A survey of Internet-of-Things: Future Vision, Architecture, Challenges and Services

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***Abstract*— Internet-of-Things (IoT) is the convergence of Internet with RFID, Sensor and smart objects. IoT can be defined as "things belonging to the Internet" to supply and access all of real-world information. Billions of devices are expected to be associated into the system and that shall require huge distribution of networks as well as the process of transforming raw data into meaningful inferences. IoT is the biggest promise of the technology today, but still lacking a novel mechanism, which can be perceived through the lenses of Internet, things and semantic vision. This paper presents a novel architecture model for IoT with the help of Semantic Fusion Model (SFM). This architecture introduces the use of Smart Semantic framework to encapsulate the processed information from sensor networks. The smart embedded system is having semantic logic and semantic value based Information to make the system an intelligent system. This paper presents a discussion on Internet oriented applications, services, visual aspect and challenges for Internet of things using RFID, 6lowpan and sensor networks.**

Keywords*— *Internet-of-Things; Architecture; Internet Services; Semantic Web; 6lowpan; SensorNetworks

I. Introduction

The Internet of Things is the expansion of the current Internet services so as to accommodate each and every object which exists in this world or likely to exist in the coming future. This article discusses the perspectives, challenges and opportunities behind a future Internet that fully supports the "things", as well as how the things can help in the design of a more synergistic future Internet. Things having identities and virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate within social, environmental, and user contexts [1-3]. There are several fuzziness about the concept of Internet of Things such as IoT can be broken in two parts Internet and Things. The world-wide network of interconnected computer networks based on a standard communication protocol, the Internet suite (TCP/IP) while a things is an object not precisely identifiable [2-6]. The world around us is full of objects, smart objects and the existing service provider known as Internet. The convergence of the sensors like smart objects, RFID based sensor networks and Internet gives rise to the Internet of Things. With increased usage of sensors the raw data as well as distributed data is increasing. Smart devices are now connected to Internet using their communication protocol and continuously collecting and processing the data[7]. Ubiquitous computing which was thought as a difficult task has now become a reality due to advances in the field of Automatic Identification, wireless communications, distributed computation process and fast speed of Internet [8]. From just a data perspective the amount of data generated, stored and processed will be enormous. We focused on making this architecture as a sensor based architecture where each sensor node will be as important as the sensor network itself. Visualizing each sensor as having intelligence is the ultimate aim of any architecture in the IoT domain [9].

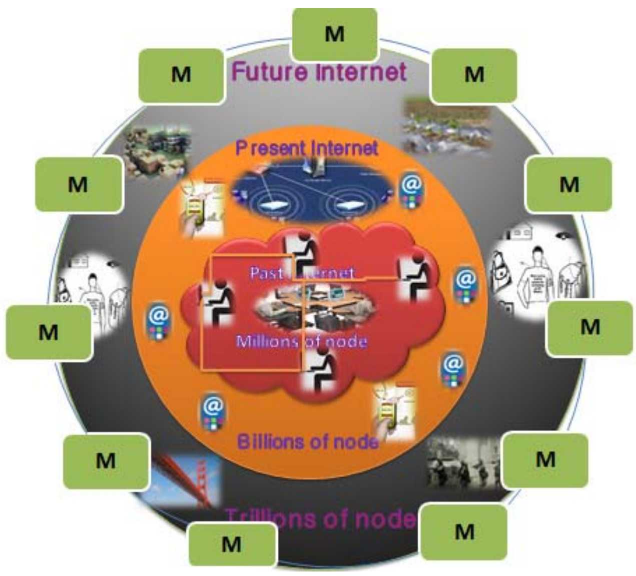

Fig.1 Internet evolutionary prospective and IoT services.

There is a lot of pervasive presence in the human environment of things or objects, such as Fig.1 described general overview of internet evolution with several IoT services with the use of radio-frequency identification (RFID) tags, sensors, actuators, mobile phones, smart embedded devices, etc. – which, through unique addressing schemes, are able to effectively communicate and interact with each other and work together to reach a common goal of making the system easier to operate and utilize. The objects that will be connected will be adaptive, intelligent, and responsive[2-4].

The IoT is changing at fast pace and is in the process of constructing current static Internet into a fully integrated Future Internet [12]. This revolution will change the way people work, think and live life. Imagine each of the vital objects in day to day life connected to each other. For any individual his wallet and watch will themselves present an alert to the user keeping them safe. The individual will be able to keep track of his belongings from anywhere and anytime and from any network.

This paper provides a first glance discussion on the current trends in the IoT research and relationships between the IoT and FI considering a full convergence point of view. The remaining of this paper is organized as follows. Section II covers the IoT vision and perspectives issues. Section III focuses on the role of IoT challenges which considering a more deep integration between the real and virtual worlds. Section IV concerns the Semantic Fusion concept and architecture Section V addresses IoT management and human intervention related services and applications. Section VI covers the relationships between IoT and the surveillance related discussion. Finally, the Section VII does some final remarks.

II. FUTURE VISION OF INTERNET OF THINGS

The Internet of Things is a vision which is under development and there can be many stake holders in this development depending upon their interests and usage. It is still in nascent stages where everybody is trying to interpret IoT in with respect to their needs. Sensor based data collection, data management, data mining and World Wide Web is involved in the present vision. Of course sensor based hardware is also involved. A simple and broad definition of the internet of things [10, 11] and the basic idea of this concept is the pervasive presence around us of a variety of things or objects – such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through unique addressing schemes, are able to interact with each other and cooperate with their neighbors to reach common goals [17]. Fig. 2 has been discussion on three particular visions given by [12]. They are:

- Things Oriented Vision
- Internet Oriented Vision
- Semantic Oriented Vision

A. Things Oriented Vision

This vision is supported by the fact that we can track anything using sensors and pervasive technologies using RFID [21]. The basic philosophy is uniquely identifying any object using specifications of Electronic Product Code (EPC) .This technique is extended using sensors. It is important to appreciate the fact that future vision will depend upon sensors and its capabilities to fulfill the "things" oriented vision. We will be able to generate the data collectively with the help of sensors, and sensor type embedded system. The summarized vision will be dependent upon sensor based networks as well as RFID-based Sensor Networks which will take care of the integration of technology based on RFID and sophisticated sensing and computing devices and the global connectivity.

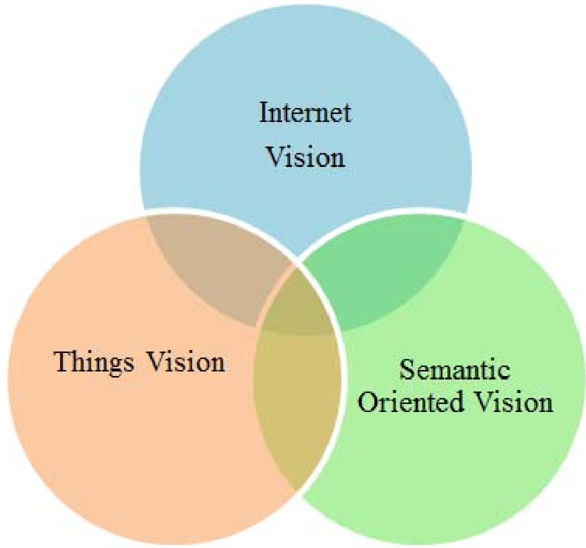

Fig.2 Three main visions of Internet of Things.

B. Internet Oriented Vision

The internet-oriented vision has pressed upon the need to make smart objects which are connected. The objects need to have characteristics of IP protocols as this is one of the major protocols being followed in the world of Internet. The sensor based object can be converted in to an understandable format, which can be identified uniquely and its attributes can be continuously monitored. This makes the base for smart embedded objects which can be assumed to be a microcomputers having computing resources.

C. Semantic Oriented Vision

This vision is powered by the fact that the amount of sensors which will be available at our disposal will be huge and the data that they will collect will be massive in nature. Thus we will have vast amount of information, possibly redundant, which needs to be processed meaningfully. The raw data needs to be managed, processed and churned out in an understandable manner for better representations and understanding. If we are able to make the sets of data into homogeneous and heterogeneous formats then the interoperability issues of understanding the data will be dependent upon the semantic technologies to process the data. It is here that needs a generic vision of processing the raw data in to meaningful data and a marked separation of data and their interpretation.

III. INTERNET OF THINGS CHALLENGES

As identified by Atzori et. al. [7], Internet of Things can be realized in three paradigms – Middleware, Sensors and The Knowledge base to interact and fulfill the visions of internet-oriented, things oriented and semantic oriented. Individual visions will not fulfill the whole connectivity vision. The intersection of these visions will be main focus for making and connecting the objects in to the network. For any network, *things* will be active participants in business, information and social processes.

We have thought of giving more focus on the user requirements of the sensors and smartness to enable IoT for sensible smart environments with any interconnection of sensors and actuators that have ability to process raw sensor information, and meaningful inferences to develop a unified picture of the situation for smart applications. This is possible through large scale sensor networks, data processing and inferences using smart sensing and cloud computing. The inferences will make the sensors sensible enough to rectify the whole process which in turn will move towards making the whole process intelligent.

The components that make up the WSN monitoring network include:

- Wireless Sensor Networks hardware - Typically a WSN node contains interfaces to sensors, computing and processing units, transceiver units and power supply. More sophisticated sensor nodes can communicate over multiple frequencies as stated in [5].
- Wireless Sensor Networks Communication Stack (WSNCS) – The nodes will be deployed in an adhoc manner. Communication topology will be an important factor for communication through the system of WSN nodes. There is this communication stack at one central node which will be able to interact with the connected world through the Internet and which will act as a gateway to the WSN subnet and the Internet [16].
- Middleware–This is associated with the internet infrastructure and the concept of service oriented architecture (SOA) for access to heterogeneous sensor resources as described in [11].

WSNs technological advances in hardware domain catering to circuits and wireless communications have made robust and cost effective devices in sensing applications. This has led to the use of sensors in wireless communication devices in diversified environments as described in [5]. Sensor data is collected and sent for centralized, distributed or any hybrid processing module for data processing. Hence, there are several challenges WSN has to face to develop a successful IoT communication networks.

A. Communication Mechanism- 6lowpan Challenges

All the objects that are present in the environment can be called object fit to be the "things" of the internet. All these objects need an address which must be unique. This uniqueness property will be a unique constraint and it will pave the way to gather information and even control sensor based devices. Internet Protocol is the standard based protocol which is used for internetworking methods of Internet. The first version was IPv4 and was thought of having huge address spaces. But IPv4 got exhausted. The solution is Internet Protocol version 6 (IPv6), which is being deployed as we discuss. IPv6 uses 128-bit (16-byte) addresses, so the new address space supports 2^{128} (approximately 340 undecillion or 3.4×10^{38}) addresses. Nodes here can be regular computers, smart embedded devices or simply a sensor. Their communication mechanisms will be Wi-Fi, DSL, Satellite, Cable, Ethernet and so forth. The typical packet size of the communicating protocol will be around 1500 data bytes to 9000 data bytes and even more.

Today large amount of spatial data is also being generated and thus we can use to use metadata for connecting database and Internet. As happens in World Wide Web, the operations with sensor nodes may not be possible by giving unique names to the sensors. Instead a unique address scheme must be formulated and will be known as Unique Resource Name (URN).A look up table of these URN must be present at the centralized node commonly known as gateway to the sensor sub system. Thus entire network now forms a web of connectivity from users (high-level) to sensors (low-level) that is addressable (through URN) accessible (through URL) and controllable (through Uniform Resource Characteristics - URC) [11]

- Data Storage - As IoT is getting developed the amount of data getting created is huge. The data centers which will be storing this data will also needs space requirement as well as the energy and power resources. It is this data which needs to be organized and processed. Semantic data fusion models will also be required to create meaning out of this data. Artificial Intelligence algorithms must be applied to extract meaning from this redundant data. Data storage and analysis will be a challenge when the whole world will be connected through IoT.
- Visualization - Any interaction of user with the environment will need proper visualization software which will highlight the sensing mechanism as well the interpretation of data scenario too. Touch screens and smart embedded tablets have created a conductive environment for the system. The information which is being processed in to meaningful data using sensor fusion algorithms will present lot many inferences about the current situation and scenarios. These inferences need to be depicted on visually attractive methods using fuzzy logic.

B. Data Fusion Mechanism and challenges

The IoT architecture can be internet oriented as well as participating object oriented. The computational part is extremely important and that can be developed using distributed processing or cloud computing [14]. Internet of Things-Architecture (IoT-A) [12], has been evolving the WSN based architecture which has been proved successful. Data fusion is an important part generally used for military processing requirements. There are different data fusion model in use but the most important of them is Joint Director of Labs (JDL) [18]. The Joint Director of Labs (JDL) revised model incorporates five levels for fusion methodologies including level 0 for preprocessing, level 1 for object refinement, level 2 for situation refinement, level 3 for threat refinement, and level 4 for process refinement. The model was developed to define the data fusion process.

Each level has a specific responsibility and at each level certain information is being processed and forwarded to upper levels for further processing and inferences. We present architecture of Semantic perspective. The amount of information that will be processed in the system will be huge considering the dynamic creation and cremation of sensor nodes in IoT. We need to have an approach whereby we must be able to distinguish random and redundant data from its subtle meaning. We are also interested in further assessment of processed data and process it to make the system better and sensible. All our requirements are being fulfilled if we use JDL model based architecture .All the processed information and output will have a semantic base which will be user friendly and domain specific. Cross domain semantic issues will be tackled later. Identification of domain is extremely important to develop ontology for specific domain.

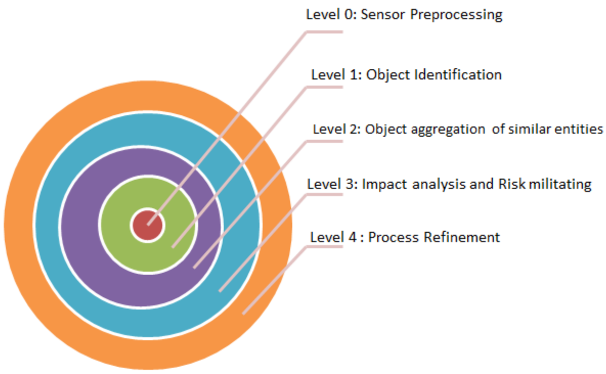

Fig.3 Levels of JDL data fusion model.

Fig. 3 presents data fusion in IoT domain will be from ontological perspective. Each level described in the figure 6 will have own ontology according to the levels. All the inferences, assessment, alarms, triggers etc. will be in ontologically understandable format. This will benefit the user for understanding. All this ontological inferences and fusion will happen at a dedicated gateway which will be responsible for collecting data from a particular location.

Cloud computing is a new concept emerging in the field of computation where all the user demands come in as a part of services. As compared to traditional computing, cloud computing gives far better advantage on the agility front, cost front, independent management of devices, location independent and is highly scalable [13]. We may use cloud computing for the computing resources of the gateway. Thus the system even at the sensor level will be virtually connected to the cloud.

IV. Semantic Fusion Based IoT Architecture

The Semantic Fusion concept is based upon the idea that improved situation awareness requires improved high-level data representations and human like intelligence and reasoning capabilities. It approaches data fusion from ontology and concept-modeling perspective, rather than a traditional data-analysis approach. Semantic Web technologies provide extensible high-level data representations, advanced query capabilities. Fig. 5 describes the sensor gateway among many sensors which will be able to compute the ontological representation and will perform parametric and non-parametric fusion over sensor data [18].

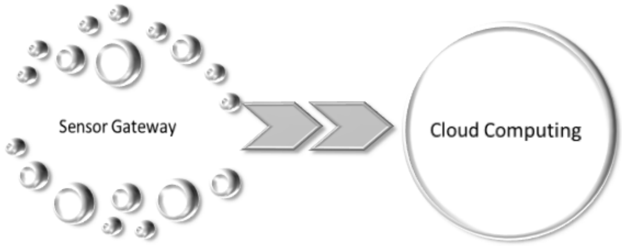

Fig.4 Sensor gateway and cloud computing.

The JDL model will now have a semantic layer at the sensor gateway and then it will interact with the computing resources which may be a cloud. The layer can be somewhat similar to the process as represented in the architecture for semantic data fusion called KnoFuss [11]. We are emphasizing on the fact that semantically evolved data representations at the semantic gateways of a particular sensor enriched domains will certainly help the system to become semantically richer datasets which, at any point of time, can be useful for the machine as well as human beings. The following diagram will represent this fact in a precise manner. The vertical bars represent numerical data processing and horizontal bar represent ontological representation in to the higher level.

Fig.5 Vertical and horizontal ontological JDL diagram.

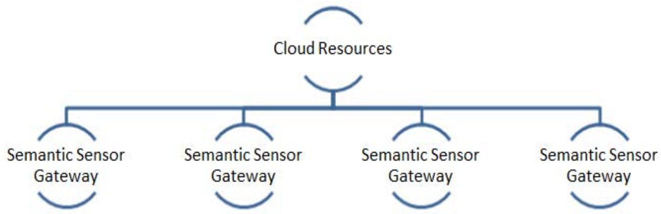

Fig.6 Semantic sensor gateway with cloud based computing architecture.

Fig.5 is clearly manifest about the processing of any system as per the fusion of ontological semantic in to the JDL model. Fig.6 presents semantic smart gateway framework which can be found where each of the data sets of sensors in the specific domain can be forces to register as an IoT entities which can be further used to develop ontological bases for the domain and IoT entities.

V. IoT: Services And Applications

Let us look into the possible set of future possibilities which we can have a rewarding applications. Some of the attributes which can be considered while developing application is highlighted in which says the network availability, bandwidth, area of coverage, redundancy, user involvement and impact analysis. Fig.7 mainly focuses on the properties of the RFID, sensors and 6lowpan communication networks based IoT services.

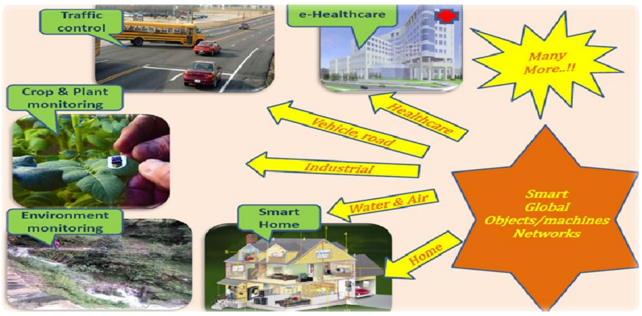

Fig.7 IoT Services and Applications.

The 6lowpan communication can be used to gather the sensor data and process the information in a variety of applications which will change the way we live and work. In this section has discussed several services and typical applications of various domains.

A. Tracking: People, Inventory and Logistic

The basis of this tracking is indeed RFID tags which are placed on object, human beings, animals, logistics etc. RFID tag reader may be used in all the intermediate stages for tracking anything which has the RFID tag in it. This object position identification can be smartly used to trigger an alarm, event or a specific inference regarding a specific subject.

B. Smart Environment and Enterprise Collection

In any work environment an enterprise based application can come up with the fact that it is based on smarter environment. Here the individual or the enterprise may give data to outside world on its own discretion. Smart embedded sensor technology can be used in order to monitor and transmit critical parameters of the environment. Common attributes of the environment are temperature, humidity, pressure etc. Smart monitoring of soil parameters can allow informed decision making about agriculture and increase production of food grains and prevent loss of crops [19]. Water conservation is huge topic of concern where droughts are frequent. To limit water wastage, smart technology can be used in water conservation.

C. Smart Unit

Another IoT application which is making waves is the Smart grid and smart metering technology as discussed in [17]. The energy consumption can be efficiently monitored in a smart home [12] or in a small office or even a locality. This model can be extended over a city for better load balancing. The world is fast changing and now camera based surveillance is high in demand. This surveillance will not only require image processing but also computer vision. IoT which will be based on video processing [14] is a new technological challenge to integrate large computation with small embedded device. Smart homes can be developed where things of daily use will be tracked using sensor enabled technologies.

D. Local, Global and Social Sensing

Imagine a scenario where each of the family members of the family have a RFID enabled gadget and thus object tracking can result actually in human tracking. This can readily happen in IoT where common mobile phones can be used for tracking human beings. There can be various types of sensors based devices which can be used for such type of tracking. This is whole process is known as local, global and social sensing. The object can be tracked locally, globally and in any place, any time and over any network.

E. Healthcare Monitoring Applications

Imagine a scenario in a village where old age persons, infants, pregnant ladies etc. have RFID enabled chips over their bodies to track their vital health parameters. Any unusual activity on their part will raise an alarm or an alert in the nearby local medical assistance home. For example, RFID chips can be implanted in patients in order to track their medical history. Sensor technology can be used in emergency response, and health monitoring applications as discussed in [17]. The information can be used to give medical assistance to the needful person and in case of higher abnormalities, the nearby efficient hospitals can be alerted and thus the hospitalization costs can be reduced through early intervention and treatment [12, 13]. This is the advantage of smart healthcare using IoT.

F. Traffic Monitoring

In any city in the world, traffic monitoring is an important part of the smart-city infrastructure. Normal traffic to highway traffic all requires adequate information about the support and logistics available on the highway and in turn the system can be made self-reliable and intelligent. Any type of congestion on roads will ultimately lead to loss of fuel and economic loss. Any foresight on traffic will always help to improve the whole system. With number of WSN and Sensor enabled communications, an IoT of traffic will be generated. This will be known as Traffic IoT (TIoT). The information collected from TIoT can be presented to travelers as in [10]. The traffic information will be dependent upon the queuing model on roads and infrastructure of roads itself. This identification of critical road points and present state of traffic information on all roads can be provided to the user. However this traffic monitoring application needs to be secure to prevent any terrorist attack frequent in urban cities. Few such prototype implementations can be found in [15][16] and the Smart Santander EU project [20].

VI. DISCUSSION ON SURVEILLANCE

Let us visualize a scenario of civilian surveillance defense system (CSDS) where vital installations, roads, street lights, paths, post box, dustbins, children park, cinema halls, market etc. all are equipped with various types of sensors. These sensors will collect information about detection of explosives and hazardous material. The city will be divided in to sectors and each sector will have a semantic sensor gateway which will communicate among them. Ontology of explosives, their usages, possible threats, assessments, alarms, alerts and triggers will be used for the CSDS. Cloud computing resource will be at any central monitoring location of the city which will be guided by the advanced semantic data fusion which will collect data from all the semantic sensor gateways to form a common operational picture and in turn will also do the level 4 process for process refinement of JDL model through which they can always adjust the sensor location, edit rules for assessment and can have all types of alarms and alerts of the system to thwart any terrorist attack with the use of explosives[17-19].

The above architecture has its own issues. The bandwidth issue is the most important. As the number of sensor nodes increases the system has to use resources in constraints. Another issue is the security issue. We can use the sensor data to prevent sensors itself from any intrusion/attack. A similar level three enabled situational and threat refinement has to be developed to cope up with the security and privacy challenges. The semantic specification of sensors [20, 21] must be clearly defined and revisited so as to make them ontologically feasible to the semantic layer architecture. The challenge is to provide unique address, the challenge to talk on the minimum bandwidth possible, to develop a new framework for the packets etc. Privacy and security are other challenges which need to be addressed. The JDL model has been primarily used for defense purposes. The challenge is to use this model for common architectural patterns.

VII. FINAL REMARKS

The Internet of Things is a vision, which is currently under progress. The idea to connect everything and anything and anytime is appealing. The dynamic nature of IoT and the scale on which it will be functional is hard to imagine and thus there will be huge responsibility to overcome the challenges. There will be challenges of scale in terms of IP-addressability, privacy, security, and data management and analytics. This paper develops an insight into IoT vision, and gives a novel architecture on the semantic front of the data collected by the sensors. It brings in a new flavor by bringing JDL model into the picture which will enable the semantic layer into the system and a semantically rich architecture for IoT using cloud computing can be formulated. In conclusion, we believe that this paper is a starting point of the beginning of a new architecture. The present architecture has the scope to improve a lot on the semantic and security front. Development of domain specific ontology or an independent ontology format can be a point of discussion in future papers. We hope that this effort will be useful for a new IoT based architecture development and will contribute to the research of our IoT Community.

ACKNOWLEDGMENTS

This work was supported by Hankuk University of Foreign Studies South Korea fund 2014 and partially funded by the European Project "Universal Integration of the Internet of Things through an IPv6-based Service Oriented Architecture enabling heterogeneous components interoperability (IoT6)" from the FP7 with the grant agreement no: 288445.

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