals, consumer electronics, manufacturing and supply chain, automotive and transportation, and consumer and residential verticals are expected to be the top verticals with the largest revenue over the period 2014–2019, followed by industrial and commercial buildings, healthcare, government, and others.

Applications of IOT: There are several application domains which will be impacted by the emerging Internet of Things. The applications can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact. We categorize the applications into four application domains: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile. There is a huge crossover in applications and the use of data between the domains. For instance, the Personal and Home IoT produces electricity usage data in the house and makes it available to the electricity (utility) company which can in turn optimizes the supply and demand in the Utility IoT. Internet enables sharing of data between different service providers in a seamless manner creating multiple business opportunities. A few typical applications in each domain are given.
1. **Personal and Home**

The sensor information collected is used only by the individuals who directly own the network. Usually WiFi is used as the backbone enabling higher bandwidth data (video) transfer as well as higher sampling rates (Sound).

Ubiquitous healthcare has been envisioned for the past two decades. IoT gives a perfect platform to realize this vision using body area sensors and IoT backend to upload the data to servers. For instance, a Smartphone can be used for communication along with several interfaces like Bluetooth for interfacing sensors measuring physiological parameters. So far, there are several applications available for Apple iOS, Google Android and Windows Phone operating system that measure various parameters. However, it is yet to be centralized in the cloud for general physicians to access the same. An extension of the personal body area network is creating a home monitoring system for aged-care, which allows the doctor to monitor patients and elderly in their homes thereby reducing hospitalization costs through early intervention and treatment.

Control of home equipment such as air conditioners, refrigerators, washing machines etc., will allow better home and energy management. This will see consumers become involved in IoT revolution in the same manner as the Internet revolution itself. Social networking is set to undergo another transformation with billions of interconnected objects. An interesting development will be using a Twitter like concept where individual "Things" in the house can periodically tweet the readings which can be easily followed from anywhere creating a TweetOT. Although this provides a common framework using cloud for information access, a new security paradigm will be required for this to be fully realized.

2. **Enterprise**

We refer to the "Network of Things" within a work environment as an enterprise based application. Information collected from such networks is used only by the owners and the data may be released selectively. Environmental monitoring is the first common application which is implemented to keep a track of the number of occupants and manage the utilities within the building (e.g., HVAC, lighting).

3. **Utilities**

The information from the networks in this application domain are usually for service optimisation rather than consumer consumption. It is already being used by utility companies (smart meter by electricity supply companies) for resource management in order to optimise cost vs. profit. These are made up of very extensive networks (usually laid out by large organisation on regional and national scale) for monitoring critical utilities and efficient resource management. The backbone network used can vary between cellular, WiFi and satellite communication.

Smart grid and smart metering is another potential IoT application which is being implemented around the world. Efficient energy consumption can be achieved by continuously monitoring every electricity point within a house and using this information to modify the way electricity is consumed. This information at the city scale is used for maintaining the load balance within the grid ensuring high quality of service.

Video based IoT which integrates image processing, computer vision and networking frameworks will help develop a new challenging scientific research area at the intersection of video, infrared, microphone and network technologies. Surveillance, the most widely used camera network applications, helps track targets, identify suspicious activities, detect left luggage and monitor unauthorized access.

4.4. **Mobile**

Smart transportation and smart logistics are placed in a separate domain due to the nature of data sharing and backbone implementation required. Urban traffic is the main contributor to traffic noise pollution and a major contributor to urban air quality degradation and greenhouse gas emissions. Traffic congestion directly imposes significant costs on economic and social activities in most cities. Supply chain efficiencies and productivity, including just-in-time operations, are severely impacted by
this congestion causing freight delays and delivery schedule failures. Dynamic traffic information will affect freight movement, allow better planning and improved scheduling. The transport IoT will enable the use of large scale WSNs for online monitoring of travel times, origin-destination (O-D) route choice behaviour, queue lengths and air pollutant and noise emissions. The IoT is likely to replace the traffic information provided by the existing sensor networks of inductive loop vehicle detectors employed at the intersections of existing traffic control systems. They will also underpin the development of scenario-based models for planning and design of mitigation and alleviation plans, as well as improved algorithms for urban traffic control, including multi-objective control systems. Combined with information gathered from the urban traffic control system, valid and relevant information on traffic conditions can be presented to travellers.

APPLICATIONS OF IOT: The potentialities offered by the IoT make it possible to develop numerous applications based on it, of which only a few applications are currently deployed. In future, there will be intelligent applications for smarter homes and offices, smarter transportation systems, smarter hospitals, smarter enterprises and factories. Some of the important example applications of IoT are

1 **Aerospace and Aviation Industry**
   Internet of Things can help to improve safety and security of products and services by reliably identifying counterfeit products and elements. The aviation industry, for example, is vulnerable to the problem of **suspected unapproved parts** (SUP). An SUP is an aircraft part that is not guaranteed to meet the requirements of an approved aircraft part (e.g., counterfeits, which do not conform to the strict quality constraints of the aviation industry).  

2 **Automotive Industries**
   Advanced cars, trains, buses as well as bicycles are becoming equipped with advanced sensors, actuators with increased processing powers. Applications in the automobile industry include the use of smart things to monitor and report various parameters from pressure in tires to proximity of other vehicles. Radio Frequency Identification technology has already been used to streamline vehicle production, improves logistics, increase quality control and improve customer services.

3 **Telecommunications Industry**
   IoT will create the possibility of merging of diverse telecommunication technologies and create new services. An illustrative example is the use of GSM, NFC (Near Field Communication), low power Bluetooth, WLAN, multi-hop networks, GPS and sensor networks together with SIM-card technology. In these types of applications the reader (i.e., tag) is a part of the mobile phone, and different applications share the SIM-card. NFC enables communications among objects in a simple and secure way just by having them close to each other.

4 **Medical and Healthcare Industry**
   IoT will have many applications in the healthcare sector, with the possibility of using the cell phone with RFID-sensor capabilities as a platform for monitoring of medical parameters and drug delivery. The advantage gained is in prevention and easy monitoring of diseases, ad hoc diagnosis and providing prompt medical attention in cases of accidents. Implantable and addressable wireless devices can be used to store health records that can save a patient’s life in emergency situations, especially for people with diabetes, cancer, coronary heart disease, stroke, chronic obstructive pulmonary disease, cognitive impairments, seizure disorders and Alzheimer’s disease.

5 **Independent Living**
   IoT applications and services will have an important impact on independent living by providing support for an aging population by detecting the activities of daily living using wearable and ambient sensors, monitoring social interactions using wearable and ambient sensors, monitoring chronic disease using wearable vital signs sensors, and in body sensors.

6 **Pharmaceutical Industry**
For pharmaceutical products, security and safety is of utmost importance. In IoT paradigm, attaching smart labels to drugs, tracking them through the supply chain and monitoring their status with sensors has many potential benefits. For example, items requiring specific storage conditions, e.g. maintenance of a cool chain, can be continuously monitored and discarded if conditions were violated during transport.

7 Retail, Logistics and Supply Chain Management
IoT can provide several advantages in retail and supply chain management (SCM) operations. For example, with RFID-equipped items and smart shelves that track the present items in real time, a retailer can optimize many applications.

8 Manufacturing Industries
By linking items with information technology, either through embedded smart devices or through unique identifiers and data carriers that can interact with an intelligent supporting network infrastructure and information systems, production processes can be optimized or the entire lifecycle of objects, from production to disposal can be monitored.

9 Process Industry
In many plants of the oil and gas industry, scalable architectures are being used that consider possibilities for plug-and-play new ID methods combined with sensing/actuating integrated with the IoT infrastructure and integrate the wireless monitoring of petroleum personnel in critical onshore and offshore operations, container tracking, tracking of drill string components, pipes, monitoring and managing of fixed equipment etc.

The Enabling Building Blocks
Progress in the following technologies will contribute to the development of the IoT:

- **Machine-to-machine interfaces and protocols of electronic communication** set the rules of engagement for two or more nodes on a network.
- **Microcontrollers** are computer chips that are designed to be embedded into objects other than computers.
- **Wireless communication** is familiar to most people in the developed world. Many different wireless technologies have the potential to play important roles in the IoT including short-range and long-range channels; as well as bidirectional and unidirectional channels. Wireless devices identify themselves; in practice virtually all wireless Internet devices contain unique identifiers, including all cell phones and Wi-Fi clients. However, see the next bullet.
- **RFID technology** resembles an electronic barcode that a reader device can detect even without line of sight. Some RFID readers can identify multiple objects concurrently. And some RFID tag-reader architectures support security features such as requiring a human operator to input a challenge code before decoding an ID. RFID have varying sizes, power requirements, operating frequencies, amounts of rewriteable and non-volatile storage, and software intelligence; ranges vary from a few cm to hundreds of meters. However, larger devices having an internal power source tend to operate at longer ranges; conversely, smaller devices having no internal power source (RF engineers say they are illuminated by the reader device, much as radar illuminates a target) tend to operate at shorter ranges. Also, architectures that support more storage, rewriteability, and processing tend to cost more than simpler architectures.
- **Energy harvesting technologies** capture small but usable amounts of electrical energy from the environment. Current energy-harvesting R&D concentrates on adventitious temperature variations, ambient sound and vibration, and ambient RF. Unlike passive RFIDs, which simply resonate when illuminated, an energy-harvesting transducer produces electrical power that runs a microcontroller, sensor, and/or network interface in whole or part. Technically, energy-harvesting transducers respond not only to adventitious sources but also to intentional transmissions of power, say, via RF and acoustic channels. A dramatic example of intentional transmission of power via RF channel: MIT’s recent “Witricity” demonstration of closely-coupled resonators, enabling relatively efficient wireless power transfers over a distance of a few feet.
• **Sensors** detect changing attributes in the environment and report them to a system; sensor networks aim to exploit the benefits of sensing at more than one location. Sensors are a type of transducer that must produce the miniscule amount of power required to convey information at a usable error rate. Sound, light, atmospheric conditions, vibrations, and other environmental signals are all fair game for sensor designers.

• **Actuators** detect an incoming signal and respond by changing something in the environment. For example, a relay is an actuator that toggles a mechanical switch, and can thus cause a good number of responses to occur such as enabling illumination, heating system, audible alarm, and so on. Actuators such as motors, pneumatics, and hydraulics can move objects and pump fluids.

• **Location technology** helps people and machines find things and determine their physical whereabouts. Sensors play a role in dead reckoning, but that approach does not satisfy practical needs for geolocation, resulting in the rise of wireless approaches including GPS (which is often augmented by other signals) and cellular towers. Fixed or orbiting transmitters have known locations. They broadcast timing signals, and receiving devices triangulate by calculating the amount of delay from each transmitter.

Radar, lidar, and sonar can detect relative locations of things, depending on their electromagnetic, optical, and acoustic properties. And some things transmit their own radio, light, and/or sound in order to disclose their whereabouts to people and machines.

• **Software** comprises a broad domain of development. Development of the IoT will rely on many dimensions of software capabilities including distributed execution, self-describing data structures, and more. No theoretical framework exists to circumscribe the limits of software development, leading to speculation about software that emulates human reasoning and performs tasks on behalf of people.

Regardless of the merit of long-awaited artificial intelligence, software will no doubt help future users make sense of complex data sets collected from networks of everyday objects and sensors.

**Factors for adoption of IOT:**

**Hardware costs are falling.** The costs of Internet of Things components such as microchips, GPS sensors, and accelerometers have fallen as volumes have increased. And it is not simply a cost reduction—tiny microchips are now capable of running more advanced software than ever.

**More machines are talking to each other.** Machine-to-machine (M2M) solutions are going mainstream. Vodafone forecasts that 50 percent of companies will have adopted M2M communications technologies by 2020.

**Software is more advanced than ever.** Today’s rich, dynamic business software is putting high-level data analysis capabilities into the hands of companies around the globe.

**Connectivity is proliferating.** Previously, IoT solutions were limited to wired or wireless local area network connections as mobile operators priced M2M connections out of range. No longer. Fuelled by the additional capacity that advanced cellular networks provide, mobile operators are embracing the Internet of Things.

**Cloud solutions offer lower costs, scale, and flexibility.** With the growth of services like Microsoft Azure, cloud storage and processing power is becoming more affordable and available, expanding the capability to analyze large amounts of data. Internet of Things scenarios that incorporate cloud-based storage, analysis, and other tools provide the added benefit of scalability and flexibility that businesses need when starting or expanding an IoT solution.

**Potential economic benefits are enormous.** The Internet of Things has the potential to create economic impact of $2.7 trillion to $6.2 trillion annually by 2025, according to McKinsey Global Institute.

**Conclusion:**

The Internet of Your Things represents an immense opportunity. Imagine the power of unlocking the insights and data in the following scenarios:

Point-of-sale scanners on a retail floor are connected to warehouse systems and analytics software at headquarters, for industry-leading efficiency in inventory.
Robots on a factory floor send production and maintenance information directly to those who need it, for unparalleled reliability and uptime. Diagnostic images from a CT-scan machine are shared in near real time with radiologists at another medical facility and the family doctor, for improved patient care. Other industry leaders aren’t waiting. Microsoft is delivering the mobile and cloud services for the Internet of Things today, helping customers drive operational efficiency, improve innovation and enable the creation of new business models. Working together, we can transform your business by starting from your existing assets and creating new insights. Microsoft looks forward to seeing what we can help you create with the Internet of Your Things. The potential is as limitless as your imagination and as unique as your business.

References: