International Journal For Technological Research In Engineering
Volume 5, Issue 10, June-2018 ISSN (Online): 2347 - 4718

INTERNET OF THINGS: RESEARCH CHALLENGES AND FUTURE DIRECTIONS

Prashantkumar P. Oza[1], Dipesh Kamdar[2]
Department of Electronics and Communication
LDRP-Institute of Technology and Research, Gandhinagar, Gujarat-INDIA

Abstract: Ubiquitous sensing enabled by Wireless Sensor Network (WSN) technologies cuts across many areas of modern day living. This offers the ability to measure, infer and understand environmental indicators, from delicate ecologies and natural resources to urban environments. The proliferation of these devices in a communicating actuating network creates the Internet of Things (IoT), wherein sensors and actuators blend seamlessly with the environment around us, and the information is shared across platforms in order to develop a common operating picture (COP). To provide a basis for discussing open research problems in IoT, a vision for how IoT could change the world in the distant future is first presented. Then, eight key research topics are enumerated and research problems within those topics are discussed. Internet of Things envisions a future in which digital and physical entities can be linked, by means of appropriate information and communication technologies, to enable a whole new class of applications and services. In this article, we present a survey of technologies, applications and research challenges for Internet of Things.
Keyword: Cyber Physical Systems, Internet of Things, Mobile Computing, Pervasive Computing, Wireless Sensor Networks.

I. INTRODUCTION

The next wave in the era of computing will be outside the realm of the traditional desktop. In the Internet of Things (IoT) paradigm, many of the objects that surround us will be on the network in one form or another. Radio Frequency IDentification (RFID) and sensor network technologies will rise to meet this new challenge, in which information and communication systems are invisibly embedded in the environment around us. This results in the generation of enormous amounts of data which have to be stored, processed and presented in a seamless, efficient, and easily interpretable form. This model will consist of services that are commodities and delivered in a manner similar to traditional commodities.

Over last twenty years innovative information technologies have wrought significant change in human civilization For example, imagine that you were to give a speech in another city which is normally one hour away from where you live. Unfortunately, there was a traffic jam on the highway and you were expected to be late. If this happened 20 years ago, there was literally no way you can communicate the news to your audience. Nowadays, if you get stuck on the highway, you can simply use your cell phone to tell your audience. This is because cell phones and telecommunication service are affordable and available to almost everyone. Question: can technologies do better?

The term Internet of Things was first coined by Kevin Ashton in 1999 in the context of supply chain management [1]. However, in the past decade, the definition has been more inclusive covering wide range of applications like healthcare, utilities, transport, etc. [2]. Although the definition of Things has changed as technology evolved, the main goal of making a computer sense information without the aid of human intervention remains the same. A radical evolution of the current Internet into a Network of interconnected objects that not only harvests information from the environment (sensing) and interacts with the physical world (actuation/command/control), but also uses existing Internet standards to provide services for information transfer, analytics, applications, and communications. Fueled by the prevalence of devices enabled by open wireless technology such as Bluetooth, radio frequency identification (RFID), Wi-Fi, and telephonic data services as well as embedded sensor and actuator nodes, IoT has stepped out of its infancy and is on the verge of transforming the current static appropriate. Further, research in IoT, PC, MC, WSN and CPS often relies on underlying technologies such as real-time computing, machine learning, security, privacy, signal processing, big data, and others. Consequently, the smart vision of the world involves much of computer science, computer engineering, and electrical engineering. Greater interactions among these communities will speed progress.

II. VISION AND IOT SCOPE

Many people [4], including myself [5][6], hold the view that cities and the world itself will be overlaid with sensing and actuation, many embedded in things creating what is referred to as a smart world. But it is important to note that one key issue is the degree of the density of sensing and actuation coverage. I believe that there will be a transition point when the degree of coverage triples or quadruples from what we have today. At that time there will be a qualitative change. For example, today many buildings already have sensors for attempting to save energy [7][8]; home automation is occurring [3]; cars, taxis, and traffic lights have devices to try and improve safety and transportation [9]; people have smartphones with sensors for running many useful apps [2]; industrial plants are connecting to the Internet [10]; and healthcare services are relying on increased home sensing to support remote medicine and wellness [11]. However, all of these are just the tip of the iceberg. They are all still at early stages of development. The steady increasing density of sensing and the sophistication of the associated processing will make for a significant qualitative change in how we work and live. We will truly have systems of systems that synergistically interact to form totally new and unpredictable services.

A sensing and actuation utility will not only exist in public spaces, but also extend into the home, apartments, and condominiums. Here people will be able to run health, energy, security, and entertainment apps on the infrastructure. Installing and running new apps will be as easy as plugging in a new toaster into the electric utility. One app may help monitor and control heart rate, another perform financial and investments services, another automatically ordering food and wine, or even predicting a impending medical problem that should be addressed early to mitigate or even avoid the problem. Humans will often be integral parts of the IoT system. The Industrial Internet is also a form of IoT where the devices (things) are objects in manufacturing plants, dispatch centers, process control industries, etc. Consequently, in the future the scope of IoT is enormous and will affect every aspect of all our lives.

Recently, sensor networks, cyber physical systems, and internet of things have become more common as sensing, communication, and analytics technologies have matured. In the future, digital sensing, communication, and processing capabilities will be ubiquitously embedded into everyday objects, turning them into the Internet of Things (IoT, or machine-to-machine, M2M). In this new paradigm, smart devices will collect data, relay the information or context to each another, and process the information collaboratively using cloud computing and similar technologies. Finally, either humans will be prompted to take action, or the machines themselves will act automatically.

There are many applications of this new paradigm [12][13][14], as shown in Figure 1. Some examples are highlighted below:

- Smart home: At home, embedded sensors can understand the human activities and properly adjust the air temperatures or lighting to reduce our energy usage without sacrificing human comforts.
- Economical agriculture: In a farm field, remote bug traps can detect the outbreak of pests and initiate spreading the right amount of pesticide. This will reduce the chance of overspreading and potential damage to the crops.
- Vehicle safety: Sensors on a car can help drivers understand the potential risk of running into each other; in particular, sensors and inter-vehicle communication can help us see what we cannot see. With timely and proper warning, we can reduce the vehicle collision rate.
- Assisted living: The population is aging. There is an increasing need to take care of more elders. Sensors can help us monitor the health condition of elders and properly provide help (e.g., reminders of missing a dose, warning of high blood pressure, requesting medical emergency).

In short, connected embedded sensors help humans hear/see things that they could not hear or see in the past and do something that we could not do in the past. This paradigm shift creates numerous challenges and opportunities for engineering.

III. INTERNET OF THINGS STANDARDIZATIONS AND PROTOCOLS

By the 2020 around 50 to 100 billion things will be connected electronically by internet [15]. Figure 2 shows the growth of the things connected to the internet from 1988 to forecast 2020. The Internet of Things (IoT) will provide a technology to creating the means of smart action for machines to communicate with one another and with many different types of information [16]. The success of IoT depends on standardization, which provides interoperability, compatibility, reliability, and effective operations on a global scale [17]. Today more than 60 companies for leading technology, in communications and energy, working with standards, such as IETF, IEEE and ITU to specify new IP based technologies for the Internet of Things [18].

The design of the IoT standards is required to consider the efficient use of energy and network capacity, as well as respecting other constraints such as frequency bands and power levels for radio frequency communications. As IoT evolves, it may be necessary to review such constraints and investigate ways to ensure sufficient capacity for expansion, for example in case of additional radio spectrum allocation as it becomes available.

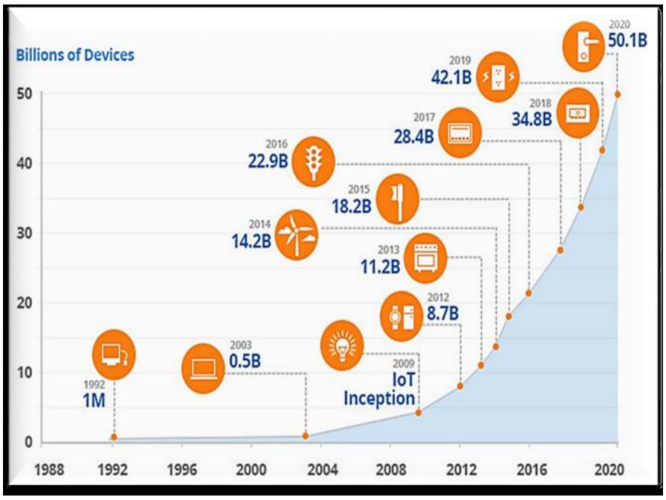

Figure 1. Internet of Things Growth

IEEE Standards Association (IEEE-SA) develops a number of standards that are related to environment need for an IoT. The main focus of the IEEE standardization activities are on the Physical and MAC layers. The IEEE provides an early foundation for the IoT with the IEEE802.15.4 standard for short range low power radios, typically operating in the industrial, scientific and medical band in addition to use ZigBee technology. The IEEE-SA has an over 900 active standards and more than 500 standards under development.

In its research into IoT, it has identified over 140 existing standards and projects that are relevant to the IoT. The base project related to IoT is IEEE P2413 which it is currently considering the architecture of IoT.

Internet Engineering Task Force (IETF) is concerned with the evolution of the Internet architecture and the smooth operation of the Internet and known as large, open to international community of network designers, operators, vendors and researchers [19]. IETF provides its own description of IoT which provides a most recognizable enhancement to support IPv6, with the 6LoWPAN [20]. The 6TiSCH Working Group is being formed at the IETF to address the networking piece of that unifying standard. Based on open standards, 6TiSCH will provide a complete suite protocols for distributed and centralized routing operation over the IEEE802.15.4e TSCH MAC [21]. ITU's Telecommunication Standardization Sector (ITU-T) considered as a first organization of standards development and coordination of the Internet of Things. They buts standards to gain benefit of integrated information processing capacity, and industrial products with smart capabilities [22]. In addition to make development on electronic identities that can be queried remotely, or be equipped with sensors for detecting physical changes around them.

IV. CHALLENGES

M2M can be broken down into four major layers as shown in Figure. Sensors collect data, communication units relay the information collected, computing units analyze the information, and service layers take action. In the future, enormous numbers of sensors will be deployed. The costs of servicing such sensors will be a major concern. Hence, one challenge is sensor technology that requires minimal or even zero effort to deploy and maintain. According to [23], many domestic ubiquitous computing projects have failed because the complexity of sensor deployment. Additionally, one important sensor service cost is battery replacement. It is often almost impossible to replace sensor batteries once they are in the field. Therefore, another challenge is low power sensor design, or designs which do not require a battery change over the lifetime of the sensor. For example, if a sensor is deployed on an animal for tracking purposes, the battery of the sensor should outlive the animal.

After the sensors collect the data, the next step is to communicate the information collected. Even today the number of devices connected to the internet exceeds the number of humans; in the future this gap will only increase. Many of the sensors will be connected wirelessly through systems like Bluetooth, WiFi, or 3G/4G cellular networks. Connecting the growing number of devices is a huge challenge. Most base stations are designed to provide a certain quality of service up to a given number of users. When there are too many simultaneous users, some users will not receive service. Since the number of devices will be orders of magnitude larger than the number of human users, this problem will become even more serious. Too, as the number of devices connected to the internet grows, so do security and privacy issues [24].

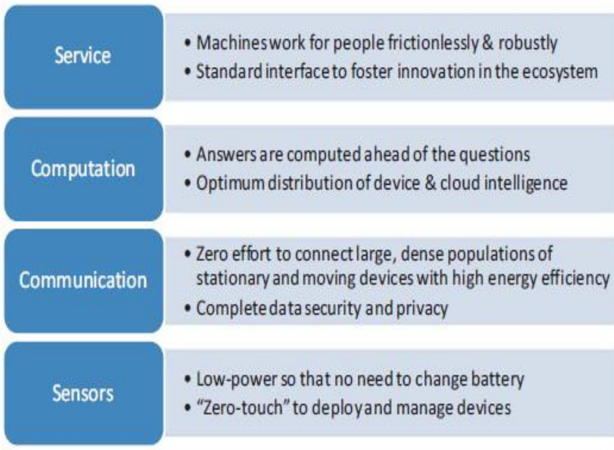

Figure 2. Major components in M2M and their challenges

Sensor generated data are different from human generated data:
- There are often real-time requirements for data processing, e.g., natural disaster warning. Stream data processing or mining is a critical component in the analysis.
- There is often a huge amount of temporal and spatial redundancy in the information. It will be more efficient if the analytical algorithm can take advantage of such redundancy. However, synchronization of data from different sensors may be inaccurate.
- Reliability or accuracy of the data may be unpredictable. Separating in reliable from unreliable signals will be a critical component of the analysis.
- The goal for the sensor data processing is either machine or human action, meaning that the requirement for data processing is more stringent.

V. OPPORTUNITIES

While there are many challenges, they are also many research and development opportunities. The following subsections will discuss these opportunities.

Low-power wireless sensors: One of the challenges is to design low-power sensors which do not need battery replacement over their lifetimes. This creates a demand for energy-efficient designs. A typical wireless sensor has 4 major components: a sensing unit, a processing unit, a transmitting/receiving unit, and a power unit, as shown in Figure. One of the opportunities is to design low-power sensing unit. Highly accurate sensor modules often consume great amounts of power. One alternative is to use an array of low-accuracy modules with lower power consumption, and then use data fusion to create high-accuracy information. To prolong the battery life of the sensor, we can harvest energy from the ambient environment from sources such as lights, heat, vibration, or radio frequency. The efficiency of today's RF energy harvesting solutions is around 16.3% [25]. More efficient solution are thus an urgent need. Further, the amount of energy that can be harvested from RF is at the uW level, still to low to power a wireless sensor. We also need a high-efficiency energy harvesting circuit adaptable to different sources.

Better connectivity: Another challenge in M2M is autonomous networking to connect large, dense populations of stationary and moving devices with efficient energy usage. First, many existing wireless standards are optimized for human-to-human applications, but may not be able to support large numbers of devices in a limited spectrum. Moreover, in the future, the rate of increase in the available spectrum will be slower than the rate of increase in the number of wireless sensors. Fortunately, machine-to-machine communication has several unique characteristics: the data rate is often lower, the information from different sensors or at different time steps may have strong correlations, and some messages do not require real-time delivery.

Finally, wireless communication consumes large amounts of bandwidth. A recent study shows that up to 70% of the power used when a person is playing an on-line game on a mobile device goes to wireless communication [26]. As Moores Law continues to scale down the power consumption of the computation circuits, the power consumption of the communication circuits will become even more dominant. Many connected devices are battery-powered, and current human-to-human communication designs do not consider energy efficiency as the first priority. Yet, energy-efficient machine-to-machine communication is crucial. In particular, signaling costs are high. Self-organizing hybrid distributed and centralized competition and cooperation framework may be one approach to reducing signaling overhead.

Smart service for People: Diverse and fragmented standards and interfaces between layers of the systems hinder the innovation capabilities of M2M application developers and service providers. If we want the M2M industry to grow as reliably and powerfully as Moores Law, we will need to develop the same kind of interdependent, mutually advantageous industry structure that causes the PC software and hardware industry spiral to function. Standard interfaces are the key to the spiral. When each individual component provider has a fixed boundary condition, it is easier and faster to create innovative solutions. It is not easy for one single component or solution provider to define a generic system architecture and the interface.

The broader the diverse set of applications is (use fixed and mobile sensors to monitor both human and non-human objects and perform energy saving, vehicle safety, health/wellness monitoring, and environmental monitoring functions), the easier we can define the generic architecture and standard interfaces. After that, we can focus on building innovative M2M services to server humans.

VI. RESEARCH

The spectrum of research required to achieve IoT at the scale envisioned above requires significant research along many directions. In this section problems and required research are highlighted in 8 topic areas: massive scaling, architecture and dependencies, creating knowledge and big data, robustness, openness, security, privacy, and human in the loop. Each of the topic discussions primarily focuses on new problems that arise for future IoT systems of the type described in Section II. The research topics presented in each case are representative and not complete. Many important topics such as the development of standards, the impact of privacy laws, and the cultural impact on use of these technologies are outside the scope of the paper.

Massive Scaling: The current trajectory of the numbers of smart devices being deployed implies that eventually trillions of things will be on the Internet. How to name, authenticate access, maintain, protect, use, and support such a large scale of things are major problems. Will IPv6 suffice? Will protocols such a 6LowPAN play a role? Will entirely new standards and protocols emerge? Since many of the things on the Internet will require their own energy source, will energy scavenging and enormously low power circuits eliminate the need for batteries? How will the massive amounts of data be collected, Many protocols and variations will co-exist. What will be the architectural model that can support the expected heterogeneity of devices and applications?

Architecture and Dependencies: As trillions of things (objects) are connected to the Internet it is necessary to have an adequate architecture that permits easy connectivity, control, communications, and useful applications. How will these objects interact in and across applications? Many times, things or sets of things must be disjoint and protected from other devices. At other times it makes sense to share devices and information. One possible architectural approach for IoT is to borrow from the smartphone world. Smartphones employ an approach where applications are implemented and made available from an app store. This has many advantages including an unbounded development of novel applications that can execute on the smartphones. Various standards and automatic checks are made to ensure that an app can execute on a given platform. For example, the correct version of the underlying OS and the required sensors and actuators can be checked when the app is installed.

Creating Knowledge and Big Data: In an IoT world there will exist a vast amount of raw data being continuously collected. It will be necessary to develop techniques that convert this raw data into usable knowledge. For example, in the medical area, raw streams of sensor values must be converted into semantically meaningful activities performed by or about a person such as eating, poor respiration, or exhibiting signs of depression. Main challenges for data interpretation and the formation of knowledge include addressing noisy, physical world data and developing new inference techniques that do not suffer the limitations of Bayesian or Dempster-Shafer schemes. These limitations include the need to know a priori probabilities and the cost of computations. Rule based systems may be used, but may also be too ad hoc for some applications.

- Robustness: If our vision is correct, many IoT applications will be based on a deployed sensing, actuation, and communication platform (connecting a network of things). In these deployments it is common for the devices to know their locations, have synchronized clocks, know their neighbor devices when cooperating, and have a coherent set of parameter settings such as consistent sleep/wake-up schedules, appropriate power levels for communication, and pair-wise security keys. However, over time these conditions can deteriorate. The most common (and simple) example of this deterioration problem is with clock synchronization Over time, clock drift causes nodes to have different enough times to result in application failures.

- Openness: Traditionally, the majority of sensor based systems have been closed systems. For example, cars, airplanes and ships have had networked sensor systems that operate largely within that vehicle. However, these systems capabilities are expanding rapidly. Cars are automatically transmitting maintenance information and airplanes are sending real-time jet engine information to manufacturers.

There is or will be even greater cooperation and 2-way control on a wide scale: cars (and aircraft) talking to each other and controlling each other to avoid collisions, humans exchanging data automatically when they meet and this possibly affecting their next actions, and physiological data uploaded to doctors in real-time with real-time feedback from the doctor. These systems require openness to achieve these benefits. However, supporting openness creates many new research problems.

- Security: A fundamental problem that is pervasive in the Internet today that must be solved is dealing with security attacks. Security attacks are problematic for the IoT because of the minimal capacity things (devices) being used, the physical accessibility to sensors, actuators and objects, and the openness of the systems, including the fact that most devices will communicate wirelessly. The security problem is further exacerbated because transient and permanent random failures are commonplace and failures are vulnerabilities that can be exploited by attackers. However, the considerable redundancy that is available creates potential for designing applications to continue to provide their specified services even in the face of failures.

-Privacy: The ubiquity and interactions involved in IoT will provide many conveniences and useful services for individuals, but also create many opportunities to violate privacy. To solve the privacy problem created by IoT applications of the future, the privacy policies for each (system) domain must be specified. Once specified either the individual IoT application or the IoT infrastructure (e.g., the utility capability) must enforce privacy. Consequently, the IoT paradigm must be able to express users requests for data access and the policies such that the requests can be evaluated against the policies in order to decide if they should be granted or denied.

-Humans in the Loop: As IoT applications proliferate they will become more sophisticated. Many of these new applications will intimately involve humans, i.e., humans and things will operate synergistically. Human in-the-loop systems offer exciting opportunities to a broad range of applications including energy management [17], health care [15], and automobile systems [9][16]. For example, it is hypothesized that explicitly incorporating human in the loop models for driving can improve safety, and using models of activities of daily living in home health care can improve medical conditions of the elderly and keep them safe. Although having humans in the loop has its advantage, modeling human behaviors is extremely challenging due to the complex physiological, psychological and behavioral aspect of human beings. New research is necessary to raise human-in-the-loop control to a central principle in system design and to solve three main challenges [20].

VII. CONCLUSION AND FUTURE DIRECTIONS

As growing numbers of devices are added to the internet, M2M will transform the way we live, play, and work. An exciting area for innovation, it offers numerous challenges and opportunities, from scaling applications and services from billions to trillions of connected devices, and from tera to zeta bytes of data. Each objects in the world can be identified, connected to each other through internet taking decisions independently. All networks and technologies of communication are used in building the concept of the internet of things such technologies are mobile computing, RFID, wireless sensors networks, and embedded systems, in addition to many algorithms and methodologies to get management processes, storing data, and security issues. The evolution of the next generation mobile system will depend on the creativity of the users in designing new applications. IoT is an ideal emerging technology to influence this domain by providing new evolving data and the required computational resources for creating revolutionary apps. In summary, one vision of the future is that IoT becomes a utility with increased sophistication in sensing, actuation, communications, control, and in creating knowledge from vast amounts of data. This will result in qualitatively different lifestyles from today. What the lifestyles would be is anyones guess. It would be fair to say that we cannot predict how lives will change. We did not predict the Internet, the Web, social networking, Facebook, Twitter, millions of apps for smartphones, etc., and these have all qualitatively changed societies lifestyle.

REFERENCES

[1] K. Ashton, That Internet of Things thing, RFiD Journal (2009).
[2] H. Sundmaeker, P. Guillemin, P. Friess, S. Woelffl, Vision and challenges for realising the Internet of Things, Cluster of European Research Projects on the Internet of ThingsCERP IoT, 2010.
[3] J. Buckley (Ed.), The Internet of Things: From RFID to the Next- Generation Pervasive Networked Systems, Auerbach Publications, New York, 2006.
[4] G. Nussbaum, People with disabilities: assistive

homes and environments, in: Computers Helping People with Special Needs, 2006.

[5] M. Darianian, M.P. Michael, Smart home mobile RFID-based Internet-of- Things systems and services, in: 2008 International Conference on Advanced Computer Theory and Engineering, 2008, pp. 116120.

[6] L. Atzori, A. Iera, G. Morabito, SIoT: giving a social structure to the Internet of Things, IEEE Communications Letters 15 (2011) 11931195.

[7] C. Kidd, R. Orr, G. Abowd, C. Atkeson, I. Essa, B. MacIntyre, et al., The Aware Home: a living laboratory for ubiquitous computing research, in: Lecture Notes in Computer Science, 1999, pp. 191198.

[8] R.N. Murty, G. Mainland, I. Rose, A.R. Chowdhury, A. Gosain, J. Bers, et al., CitySense: an urban-scale wireless sensor network and testbed, 2008, pp. 583588.

[9] L.M. Kaufman, Data security in the world of cloud computing, IEEE Security and Privacy Magazine 7 (2009) 6164.

[10] J. Al-Karaki, A. Kamal, Routing techniques in wireless sensor networks: a survey, IEEE Wireless Communications 11 (2004) 628.

[11] Y. Aguiar, M. Vieira, E. Galy, J. Mercantini, and C. Santoni, Refining a User Behavior Model based on the Observation of Emotional States. COGNITIVE , 2011.

[12] J. Deng, R. Han, and S. Mishra, Secure Code Distribution in Dynamically Programmable Wireless Sensor Networks, Proc. of ACM/IEEE IPSN, 2006. pp. 292-300.

[13] M. Huang, J. Li, X. Song, and H. Guo, Modeling Impulsive Injections of Insulin: Towards Artificial Pancreas. SIAM Journal of Applied Mathematics 72, 5, 2012, pp. 15241548.

[14] A Liu, and D. Salvucci, Modeling and Prediction of Human Driver Behavior, Intl. Conference on HCI , 2001.

[15] M. Stillwell, D. Schanzenbach, F. Vivien, and H. Casanova, Resource allocation using virtual clusters,. in Proceedings of the 9th IEEE/ACM International Symposium on Cluster Computing and the Grid (CCGrid 2009), Shanghai, China, 2009, pp. 260.267.

[16] S. Mohammed, P. Fraisse, D. Guiraud, P. Poignet, and H. Makssoud, Towards a Co-contraction Muscle Control strategy for Paraplegics. CDC-ECC, 2005.

[17] B. Rong Chen, G. Peterson, G. Mainland, and M. Welsh, LiveNet: Using Passive Monitoring to Reconstruct Sensor Network Dynamics, DCOSS 2008, June 2008.

[18] M. Balazinska, A. Deshpande, M.J. Franklin, P.B. Gibbons, J. Gray, S. Nath, M. Hansen, M. Liebhold, A. Szalay, V. Tao, ”Data Management in the Worldwide Sensor Web,” IEEE Pervasive Computing, vol.6, no.2, pp.30-40, April-June 2007

[19] G. Brumfiel, ”First Eyes Inside Nuclear Plant May Be A Robot’s,” NPR, March 23, 2011.

[20] C.-C. Chiu, S.-Y. Chien, C.-H. Lee, V. S. Somayazulu, and Y.-K. Chen, ”Distributed video coding: a promising solution for distributed wireless video sensors or not?” in Proc. Visual Communications and Image Processing 2011, Nov. 2011.

[21] L. Greenemeier, ”Can Mobile Phone Networks Be Improved to Better Cope with Emergencies?” Scientific American, August 2011.

[22] Hele-Mai Haav. linked data connections with emerging information technologies: A survey. International Journal of Computer Science and Applications Vol. 11, No. 3, (2014) 21-44.

[23] IEEE Wireless Communications, special issue on ”The Internet of things,” December 2010.

[24] J. O. Smith, The Coming of Age of M2M Standards, Connected World Conference, Keynote presentation, 2010.

[25] TIA TR-50, Telecommunications Industry Association Smart Device Communications Standards Committee

[26] Y. Yu, L. J. Rittle, V. Bhandari, and J. B. LeBrun, Supporting Concurrent Applications in Wireless Sensor Networks, ACM SenSys, 2006.

AUTHOR PROFILE

Prashantkumar P. Oza is Assistant Professor in Electronics and Communication Department at L.D.R.P. Institute of Technology and Research, Gandhinagar, Gujarat, INDIA since 2009. He graduated in Electronics and Communication Engineering at the Government Engineering College, Modasa from HNGU in 2003; then he received a Master Engineering degree in Electronics and Communication Engineering at the L.D. College of Engineering from Gujarat University in 2005. His main research topics of interest are in embedded systems and VLSI Technology and Internet of Things.

Dipesh Kamdar is Associate Professor in Electronics and Communication Department at VVP Engineering College, Virda Vajadi, Kalawad Road, Rajkot, Gujarat, INDIA. He graduated in Electronics and Communication Engineering; then he received a Master Engineering degree in Electronics and Communication
Engineering. He received Ph.D. in Electronics and Communication. He has published more than 20 journal and conference papers.

