

# M2M Architecture: Can It Realize Ubiquitous Computing in Daily life?

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## **Abstract**

Ubiquitous computing called pervasive one is based on the thought of pervading ability of computation in daily life applications. In other words, it aims to include computation in devices such as electronic equipment and automobiles. This has led to disengagement of computers from desktop form. Accordingly, the notice in ubiquitous computing being taken of a world steeped in remote and wireless computer-based-services. Handheld and wearable programmed devices such as sense and control appliances are such devices. This advancement is rapidly moving domestic tasks and life from device-and-human communication to the device-and-device model. This model called Machine to Machine (M2M) has led to acceleration of developments in sciences such as nano-science, bio-science, and information science. As a result, M2M led to appearance of applications in various fields such as, environment monitoring, agricultural, health care, logistics, and business. Since it is envisaged that M2M communications will play a big role in the future in all wireless applications and will be emerged as a progressive linkage for next-generation communications, this paper aims to consider how much M2M architectures can realize ubiquitous computing in daily life applications. This is carried out after acquainting and initiating readers with M2M architectures and arguments for M2M. Some of the applications was not achievable before but are becoming viable owing to emergence of M2M communications.

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**Keywords:** Machine to Machine, IoT, wireless device communication

## 1. Introduction

**M**<sub>2</sub>M is an acronym for the term “Machine to Machine” indicating a classification of Information and Computing Technology (ICT) for associating communications, computer and devices. M<sub>2</sub>M, in fact, aims to involve communication without (or limited) human intervention. In such a model, the human cannot operate as an input, but may do as output.

M<sub>2</sub>M communications are a growing area of home and industrial automatization where a huge volume of physical equipment whether manned or unmanned one is remotely monitored, such as vending machines, cars and buildings. In other words, M<sub>2</sub>M refers to systems that enable machines to communicate with each other via a wireless data link. **Fig. 1** shows the range of diverse devices may communicate by M<sub>2</sub>M model where *telemetry* denotes remote measurement and *telematics* denotes remote control.



**Fig. 1.** The diverse range of communicating machines in M<sub>2</sub>M model

M<sub>2</sub>M communications include a wide spectrum of concepts called *pervasive computing* [1], *hidden computing*, *invisible computing*, *wireless sensor networks*, *ubiquitous computing* [2] and *smart motes* and *smart dust* [3]. These concepts, in fact, specify different aspects of M<sub>2</sub>M; pervasive computing is used because M<sub>2</sub>M spreads to all aspects of life including work, play and learning; invisible and hidden computing is used because M<sub>2</sub>M devices may be not seen; motes are used because devices can be pint-sized and smart is used because M<sub>2</sub>M devices have intelligence to some degree and have semi-autonomous behavior; ubiquitous computing is used because M<sub>2</sub>M devices are embedded into buildings, automobiles and the human environment.

Today, smart phones are able to perform functionality of M<sub>2</sub>M terminals because they include diverse sensors such as Global Positioning System (GPS) [4] and can connect to mobile networks. M<sub>2</sub>M is a category of Information and Computing Technology that combines communications, computer and power technologies to enable remote human and machine interaction with physical, chemical and biological systems and processes. In addition, M<sub>2</sub>M represents a new kind of application for computing where data are streamed to and from the physical and biological environments.

The networking methods in M<sub>2</sub>M communications are wireless, wired or hybrid. The wireless methods include Wi-Fi [5], GPRS [6], UMTS [7], LTE [8] and WiMAX [9]. The Wi-Fi (the *Wireless Fidelity*) enabled devices such as personal computers, smartphone or wireless modems connect to the Internet via an *access point*. GPRS (General Packet Radio

Service) denotes a mobile data service for mobile communications called GSM. A GPRS connection is established by reference to its access point name (APN) where the APN defines the services such as wireless application protocol (WAP) access, short message service (SMS), multimedia messaging service (MMS) and Internet communication services such as email and World Wide Web access.

UMTS (Universal Mobile Telecommunications System) is the third generation mobile cellular technology for networks and offers more efficiency and bandwidth to mobile network operators. UMTS supports authentication of users via SIM (Subscriber Identity Module) cards. Popularized since 2006 in many countries, UMTS theoretically provides data transfer rates of 45 Mbit/s. UMTS networks started in 2002 with emphasis on mobile applications such as mobile TV and video calling. Now, due to high speed data transfer, UMTS are used for Internet access.

LTE (Long Term Evolution) is a standard for wireless communication of high-speed data. It is based upon GSM and UMTS network technologies. Increase of the capacity and speed of wireless is the LTE goal by utilizing networks that use cutting-edge hardware. LTE is intended to low-latency communications with download rates about 300 Mega-bit per second and capacity of 200 active users per cell. This leads to handle fast-moving mobiles, and support multi-cast and broadcast streams.

WiMAX (Worldwide Interoperability for Microwave Access) supports both fixed and mobile Internet access at a rate of 1 Giga-bit and 40 Mega-bit per second respectively. It was formed to enable wireless broadband access. The WiMAX aims to provide: (1) connectivity of mobile broadband among cities and countries, (2) Voice over Internet (VoIP) service, (3) a business plan over internet, (4) at home Internet access across cities or countries by mobile devices. In comparison with similar technologies, deployment of a WiMAX network is more cost-effective; accordingly, broadband Internet access in remote locations becomes economically viable.

## 2. M2M Architecture

The European Telecommunications Standards Institute (ETSI) [10] setting standards for Information and Communications Technologies, considers an M2M network as a five-part structure. (1) Device, embedded in a smart device and replies to requests or sends data. A device replies to requests for data contained within the device. (2) Gateway, to provide negotiation of device with the network. In fact, it provides device inter-working and inter-connection. (3) Server (Application), passes data through various applications services and used by the specific business-processing engines. It is a software agent that analyzes data, takes action and reports data. (4) Network, furnishes connection between devices and gateways. (5) Communication network furnishes connection between gateways and servers (applications). **Fig. 2** shows a simple M2M architecture and **Fig. 3** shows domains of M2M architecture.

According to ETSI, this standardization plays an indispensable role in long term development of the M2M technology. The five-element structure proposed by ETSI forms the three domains: (1) device, (2) network consisting of area network and gateway and (3) application consisting of server and communication network.

To realize a unified architecture of M2M communications, M2M networks are required to be bridged seamlessly with various communication systems using multiple communication technologies: mobile broadband communications (e.g., WiMAX and Long Term Evolution (LTE) and local area networking (e.g., Wi-Fi). In home networks, ubiquitous smart electronic

devices other than traditional telephones and computers are kitted out with wireless communication technologies. Communications among the smart electronic devices generally feature low data rate, low mobility, and low power consumption. Short-range communication technologies like Bluetooth, ultra wideband (UWB) [11], and Infrared Data Association (IrDA) [12] can be employed for connection between smart electronic devices (i.e., M2M components) and an M2M gateway in the home environment.

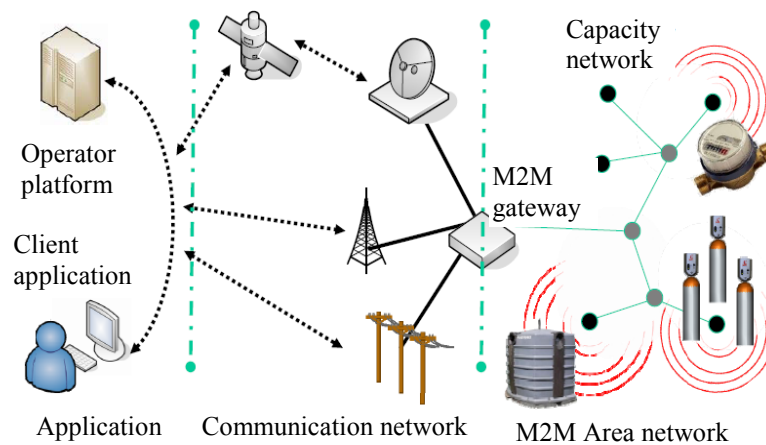


Fig. 2. Simple Architecture of M2M

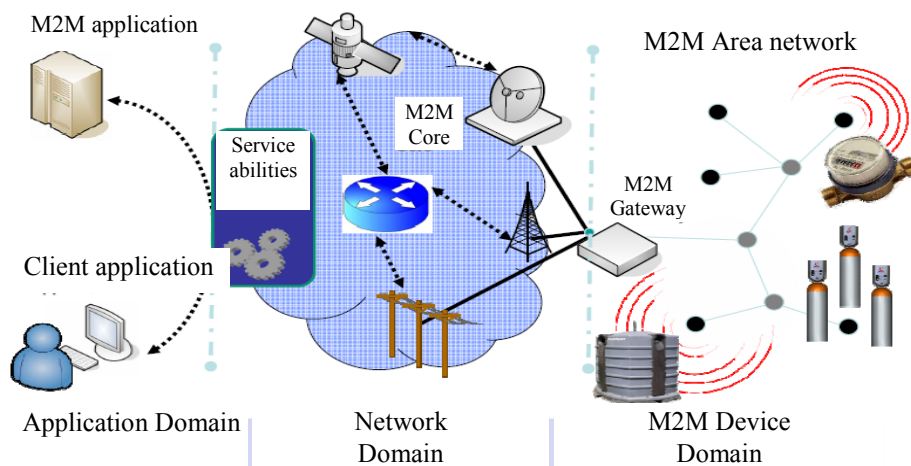


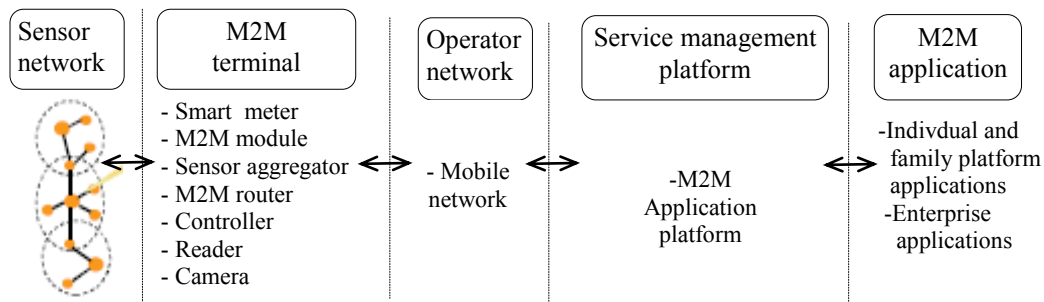
Fig. 3. M2M architecture domains

An ad hoc network provides the connectivity among multiple decentralized nodes without a preexisting infrastructure, which is the case for most M2M components in the real world. Fast and low cost interconnection of dispersive M2M components can be achieved by ad hoc networking. For M2M components in an ad hoc environment, medium-range communication technologies like IEEE 802.15.4 (ZigBee) [13] and IEEE 802.11 (Wi-Fi) can be adopted to cover the transmission range.

The cellular network is presently one of the most widely deployed wireless networks around the world, and offers a great advantage to developing M2M communications. It provides radio coverage over a wide geographic area; accordingly, it enables a large number of distributed and remote M2M components (e.g., sensors) to communicate with each other via base stations. Also, since the cellular network supports mobility, more flexible M2M applications (e.g., intelligent transportation system) can be accommodated.

### 3. M2M Components

An M2M communication consists of four major components **Fig. 4** [14]. The first one consisting of sensor network and M2M terminals stands for input and output of the M2M communication. Sensors used to calculate parameters such as location, pressure, speed, temperature. Then, the collected data is transferred through wireless devices (Wi-Fi), mobile network (GPRS), Universal Mobile Telecommunication System (UMTS), and wireless communication of high-speed data (LTE) or via wired network such as Local Area Network. Today, smart phones are able to perform functionality of M2M terminals because they include diverse sensors such as Global Positioning System (GPS) that can connect the phones to mobile networks.



**Fig. 4.** Components of M2M communication [14]

The second one called *Operator Network* is to make connection between the sensors/terminal and the M2M infrastructure. The connection is made by wireless communications such as Wi-Fi, GPRS, UMTS, LTE or wired communications such as LAN. This component undertakes task of quality of services should be provided by an M2M communication. Suitable throughput, for instance, is a quality should be provided for the applications such as online chat. In addition, SIM card (*Subscriber Identity Module*, the memory chip used in cellphones) management should be provided if communication is made by mobile wireless. The management should support diverse *business models* presented by different SIM cards.

The third one called *Service Management Platform* is the central component of an M2M communication. The input data originated from sensors/terminals should be prepared (i.e., collected, saved and formatted) to use by different kinds of M2M applications. This is the task should be undertaken by this component. In addition, when SIM cards are used, this component should manage charging based on different applications. The last one called *M2M application* utilizes processed data originated from sensors/terminals. Typical utilizations are employments of GPS data by traffic monitoring systems such as traffic court or reaction of a real-time system to its environment events.

#### 4. Internet of Things

The new architecture for M2M communications is an extension of M2M over the Internet called *Internet of Things*. The Internet of Things referring to objects (Things) is uniquely distinguished in the Internet. The term “Internet of Things” has first been used by Kevin Ashton in 1999 [15]. The essential requirement for the Internet of Things is RFID (Radio-frequency identification) [15]. The requirement says that if all objects of daily life are provided with radio labels, they could be recognized by computers. Providing objects with detectors devices in daily life evolves the human life [16][17][18] because objects become aware of their environment and human is encompassed by the objects concurrently create events. The Internet of Things is ideally expected that should connect and encode 50 to 100 trillion objects all over the world. Since it is expected that each individual is encompassed by 1000 to 5000 objects, the Internet of Things should enable human to trace the objects motion.

By Internet of Things, Alcatel-Lucent *touch-a-tag* service [19] provided a method by which objects can be connected using RFID labels. The *touch-a-tag* package plus the *touch-a-tag* service are used to create Internet of Things. Objects can be made smart and applications can become reachable via a simple touch. The *touch-a-tag* package contains one USB RFID reader and 10 RFID labels, which works on PC Windows and Mac. The USB reader works at a distance of about 4 cm when used with the *touch-a-tag* RFID labels. Also, Alcatel-Lucent presented *touch-a-tag 500* tag package to create the Internet of things providing 500 labels to use with NFC (Near Field Communication) phones [20]. NFC is a wireless technology that enables two-way communication between two devices near to each other. Accordingly, it can be applied in paying goods and services with your NFC phone, or information sharing and several others.

Arrayent, Inc. [21], a business to business corporation, connects consumer products such as electronic devices, i.e. thermostats and healthcare devices and smart devices, i.e. smartphones, tablets over the internet. Arrayent enables saving energy and cost for standard home control devices by connection of home energy systems over the Internet. This is carried out by receiving real-time alerts via email or SMS for smoke and threats. In addition, it monitors and controls lights, doors and security systems by a smartphone or PC. Web based application software learns sequence pattern of room lighting for business or vacation days. Connected Environments Ltd built *Pachube* [22] to support data management for sensors, devices and environments on the internet.

*Nimbits* [23] is a server built on a cloud computing architecture and connects devices using data points. It has been designed to record temporal data such as readings from a temperature probe, a stock price over time. Nimbits Server includes a collection of web services and an interactive portal to record data on the cloud computing infrastructure. When data flowed into a Nimbits, alarms may be triggered, calculations may be performed and data may be relayed to social networks such as Facebook and Twitter. Fig. 5 shows the advancement of technology for the “Internet of Things”.

#### 5. Machine to Machine to Human

Machine-to-Machine communications using the “Internet of Things” is expected to connect 15 billion devices by 2015 [24]. The “Internet of Things” offers new opportunities to connect machines, devices, systems and people called Machine-to-Machine-to-Human (M2M2H) communications Fig. 6. However, this type of the Internet of Things requires a new approach to communication models, operations, processes and technologies.



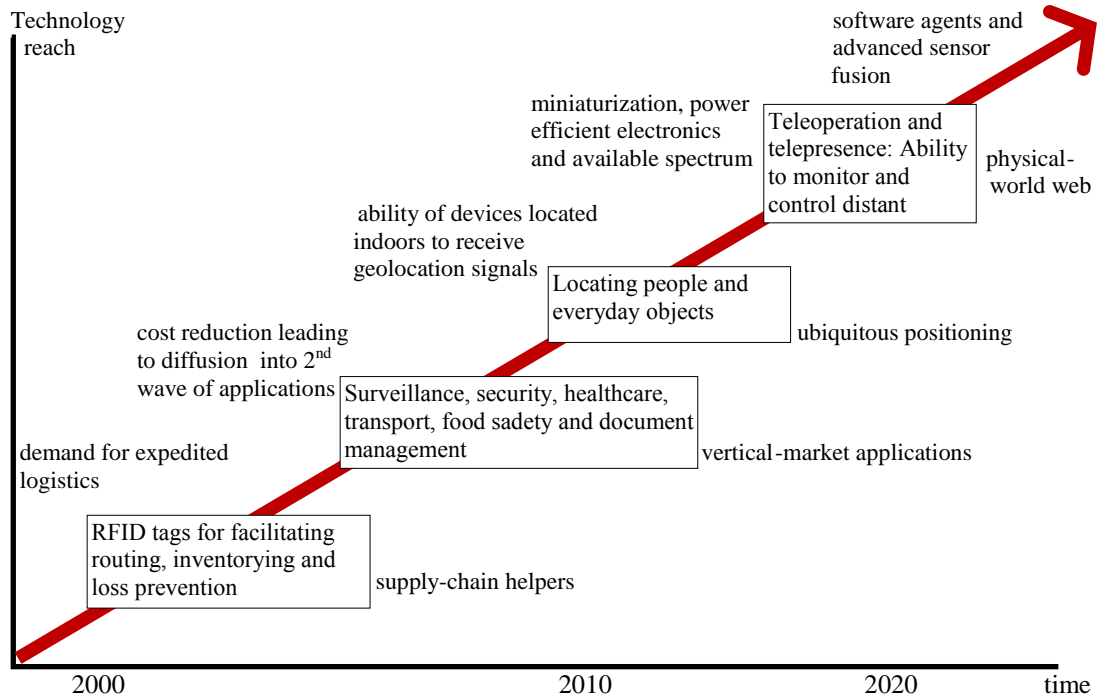


Fig. 5. Technology Advancement: Internet of Things [24]

As Fig. 6 shows the environment part may consist of diverse devices such as computers servers for measuring and processing, HVAC (heating, ventilation, and air conditioning) system for consumption control and optimization, Fridge for controlling the temperature process and compressor, Neon fluorescent tube for controlling energy consumption or Satellite. The M2M part consists of devices such as: (1) temperature, pressure or motion sensors, (2) switches to control lighting or (3) GSM device to communicate to the internet via networks infrastructure such as ZigBee or WiFi or via Ethernet connection having IP enabled gateway (web-enabled computer). Such a configuration enables us to remotely observe and control the environment. The communication part denotes the Internet, Intranet or GSM networks.

The Web applications and services part consists of web services meant to service to human equipped with machines such as laptop and mobile. It provides the communication between human machines and the gateway. Devices used in the Machine-to-Machine part are those include specific features. Bluetooth low energy (BLE) [25] is a type of Bluetooth 4.0 wireless radio technology meant in low-power and *low-latency* applications for wireless devices within a short range (Up to 50 meters). Low-latency applications accept human-unnoticeable delays between their input and the corresponding output. This is significant for internet connections utilizing services such as VOIP. In a VOIP application a slight delay between inputs from conversation participants can be ignored but significant delays may weaken conversation. Low-latency has diverse applications in the healthcare, security and home entertainment.

Wireless communication devices operate at three different distances: very short range (distance up to few centimeters), short range (distance up to 10-15 meters) and long range up to hundreds of kilometers. Mostly, GPRS is used for the long range communication.

The advent of the “Internet of Things” model is initiating a new Machine-to-Machine

application in market and in vehicle applications areas aiming at the effectiveness of energy and transport. As a result, M2M communications over the internet enable us to network electronic devices of consumers and remotely monitor them.

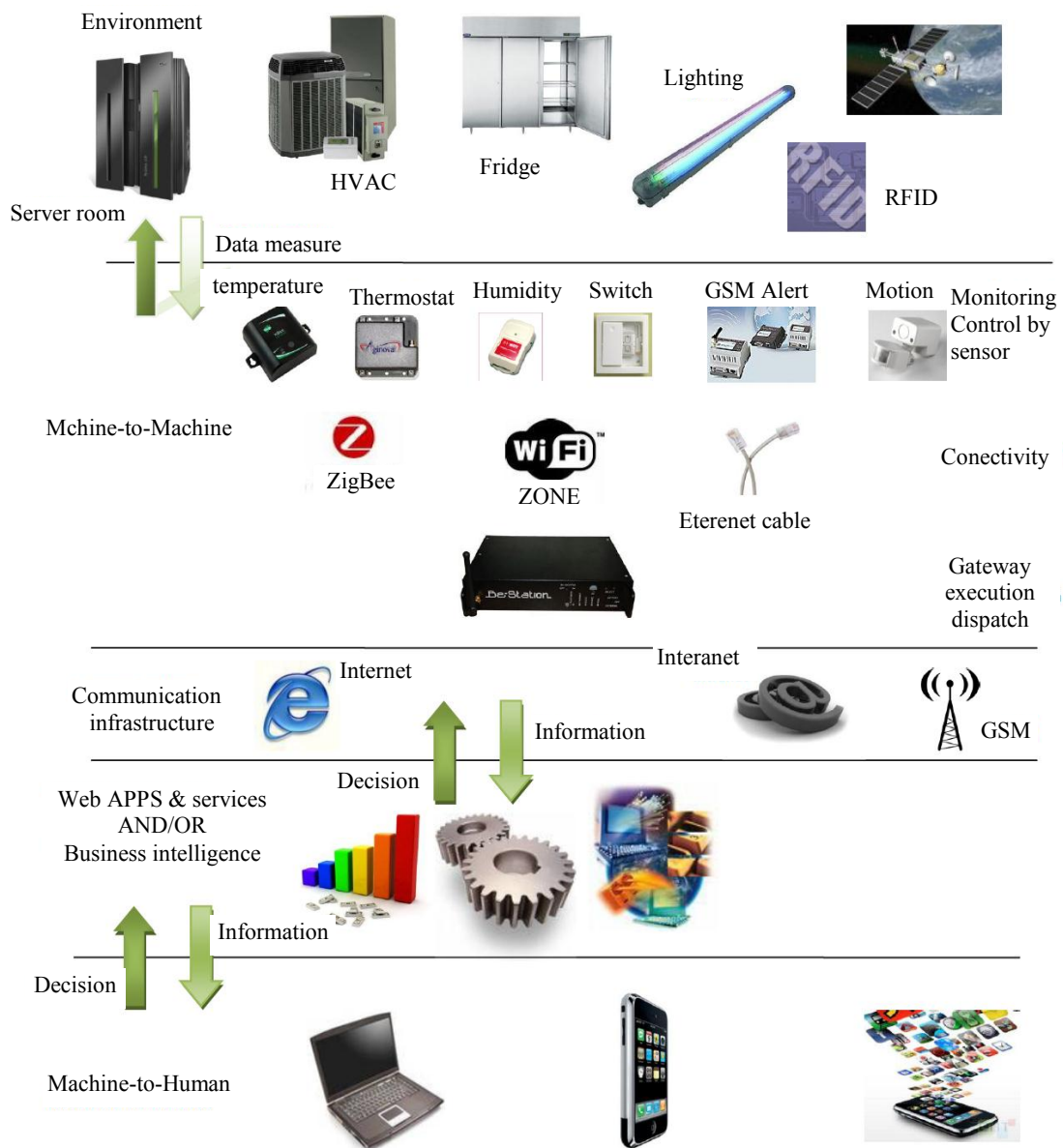


Fig. 6. M2M2H configuration

## 6. Arguments of Marked Tendencies for M2M

The M2M market is growing significantly. Harbor Research anticipates 280 billion € in 2013 with an average growth rate of 33% for the total M2M market [26]. The M2M market grows



steadily resulting in CAGR (Compound Annual Growth Rate) of 20 to 40%, depending on the actual segment. CAGR means the year-over-year growth rate of an investment over a specified period of time and it is calculated by taking the  $n^{\text{th}}$  root of the total percentage growth rate,

where  $n$  is the number of years in the period being considered:  $\text{CAGR} = \sqrt[n]{\frac{\text{ending value}}{\text{beginning value}}} - 1$ .

CAGR is an imaginary number that describes the rate at which an investment would have grown if it grew at a steady rate. Anticipation of overall M2M service market for diverse industries has been shown in Fig. 7 [14]. The arguments in favor of tendencies to M2M are as follows Fig. 8 [14]:

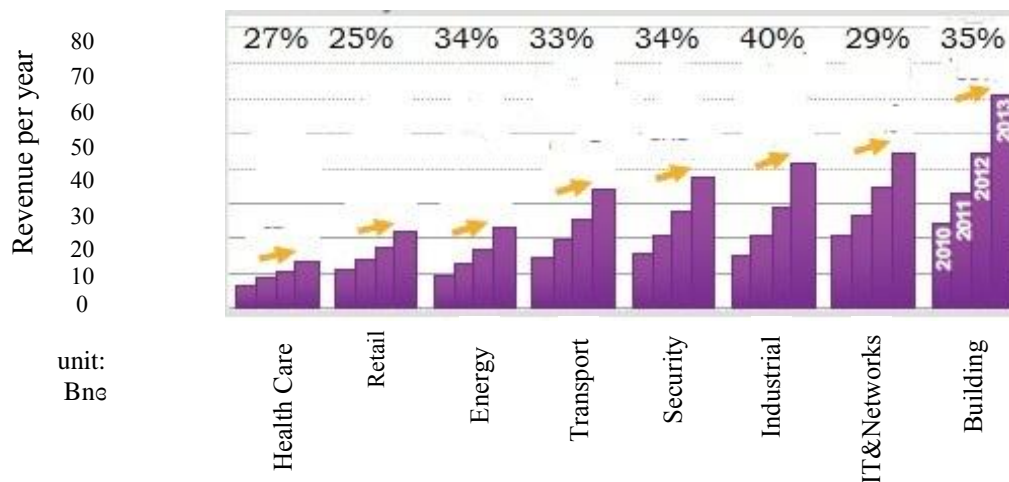


Fig. 7. Overall M2M service market for industries [14]

To improve information flow Through new data creation and capture 20%	To reduce operational cost through real time data 16%	To increase revenue through new service offerings 16%
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Fig. 8. Argument of M2M solution [14]

(1) *Increase of flowing information.* This leads to more effortless response to business circumstances when the required data are globally available in time. Smart metering for electricity and gas to monitor house are typical instances. (2) *Decrease of operating expense (OpEx).* It is an ongoing cost for running a product, business, or system. In contrast to OPEX, a *capital expenditure (CaPex)* is the cost of providing non-consumable parts for the product or system. Many companies have understood that M2M data are necessary to keep OPEX low because they are able to response react to new conditions in time. (3) *Increase of income.* Thanks to M2M communication, companies will able to offer new services such as new health care options and new business models on the market.

## 7. M2M: Horizon of Realizing Pervasive Computing in Daily Life

Having no need of cable set up for M2M components (see Section 2.1) and enabling mobility by the new wireless technologies led to realizing ubiquitous computing in daily life applications. This is thanks to diversity of M2M components in types, sizes and limitation of availability, where results in effectiveness in cost and flexibility in placement. Realizing ubiquitous computing for daily life applications by M2M communications depends on four factors: (1) Exploitation of smart spaces, (2) Transparency, (3) Localization and (4) Heterogeneity.

*Exploitation of smart spaces.* A daily life application based on M2M architecture may be used in an enclosed area such as a meeting room or in a defined open area such as a shopping center or a university. Such spaces called smart because of integrating two separate spaces to one space that recognizes and supervises the other. Automatic tuning heat, cool and light in a place, for instance, depends on whether there is some resident in the place or not.

A typical example of smart spaces is smart grids. On-Ramp is a rising Machine-to-Machine (M2M) communications space developed by On-Ramp Wireless in cooperation with Korea Telecom for Fountain Springs, a South Korean smart metering company. The project, as one of the largest smart grid projects in the world, will lead to energy efficiency, decrease of costs and speed up deployment of its smart grid applications [27].

The project promises to establish a national grid by 2030 and to connect about 6,000 homes with schools, transmission lines, energy storage systems, and plug-in vehicles. Moreover, it is expected that more than 160 companies use it to test advanced technology and systems [27]. Smart meters, smart thermostats and smart sensors are typical examples of the combination of M2M and the smart grid enabling remote access to data, such as energy consumption and energy disruptions.

*Transparency.* It indicates that the architecture of M2M (see Section 2) for pervasive computing is invisible for M2M communicating users. This leads to an abstract view of the architecture for the M2M users leading to complexity reduction of the applications should be developed for the M2M environment. In other words, if a computing environment involves an application developer in just satisfaction of users' concerns and seldom confronts the developer with issues of environment architecture and pervasiveness will be realized easily.

*Localization.* The accretion of smart spaces causes increase of the amount of interactions between the space users and their environment. Such a concern needs more bandwidth for the wireless space specially when there are many active users in the space; accordingly, the space growth becomes a concern. This is significant because the M2M architecture is supposed to be used for a ubiquitous computing environment. Typical example is when ubiquitous computing environment should handle many client requests whether they are in a local area such as a building or wide one such as a country. Up to now, complete transparency has not been possible; however, it is on the increase. In other words, characteristics of traffic exchanged among M2M components have not been well studied so far. Traffic characterization is the fundamental to the design and optimization of M2M based network infrastructures.

Moreover, it is necessary to support quality of service (QoS) of M2M applications, which some solutions have already presented. IEEE standards committee proposed protocol 802.11e [28], for instance, for the betterment of protocol layer for QoS, which is a suitable protocol to transmit multimedia radio in M2M local areas. Consider smart grid home applications [29], for instance. In such applications, a Local Area Network (LAN) gathers data about energy consumption from households in the vicinity and transmits them to a utility company through the Wide Area Network (WAN). A LAN typically comprises multiple utility meters, each of which is installed on the outside of a house. For automatic communications among these

machines a LAN is needed when the number of multimedia devices in the house (e.g., personal computers, TVs, mobile phones and laptops) increases. In this case, the demand on sharing multimedia among different devices becomes very significant.

*Heterogeneity.* Heterogeneity of ubiquitous environments handled by M2M architecture is a concern because of having different organizational and business structures. Thinking of homogeneous environments in M2M communication is oversimplification and leads to debilitating ubiquity of computing in the M2M architecture. However, heterogeneity should cover different smartness levels of M2M devices. Accordingly, an M2M application should think of equipment of an M2M environment such as a conference center or an office by heterogeneous devices. Despite such limitation, M2M has enabled a diversity of services in home surroundings such as smart grids, mobile healthcare, home automation, security, appliance monitoring, lighting and entertainment.

Consider Pervasive computing in Body Area Network (BAN) [30][31] supporting human-centric services for distances less than 2 meters. In this area, M2M communications are carried out in 2 layers: intra and inter BAN communications. The former is related to the communications among sensors implanted in the human body and the latter is related to the communications between BANs and external access points. M2M communications over the human body consist of specific features that are different from conventional wireless ad hoc networks because BANs are exploited in human-intensive environments with radio waves. In a BAN, medical sensors suffer limitations such as power, sensing, communication and computation. Moreover, human tissues emit radio waves, which is difficult to handling. All these features pose exceptional problems in the development of M2M communications in body areas [32].

Home healthcare applications, for instance, use M2M communications over body areas. These applications consist of biomedical sensor networks inside, on or around of human to carry out sensing, collection, and transmission of medical vital signs such as blood pressure, electrocardiogram, oxygen saturation, pulse rate, temperature, and heart rate. The biomedical data are stored in the body area for on demand remote access and periodically transmitted to remote physicians or nurses. By M2M communication, one can extend such applications to pervasive computing patterns such as e-health (electronic health), healthy lifestyle, location-based services and ambient assisted living.

Another problem relates to “Internet of Things”. TCP/IP, the current transmission protocols over the Internet are inefficient for exchanging data via M2M communications because it has energy-wasting overhead. Thus, transmission protocols should be specially designed for M2M communications.

The heterogeneity can be resolved by imposing protocol and architecture standardization. This is why that today standardization of a seamless and unified M2M architecture is highly demanded to promote rapid development and application of M2M communications.

## 8. Conclusions and Related Work

This paper presented three basic concepts of Machine to Machine: architecture and its extension (Machine to Machine to Human), components and Web based configuration called Internet of Things. Based on these concepts, marked tendencies for M2M, coverage and realization of pervasive computing in daily life application by M2M were discussed. The discussion showed what obstacles exit in the way of full realization of pervasive computing such as e-healthcare and, energy management by M2M communications. Moreover, it was discussed that how M2M can be adapted to support daily life applications, improves efficiency

and reduces cost. To this end, some typical case studies such as smart grids were explained.

Some researches dealt with introducing concepts, basic principle of M2M communications [33] and pervasiveness of M2M in daily life [33][34]. [34] had anticipated the wide growth of M2M in recent years and [33] anticipates 50 billion connected devices world-wide by the end of 2020. Accordingly, [33] claims that such calculation tempts the industry to start a trend toward a wide range of openings that the M2M communication proposes. They include new business cases and enhancement of workflow efficiency amending life circumstances. By some specific examples, [33] has tried to provide a vision of M2M current industry adoption.

Similarly, [35] has addressed current advancement in Machine-to-Machine communications and [36] has shown advancement made in developing M2M communication standards. The requirements management in daily life M2M applications has been discussed by [37][38][39] based on existing M2M network use cases and services. The paper tries to show potentiality of M2M in increasing revenue, decreasing costs and enhancing the customer services of an organization.

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