UNIT-5

THE INTERNET OF THINGS

One of the things that makes people smart—smarter than all the other creatures who creep, flap, hoof, and slither round the planet—is our ability to communicate with one another. We can talk to other people, listen to them, and collaborate to achieve very complicated goals, from finding cures for cancer to putting astronauts on the Moon. Even before the invention of the Internet, people were intricately networked, right round the world; famously, according to sociological theory, there are only six degrees of separation (six links) necessary to connect any one person on the planet with any other.

Now what if gadgets and machines could talk to each other the same way? What if an accelerometer embedded in a cardigan could automatically detect when an old person fell down the stairs and telephone an ambulance? What if all the homes in the United States had smart power meters that could signal energy consumption to utility companies in real-time? Suppose car engines could monitor their own mechanical efficiency, and, if it fell below a certain level, dial into a garage computer and be remotely tweaked back to some optimum level, all without leaving our drives? What if highway control systems could measure and monitor cars streaming down different routes at different times of day and automatically re-route traffic round jams and snarl-ups? These things might sound fanciful, but they'd all become possible if the machines in our homes, offices, and transportation systems could communicate with one another automatically—if, in other words, there were a giant network of machines: an **Internet of things**.

What is the Internet of Things?

People have been getting excited about this idea since it was originally suggested in 1999 by technology entrepreneur Kevin Ashton, then working in brand marketing at Proctor & Gamble. He'd been researching electronic sensors and RFID tags (wireless printed circuits that allow objects to identify themselves automatically to computer systems; they're used in library self-checkouts) and, in a moment of insight, wondered what would happen if all kinds of everyday objects and machines could communicate through a standard computer network. Ashton realized his Internet of Things was a yellow-brick road to better efficiency and less waste for all kinds of businesses.

In popular news articles, the Internet of Things is often explained by introducing a well-known but frivolous and now rather hackneyed example. Suppose your refrigerator could use RFID tags to detect what products it contained and how old they were. If it were linked to the Internet, it could automatically reorder new supplies whenever it needed to. It sounds harmless enough, but the infamous Internet fridge has actually become something of a distraction from much more valuable applications: most of us are capable of keeping tabs on our sour milk and moldy cheese, the argument goes, so what possible use could there be for an Internet of Things? But suppose similar technology were being used to monitor elderly or disabled people so they could continue to live safely, with independence and dignity, in their own homes? It's easy to build a home that uses motion sensors to monitor when someone is regularly walking around (intruder alarms have been using this technology for years), and not much harder to monitor that data remotely. That's a much more persuasive example of how the Internet of Things could prove really helpful to a society with a rapidly aging population.

Although people sometimes talk about the Internet of Things as though it's merely an extension of smart home technology, it's actually a much bigger and more general idea. Imagine our system for monitoring the elderly transplanted to a hospital and scaled up into a kind of e-care, in which noncritical patients are routinely monitored not by nurse's observations but by remotely gathered electronic sensors, communicating their measurements over a network. Or, to take another example, what about automatically monitoring your home while you're on holiday using sensors and webcams? If it works in a house, it works anywhere: for checking and automatically restocking shelves in a supermarket, for remotely monitoring the crumbling concrete on a highway bridge, or in a hundred other places.

How does it work?

Five basic things are needed to make the Internet of Things work.

1. The thing

First, there's the "thing" itself—which could be anything from a person or animal to a robot or computer; champions of the technology have even speculated that one day the Internet of Things could extend to things as small as bits of dust. Generally speaking, the "thing" is something we want to track, measure, or monitor. It could be your own body, a pet, an elderly relative, a home, an office block, or pretty much anything else you can imagine.

2. The identifier

Photo: RFID tags, like this one concealed in a price label on a pair of shoes, allow objects to identify themselves to the Internet of Things.

If we want to be able to connect things, monitor them, or measure them, we need to be able to identify them and tell them apart. It's easy enough with people: we all have names, faces, and other unique identifiers. It's also relatively easy with products we buy from stores. Since the 1970s, most of them carried have unique numbers called Universal Product Codes (UPC), printed on their packs using black-and-white zebra patterns—barcodes, in other words. The trouble with barcodes is that someone has to scan them and they can "store" only a very small amount of information (just a few digits). A better technology, RFID, allows objects to identify themselves to a network automatically using radio waves, with little or no human intervention. It can also transmit much more information.

3. The sensors

If an object simply identifies itself to a network, that doesn't necessarily tell us very much, other than where it is at a certain time. If the object has built-in sensors, we can collect much more useful information. So automatic sensors that can routinely transmit automatic measurements are another key part of the Internet of Things. Any type of sensor could be wired up this way, from electronic thermometers and thermocouples to strain gauges and reed switches.

4. The network

It makes sense for things to exist and communicate on a network the same way that computers exist and talk to one another over the Internet—using a standard agreed communication method called the Internet Protocol (IP). IP is based on the idea that everything has a unique address (an IP address) and exchanges data in little bits called packets. If things communicate using IP, or use something like WiFi to talk to an Internet-connected router, it opens up the possibility of controlling them from a Web browser anywhere in the world. That's why we're now seeing home security and monitoring systems that allow you to do things like turning your central heating on and off with smartphone apps.

5: The data analyzer

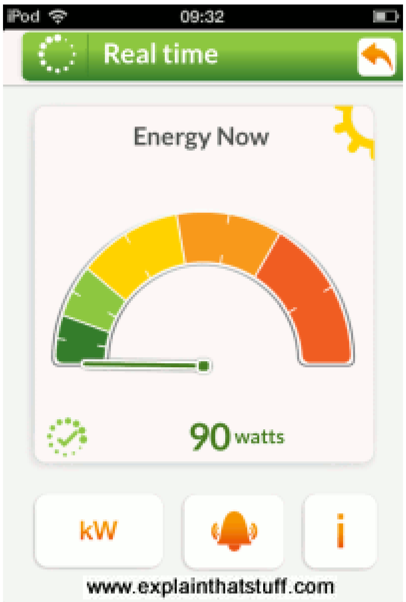
Once we're collecting masses of data, from hundreds, thousands, millions, or even billions of things, analyzing it could find patterns that help us work, move, and live much more smartly—at least in theory. Data mining the information we gather from people or car movements and optimizing our transportation systems could help us reduce travel times or congestion, for example, with major benefits for people's quality of life and the environment. Cloud computing systems (the idea of using powerful computer services supplied over the Internet) are likely to play a very big part in the Internet of Things, not least because the amount of data collected from so many things, so regularly, is likely to be enormous.

Who's using it already?

Photo: Smartphone apps are likely to be one of the ways people interact with the Internet of Things. Above: Hive's app lets you control your heating using your phone, wherever in the world you find yourself. Below: Efergy's energy monitoring app keeps tabs on your home energy consumption.

You don't have to look too far to see the Internet of Things in action. Libraries were early adopters, embedding RFID chips in book covers so that people could borrow and return items themselves using self-checkout machines. That gave instant stock-control, better security, and (in theory) the possibility of freeing up librarians to spend more time helping people (in practice, many libraries simply have fewer staff now). Tracking your home-delivery purchases over the Internet is another very basic example: if every parcel is barcoded and scanned at every point of its journey from warehouse to customer, with the scanners all wired to a central database, it's easy to work out where anything is at any time.

Much more interesting examples are also starting to emerge. Hive, a home-heating system launched by British Gas, uses a wireless thermostat that communicates with your home Internet router—making it possible to adjust your heating or hot water using a smartphone app or web browser; the Nest Learning Thermostat, a rival home thermostat system, is more sophisticated but can be controlled by an app in a similar way. Piper, a home management and security system, goes even further: it connects a whole raft of sensors and alarms to a web interface so people can monitor and manage their homes when they're at work or on vacation.



Even the infamous Internet fridge is starting to arrive—albeit in rather slow motion. Between 2014 and 2019, Amazon tested a system called Dash, featuring a handheld scanner that you could swipe over products to reorder things when supplies got low. A related idea was to stick simple Internet-connected "Dash buttons" around your home that you could use to reorder things with a single click.

In one way or another, all the big digital technology companies are exploring variations on the Internet of Things. Apple has HomeKit (which turns iPods and iPhones into smart home controllers) and HealthKit (which lets you monitor your health and fitness and, if you wish, share the data with your doctor or hospital through a smartphone app). Google has Home and Fit, which lets people monitor and analyze exercise data collected from wearable sensors and trackers developed by a whole collection of partner companies. Samsung, leading maker of both smartphones and home appliances, sees a great opportunity in linking the two in a system called the SmartThings Hub. Microsoft is also believed to be working on smart home systems linked to its Kinect motion tracker and Xbox gaming system. And Amazon has Alexa.

Good points and bad points

It's easy enough to see benefits from a world in which we connect, monitor, and analyze things much more intelligently. The natural world manages perfectly well without top-down organization, coordination, and control, but our human-dominated planet, packed with over 7 billion people, plagued with problems like poverty, disease, and looming environmental challenges such as climate change, probably can't afford the luxury of hapless, chaotic self-organization for much longer. The benefits of tracking and organizing things seem overwhelming to some people; even so, critics point out equally clear risks of monitoring people and things so much more closely. Do we all want our cars to be tracked at all times? Do we want grocery stores to know even more about what we're heating than they do already? Do we want our homes packed with sensors, keeping tabs on us at all times? There are all kinds of privacy, security, and ethical issues to consider before we get anywhere near the technological difficulties of building something so all-encompassing as an Internet of Things.

Photo: Privacy problems ahead? Will an Internet of Things designed for tracking and tracing things turn into a perfect tool for spying on people?

Given that much of the technology exists already, you might think building an Internet of Things is really quite a simple task, but putting everything together is likely to prove much more complex. One problem is that the whole concept has been hyped as a massive commercial opportunity, so lots of different companies are rushing to develop and market competing technologies. That raises the immediate difficulty of getting rival systems to talk to one another. If I buy a smart home-heating system from one utility company, will I be able to control it using another company's smartphone app if I decide to switch utilities in a couple of years time? If I buy myself an Amazon product scanner, will I only ever be able to order products from Amazon? Or will I have to order a different scanner for every different company I buy from? While companies such as Amazon and Apple are notorious for taking a "closed" (or "walled-garden") approach to their products and services (for example, you can only read Kindle ebooks, sold by Amazon, on an Amazon Kindle reader), rivals such as Google and Samsung are notable champions of "open" standards. Whether closed, open, or mixed systems prevail, there's likely to be a great deal of consumer confusion about what works with what, and there's a real risk that the Internet of Things fragments, in practice, into many highly compartmentalized systems—many Internets of Things—that have little or nothing in common.

That's not so surprising when the Internet of Things is so broadly defined that the whole idea verges on the meaningless. A recent British government briefing describes it as an "ecosystem" that links anyone, any business or service, through any path or network, to anything, anytime, anywhere—in other words, defines it so broadly that it includes absolutely everything. Is that a helpful idea? Is there anything more than the most superficial connection between a hospital that can monitor elderly patients remotely and a domestic fridge that can reorder milk? Does it make any sense at all to link such disparate ideas together, if all we're really saying is that everything should be able to interoperate by relying on common systems and standards as much as possible? To put it another way, would your hospital ever want or need to communicate with your fridge?

Although often hyped as a means of doing things more efficiently and saving time and money, there's no guarantee at all that an Internet of Things will deliver cost, energy, or efficiency savings. Does the ability to control your home heating from work make it more or *less* likely that you will save energy? Will you simply shuffle energy around and use it at a different time? Why can't you leave the job to an intelligent electronic thermostat (a perfectly reliable and efficient piece of technology we've all been using for decades)? Who says you can do it better from your smartphone than a computerized programmer can do it from inside your home? To use a different example, it's absolutely fascinating to track parcels all the way from the warehouse to your doorstep—but do you really need to know anything more than the date when they'll finally arrive? Every extra bit of computer power we use managing, monitoring, and generally fiddling about with the Internet of Things is extra energy for the world to consume. Cloud computing powers the Internet of Things—and is already one of the world's biggest and fastest growing forms of energy consumption. There's a very real risk that, far from helping us reduce resources and use energy more widely, the Internet of Things will simply add another unnecessary layer of micromanagement on top of what we do already—increasing the world's energy consumption overall. It's very telling that data from American homes reveals steadily *growing* energy consumption despite significant improvements in energy reduction and massive reductions in the energy we need for basic things like home heating.

Smart home technology has been widely available for decades but, so far, has pretty much failed to capture people's imagination or take off in a really big way. Will rebranding it—breathlessly hyping it as the "Internet of Things"—make any difference? Home electrical energy monitors have been around for years, for example, and seem to offer the very compelling benefit of *saving money*, but they're still relatively underused. Smart homes aside, there are very compelling reasons for businesses and public services to invest in Internet of Things technology—especially if they can demonstrate real customer benefits, cost or energy savings, or other good reasons for doing so. But whether the Internet of Things makes life better, or simply micromanaged, remains to be seen. Libraries and supermarkets are perfect examples: they use more technology and employ fewer people than ever before, but do they serve us better, and do we like them more or less than we did before? Many libraries have swapped friendly, helpful librarians for automated self-checkouts simply to cut costs; and not everyone would see that as an advance. Will the Internet of Things revolutionize our homes, offices, and transportation systems, making everything better organized and more cost-effective? Will the Internet help us control things more effectively—or simply turn people into "things" that can be connected, analyzed, and monitored?

SMART CITY APPLICATIONS AND SMART AGRICLETURE

Internet of Things (IoT) are contributing enormous amount of data. The recent use of Internet of Things in Smart City infrastructures has led to very large amounts of data being generated each day across various domains, with applications including defense applications, healthcare monitoring and transport monitoring. To take expediency of the increasing amounts of data there is a need for new practices and techniques for effective data management and analysis to generate information that can assist in the utilization of resources intelligently and effectively. Through this paper, a IoT based Smart City architecture is proposed based on semantic web technologies and Dempster-Shafer uncertainty theory. The proposed architecture for a multi layered smart city is explained.

INTRODUCTION

In recent years, there has been an increasing trend of large numbers of people moving towards urban living. As forecasted in1 by 2030 more than 60 % of the population will live in an urban environment. Some of the systems that can address the challenges related to increased population will contribute to the development of the Smart City. The Smart City concept operates in a complex urban environment, incorporating several complex systems of infrastructure, human behavior, technology, social and political structures and the economy. A Smart City provides an intelligent way to manage components such as transport, health, energy, homes and buildings and the environment. The data generated by these components are primarily by wireless sensor networks. Wireless sensor networks have been deployed in many industrial and consumer applications such as health monitoring, smart home applications, water monitoring and environment monitoring. Sensor nodes associated with different Smart City applications generate large amounts of data that are currently significantly under-used. Using existing ICT infrastructure, generated heterogeneous information can be brought together. Some of the existing wireless communication technologies that can be exploited to achieve this information aggregation are 3G, LTE and Wi-Fi. In the context of usage of embedded devices and existing internet infrastructure the Internet of things (IoT) encompasses PC's and other surrounding electronic devices. The Smart City vision is dependent on operating billions of IoT devices from a common place. The recent emergence of low power wireless network standards for sensors and actuators has enabled administrators to manage and control wide ranges of sensor networks and actuators remotely. In order to facilitate the interaction between wireless sensor networks and information and communication technologies, Smart City architecture is proposed in this paper. The proposal is to deploy the architecture on a service platform. Through this platform, sensor applications can be connected and utilized by different web applications for an intelligent operating condition. The proposed architecture helps in exploiting very large volumes of data and information using semantic web technologies and uncertain reasoning rules. We use a reasoning approach for knowledge extraction and information combination from different Smart City domains such as vehicle, health, home and environment domain and knowledge extraction

1) A Multi-Level Smart City architecture; and 2) some of the realtime context aware solutions associated with the Smart City architecture. In this paper, related work is described briefly in section 2. Section 3 describes the Multi-Level Smart City architecture. Section 4 concludes and describes future work.

2. RELATED WORK In a Smart City, wireless sensor networks are the major sources of heterogeneous information generation. The information generated by different sensors often overlaps and is partial in nature. Addressing the challenges related to fusion of partial data is a research challenge. The Dempster Shafer theory of evidence, originally proposed by Dempster2 and then extended by Shafer3 is an extension of traditional probability and can be used for uncertain reasoning under these circumstances. Similarly, Tazid et al4 considers the merits and demerits of different combination rules (such as the Dempster rule, Yager rule, Sun rule) that are used in sensor data fusion. Yoon and Suh5 and Javadi et al6 use the Dempster-Shafer approach, or uncertain reasoning, for sensor data fusion in the environmental domain. The proposed data fusion approaches were limited to the devices and their functionality for a single Smart City domain only. Through this research, we aim to address multi- domain sensor data fusion. Some existing Smart City projects, such as the IBM project SCRIBE7 , define the Smart City in term of semantic model based on data gathered from around the world. The SCRIBE ontology is defined using open standards such as Common Alerting Protocol and the National Information Exchange Model (NIEM) and addresses the heterogeneous data issue in different Smart City domains. Similarly, the Smart Santander project8 aims to evaluate the key building blocks of the IoT, which are mainly the interaction and management protocol mechanisms. In the Smart Santander project, a large number of sensors will be deployed in different cities and exploited for different applications. The developed test bed will help in exploiting various Smart City domains such as environment monitoring, traffic intensity pattern monitoring and guidance for drivers on available parking spaces. The City Sense project9 aimed to improve existing human infrastructure and thus help in providing better services to citizens by exploiting available resources (such as electricity, water, and traffic) in a more efficient manner. However, these Smart City projects do not provide detailed information about their implementation. In addition, their semantic models do not specify how they will incorporate uncertainty aspects.

Considering these aspects, our approach will use a multi-level system design, in which low-level raw information is semantically enriched and inferred by intelligent customized applications in a Smart City domain. Furthermore, our sensor fusion approach is based on domain expert knowledge and a reasoning process that uses the Dempster-Shafer theory of evidence. This approach is also well suited to dealing with uncertainty in heterogeneous data for the Smart City model. 3. Multi-level Smart City Architecture With the aid of modern wireless technologies and wireless sensor networks, we envisage the future of the Smart City systems providing powerful, intelligent and flexible support for people living in urban societies. As shown in Figure1 we propose a Smart City architecture that is an extension of10, which was restricted to the vehicle domain only. By integrating wireless sensor networks and available wireless communication services, the following research aims are targeted: 1) real-time high-level context-aware customized services;

2) better living environments;

3) improved utilization of the available resources.

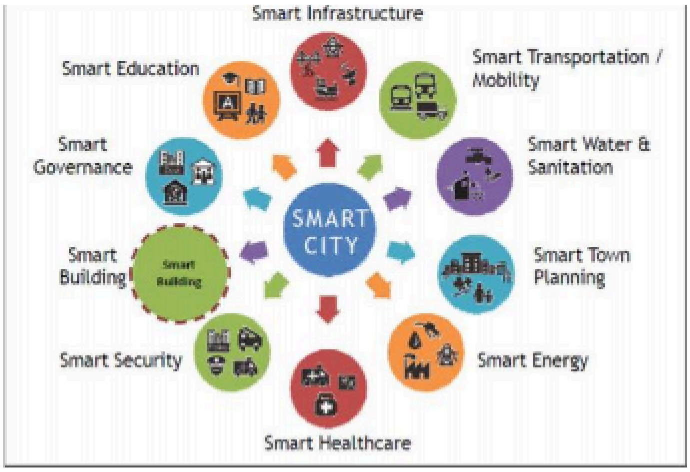


Fig1: Smart City Components

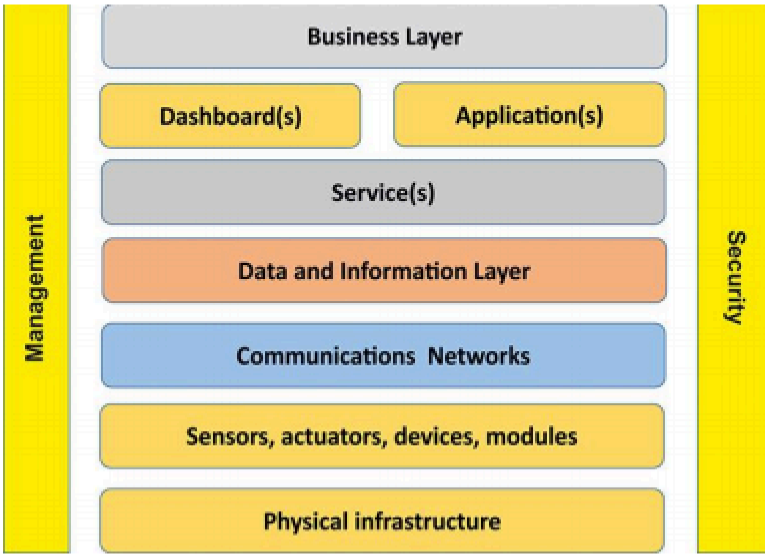


Fig 2.Multi level smart city architecture

Smart City Components Fig 2.Multi level smart city architecture As shown in Figure 1, we envisage the main elements of the Smart City architecture to be smart health, smart environment, smart energy, smart security, smart office and residential buildings, smart administration, smart transport and smart industries. The sensor nodes deployed in each Smart City domain provide the primary data source for heterogeneous information generation. Information generated through the sensor nodes are collected using the existing communication services (see Section 3.2). For example, the use of satellite network for GPS devices, cellular services such as GSM/3G/4G for smart phones and the use of internet for PC's and other navigation devices for raw data collection. The collected data are then processed and analyzed using semantic web technologies and Dempster-Shafer combination rules. The focus is on deploying the architecture on a cloud platform for use as a software as a service (SaaS). The proposed architecture can help Alzheimer's patients and elderly people with their daily living activities, for example, by sending alerts and warnings to end users if they forget, or are unable to complete, daily living activities. The system will also serve as an intelligent platform for people living in a Smart society. By combining data from different Smart City domains, this architecture will help in assisting people in an intelligent manner, for example, guiding a driver to take another route in case of road congestion, alerting heart patients in situations where their heart rate is exceeding a threshold limit while performing an activity, assisting people with alerts and warnings for their household items such as sending alerts for buying food items via a Smart fridge. The implementation of the architecture will follow the steps outlined below. Firstly the raw data are collected and processed to make them web consumable. Once the data are converted into a common format they are then semantically enriched with OWL concepts based on the knowledge of domain experts. At the same level, the collected data are processed using the Dempster-Shafer rules to deal with the uncertainty aspects of the semantic model. The idea is to recognize activity and learn new rules that are governing an activity. The new rules learned at this level will be used in defining the knowledge of the semantic model. The same approach will be used in defining customized services that will provide feedback to the end users (citizens) in the form of alerts and warnings as mentioned in Level 4 of the Smart City architecture. 3.1 Multi-Level Smart City Architecture As shown in Figure 2, sensors form the primary source of information generation. The raw data sensed by the sensor node are transferred to Level 1 of the Smart City architecture using communication services to perform further information processing. A detailed description of each Level is explained below. 3.1.1 Level 1: Data collection In this level, raw information collected from sensors is stored for further processing. Some of the formats in which heterogeneous data are collected are csv, tweets, database schemas and text messages. The collected formats are then processed using semantic web technologies in order to convert them into a common format. The next level describes the steps used in conversion of data into a common format. 3.1.2 Level 2: Data processing Information gathered from the data collection level is summarized prior to transmission, analysis and fusion in the further levels using semantic web technologies. The main objective of this level is to convert the collected heterogeneous information into a common format, e.g. Resource Description Framework (RDF). RDF11 is the most common way to exchange information over the web and it facilitates heterogeneous data sharing and integration for different Smart City domains. RDF also helps in defining metadata about the resources on the web. Different software applications can then utilize RDF data for intelligent reasoning operations. Pre- processed RDF data generated at this level will be exploited using semantic knowledge and uncertain reasoning rules in the next level for high-level context-aware information retrieval. 3.1.3 Level 3: Data integration and reasoning Semantic web technologies enable exploitation of domain specific data based on the concepts and relationships between those concepts. The techniques used in this level are summarized below. Web ontology language (OWL)12 is used for publishing the ontologies. OWL is an RDF graph that is built using the RDF and ontologies. It allows the classification of the individual/concepts based on the classes. It also provides two different types of properties, which can be used to form relationships between different classes, namely the Data property and Object property. Once data classification is done, knowledge can be further enriched with domain experts and uncertain reasoning. Dempster-Shafer will be used here for activity recognition and learning new rules in a particular domain of discourse. In this paper the Dempster-Shafer approach is used for combining sensor data 6 from different Smart City domains. This approach will help in learning new knowledge through uncertain reasoning and thus assist in achieving an intelligent smart system. SPARQL is an RDF query language13 that is used to query, retrieve and manipulate data/records stored in the RDF format. Once the whole database is expressed in the form of RDF triples, SPARQL enables the query and retrieval of data in the same format. Therefore, this level motivates towards low-level information fusion. The new rules learned during the process of extraction of high-level context information from raw sensor data can then be stored and used for building up knowledge in the Smart City architecture. 72 J Srinivasa Rao, Mamatha Syamala International Journal of Computer & Mathematical

Sciences IJCMS ISSN 2347 – 8527 Volume 6, Issue 10 October 2017 3.1.4 Level 4: Device control and alerts Data obtained from level 3 can be utilized by different web applications for intelligent operating conditions. The inferred data can be utilized in many ways such as input/output, messaging, alerts and warnings14 . 3.2 Communication Services The communication medium plays an important role in achieving the Smart City concept. The existing communication services that are utilized in a Smart City infrastructure: 3G (3rd generation), LTE (Longterm evolution), Wi-Fi (Wireless fidelity), WiMAX (worldwide interoperability for microwave access), ZigBee, CATV (cable television) and satellite communication. The main aim is to connect all sorts of things (sensors and IoT's) that can help in making the life of citizens more comfortable and safer. An example is provided by communication services in the home domain for connecting telephone devices and PC through the internet. In the case of the Government sector, cloud and communication services are combined to obtain a better governance system. In the case of the health sector, communication technologies can be used to connect health statistics, medication and location of the patient from a remote location thus helps to achieve a Smart Health system. Hence, with Smart City and communication technologies we can provide a more secure and convenient infrastructure for better living. 3.3 Customized Services In the case of the vehicle and health domains, by combining sensor data we can measure the impact of driver health parameters on driving conditions. Combining health parameters like blood pressure and heart rate with vehicle status can help the driver to measure their real-time health condition, which can help in creating a safe environment for drivers. Similarly using vehicle location, vehicle speed and volume of traffic approaching a junction, we can help in better monitoring of vehicle status. In the case of the healthcare domain, information collected through wireless sensor networks about patient health and activity can assist the disabled person. Similarly, by combining the home and environment domains data, the effect of temperature on home activities like eating, bathing, sleeping and cooking can be learned. This can help in recognizing correct activity status, which in turn can be a useful care tool for the elderly and people suffering from dementia. In the case of the environment and administration domains, low-level information collected from the environment domain such as temperature and water level will help in deriving high-level customized information. When high level customized information (such as flood, earthquake, forest fire, landslide and other natural calamities) is combined with city administration services, it could help in saving lives. Similarly, in the case of the industrial sector, context-aware services obtained through heterogeneous data fusion will help in creating a safe working environment for factory workers. By continuous monitoring, recording and exploiting the ambient sensor information from different domains (such as harmful gas detection, machine conditions and workers' health) in an industrial environment, a better, more productive and safer environment for workers can be created. 4. Discussion and Conclusion The Smart City concept has been revolutionized and has evolved into a new era with recent developments in ICT that combine wireless sensor networks and computer networks. We aim to address some of the customized services in a Smart City environment by using semantic modeling and Dempster-Shafer theory. In addition, through the Dempster-Shafer approach in our Smart City architecture we aim to address the uncertainty aspect of our Smart City semantic model. Although it is very difficult to cover each and every aspect of the Smart City, through our architecture we aim to focus on the most important areas of the Smart City environment. Future work is planned to perform experiments on the ideas discussed, which includes discovering real-time heterogeneous information, proposing a common semantic knowledge model, using Dempster-Shafer models for combining sensor data and for reasoning, and defining data interoperability and scalability aspects in our architecture.