Emerging Applications Perspective for Internet of Things

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ABSTRACT
Internet of Things (IoT) is the interconnection of smart physical objects which have Internet connectivity, enabling them to collect data and interact with other devices. It is an evolving technology, which will revolutionize the way we interact with homes, offices, factories, farms, retailing, transportation, logistics etc. In essence, IoT is bound to change how we interact with the physical objects in our surroundings. Technologies like Wireless Sensor Networks and Radio-Frequency Identification are paving the way for the development of this concept. This paper classifies different application domains with a description of some emerging projects and applications in each domain along with the tools which have been used for the same. Next, the challenges and issues in the adoption of IoT have also been conferred.

Categories and Subject Descriptors
•**General and reference~Surveys and overviews**
• *Networks~Sensor networks* • *Networks~Wireless local area networks* • *Networks~Wireless personal area networks*
• *Human-centered computing~Ubiquitous and mobile computing*
• Applied computing~Computers in other domains

General Terms
Management, Measurement, Documentation, Design, Reliability, Security, Human Factors, Standardization, Theory.

Keywords
Application Domains, Internet of Things, Ubiquitous Computing, Pervasive Computing, Wireless Sensor Networks.

1. INTRODUCTION
The next big thing in the near future will be the extensive implementation of Internet of Things (IoT). The concept is gaining momentum very expeditiously and a lot of projects have been going on to make the aforementioned statement a reality. IoT's competency to communicate with physical objects and to take intelligent decisions has made its potential grand.

The future in IoT was envisioned by Mark Weiser in the early 1990s and the concept has had various names such as- Ubiquitous Computing, Pervasive Computing, and Ambient Computing. It was in 1999 when the term 'Internet of Things' was first coined by Kevin Ashton.

IoT has the ability to accumulate, analyze, and distribute data that can be transformed into useful information, knowledge and eventually wisdom.Before discussing the applications of IoT, it is consequential to understand the same in a better way. Albeit research in this area has been going on for more than a decade, the definition of IoT still remains fuzzy. Hence, addressing this challenge, let us consider a few definitions from some sources followed by a simplified definition.

According to European Research Cluster (IERC), IoT is: *"*A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual "things" have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network*."*[1]

Internet Engineering Task Force (IETF) describes IoT as: "The basic idea is that IoT will connect objects around us (electronic, electrical, and non-electrical) to provide seamless communication and contextual services provided by them. Development of RFID tags, sensors, actuators, mobile phones make it possible to materialize IoT which interact and co-operate each other to make the service better and accessible anytime, from anywhere."[2].

In a lucid way, IoT can be defined as: "It is an interconnection of uniquely identifiable physical objects which are smart due to the inclusion of sensors and actuators. They are connected to the Internet through interoperable standard protocols so they are always available wherever it is essential and whenever it is needed, simplifying the life of the user. This system features self-configurational ability and programmability making it dynamic."

The structure of the paper is as follows: Section 2 confers the application domains and present cases of some current projects working towards developing smart applications. Section 3 discusses the hurdles in the adoption of IoT. Finally, the paper is concluded in Section 4.

2. APPLICATION DOMAINS
IoT has a myriad of applications in every field. It is set to transform every sector and so we have broadly classified them into eight categories- home and building, transport, logistics, industrial control, retail, environment, agriculture, and health (see figure 1). Uses in the home could be like automation of daily tasks, security monitoring, locating day to day items, etc. Factory managers can be aided by easy monitoring of material flow, downtime analysis, and production efficiency. Farmers can automate the irrigation process and manage operations remotely.

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2.1 Smart Homes

The increasing popularity of mobile computing devices combined with the need of automating the mundane tasks have ensured that the consumers use portable controllers to control different appliances connected to a network.

In this context, many companies have been working towards making smart home systems. 'OOMI' is one such initiative [3]. It provides Home Security, Entertainment, Comfort, and Ambiance. It is built with the next generation of Z-Wave [4] and allows easy integration with other 3rd party devices too. Moreover, the system works even when the Internet is down as the decision-making base station is located within the house-'Oomi Cube', instead of relying on cloud-based services. The list of smart devices include: Oomi- Touch (controller), Cube (hub), Cam (intrusion alarm system), MultiSensor (multiple sensors comprising unit for detecting motion, temperature etc.), bulbs, lighting strips, plug, sensors for door and windows, water sensors, Streamer (a multimedia device for T.V.) and Air (monitors air contamination).

Another prominent name in this initiative is of Nest [5], a subsidiary of Alphabet Inc. It has introduced three products. First is the Smart Thermostat which has heating and cooling system, which sends alerts to the phone and features smart learning, making it possible for the device to automatically adapt to the user's lifestyle. Second is Nest Cam which streams every detail from the camera to the phone, intimates when something is wrong, makes monitoring in dark better with night vision sensors, allows the user to talk and listen through mic and speaker. The last one is smoke and carbon monoxide detector which detects both fast and slow burning fires with split-spectrum sensors. All these devices are interconnected by a smart home hub called 'works with nest' [6] acquired by Nest from revolv.

2.2 Transportation

With age, the structural health of transport infrastructures - roads, bridges, flyovers, tunnels, subways deteriorates leading to collapse. Further, poorly lit roads and their potholes result in grave accidents. To illustrate this, it would be appropriate to quote the example of the interstate highway bridge in Minneapolis that took the life of 13 people, leaving 145 others injured. A year later in 2008, the bridge was reconstructed with a system having sensors for monitoring its structural health.

Deployment of sensors, actuators and networking capabilities to transport infrastructures will aid in creating intelligent applications making the system more organized, stable and hence safe. In this discourse, a concept called Internet of Vehicles (IoV) [7] can also be brought into the picture, raising a host of new features and functionalities. "IoV technology refers to dynamic mobile communication systems that communicate between vehicles and public networks using V2V (vehicle-to-vehicle), V2R (vehicle-to-road), V2H (vehicle-to-human) and V2S (vehicle-to-sensor) interactions. It enables information sharing and the gathering of information on vehicles, roads, and their surroundings". [7]

Solar Roadways, an indiegogo project [8] plans to replace roads, pavements, and other outdoor flooring with smart hexagonal solar panels comprising microprocessors, LEDs and data lines [9]. The asphalt/concrete surfaces will be replaced by tempered glass made by recycling and capable of load and traction requirements. These smart roadways will keep the surface temperature few degrees above the freezing point, making it ice-free during snowfall. Further, each panel has a series of LEDs which are programmable and can be used to re-define parking lines, road lanes, desired playground layout and give warning signs. It can warn about impaired driving patterns, pedestrians and animals crossing the road and the road lights up at night improving night visibility.

The system recommends detours around traffic congestion and arrows can appear on the road for guidance once the destination is entered on the GPS device. Another fascinating feature is its capability to carry data lines using leaky cables alongside the roadways, virtually eliminating dead spots and need for cell towers.Another similar project is Smart Highway by designer Daan Roosegaarde and Heijmans Infrastructure, featuring - Electric Priority Lane, Glowing Lines, Interactive Lights [10].

2.2.2 Parking Management

The city of Santander in Spain serves as an excellent example for Internet-connected parking management [11]. A wireless sensor network [WSN] is deployed in the city with ferromagnetic sensor nodes under each bay. These nodes collect parking occupancy data, which is promptly forwarded to the drivers and traffic regulating author through the Internet. Moreover, display panels are setup at the street intersections which display information about empty parking lots. To this, a parking history feature can be added for analysis by the authorities, which could help in determining parking provisions in the city. Further, to tackle traffic congestion; vehicles and pedestrian levels are monitored, thereby suggesting optimal routes for driving and walking.

2.3 Logistics

With the inception of IoT in the field of logistics, myriad promising payoffs would be brought to logistics operators, their business collaborators, and the end users. These would be across freight transportation, value chains, warehouse operations, and last mile delivery. Moreover, assets along the supply chain could be analyzed to greater detail and new insights could be captured. This would lead to improved operational efficiency, flexibility and will eventually aid in automating the facilities. Accurate details about the real-time location of the package, the condition of the package, and estimated delivery time would be quotidian. Again, being connected to smart roads, information about road blockages and traffic statistics would be available beforehand, along with suggestions for the shortest route to the destination.

Taking the case of last mile delivery, IoT can help enhance the collection of parcels or letters from the mailboxes. Postybell is an example of such a mailbox, which has a sensor installed, and sends real-time data to the delivery person [12]. Thus, the person will only have to visit the boxes which have parcels/letters, resulting in optimization of collection time.

Another example is having the product related information such as relevant life cycle data stored digitally on the product using RFID tag. SemProM-Semantic Product Memory project [13] has created Smart Labels for products, which can store related information over the product's lifecycle. For instance, transport related information can be stored in the product memory and the logistics company can then take appropriate care while handling.

2.4 Smart Industry

Unprecedented developmental prospects and innovation are all set to be unleashed by the Industrial Internet of Things (IIoT). According to Accenture, IIoT has the capacity to add $14.2 trillion to the global economy by 2030 [14]. IoT is now shifting the earlier proprietary communication standards to open IP standards at production floors. It is also facilitating the managers with real-time monitoring of the factory performance data such as energy consumption, route for material flow, inventory status etc.

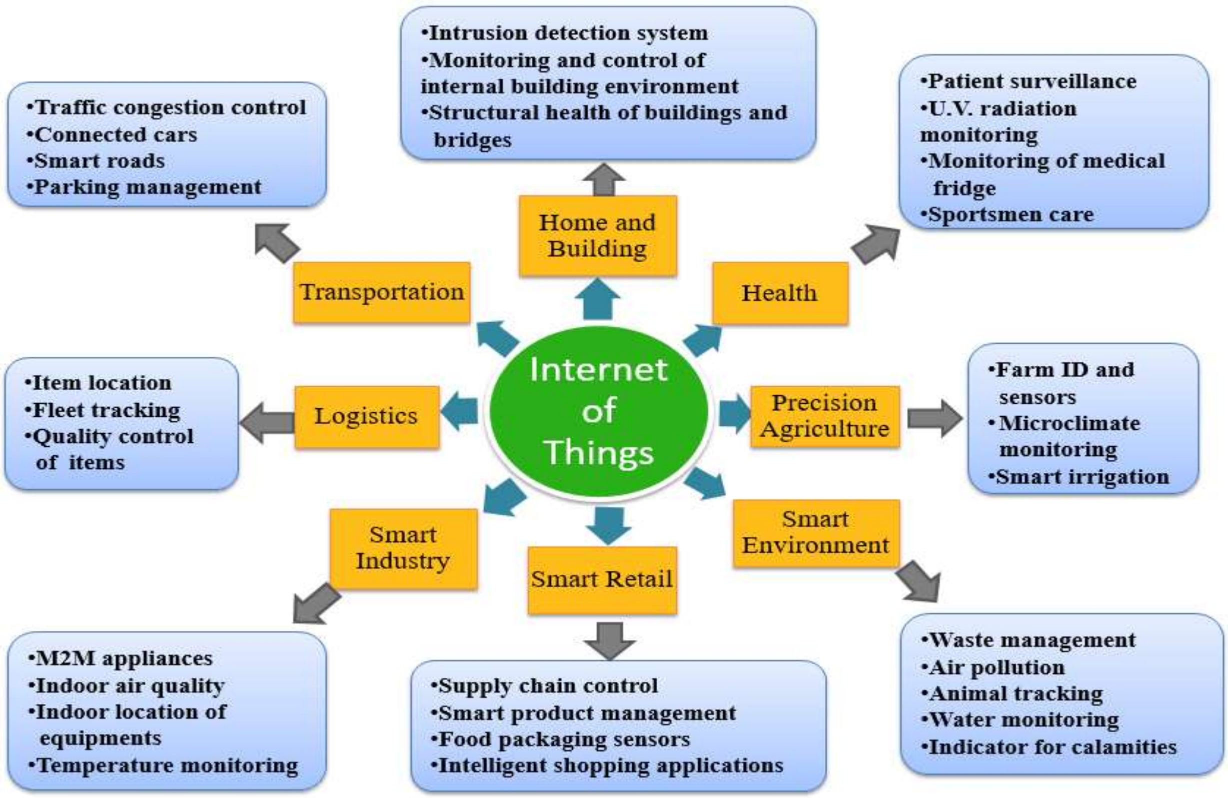

Figure 1. Application Domains of IoT

Applications most pertinent to IIoT aim at boosting revenues. This is achieved by enhancing the operational efficiency, which can further be realized by having smart devices sense relevant parameters and then communicate performance status that can be used accordingly. Monitoring can happen at various levels such as level of a chemical in tanks, indoor air quality, temperature, ozone presence (in food factories), equipment wear and tear etc., all leading to improvement in equipment lifespan and enhancing process visibility. With such information, equipment failures can be prevented and ultimately the downtime of machines can be reduced. Furthermore, the equipment is installed in an intricate fashion in the factory, and, therefore, locating a faulty equipment could be a time-consuming task. Hence easy location identification can be achieved by active (ZigBee [15], Ultra-Wideband [16]) and passive (RFID, Near Field Communications [17]) tagging.

One major area of IoT application in the industry is Preventive Maintenance (PM). PM has a vital role to play in production industries. Moreover, sensors can be employed to alert whenever the equipment performance exceeds the safety limits. Continental Tires, serves as an example, whereby they reduced their waste component costs and increased their production efficiency, by implementing this concept of connected production floor [18].

2.5 Retail

Having interactions with a large population of technology patrons, the retail sector needs to stay abreast with modern technologies to win the fidelity of the tech savvy generation. IoT promises to bring about a change in the following areas in retail: (1) Supply chain management, (2) Inventory and warehouse management, (3) Marketing, (4) in-store experience. This has been made possible through Radio Frequency Identification enabled sensors on products [19], automated shelves [20], consumable goods monitoring, fleet assignment tracking, automated store lighting, tailored marketing by proximity-based consumer interaction in the corridor, parking aid, fraud and counterfeiting controls, automatic checkouts through mobile phones, automated vending machines, connected homes, etc. A wholesome retail experience has been the main target which includes location based services, reminding the customer of the latest trends and offers in the market as and when the customer passes by it, updating the inventory according to the trends in the area, assisting customers, and increasing sales [21].

2.6 Smart Environment

An intelligent environment monitoring system using IoT can be used to predict natural calamities, collect information on temperature, humidity, light, wind, rainfall, etc. The extensive implementation of miniature devices has allowed access to remote areas where human presence might not be feasible.

With the better living standards, the amount of domestic waste is increasing swiftly. IoT can also be implemented for tracking and monitoring of waste sources, transport vehicles, waste disposal sites, etc. [22].

Fire detection is yet another case in which IoT can be efficacious. The detection of afire by the array of sensors (temperature, smoke or dust sensors) sets off alerts to the fire department in a moment about parameters such as details of the region caught under fire, presence/absence of people and of the combustible substances nearby, etc. [23].

With the upsurge of development in the nuclear sector, the necessity for affordable radiation meters arises. One such initiative is the Radiation Sensor Board for Arduino by Libelium, which can measure levels of radiation in everyday life and can be used directly by the citizens. It has open hardware design and publicly available source code [24].

As a part of smart city initiative, Opticits [25], a Barcelona startup created and deployed a 'City Resilience Management' platform that integrates Libelium's 'Waspmote Plug and Sense' sensor nodes [26], and 'Meshlium gateways' [27]. It helps resist and recover from natural disasters [28].

2.7 Precision Agriculture

Precision Agriculture is a method of agriculture wherein technology is employed to obtain accurate land and crop data for timely analysis. By using technology such as Geographic Information System (GIS) [29], Remote Sensing (RS), Global Positioning System (GPS), numerous parameters can be measured and monitored, helping farmers to make the right decision. This will result in increased production, economic benefit and mitigate environmental impact caused by traditional practices. The areas of application include tracking farm vehicles, livestock monitoring, indoor farming, fish farming, monitoring of water tanks, fuel tanks, and storage house.

An IoT and WebGIS [30] based Precision Agriculture Management System (PAMS) was implemented at Hunan, China in an ecology farm [31]. In this, a farmer can post real-time data such as images and environmental conditions through the mobile client of PAMS, which is analyzed and relevant recommendations are given to the farmer.

Other features include video monitoring of the farm, production management, remote operation and information publishing with feedback. PAMS has aided in reducing monitoring time of the farmer and also the results indicated better growth of plants. Hardware and network architectures, along with software tools used in IoT-based precision irrigation systems, which has been practically implemented and discussed in [32].

Dolphin Engineering [33], a firm in Switzerland has developed a 'PreDiVine' system which is a Decision Support System (DSS) monitoring microclimate conditions such as leaf wetness, rainfall, humidity, temperature. Moreover, it predicts the span of grapevine pests and diseases. The firm implements these functionalities using a WSN based on Libelium's 'Waspmote' sensor platform [34]. Another advantage that it offers is the timely corrective treatment suggestions, needed to keep vineyards in good health and generate more profit. Also, an adaptive web-based management framework makes the system dynamic.

2.8 Health

Human health is of utmost importance when it comes to survival. IoT technologies can be implemented to improve the assisted living conditions and monitor conditions like body temperature, breathing rate, blood pressure, pulse rate, blood sugar, etc. [35]. People with disabilities who have to overly depend on others for living their normal life can be helped by the implementation of IoT. A comprehensive approach on how to aid people with disabilities is discussed in [36].

Information can be collected locally through wearable or ambient sensors. This information can be transmitted to remote medical centers which can monitor the conditions and provide a response when needed. This has been attempted through telemedicine, mHealth [37], Home Health Hub Internet of Things (H3IoT), [38] etc. Wearable sensors can also be used to monitor daily activities to provide personalized health care solutions for better lifestyle and prevention of health problems [39].

To promote developers, Broadcom brings in another smart invention-WICED (Wireless Internet Connectivity for Embedded Devices) [40]. It is a smart development kit with low power Bluetooth Smart, and five MEMS sensors for easy and quick prototyping. It is a cost effective and setsup in about five minutes, enabling devices to team with portable technology like mobile phones. They, in turn, connect to the Internet to transmit and receive data from cloud-based applications. It has a great potential in wearable technology, especially in health and personal care. It facilitates users to constantly monitor and control heart rate, blood glucose and other health parameters from their phones. This information can be uploaded to the cloud in real time so that the data from a single sensor can be accessed by any device at any time.

3. CHALLENGES IN ADOPTION OF IOT

IoT being an interdisciplinary research area requires close collaboration among application domain veterans, developers, designers, and users. Hence, in spite of having a slew of useful applications, there are issues and challenges which have to be addressed before IoT can be brought into implementation ubiquitously.

3.1 Interoperability of Technologies

As each class of smart devices uses different technology, it becomes difficult to ensure compatibility among devices and services. So it is of prime importance that provisions are made to make devices from different manufacturers, operating on varied protocols and technologies, interact easily [41] [42].

3.2 Bulk Data

Implementation of IoT will require intricate algorithms to manage the sheer amount of collected data, and to deliver useful information from it. Further, generating valuable information in a timely and pertinent way makes the task even more challenging.

3.3 Protection of Information

With the advent of IoT, a tremendous amount of data will be collected thereby raising a concern for data privacy and security. With automation stepping in all spheres of life, human intervention is decreasing leading to greater chances of unauthorized use and criminal attacks [43].

3.4 Bandwidth Management

As the amount of data increases rapidly, the current bandwidth capabilities will be insufficient for the transfer of increasing amount of data. This will lead to the need of distributed data centers at multiple locations.

3.5 Distribution of Data Centers

The current data center links for the Wide Area Networks having moderate bandwidths will be insufficient for the transfer of increasing amount of data as IoT escalates. This will lead to the need for distributed data centers at multiple locations, as keeping it at a single location will not be economically feasible.

3.6 Universal Implementation of IPv6

The growth of IoT and Machine to Machine (M2M) [44] technologies will lead to an extremely large demand of addressing space, which the IPv4 will not be able to support [45]. Therefore, universal deployment of IPv6 will be required.

3.7 Low-profit margin and acceptance rate

Due to low- profit margin and difficulty in understanding the sophisticated technology, investments in innovation and easy adoption suffers in some sectors such as in precision agriculture.

4. CONCLUSION

Sensors, actuators, and networks have been in existence for long now, but with the onset of IoT, a common platform could be made to incorporate all of them into a single smart unit for smart applications. The premier goal of these applications is to keep fore the needs of the end user. It can be achieved by designing simpler mechanisms for using smart devices, making hardware and software knowledge available to all, setting up multidisciplinary projects, spreading awareness about the perks of the technology and by stimulating standardization. The applications of IoT are spread over a variety of sectors affecting different groups of individuals. Individual challenges in applications do exist which revolve around bottlenecks such as ubiquitous Internet access, requisite apps/OS in devices, Bluetooth & location services always enabled, loyal customer base, and allocation of funds by the government for upgrading infrastructure. Apart from eliminating these bottlenecks, the main challenge lies in developing a common platform which integrates all sectors of applications along with providing the necessary solitariness.

To conclude, a comparative analysis of emerging applications in the field of IoT as per the worldwide google web search trends [46] is shown in figure 2. The number against each item indicates its average popularity which is calculated by taking the average of interest over the period - February 2015 to January 2016.

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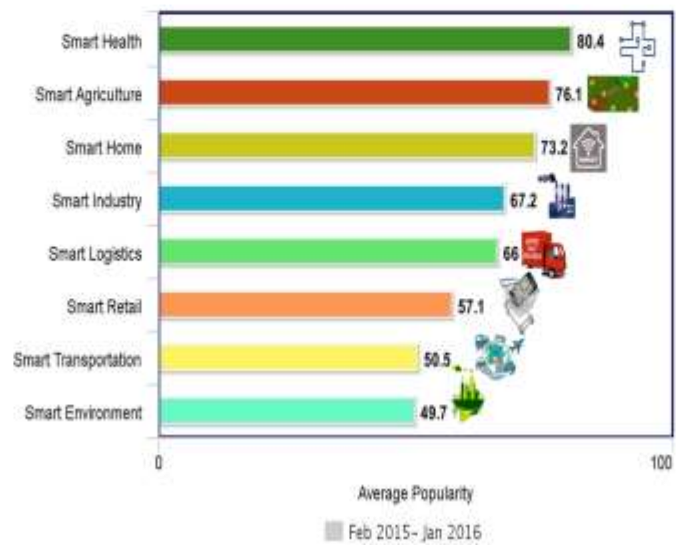

Figure 2. Trends in Applications of IoT