INTERNET OF THINGS: A REVIEW OF APPLICATIONS & TECHNOLOGIES

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Abstract

This paper presents the state-of-art of Internet of Things (IoT), an enabler of new forms of communication between people and things, and between things. The main strength of IoT concept is the high influence it has to everyday life by creating new dimension to the world, resembling to what the Internet once did. This paper describes the definitions of IoT, summarizes its main enabling technologies. The content includes strengths and limitations of applications based IoT in logistic, transportation, healthcare, and environment and disaster. Finally, the open challenges of IoT are debated to encourage more investigations into the domains.

Keywords : Internet of Things, IoT, limitations, strengths

Introduction

The term "Internet of Things (IoT)" (Huang & Li, 2010; Uckelmann, Harrison, & Michahelles, 2011) has been around since the past few years and gaining recognition with the breakthrough of advanced wireless technology. Even though there are heterogeneous definitions on the interpretation of "Internet of Things" but it has a corresponding boundary related to the integration of the physical world with the virtual world of the Internet. IoT can broadly be defined as a global network infrastructure, linking uniquely identified physical and virtual objects, things and devices through the intelligent objects, communication and actuation capabilities. In other words, the paradigm of IoT is described as "any-time, any-place and any-one connected" (Ryu, Kim, Lee, & Song, 2012). Its implication is based on the technology that makes things and people getting closer than the old days.

In the perspective of "things", numerous devices and objects will be connected to the Internet. Each individually provides data, information or even services. The devices providing things can be personal objects we carry around such as smart phones, tablets and digital cameras. Our daily environment, home, vehicle or office connected through a gateway device can also provide "things" (Coetzee & Eksteen, 2011). Although Radio-Frequency IDentification (RFID) is precisely the first idea popped up, but indeed many more technologies such as sensor technologies, smart things and actuators are also contributed. Whereas the Machine-to-Machine Communication (M2M) and Vehicular-to-Vehicular communication (V2V) are the real applications in the markets revealing the most benefits of IoT (Atzori, Iera, & Morabito, 2010; Uckelmann et al., 2011).

The aim of this paper is to explore the development and the deployment of IoT in significant application domains. The organization of paper is as follows, Section 2 describes the structure of IoT. Section 3 presents a review of the existing application of IoT categorized into the areas of logistics, transportation, healthcare, and environment and disaster. Section 4 is the discussion of IoT applications based on its benefits and limitations. Section 5 is the challenge of IoT in those application domains.

The Structure of Internet of Things

The Internet of Things can be viewed as a gigantic network consisting of networks of devices and computers connected through a series of intermediate technologies where numerous technologies such as RFIDs, barcodes, wired and wireless connections may act as enablers of this connectivity. By International Telecommunications Union (ITU), the perception of IoT was structured as four dimensions of things as illustrated (Figure 1) (Atzori et al., 2010; Coetzee & Eksteen, 2011).

Tagging Things

Real-time item traceability and addressability of RFIDs is what make them stand at the forefront in terms of the IoT vision. RFIDs are gaining strong support from the business community due to their maturity, low cost, and low power. RFIDs act as an electronic barcode to help in the automatic identification of anything attached. For RFID tags, they are available in 2 types: active and passive. The active tags embedded with battery on-board, are widely used in retail, healthcare, and facilities management. The passive tags, containing no batteries, are powered by the reader and are more likely to be used in bank cards and road toll tags (Aggarwal, 2012).

Feeling Things

Sensors act as primary devices to collect data from the environment. Necessary data is provided via communications established between the physical and the information worlds (Vermesan & Friess, 2013). Recent advances in technologies make them consume less power with low cost and high efficiency.

Shrinking Things

Miniaturization and nanotechnology has provoked the ability of smaller things to interact and connect within the "things" or "smart devices". A clear advantage is the improvement in quality of life. For example, the application of nano-sensors for monitoring water quality at reduced cost, and nano-membranes for assisting in the treatment of waste water (Vermesan & Friess, 2013). In healthcare, its application can be seen in the diagnosis and treatment of disease, including the diagnosis of HIV and AIDS and nano-drugs for other diseases (Gubbia, Buyyab, Marusic, & Palaniswami, 2013).

Thinking Things

Embedded intelligence in devices through sensors has formed the network connection to the Internet. It can make the domestic electric appliances realizing the intelligent control, for example refrigerators that can detect the quantities of various items and the freshness of perishable items. Embedded smart sensors may provide the means to communicate with users by sending alert via the Internet connectivity. The connection can primarily be wireless or other available communications such as DSL, GPRS, WiFi, LAN and 3G (Uckelmann et al., 2011). Not only to communicate, smart things must also be able to "…process information, self-configure, self-maintain, self-repair, make independent decisions, or even play an active role in their own disposal…" (Vermesan & Friess, 2013) which will change the way information communicates from human-human to human-thing and to thing-thing.

Applications based IoT

One of the most important engines of the innovation and development of IoT is its applications, otherwise public acceptance of IoT will never happen (Coetzee & Eksteen, 2011). Based on the concept of IoT, information generated from daily enabling objects in our environment can possibly communicate with each other. This information can drive many applications possible. Applications directly applicable or closer to our current living habitudes, can possibly be categorized into four following domains (Q. Yang, Wang, & Yue, 2012).

Logistics and Supply Chain Management

Traditionally, most of the logistic enterprises require manifold reports tracking, along with specific time and location to control the movement of goods. However, in the IoT society, the logistic commodity has tremendously changed to an autonomous society by variety of applications available to support the needs. The systems in (Li & Luo, 2010), (Wei, 2011), and (El-Baz, Bourgeois, Saadi, & Bassi, 2013) are logistic applications implemented to track the movement of goods in real-time. The data scanned from tags of barcode or RFID was transmitted to the logistic center or RFID receivers. Data was then transmitted through Wireless Sensor Networks (WSNs) (Li & Luo, 2010), GSM network (Wei, 2011), 3G network or a new High Performance Computing (HPC) infrastructure through broker (El-Baz et al., 2013) to be processed at the data center. The solutions in this domain are very promising since they have adopted comprehensive and diversified transmission protocols. Several devices such as RFID, Near Field Communication (NFC), and mobile phone can also act as data collectors. But they do have substantial limitations.

For example, the supermarket chain management (Li & Luo, 2010) was developed based on standard relational database, which can lead to worrisome situation when dealing with large volume of “things”. The occurrence of incomplete information or missing information procreated from the communication distance of the mobile logistic information reader (Wei, 2011) and the data collision during transmission may as well jeopardize the results.

Not only the applications to support the front-end and back-end operation are essential, the abilities to control and identify the next destination of goods/raw material are also indispensable. The real time tracking of logistic entities using the combination capabilities of RFIDs, mobile devices and the integrated browser interface was conducted (Lin, 2011). The position of objects was derived from GPS, WIFI, GSM, and GPRS. Even overall detection accuracy of geographical location was over 97% for moving entities and roughly 100% for the action-less entities. However its hindrances are i) the detection of geographical position function needed to support variety of browsers since different logistic users may use different mobile devices and ii) the browsers themselves should have the ability to automatically detect and confirm on what positioning devices to be launched.

To increase the accuracy of the logistic process, not only the ability to detect location of goods is desired, the reliability of RFIDs signals is also essential. Particularly in the environment where there is limited accessibility to the IoT infrastructure. A launch of AspireRFID (Soldatos et al., 2010) , a RFID middleware with a range of tools to facilitate RFID deployment ("RFID Journal," 2009) was a breakthrough. The integration of the EPC (Electronic Product Code)global based RFID architecture with “Session Initiation Protocol (SIP)” (Anggorojati, Mahalle, Prasad, & Prasad, 2013) to simultaneously detect locations and mobility management of RFID tags revealed outstanding performance in cost consumption of tags registration and tracking.

In large logistic enterprises, the efficacy to automatically locate and move assembly parts has incurred the adoption of robots. The infrared motion capture system or computer vision system with complex machine learning algorithms was basically used to control the navigation and object manipulation of robots. However, that feature of the proposed robot was handled by RF-Compass and RFID (Wang, Adib, Knepper, Katabi, & Rus, 2013). Both the robots and the objects the robot will work on, are embedded with an ultra low-power RF-compass and a low cost RFIDs as a replacement of WiFi-nodes. The RF-Compass could pinpoint the center position and the orientation of objects with 80-90% accuracy when robots were grasping objects. Even though this study demonstrates low computation time when compared with machine-learning architecture, it has a limited line-of-sight detection and no proven evidence on handling small objects.

The review of IoT applications in logistics (Table 1) indicates that in order to maintain the effectiveness of IoT, the system should at least comprise the basic following capabilities:

Autonomous control: Mechanisms to overcome limitations in the management and exploitation of millions of unreliable, non-autonomous things and of the corresponding data and information flows should be implemented. Instead of having a central control unit for decision making responsibilities, decentralized control of multiplicity of smaller self-organizing units will be more efficient. The capability and possibility to render decisions independently will as well improve the robustness and increase the scalability of process control.

Smart logistic entities: Each commodity in logistic networks is embedded with sensors to record information of items for fast updating of transactions of specific goods. The protection of thieves, and fast tracking and tracing of goods states can as well be autonomously triggered as alarm mechanisms by these sensors.

Unique addressability: Right product, right quantity, right time, right place, right condition and right price are what expected in logistics. Right product relates to accurate and appropriate information on product which can be deduced from auto-ID, sensor information or any other kinds of linked information. Right time means product can be acquired anytime when needed. Right place refers to goods located independently of unreliable network connectivity. Effective data synchronization protocols and caching techniques are necessary to ensure availability of information at the right place. The right price means the product price lies between the costs for information provisioning and the achievable market price.

ERP interface: Real-time access to the ERP solution helps the shop administrators to better inform customers about availability of products and give them more product information in general.

Transportation

The development in transportation is presumed to be one of the factors to indicate the well-being of the country. That is why transportation problems are very challenging in the field of IoT. A proposal on a road condition monitoring and alert application was initiated (Ghose et al., 2012). Its main idea was to apply the principles of crowd sourcing and participatory sensing. The process began with user identified the route he wishes and marked some points as pothole in the smart phone's application. When the vehicle ran over the defined route, accelerometer which continuously captured data would send raw data via mobile network. Related features were then extracted to generate a confidence score to indicate the abnormalities of the routes by showing the plot of pothole information. Distinct advantage has expressed from the adoption of user's smart phone as a connector device with no additional cost applying on the existing hardware. Albiet, remain issues are the upload and download process of route-map which involve considerable network traffic may induce vulnerability to the system. Moreover, the road condition classification is performed at the phone itself is very time-consuming and it may drain out the battery of the mobile phone.

For large cities, problems such as finding parking spaces, waiting in line for toll-way payment can be cumbersome which had urged the idea of applying the license plate as a unique identity of driver (Ren, Jiang, Wu, Yang, & Liu, 2012). The license plate was captured by the recognition equipment whereas sensors embedded in license plate would collect the information of road surface. The data was then forwarded to calculate the optimal path and guiding passage of vehicles. The system are not only able to invoke the traffic scheduling, vehicle positioning and vehicle query for passenger, it also can locate the parking spaces in nearby location. This design provides variety of benefits to driver in terms of managing highway automatic toll collection, avoiding busy traffic induction, locating parking space and adding more security to the vehicle. A clear drawback, however is this design struggles to support too many functions which invoke high cost and difficulties for implementation.

Electric vehicles, an important means to reduce both the fuel cost and the impact of global warming have also gained considerable attention from drivers. Government in many countries has supported researches on systems to monitor performance of Lithium-ion (Li-on) battery for electric vehicle as explored (Haiying et al., 2012). The system presented was designed to detect the functions of Li-on power battery by deriving the driving situation from the realistic working conditions for driver so that the driver was able to get the idea of the route status. This solution was embedded with many essential functions such as dynamic performance test of the Li-on battery, remote monitoring with on-line debugging and error correction that could significantly reduce the maintenance cost. For as much as the underlying issue of such design is the battery life, the extensible function of age-tracking and end-of-life predictions of battery should be bundled so that the fading battery can be tracked to assure of the readiness, reliability, and security of the electric buses.

The safety supervision in the distribution of hazardous or valuable goods is imperative for shipping companies. A study to master the operation of the entire fleet from the command center in real time was conducted (Shengguang, Lin, Yuanshuo, & Rucai, 2013). Each vehicle was embedded with GPS to form a multi-hop network for the command center to share the perception of drivers. A combination of RFID reader and 3G video surveillance was used to monitor status of goods whereas temperature and humidity sensors in the vehicle were used to detect a quality of transport goods. If indicators exceeded the limit, the alarm would be raised. Other unpredicted events such as driver fatigue or unauthorized access were also detected and forwarded to command center. This design has achieved the effectiveness in road traffic safety and travel reliability. The limitations disengaged are the adoption of several technologies in this design will increase the cost of both deployment and support. Moreover, the location of vehicles can be inaccurate when vehicles are moving in high speed or approaching blind spots for GPS.

The IoT applications in transportation reviewed are summarized (Table 2). From those, it can be concluded that the underlie system should at least include the following system units:

Vehicle System: main components of vehicle system are

i) GPS system: This system is mainly responsible for receiving comprehensive information such as location, time and weather from satellites. It is not only a map embedded with resources about major cities and road information, but it also gives a fast and accurate GPS positioning, even if the satellite signal is poor.

ii) Wireless communication system: GPS and RFID data are forwarded to a control center through the Internet. Data will then be displayed on electronic maps of monitoring center to facilitate the management of real-time scheduling.

Station System: The station subsystem generally consists of communication module and control module. The former includes the GPRS receiver, which is responsible for receiving and decoding the transmitted data packets from the monitoring center. The latter is a communication interface module to receive data and display real-time transit vehicle information.

Monitor Center: The collected information is transmitted to the communication equipment through the Internet. Then communication equipment will send the received information to the real-time database system to compare with the data of events. The collaboration of real-time data in the database and GIS technology, the visualization the road traffic information can be integrated for visualization.

Healthcare

Improvement in human health and well-being is the ultimate goal of any economic, technological and social development. The rapid rising and aging of population is one of the macro powers causing great pressure to healthcare systems. A solution to solve the difficulties in accessing to healthcare of people in rural area of developing countries (Rohokale, Prasad, & Prasad, 2011) was implemented. A person registered with the rural healthcare center (RHC) was requested to wear an active RFID sensor to detect any change on the normal parameters. If those parameters exceeded certain values, information would be cooperatively routed to the RHC doctor. In an environment without the Internet, the mobile network facility could be utilized to convey the information. This approach is proven to be a reliable critical healthcare application that continuously monitors and controls health parameters of human.

The other approach was the integration of clinical devices in the patient's environment (Jara, Zamora, & Skarmeta, 2012) which allowed user to use a mobile phone to transmit health data to medical centers. A home gateway was located at the patient's house to connect to the Internet while the mobile personal health device acted as an integration of medical devices from different vendors. The system continuously analyzed the vital signs from the patient to detect anomalies. The noticeable flaw of the system is the security threats and attacks in the mobile network, although GSM has adopted an encryption as protection mechanism but as it is wide-spread in nature, interception of information transmitted is possible.

A "non-contact health monitoring system (NCHMS)" (N. Yang, Zhao, & Zhang, 2012) was another choice of IoT healthcare service which is more convenient to users. The system monitored the user's facial expressions, postures, and sounds. The monitoring system collected users' data through digital cameras, microphones, and other equipment .The feature extraction, expression recognition, and classification were performed at the server. The variations in user's facial expressions, postures, and sounds were used as identifications to classify if users were in danger or having diseases. If any of these parameters changed, the system determines the necessary treatment, reminds the user and notifies the hospital and related persons. The system demonstrated promising strength in term of ease-of-use. But the adoption of camera as collector device can cause difficulties in actively synthesizing images for transmission as well as the angle of images captured. As for microphone, the recognition of voice could also be suffered from the clamor in the environment. Another serious drawback is the machine learning technique, normally involved with time-complexity in the analysis of the large volume of learning data set.

The IoT applications in healthcare reviewed are summarized (Table 3). In a nutshell, solutions for Healthcare should at least underlie the following capabilities:

Tracking and monitoring: All patients shall be tracked and monitored with any wearable WSN devices at all time regarding that sensors can effectively generate health signal in an enhancement with the communication capacity.

Remote service: Telemedicine and remote diagnosis are necessary to provide emergency detection and first aids for patients with congenital disease.

Information management: Information regarding health such as medication, therapy, and advices for patients should be distributed through the value chain.

Cross-organization integration: The integration of hospital information systems (HISs) shall be extended to patient homes and other hospital chains.

Environment and Disaster

At present, natural and accidental disasters are taking place more frequent. To lessen the effects of natural disasters, technologies in IoT could play a crucial role in alerting before disasters happen, and in disaster recovery after they end.

A heritage site monitoring system, namely "Health Monitoring and Risk Evaluation of Earthen Sites (HMRE2S)" model (Xiao et al., 2013) was conducted to monitor the environmental information of cultural sites. The environment information such as temperature, humidity, and light were collected via intelligent monitoring system. This experiment was claimed to provide accurate results but generalization for other sites may not be applicable since it was explored on a small heritage land. For larger cultural sites, the accuracy remains questionable.

Another contribution to global warming is the smart environment which increasingly attracted interest from the society. A smart heat and electricity management system (Kyriazis, Varvarigou, Rossi, White, & Cooper, 2013) was presented to monitor real-time electricity usage of the buildings and individual appliances where smart meters were used as data recorders. When the power consumption of those objects was above the limit, users would be promptly informed of such deformed situation.

Considering disaster, a waste from oil depot can cause terrible disaster to the environment because it is easy to get ablaze and burst. A surveillance system for safety management of oil depot was introduced in China (Du, Mao, & Lu, 2012). The sensing layer of the system consisted of RFID tags and non-explosive PDAs to identify and interact with the key facilities in the oil depot. 3G was used as the communication layer to forward the data from the worksite to the Internet, where users accessed the safety management information via enterprise intranet. This IoT based safety management information system was proven to be stable since it was actually deployed in 2 oil depots with 24 PDAs and 100 RFID tags.

The IoT applications in environment/disaster reviewed are summarized (Table 4). The conclusion can be drawn that the prime features of solutions should meagerly be equipped with following features:

Environment sensors: Intelligent sensors for the humidity, temperature and pressure in the air, and other natural calamities will serve as front-end devices to gather as well as process contextual information from environment. The built-in fault detection and diagnostic capability is also actuated through the convergence of global industrial system.

WSN and mobile communication: The sensor nodes will be utilized for providing senses without users' intervention. The wireless network of sensor nodes would help sense the environment and objects around and communicate to the other things. Essential pillars are WSN and advanced mobile communication technology (3G and 4G) which can provide uninterruptable high-speed communication.

Participatory sensing applications: The utilization of each person mobile phone, vehicle and associated sensors as automatic sensory stations can help capturing a multi-sensor snapshot of the immediate environment. By combining these individual snapshots in an intelligent manner, it is possible to create a clear picture of the physical world that can be shared and, for example; used as an input to the smart environment services decision processes.

Discussion on IoT in Applications

Under the vision of IoT, applications can be fully automated by configuring themselves when exposed to a new environment. The intelligence behavior driven by the system can autonomously be triggered to seamlessly cope with unforeseen situations. However the applications in the above domains can deliver more analytical results if the following hindrances are properly taken care of.

Apparently, the major players of collector in the above application domains are RFIDs and GPS. RFID is one of the most convenient devices to transmit and receive data via radio frequency without wires at the lowest cost. Some RFID devices can only be used within the industry due to the range of electromagnetic spectrum (Coetzee & Eksteen, 2011). A clear disadvantage of its technology is the reader collision which may occur when the signals from two or more readers overlap or many tags are present in a small area. Although many systems use an anti-collision protocol to enable the tags to take turns in transmitting to a reader, this problem remains. Another strong barricade is the global standards of RFIDs are not yet established (Haiying et al., 2012).

As for GPS, it is recognized as an excellent tool for data collection in many environments where users can generally see the sky and are able to get close to the objects to be mapped. GPS requires a clear line-of-sight between the receiver's antenna and several orbiting satellites. Anything hedging the antenna from a satellite can potentially weaken the signal to such a degree that it becomes too difficult to achieve reliable positioning. An obstruction like buildings, trees, crossways, and other obstructions that block sunlight can effectively block GPS signals where its potentiality could be seriously reduced (Guo, Poling, & Poppe; Vermesan & Friess, 2013).

Since the communication infrastructure of IoT can be any network available within the range. Hence mobile ad-hoc network, which allows people and devices to seamlessly form network in areas without pre-existing communication infrastructure seems to be a better choice (Bakht). The more convenience, the more applications and the more network services it supports, the more opportunities for active attackers as well as malicious or misbehaving nodes to create hostile attacks. These types of attack can seriously damage basic functions of security, such as integrity, confidentiality and privacy of the node. Currently, the security goal in mobile ad-hoc networks can only be achieved through cryptographic mechanisms. These mechanisms are generally more fragile to physical security threats than fixed wired networks. Besides, standardized communication interfaces and distributed control intelligence within an industry network remain disorganized (Lo´pez, Ranasinghe, Harrison, & McFarlane, 2012).

As far as IoT dealing with more objects, the volume of the data generated and the processes involved in the handling of those data become critical. The ability to extract content from the data becomes even more crucial and complex, especially when dealing with big data. Variety of technologies and factors involved in the data management of IoT such as data collection and analysis, data migration and integrity, sensor networks, and complex event processing are not yet convinced (Vermesan & Friess, 2013).

Advancement and Hindrances in IoT

The realization of the advancement in IoT indicates sustainable applications forming a smart environment for humans where plurality of challenges can be raised.

The first challenge was driven by embedding intelligence into things. To enable things and devices to learn and become smarter, more autonomous things are required to share and exchange experiences with other things.

The second challenge refers to the management of heterogeneous device platforms in a decentralized way. To make relationship with other devices, those platforms shall arrange the device coordinators via their social-behavior. Furthermore, pertinent issues with respect to end-to-end security, privacy and trust are also need to be addressed.

Moreover, a lot of techniques are required within and across different levels of IoT-based systems, for example; hardware-coded security at the device level, security and privacy in storage at the data level. Reputation, trust and privacy profiling of things and providers are also techniques to prevent information inference.

The third challenge refers to the support for scalable data and information management through rich metadata structures that capture the social aspects of things. Real-time analysis of data will generate the potentially valuable knowledge from the information flows of exponential amount of data.

However, there are other significant challenges which introduce a wide gap between technology and applications in business in IoT which cannot be neglect such as:

Unappealing initial investment: This is a primary hindrance of mass volume adoption. For example, when suppliers want to adopt RFIDs for tracking of goods, the initial investment cost is unacceptable for business. Besides, users do not yet trust for the services provided by the IoT application vendors as experienced from a huge failure initiated from the deployment of IoT Google Heath System (Wamba & Chatfield, 2010).

Unavailable devices and service integration: Even though there are a lot of promising technology available for IoT applications but there are very few services which can be integrated. Users need to contact several vendors if they want to deploy a complete system. Therefore, an assimilated system design framework is crucial to integrate scatter subsystems and devices for more valuable services (Lee et al., 2010).

Forwarding IoT

For the sake of IoT to achieve its vision, a number of challenges needed to overcome. These challenges range from standardization, communication, and security to data volume (Coetzee & Eksteen, 2011; Vermesan & Friess, 2013).

***Standardization*:**

There are numerous efforts towards the standardization in several principal areas such as RFIDs, EPCglobal, M2M as well as applications. Since standards are required to allow global interoperability to change this "Intranet of Things" into the more complete "Internet of Things" (Vermesan & Friess, 2013).

The integrated environment is the origin of the success to run multiplicity of user driven applications and connect various sensors and objects. Complex and interconnected IoT applications can immensely be supported by open APIs at various system levels (Agrawal & Vieira, 2013). On one side, the vertical solutions of vendors based on their own technologies are not ready. On the other side, a dynamic global network infrastructure requires self configuring capabilities. Appropriate channels shall be provided for developers to deliver new applications and combine information generated by several IoT devices to produce new added value. Interoperable protocol is also a powerful communication tool in providing access to information, media and services to synergize the open, global network connecting people, data, and things.

Communication Infrastructure

Things generated by devices can join networks and facilitate peer-to-peer communication for specialized purposes. They can increase robustness of communications channels and networks by forming ad-hoc peer-to-peer networks in disaster situations to keep the flow of imperative information going in case of telecommunication infrastructure failures. Therefore, the integrity and stability of the infrastructure is crucial to provide reliable services.

The overall cyber-physical infrastructure (e.g., hardware, connectivity, software development, communications, and specialized processes at the intersection of control and sensing) are considered as the compositionality of cyber-physical systems. The network aspects may consist of Wi-Fi, IP networks and mobile computing. Those can bring stream of technologies such as cloud, things, and mobiles. The convergent of main driven platforms with wired and wireless broadband connections shall strengthen the cloud to connect intelligent things that can sense and transmit huge data to create services. Cloud stimulates a global infrastructure for everyone to create content and applications for global users. Besides, networks of things are globally connected and maintain their identity online. This global infrastructure allows mobile connection to be available for services and businesses at anytime and anywhere leading to a globally accessible network of things, users, and consumers (Agrawal & Vieira, 2013).

Security, Privacy & Trusts:

As technologies and systems are incorporated, security remains a preponderant concern to lower system vulnerability and protect essential data. Regarding that the communication channel in IoT is not only from human to machine but also from machine to machine where the guarantee on the access control, authorization, privacy, and protection from malicious is a prime requirement for IoT acknowledgement.

In regard to its wireless and ubiquitous infrastructure, IoT is vulnerable to lashing malicious attacks. The attacks generally aim to control the physical environments or obtain private data. Thereby, IoT should autonomously tune itself to different levels of security and privacy, while not affecting the quality of service and quality of experience. The security should not only ensure the data stored in the platform but should also cover the transmission of messages from devices (sensors, actuators, etc.). Specific mechanisms to ensure the availability of infrastructure should vindicate the Internet attacks such as Denial of Services and compromised nodes. The most eligible protective action during attacks on IoT-based infrastructure should be more focusing on assisting operators than coping with automatic protection (Uckelmann et al., 2011).

Although most IoT has achieved a security trust through Public Key Infrastructures (PKI), decentralized and self-configuring systems can be considered as alternatives. Not only cryptographic mechanisms are required but technologies such as homomorphic and searchable encryption are also potential candidates for developing such approaches. Besides, more self-managed IoT is wished to serve the heterogeneity and diversity of the devices/gateways. Self-managed IoT may employ machine learning to process and share data without the information content being accessible to others. Technologies of decentralized computing and key management as well as soft identities designed for specific contexts or applications will be more essential to IoT's privacy (Vermesan & Friess, 2013).

Data collection and acquisition:

Data collection from sensors, identification and tracking systems are very crucial for real time processing. There remain several complexities of process involving as well as doubts in standards and filtering techniques.

Data generated by IoT devices from different vendors and different domains usually have different features. In most cases, not all data is significant, thus the identification of smart objects is imperative. In the backend, many more techniques such as new intelligent methods based on semantic technologies and tools for processing and analyzing historical and on-site data with the different qualities are gaining high attraction.

The first level of IoT data manipulation is mainly dealing with decoding data noise where specific filter mechanisms are welcome. Even though automatic identification helps to avoid mistakes from manual data entry, the corresponding data needs to provide a high level of accuracy upon the data quality standards agreed. While the new mechanisms of data aggregation aims to reduce the amount of transmission data and to taper the utilization of energy sensor nodes such as fuzzy-based and evaluation on quality of aggregation remain doubtful (Gubbia et al., 2013).

Big data:

One significant aspect in IoT is the large number of things being connected to the Internet, each one providing data. Mechanisms to store and assure the validity through scalable applications remain a major technological challenge.

Each record of raw RFID data generally contains EPC, location and time is at least 18 bytes long. To extract valuable data from such big data, data mining approach based data management and event processing are indispensable. Not only the data is always massive, distributed, time-related and position-related, it is also heterogeneous, and is distributed on resources with limited capabilities. The fundamental centralized data mining and preprocessing architecture may not be comprehensible to support data stored in different sites. Yet, a multi-layer mining model, distributed data mining model, grid based mining model as well as data mining model from multi-technology integration should be considered as alternatives (Bin, Yuan, & Xiaoyi, 2010).

Although IoT has to overcome huge barriers to gain trust from the societies, it has illustrated the distinguished potential to add a new dimension to the application in logistics, transportation, healthcare, and environment and disaster by enabling communication between smart objects. Therefore, IoT should be considered as a part of future internet that everything can connect in a network where objects can interact with each others. The development towards several issues will make IoT a complete solution. Hence more researches in the application of IoT are imperative. Once successfully implemented, the reduction of human efforts shall benefit the quality of life as well as business.

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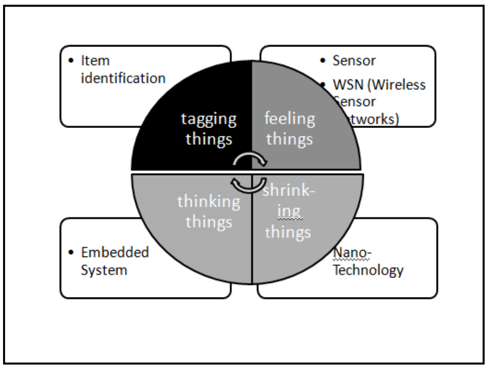

Figure 1 Four dimensions for IoT (ITU)

Table 1 Summary of IOT in Logistic and Supply Chain Management

Application	Technology/Technique	Strengths/Weaknesses
Supermarket chain management (Li & Luo, 2010)	• Tracking of goods in real-time via WSNs • Use mathematical model to track information of goods movement as well as automatically controlled of stock. • Technology: barcodes and RFIDs. • Database employed is a standard relational database.	Strengths • Ease of Implementation Weaknesses • Inefficacy of database technology when handling big data.
Aspire RFID (Soldatos et al., 2010)	• Integration of the EPCglobal based RFID architecture with "Session Initiation Protocol (SIP)". • Technology: RFIDs, SIP. • Use SIP to detect location and mobility management of RFID tags.	Strengths • Reduce problem of limited accessibility of Global IP network. • Low cost consumption of tags registration and tracking. Weaknesses • Accidental procreation of infest traffic from LAN and Internet.
Logistic IOT Unified Information System (UIS) (Wei, 2011)	• Developed on ASP.NET. • Technology: GSM/RFID collection devices and GSM modem. • Data transmitted through Internet/GSM, mobile network.	Strengths • Support both Internet and mobile network. Weaknesses • Incomplete or missing Information from communication distance. • No specific handling for data collision.
Logistic Geographical Information Detection UIS (Lin, 2011)	• Combined capability of RFIDs, mobile devices and browser interface. • Locations of goods are automatically detected from mobile browser. • Technology: GPS, Wi-Fi, GSM, GPRS. • Support various logistic mobile devices • Can operate without any extra positioning devices, only loT mobile terminals is sufficient.	Strengths • High detection accuracy of over 97% for moving entities and 100% for still entities. • Provide several source of location detection mechanism. Weaknesses • Location detection mainly depends on mobile browser. • Support for variety of logistic mobile devices is questionable.
A Logistic Mobile Application (ALMA) (El-Baz et al., 2013)	• Technology: smart phone, 3G, HPC. • Support variety of applications. • Operate on P2P based computing. • Large-scale server based.	Strengths • High performance. Weaknesses • Not suitable for small organization.

Application	Technology/Technique	Strengths/Weaknesses
		• Limitation of 3G connection in some areas.
Robot navigation and object manipulation (Wang et al., 2013)	• Enable robots to perform more complex tasks in collaboration with other robots. • Technology: RF-compass, low-cost RFIDs, infrared motion capture system or computer vision. • Machine learning based algorithms	Strengths • Accuracy of 80-90% for grasping object. • Low computation time in comparison with standard machine learning algorithms. Weaknesses • No evidence on non-straight line of sight of robots. • Unproven record for handling small particles.

Table 2 Summary of IOT in Transportation

Application	Technology/Technique	Strengths/Weaknesses
Road Condition Monitoring and Alert system (Ghose et al., 2012)	• Crowd Sourcing and participatory sensing based application. • Technology: accelerometer, smart phone, GPS(future). • Classifier based algorithm. • When a route is chosen, a confidence score for the area marked and the pothole information will be plotted on mobile.	Strengths • Reduce cost by using smart phone as a connector device. Weaknesses • Many upload and download of GIS data can induce network traffic • Ease of security attack. • Time consuming of classification.
License plate Identification(Ren et al., 2012)	• Use license plate as unique identifier. • Locate optimal path and guiding passage for vehicles. • Automatically Invoke traffic scheduling, vehicle positioning, and vehicle query. • Technology: RFID, recognition equipment.	Strengths • Automatically suggest optimal path, locating of parking space and adding security for vehicles. Weaknesses • High cost and difficulties in implementation.
Remote performance monitoring system and simulation testing (Haiying et al., 2012)	• Monitor the status of Lithium-ion power battery of electric vehicle. • A simulation of identified route for bus drivers. • A performance testing of battery pack, battery modules and battery systems. • Technology: GPS, RFID.	Strengths • Online debugging and error correction can significantly reduce the maintenance cost. Weaknesses • no support for age tracking and end-of-life predictions of battery
transport vehicle monitoring system based on IoT (Shengguang et al., 2013)	• Real-time administration of the entire fleet from the command center. • Technology: GPS, RFID, 3G. • Monitor status of goods through RFID tags attached to goods. • Combine various capabilities of technologies: vehicle electronic sensors, mobile communication technology, navigation systems, smart terminal equipment and the information network.	Strengths • Effective road traffic both safety and reliability. Weaknesses • High cost implementation • Weak signal when vehicles are moving in high speed or approaching blind spots for GPS

Table 3 Summary of IOT in Healthcare

Application	Technology/Technique	Strengths/Weaknesses
Rural Healthcare Monitoring and Control system(Rohokale et al., 2011)	• Based on Opportunistic Large Array (OLA) utilizes the cooperative transmission of the ad-hoc network nodes. • Technology: RFID, Internet, mobile network. • Data will be routed via internet to the gateway through RHC doctor. • Basic data of patient will be stored in server for comparison.	Strengths • Provide options for both Internet and mobile network. Weaknesses • Interception of information transmitted. • High computation cost for patient parameter comparison.
a knowledge acquisition and management platform (Jara et al., 2012)	• An integration of a home gateway and a global connectivity to support other medical devices. • Technology: EPR, Pro-active monitoring and alerting, Remote diagnosis and, RS232 and Bluetooth Health Device Profile (HDP) etc. • The system continuously analyses the vital signs from the patient to detect anomalies.	Strengths • Offers a function of plug and play. Weaknesses • Reduction in performance of input devices when compared with others such as Serial Port Profile.
non-contact health monitoring system (NCHMS)(N. Yang et al., 2012)	• Analyze the user's facial expressions, postures and sounds as input data. • Technology: camera, microphones and other equipment. • Classification and recognition based algorithm.	Strengths • Convenient to users. Weaknesses • Time consuming and threshold dependable. • Cost complexity of input devices.

Table 4 Summary of IOT in Environment and Disaster

Application	Technology/Technique	Strengths/Weaknesses
Safety management information system for oil depot (Du et al., 2012)	• Technology: RFID, explosion-proof PDAs, 3G. • IoT technology is adopted to monitor the process of the routine works. • Software adopted: Oracle for storing business data, others are encapsulated as web service for reuse.	Strengths • Proven record in real depot sites. Weaknesses • -
Health Monitoring and Risk Evaluation of Earthen Sites (HMRE2S) (Xiao et al., 2013)	• Evaluate healthy level of the earthen sites by applying the concept of artificial antibodies to identify unusual environmental factors. • Technology: intelligent environment monitoring system which collects temperature, humidity, light, etc.	Strengths • Self detection based on immune system. Weaknesses • Result is unlikely to be generalized to large heritage sites.
Smart heat and electricity management transportation (Kyriazis et al., 2013)	• Real-time electricity usage on the energy consumption of buildings and individual appliances. • Technology: smart meters for electricity consumption and mobile sensors.	Strengths • Application of available devices. Weaknesses. • Not applicable yet.