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Advances in Data Mining for Internet of Things

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ABSTRACT

Sensing and wireless communications have developed to such an extent that we are fully surrounded by many smart things which are Internet enabled. This also leaves back digital traces which enable collecting information that helps to build smart Internet of Things (IoT). Huge amount of digital data generated by IoT poses numerous challenges and hence data mining is the obvious choice to infer useful information from heterogeneous data generated by various devices. The massive data generated by IoT is very useful and also considered to be valuable, which will provide new ways to provide more convenient services and environments. This paper briefly reviews the features of "data from IoT" and "data mining for IoT" and discusses about the challenges, potentials, open issues, and future trends of this field.

Keywords: Data Mining, IOT (Internet of Things), Web of Things, Human Behaviours, Healthcare and Smart Devices.

1. INTRODUCTION

Internet of Things [1-3] is connecting the classical networks with the objects to be networked. This has enabled exchange of important data among the things which are IP enabled. The basic idea behind IoT is to connect all the IP enabled things together which will let the devices to identify themselves, communicate with each other and also be able to take decisions on an autonomous basis. IoT is gaining importance since there is rapid increase in the Internet usage and Internet enabled devices. This paper discusses various IoT related technical issues like challenges [4], applications [7] and also various standards [8].

Knowledge discovery in databases forms the analysis step in the data mining process which aims at discovering the hidden patterns in the large sets of data. It takes the help of various sub domains like machine learning, statistics, and artificial intelligence. The goal of data mining is to extract valuable information from a data set and transform it to understandable structure. This helps in gaining an insight into the collected raw data. Thus, IoT forms a network of physical objects or things which are embedded with electronics, sensors and network connectivity by which the devices can collect and exchange data [4].

Data mining and IoT together have made it possible to achieve such technology with new innovations to help in daily activities of mankind. A lot of applications can be thought of when we consider data mining and IoT in conjunction. Due to the emergence of IoT, huge amounts of data are being generated which is also heterogeneous. The data particularly comes from sources like sensors and various connected devices. Hence, data mining plays a major role in extracting small pieces of importance from a large and continuous feed. This was the motivation to take up this review considering both data mining and IoT.

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2. INTERNET OF THINGS

Since the physical things are connected to the Internet, the physical devices can be controlled and accessed from any part of the globe. The captured data from various devices can lead to a new kind of services that are entirely different from what the conventional embedded systems can give. This opens a new realm of interconnected services which is intelligent, robust and dependable [5]. The Internet of Things is based on this idea of interconnected things communicating over Internet and providing valuable services and also real time action. RFID technology also points to the same direction and has helped to achieve IoT in a better way.

RFID technology is an extension of the bar codes which can be found on everyday products that we use. RFID attaches a low cost electronic tag to the product. This helps in detecting the product and getting product details from a distance. By introducing a small intelligence to this tag, the product becomes a smart object [11]. The IoT is possible by the integration of various technologies and communication solutions [14], [16]. This has led to various sub applications like wireless sensor enabled communications, distributed intelligence, actuator networks. Different perspectives of IoT are reviewed in [6], [18] which form the basis of this survey.

The development of IoT also depends on the synchronous activities in various other fields like embedded systems, networks, RFID technology and other sensor based developments. Technologies like near field communication, real time localization and embedded sensors have enabled us to transform everyday objects into smart objects which are capable of understanding and reacting to the events in the environment. Novel computing applications are possible by the advent of IoT and are by far the most potential technology. Also, the smart objects or things need more architectural features that help in attaining more real world interactions.

3. DATA FROM IOT

The things on the IoT create data flood which contains heterogeneous valuable information. The issue is as to how this kind of voluminous data can be handled and also how to extract useful information from this big pool of data. One way of solving this problem could be by implementing devices that identify themselves in the big network. The data generated by such devices can be tracked down if they send the data with their identities [18], [21]. Knowledge discovery seeks to bring out such valuable information from big data pool.

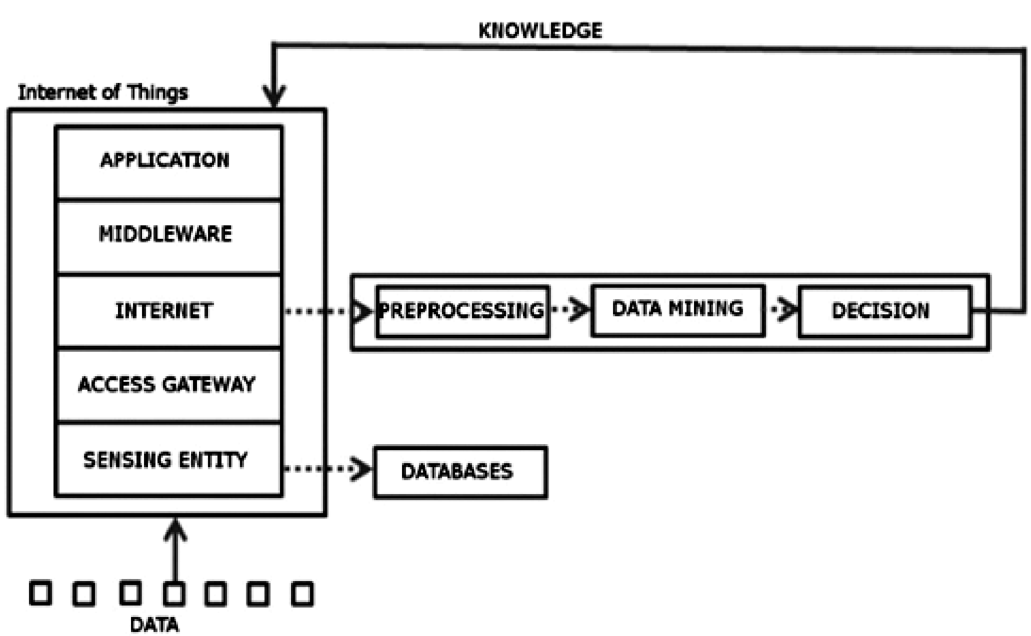

Figure 1: Data Mining for Knowledge Discovery in IoT

It is to be noted that knowledge discovery does not happen without human interaction. The various steps in the data discovery process are depicted in Figure 1.

Data mining plays an important role in the IoT domain which involves discovering useful patterns and extracting hidden information. The huge data generated by Internet of Things has high business values through which various analytics can be performed. The main purpose of any data mining process is to build effective and efficient descriptive model which depicts the existing set and also generalizes the new data [31], [33]. Extracting interesting knowledge from various sources like data ware houses, information repositories is the main process involved in data mining.

Data mining can be viewed in three different dimensions. In one dimension is in the knowledge view which involves various analyses like time series, outlier and association analysis. The second one is in the techniques dimension which involves rough set, neural networks, machine learning. Third dimension consists of application views like industry, banking, and fraud analysis [1], [5], [7].

4. STATE-OF-THE-ART IN DATA MINING FOR IOTS

Internet of Things is a technology which tends to connect the entire set of objects in the world to the Internet. The systems collect information about users using resources such as RFID devices, camera, web pages, embedded devices, mobile phones, GPS, motion sensors etc. and make appropriate data analysis, filter data and present users the smart choice. IoT Mining System depicted in Figure 2 explains the layers of IOT architecture.

4.1. Devices

Devices extract information from every source available. The information can be raw data, in image format, in text format etc. depending upon the source. In medical science, the data source is patient itself and the key touch points around the patient. An example scenario: if the patient goes to rest room the toilet outlet automatically conducts simple tests and analyses the urine and shares the information to the wrist band of the patient [31]; from the wrist band, the information is sent to the server and mapped to the corresponding doctor about the patient’s health conditions. Another scenario is monitoring the various medicines used by the patient, their effects and their side effects, if any, for further analysis. Another example is the fertilizer industry where a highly sensitive laser sensor is placed near the outlet of ammonia chamber that automatically detects the amount of ammonia released in the air by detecting its chemical composition thereby checking environmental hazards and also following legal norms and standards. The information collected regularly is sent to the server and saved in the database at backend for further analysis.

4.2. Raw Data

We need to store and manage the data in multidimensional warehouse systems. Based on the industry needs the information is disintegrated and stored in different servers. For example, in retail sector, the POS information is sent to transaction server and distributed wholesale sales data are stored in enterprise server; the archive data, raw data, market data are stored in business intelligence server [21], [22], [26]. Various data stored from various sources are perceived in dimensional model for analytics.

4.3. Data Gathering

The main intension of data gathering is to provide data access to business analysts and information technology professionals. The collected data is made available to professionals to process the data to generate vital and useful information. Certain restrictions are set by the concerned on the modules that can access the information. For example, banking RTGS transaction data is sent from bank server to customer’s sever and only accessed by the authorized IT professionals in both the ends and the information is not available to other users of the department.

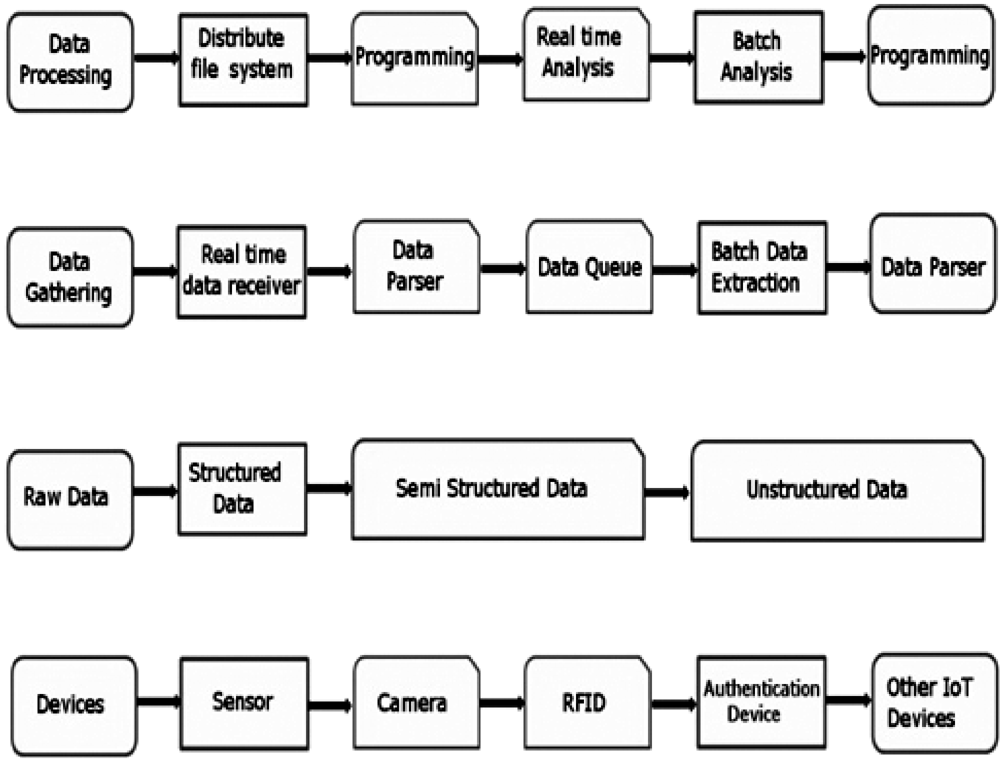

Figure 2: Layers of IoT Architecture

4.4. Data Processing

The information collected is passed through various tools. Software maps the data and applies business logic to process the data to get the appropriate intelligence information. Various algorithms such as Classification Algorithm, Regression Algorithm, Segmentation Algorithm, Association Algorithm, and Sequence Analysis Algorithm [36] are used for this purpose of mapping and segmenting the data. Based on the task and event, the software uses suitable algorithms and applies the relevant logics. For example, for security entrance accesses of the organisation either RFID user key access or image recognition (retina access) is used. Algorithms must take into consideration the characteristics of networks like energy, computational constraints, network dynamics and faults [12-14] etc.

4.5. Services

Final data is shared as graphs, tables, or intelligent reports. Also, the processed data can set appropriate workflows that can trigger automatically concerned events or transactions that can proceed as workflows. For example, the business intelligent information sent by the server can trigger SMS facility to concerned managers of the department about highest sales of product group or impact in sales due to sudden weather changes in certain places. We might as well ask whether we actually need refrigerators to communicate with cell phones and supermarkets, or whether the home entertainment system should control your own children's television habits [24]. That aside, in light of these figures the kind of estimates the experts normally work with, citing 1012 - 1015 objects [2] in the Internet of Things in future no longer seem that surprising. Not only will the aforementioned model be influenced by reality, but this is the crux the Internet of Things can also have a direct impact on reality. That is, it will actively change aspects of the real world [32]. The data can trigger a series of workflows of events like a chain. For example, smart eye wear that is connected to Internet can detect few known faces of strangers through their Facebook accounts and share their personal and professional information [32-35]. Healthcare heterogeneous medical data can generate information about patients. These quantitative data can be used for clinical research, survival analysis, patient similarity analysis, to improve care and life [7-10]. An example, for application of quantitative data is a wrist band that tracks heart beat and communicates with doctor about the patient health.

4.6. Knowledge Discovery In Database (KDD)

Analysing data is difficult compared to creating the data. Data once created in some form gets various kinds of changes and hence results in data explosion, which is nothing but huge volume of data generation [6-9]. The problem of inquiring big data on IoT is still a major challenge since it requires sophisticated techniques and also efficient tools. Currently most of the mining technologies are developed to run on a single system. But the problem with the big data with IoT is that the data is mostly from the distributed network. Hence the existing technologies cannot be applied for the distributed systems. Hence the KDD can only be applied small scale IoT systems that interchange small amount of data. It also indicates that the present KDD techniques cannot be applied directly to IoT and hence require modifications.

4.7. Resource Aware Protocol For IoT

Many protocols exist for wireless communication and for normal device to device communication. The protocols which are being used are good in terms of efficiency, scalability and portability. The parameter which is not considered in the existing protocols is the limitation of resources available in the IoT devices like memory, power, etc. The resource aware protocol [9] is based on the Zigbee technology and basically considers the limited resource capacity in the individual nodes. A new algorithm called Resource Aware Ad-hoc Networking (RAAN) is proposed which cuts down transmission time and reduces the packet loss rate that in turn saves the resources of the nodes.

4.8. Cloud Based e-Health

Cloud based e-Health is gaining a lot of importance because of its convenience, affordability and also the remote monitoring facilities it provides. Cloud based e-Health offers facilities like remote patient monitoring, data inspection, and doctor consultations and so on through network of sensors attached to the cloud. These systems are able to collect the data from various input sources and nodes, process it to create actions based on the data. Leveraging the data received from sensors attached to patients helps to transform the data into information and then to action. But this requires huge data processing system and storage for the operation. The cloud can provide such facilities for data storage and data processing [2].

4.9. Employee Performance Evaluation Based on Game Theory

In many corporate scenarios, the performance evaluation of employees is done manually by considering the performance factors like number of hours logged in the company, punctuality etc. But this data helps in determining the mere presence of employee rather than the quality of the presence. Attempts are made to use a game theoretic approach to monitor the employees for the performance that is based on the quality rather than quantity [22]. The IoT in conjunction with data mining techniques can be employed in such systems to mine the data from the sensory nodes present in the company premises. In the next step, Map Reduce approach can be applied to get the information about the employees.

4.10. Intelligent Logistics System

There are three technologies mainly used in Internet of Things: (i) perception technology, (ii) communication and network technology, and (iii) intelligent technology. They have been very well used in intelligent logistics system.

- Perception technology: RFID is widely used in the logistics information field since it is robust, reliable and also scalable. Second position is taken by the GPS which has more practical applications in the IoT. Third is the video and image perception which is widely used for monitoring the IoT data [8].

- Communication and network technology: Communication and network technology has changed the logistics system perspective. A shipment has lot of ways to track through internet and also local organizations intranet. This is possible due to various internal technologies like RFID, GPS and tracking systems [2].
- Intelligent management and control technology: Management and control of data and also logistics information is now very much easier by the enterprise level software and also hardware which enable the faster data transmissions and data exchange. The control technology has seen so much changes that a system can take autonomous decisions to alert of any error or take deviations from the planned trip [4].

4.11. Embedded Intelligence

4.11.1. Surveillance Cameras

Surveillance cameras have been widely deployed in almost all the places around us. This forms a major source of data for IoT since the video captured itself can be of very much value. These devices have become so smart that any kind of filtering can be applied to deduce some actions or group behaviour. It is widely used to observe the social presence or to detect spatial context and to study the social dynamics [3].

4.11.2. Smart Indoor Artefacts

Advancement of wireless sensing techniques and also massive production of sensors at an affordable cost has led to the development of indoor artefacts with more intelligent features [10]. Hence these sensors generate data and also are capable of sensing the surrounding environment and adapt it to the changing life conditions.

4.11.3. Life-Logging

Life –Logging involves capturing and storing various human activities like memories, health activities, mental activities etc. The wearable devices have made it possible to log these activities without intervening in the normal activities. These devices attach to the human surroundings and try to capture and sense the current situation [3].

4.11.4. Enterprise Computing and Groupware

Enterprises are now using smart things and artefacts to facilitate the business activities and also to improve the employee productivity. It facilities the communication and collaboration between other dependent business. For example many companies are using smart objects around the office premises which can detect the need of the meeting based on the people behaviour and book the conference room automatically [30].

4.12. Traffic Condition Based on IoT

Traffic condition sensing has improved lot with the help of IoT. Various smart objects can be installed at the busy junction to get the data from those locations. These smart objects can be connected using a mesh network which takes in feed and sends across the server. Based on this actuator objects can deviate the traffic to other route. In an adaptive traffic system the same device can provide connectivity to vehicles and also to traffic management system which enables to take decisions [6].

5. CHALLENGES AND POSSIBLE SOLUTIONS

5.1. Challenges

The main challenge is how to handle the big data that is heterogeneous in nature. One thing to be observed is that the data quantity is high, but the quality is low. The data is semi structured or may be no structure at all. This poses challenge to current algorithms and techniques which expect well-structured data. The primary challenge is accessing and extracting big data from various sources. Noise is not an exception since it comes embedded with the data. Hence modifying the current algorithm to suit IoT environment is another challenging task. Some of the other important challenges in the IoT domain are as follows:

- Sensing complex environment
- Connectivity
- Powering the device
- Security
- Cloud requirement

Volume of data – Exploring and analysing large volume of data effectively in short time is complex. Big data techniques can be used to process huge data. Computational requirements are also getting complex as diverse information collected need to be processed in short time.

Diverse data- Diverse data is due to various data formats like text, raw data, image format, sensor data, and social media data. Various algorithms are applied for each source of information to compile the data to make it knowledgeable information. The data is to be analysed to find the properties of data and find associations of different data. On the other hand, the data on the usage of Things and the associated services are extremely sensitive. But far worse is the case today, unauthorized access in the Internet of Things will not only lead to potentially confidential information being divulged, it might also result in the owner or authorized user losing control of their Things in the physical world.

In "IoT Security: On-going Challenges and Research Opportunities" by Tobias Heer et.al outlined various challenges related to security in IoT. Tight resource constraints is applicable for all the IoT devices since the devices communicate among small nodes which have a lossy and low bandwidth channels. This has direct impact on the security of the connected devices. Denials of Service (DoS) attacks are also possible in the IoT domain since the communication is open ended [20]. Protocol translation and end-to-end security is also needed to have secure communication among the devices. Unauthorized access to the tags is possible since large number of RFID systems lack proper authentication mechanisms. This leads to the modification or deletion of the data [4]. Sinkhole attack is a kind in which a malicious node lures all other nearby nodes that are genuine; by this, all the data from the genuine nodes leaks to malicious node [23] compromising the security of the system.

5.2. Solutions

Some of the potential solutions for the numerous challenges faced in handling IoT especially in the context of the huge data generated by IoT are:

- Huge volume of data can be stamped and categorized to solve large bundles of heterogeneous data.
- The IoT devices can be implemented with various network layer security protocols, which help in identifying suspicious activities.
- Power consumption of devices can be minimized by using energy efficient algorithms and hardware with sleep functionality.

- Connectivity can be increased by using various repeaters in between and also by using sensors with high range capacity.
- Activities of the various connected IoT devices can be monitored for any malicious behavior.

The sinkhole attacks on the IoT nodes can be detected by using rule based technique. In this method, all the sensor nodes are bound by the rules embedded into the nodes. If any node violates the rule, it is considered as malicious activity and all the other nearby nodes get the attack information. One more approach is the anomaly based detection in which the normal behaviour of the node is defined. Any deviation is considered to be attack and other nodes are intimated [37]. End-to-end security can be enhanced by using symmetric keys with gateways to transform the packets and apply security features [28]. IoT specific optimizations can include encryption at both sender and receiver ends to ensure authentication and integrity. Additional security can be achieved by using secure router/gateways, secure runtime environments in the nodes and also secure interfaces among all the devices [39].

6. CONCLUDING REMARKS

The Internet of Things has risen from the need to connect all the IP enabled devices together in order to automate, manage all the devices and sensors. Data mining techniques are integrated with devices and also in sensors for smart features. There is no doubt that the big data is the future trend as all the devices start uploading the data as soon as they are connected to the Internet. Data mining technology plays a major role in handling such huge data. Data mining involves discovering novel, interesting, and potentially useful patterns from data and applying algorithms to extract the hidden information. We reviewed various aspects including knowledge discovery, embedded intelligence and so on in the context of IoT and big data. We also reviewed the data mining technologies like clustering and KDD which help the process of data mining in IoT. Various challenges and possible solutions pertaining to IoT and data mining have been highlighted. It is clear that data mining techniques are very much essential to bring about more applications targeted for better and sophisticated utilization of Internet of Things.

REFERENCES

[1] Chun-Wei Tsai, Chin-Feng Lai, Ming-Chao Chiang and Laurence T. Yang, “Data Mining for Internet of Things: A Survey,” IEEE Communications Surveys & Tutorials, 1553-877X/14, vol 16, no 1, first quarter 2014.

[2] “Sensing the future of the Internet of Things”, PwC 6th Annual Digital IQ, 2014

[3] Rajesh Vargheese, Yannis Viniotis “Influencing Data Availability in loT Enabled Cloud based e-Health in a 30 day Readmission Context” in 10th IEEE International Conference on Collaborative Computing: Networking, Applications and Worksharing, 2014

[4] Mr. Ravi Uttarkar and Prof. Raj Kulkarni, Internet of Things: Architecture and Security, in International Journal of Computer Application, Volume 3, Issue 4, 2014

[5] M. Palattella, N. Accettura, X. Vilajosana, T. Watteyne, L. Grieco, G. Boggia and M. Dohler, “Standardized protocol stack for the Internet of (important) things,” IEEE Commun. Surveys Tutorials, In Press, 2013.

[6] M. Palattella, N. Accettura, X. Vilajosana, T. Watteyne, L. Grieco, G. Boggia, and M. Dohler, “Standardized protocol stack for the Internet of (important) things,” IEEE Commun. Surveys Tutorials, In Press, 2013.

[7] Auto-ID Labs, Massachusetts Institute of Technology, available at http://www.autoidlabs.org/, 2012 , “Accessed on 22-Jul-2016.”

[8] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, “Internet of things: Vision, applications and research challenges,” Ad Hoc Networks, vol 10, no 7, pp. 1497–1516, 2012.

[9] M&M Research Group, “Internet of Things (IoT) & M2M commu-nication market - advanced technologies, future cities & adoption trends, roadmaps & worldwide forecasts 2012-2017,” Electronics.caPublications, Tech. Rep., 2012.

[10] M. C. Domingo, “An overview of the Internet of things for people with disabilities,” Journal of Network and Computer Applications, vol 35, no 2, pp. 584–596, 2012.

[11] T. S´anchez Lopez, D. C. Ranasinghe, M. Harrison and D. Mcfarlane, “Adding sense to the Internet of things,” Personal and Ubiquitous Computing, vol 16, no 3, pp. 291–308, 2012.

[12] Xiaoni Wang, “Resource-aware clustering based routing protocol in the Internet of Things” 978-1-4673-2112-9/12, 2012 IEEE

[13] N. Ali and M. Abu-Elkheir, “Data management for the Internet of things: Green directions,” in Proc. IEEE Globecom Workshops, pp. 386–390, 2012.

[14] Auto-ID Labs, Massachusetts Institute of Technology, Available at http://www.autoidlabs.org/, 2012, “Accessed on 07-Aug-2016.”

[15] D. Miorandi, S. Sicari, F. De Pellegrini, and I. Chlamtac, “Internet of things: Vision, applications and research challenges,” Ad Hoc Networks, vol 10, no 7, pp. 1497–1516, 2012.

[16] M&M Research Group, “Internet of Things (IoT) & M2M commu-nication market - advanced technologies, future cities & adoption trends, roadmaps & worldwide forecasts 2012-2017,” Electronics.caPublications, Tech. Rep., 2012.

[17] M. C. Domingo, “An overview of the Internet of things for people with disabilities,” Journal of Network and Computer Applications, vol 35, no 2, pp. 584–596, 2012.

[18] T. S´anchez L´opez, D. C. Ranasinghe, M. Harrison, and D. Mcfarlane, “Adding sense to the Internet of things,” Personal and Ubiquitous Computing, vol 16, no 3, pp. 291–308, 2012.

[19] D. Bandyopadhyay and J. Sen, “Internet of things: Applications and challenges in technology and standardization,” Wireless Personal Communications, vol 58, no 1, pp. 49–69, 2011.

[20] R. Kulkarni, A. Forster and G. Venayagamoorthy, “Computational intelligence in wireless sensor networks: A survey,” IEEE Commun. Surveys Tutorials, vol 13, no 1, pp. 68–96, 2011

[21] Tobias Heer , Oscar Garcia-Morchon et al, “Security Challenges in the IP-based Internet of Things” ,Springer Wireless Personal Communications, Volume 61, 2011

[22] T. S. L´opez, D. C. Ranasinghe, B. Patkai and D. C. McFarlane, “Taxonomy, technology and applications of smart objects,” Information Systems Frontiers, vol 13, no 2, pp. 281–300, 2011.

[23] T. Keller, “Mining the Internet of things: Detection of false-positive RFID tag reads using low-level reader data,” Ph.D. dissertation, The University of St. Gallen, Germany, 2011.

[24] Bin Guo, Daqing Zhang, Zhu Wang, “Living with Internet of Things: The Emergence of Embedded Intelligence,” 2011 IEEE International Conferences on Internet of Things, and Cyber, Physical and Social Computing, 978-0-7695-4580-6/11.

[25] T. Keller, “Mining the Internet of things: Detection of false-positive RFID tag reads using low-level reader data,” Ph.D. dissertation, The University of St. Gallen, Germany, 2011.

[26] D. Bandyopadhyay and J. Sen, “Internet of things: Applications and challenges in technology and standardization,” Wireless Personal Communications, vol 58, no 1, pp. 49–69, 2011.

[27] R. Kulkarni, A. Forster, and G. Venayagamoorthy, “Computational intelligence in wireless sensor networks: A survey,” IEEE Commun. Surveys Tutorials, vol 13, no 1, pp. 68–96, 2011.

[28] T. S. L´opez, D. C. Ranasinghe, B. Patkai and D. C. McFarlane, “Taxonomy, technology and applications of smart objects,” Information Systems Frontiers, vol 13, no 2, pp. 281–300, 2011.

[29] T. Keller, “Mining the Internet of things: Detection of false-positive RFID tag reads using low-level reader data,” Ph.D. dissertation, The University of St. Gallen, Germany, 2011.

[30] G. Kortuem, F. Kawsar, V. Sundramoorthy and D. Fitton, “Smart objects as building blocks for the Internet of things,” IEEE Internet Computing, vol 14, no 1, pp. 44–51, 2010.

[31] S. Bin, L. Yuan and W. Xiaoyi, “Research on data mining models for the Internet of things,” in Proc. International Conference on Image Analysis and Signal Processing, pp. 127–132, 2010.

[32] L. Atzori, A. Iera and G. Morabito, “The Internet of things: A survey,” Computer Networks, vol 54, no 15, pp. 2787–2805, 2010.

[33] S. Bin, L. Yuan, and W. Xiaoyi, “Research on data mining models for the Internet of things,” in Proc. International Conference on Image Analysis and Signal Processing, pp. 127–132, 2010.

[34] L. Atzori, A. Iera, and G. Morabito, “The Internet of things: A survey,” Computer Networks, vol 54, no 15, pp. 2787–2805, 2010.

[35] G. Kortuem, F. Kawsar, V. Sundramoorthy and D. Fitton, “Smart objects as building blocks for the Internet of things,” IEEE Internet Computing, vol 14, no 1, pp. 44–51, 2010.

[36] S. Bin, L. Yuan and W. Xiaoyi, “Research on data mining models for the Internet of things,” in Proc. International Conference on Image Analysis and Signal Processing, pp. 127–132, 2010.

[37] Krontiris, I., Giannetsos, T. and Dimitriou, T. (2008). Launch Sinkhole Attack in Wireless Sensor Network; the Intruder Side. In Networking and Communications, 2008. WIMOB’08. IEEE International Conference on Wireless and Mobile Computing, (pp.. 526-531). IEEE.

[38] K. Ashton,"That 'Internet of Things' Thing," RFID Journal, available at http://www.rfidjournal.com/article/print/4986, 2009, "Accessed on 07-Aug-2016."

[39] E. Masciari, "A framework for outlier mining in RFID data," in Proc. International Database Engineering and Applications Symposium, pp. 263–267, 2007

[40] V. Cantoni, L. Lombardi and P. Lombardi, "Challenges for data mining in distributed sensor networks," in Proc. International Conference on Pattern Recognition, vol 1, pp. 1000–1007, 2006.

[41] F. Siegemund, "A Context-Aware communication platform for smart objects," in Proc. International Conference on Pervasive Computing, pp. 69–86, 2004.

[42] E. Keogh, K. Chakrabarti, M. Pazzani and Mehrotra, "Dimensionality reduction for fast similarity search in large time series databases", Journal of Knowledge and Information Systems, 2000