Smart Cities Based on Internet of Things (IoT) -A vision, Architectural Elements and Future Applications

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1.HIGHLIGHTS

- Presents vision and motivations for Internet of Things (IoT).
- Application domains in the IoT with a new approach in defining them.
- Cloud-centric IoT realization and challenges.
- Different parts of smart city namely parking system, Hydroponics, Waste Management system.

2.ABSTRACT

Increasing population density in urban centers demands suitable provision of services and infrastructure to meet the needs of city inhabitants, surrounding residents, workers and visitors. The utilization of information and communications technologies (ICT) to achieve this objective presents an opportunity for the development of smart cities, where city management and citizens are given access to a wealth of real time information about the urban environment upon which to base decisions, actions and future planning. This paper presents a framework for the realization of smart cities through the Internet of Things (IoT). The framework encompasses the complete urban information system, from the sensory level and networking support structure through to data management and Cloud based integration of respective systems and services, and forms a transformational part of the existing cyber-physical system.

This IoT vision for a smart city is applied to a noise mapping case study to illustrate a new Method for existing operations that can be adapted for the enhancement and delivery of important city services.

3.INTRODUCTION

It is estimated that 70% of the world's population, over 6 billion people, will live in cities and nearby regions by 2050. The rapid increase of the population density inside urban environments, infrastructures and services has been needed to supply the requirements of the citizens. So, cities need to be smart, if only to survive as platforms that allow economic, social and environmental safety. Smart city is the one that uses information and communications technologies (ICT) to make the city services and monitoring more aware, interactive and competent. Smartness of a city is driven and enabled technologically by the growing Internet of Things (IoT) - a radical evolution of the current Internet into a global network of interconnected objects that not only gathers information from the environments (sensing) and interacts with the physical world, but also uses existing Internet standards to provide services for information transfer, analytics, and applications. The Internet of Things (IoT) is a new model that is fast gaining ground in the result of modern wireless telecommunications. The basic idea of this concept is the ubiquitous presence around us of a variety of things or objects – such as Radiofrequency Identification (RFID) tags, sensors, actuators, mobile phones, etc. – which, through distinctive addressing schemes, are able to relate with each other and cooperate with their neighbors to reach common goals powered by the adaptation of a variety of facilitating devices such as embedded sensor and actuator nodes, the IoT has stepped out of its beginning and is on the edge of revolutionizing current fixed and mobile networking infrastructures into a fully integrated future Internet. Wireless sensor networks (WSN), as the sensing-actuation support of the IoT, effortlessly integrates into urban infrastructure forming a digital layer over it. The information generated will be shared across diverse platforms and applications to develop a common operating picture (COP) of the city. With urbanization violate the 50% obstacle; it is of utmost importance to understand the d e m a n d f or service profiles to increase the efficiency of city management. Currently, few municipalities have plan for live monitoring, and gathering of urban process parameters. The commonly employed strategy is: data collection; offline analysis; action; followed by system adjustments and repetition of the whole process. Data collection exercises are often costly and difficult to imitate. There is thus an increased demand on municipalities to incorporate smart technologies that collect the required data and analyze them for action, all in real time. With advanced sensing and computation abilities, data are assembled and evaluated in real time to extract the information, which is further transformed to usable knowledge. This will improve the decision making of city management and citizens to turn the city smart. The paper mainly focuses on IoT implementation in making parking system, also creating an up to the mark waste management system and hydroponics cultivation system.

4.MOTIVATION

The smart city is becoming smarter than in the past as a consequence of the current expansion of digital technologies. Smart cities consist of various kinds of electronic equipment applied by some applications, such as cameras in a monitoring system, sensors in a transportation system, and so on. Furthermore, utilization of individual mobile equipment can be spread. As mentioned, a smart city employs information and communications technologies (ICT) in a way that addresses quality of life by undertaking urban living challenges encompassed by more efficient utilization of limited resources (space, mobility, energy, etc.). World leading municipalities, in terms of services and quality of life, have provided efficient services to their citizens by the forward thinking and use of technology in monitoring various environmental parameters. Most of these systems consist of sensor, data storage device, and computer at a base station where experts analyze the data. From the technological perspective, the evolution of social networking in the past decade clearly shows the usability of ICT at an individual’s level. Large scale implementations at system level have made some progress in recent years. A fully integrated system of systems containing sensing, storage, analytics, and interpretation is required. The integrated system must have core capabilities of plug-and-play sensing, secure data aggregation, Quality of Service, and re-configurability. With an urban sensing system of systems in place, the ability to evaluate the impact of the preceding actions is readily available as the sensing cycle repeats. A unifying information management platform delivers a capability across application domains critical to the city. Whilst large volumes of data collection and interpretation are already performing at different levels within city councils using manual and semi-automated methods, it is mostly in isolation. As with any large organization, it is inevitable that large portions of these data remain disjoint in the time scales over which they are collected and the capacity for them to be integrated. An urban information framework enabled by IoT provides a means for consolidating these tasks and sharing data between various service providers in the city. The applications within the urban environment that can benefit from a smart city IoT capability can be grouped according to impact areas. This includes the effect on: citizens (health and wellbeing); transport (mobility, productivity, pollution); and services (critical community services). Several projects are already underway within the City of Melbourne that utilizes sensor technologies to collect application specific data. These include: public parking monitoring; micro climate monitoring; access and mobility (pedestrian, cyclists, car sand goods vehicles). A number of specific application domains have also been identified that could utilize smart city IoT infrastructure to service operations in Health Services (noise, air and water quality); Strategic Planning (mobility); Sustainability (energy usage); Tourism(visitor services, tourist activity); Business and International (city usage, access); and City Safety.

5.DEFINATIONS

Internet of Things can be realized in three paradigms—internet-oriented (middleware), things oriented (sensors) and semantic-oriented (knowledge). Although this type of delineation is required due to the interdisciplinary nature of the subject, the usefulness of IoT can be unleashed only in an application domain where the three paradigms intersect. The RFID group defines the Internet of Things as stated further-

The worldwide network of interconnected objects uniquely addressable based on standard communication protocols.

• 'Things' are active participants in business, information and social processes where they are enabled to interact and communicate among themselves and with the environment by exchanging data and information sensed about the environment, while reacting autonomously to the real/physical world events and influencing it by running processes that trigger actions and create services with or without direct human intervention.

• Uses information and communications technologies to make the critical infrastructure components and services of a city's administration, education, healthcare, public safety, real estate, transportation and utilities more aware, interactive and efficient.

• Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework.

6.TRENDS

Internet of Things has been identified as one of the emerging technologies in IT. Due to its ease of operation the IoT has gained popularity not only in industries but also in modern households where control of various parameters such as thermostat, CCTV cameras, fans, television, lightings etc. can be controlled from one central location. IoT ensures far greater security through some modern softwares that are updated from time to time in order to ensure better security. Internet of things schematics as used in different fields is shown below in figure 1.

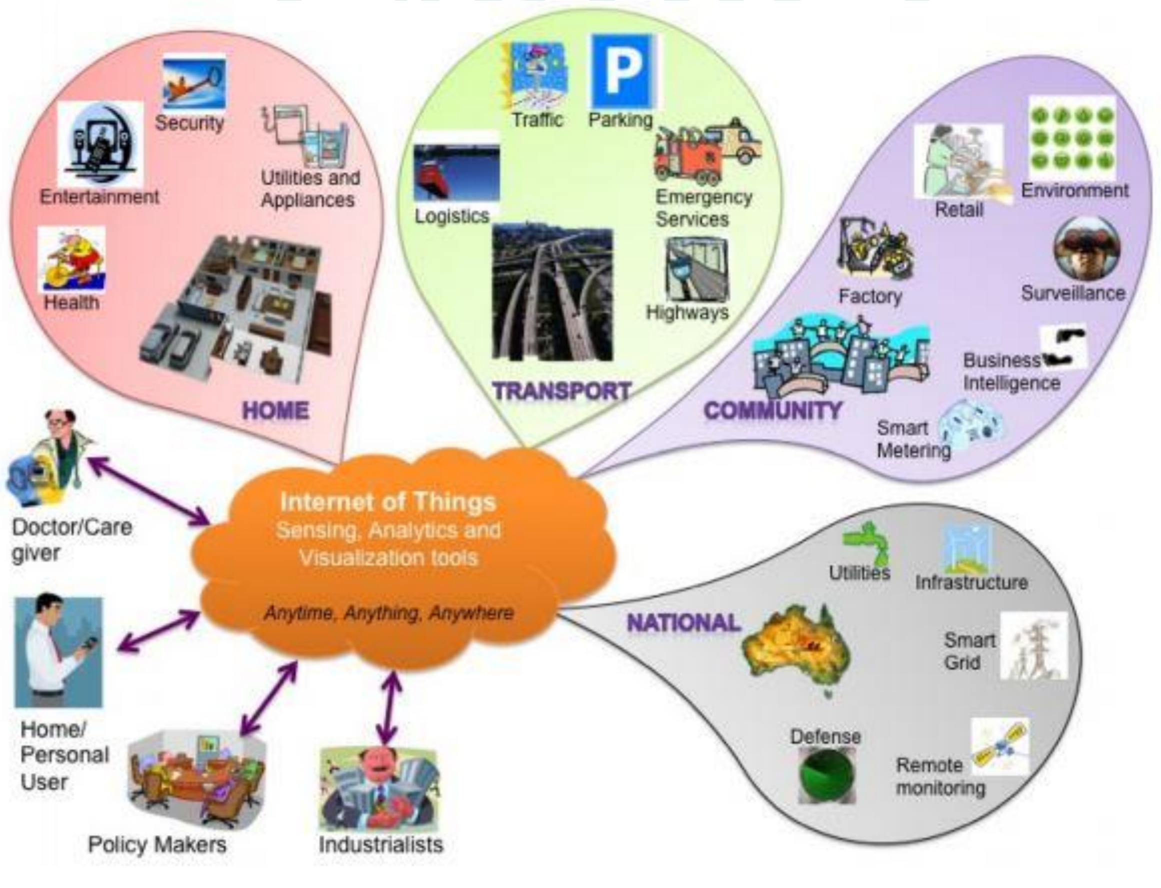


Fig. 1. Internet of Things schematic showing the end users and application areas based on data.

7.IOT ELEMENTS

We present a classification that will aid in defining the components required for the Internet of Things from a high level perspective. Specific taxonomies of each component can be found elsewhere. There are three IoT components which enables seamless functioning: (a) Hardware—made up of sensors, actuators and embedded communication hardware (b) Middleware—on demand storage and computing tools for data analytics and (c) Presentation—novel easy to understand visualization and interpretation tools which can be widely accessed on different platforms and which can be designed for different applications. In this section, we discuss a few enabling technologies in these categories which will make up the three components stated above.

7.1Radio Frequency Identification (RFID)

RFID technology is a major breakthrough in the embedded communication paradigm which enables design of microchips for wireless data communication. They help in the automatic identification of anything they are attached to acting as an electronic barcode. The passive RFID tags are not battery powered and they use the power of the reader's interrogation signal to communicate the ID to the RFID reader. This has resulted in many applications particularly in retail and supply chain management. The applications can be found in transportation (replacement of tickets, registration stickers) and access control applications as well. The passive tags are currently being used in many bank cards and road toll tags which are among the first global deployments. Active RFID readers have their own battery supply and can instantiate the communication. Of the several applications, the main application of active RFID tags is in port containers for monitoring cargo.

7.2Wireless Sensor Networks (WSN)

Recent technological advances in low power integrated circuits and wireless communications have made available efficient, low cost, low power miniature devices for use in remote sensing applications. The combination of these factors has improved the viability of utilizing a sensor network consisting of a large number of intelligent sensors, enabling the collection, processing, analysis and dissemination of valuable information, gathered in a variety of environments. Active RFID is nearly the same as the lower end WSN nodes with limited processing capability and storage. The scientific challenges that must be overcome in order to realize the enormous potential of WSNs are substantial and multidisciplinary in nature. Sensor data are shared among sensor nodes and sent to a distributed or centralized system for analytics. Better and better security protocols are being developed for WSN in order to prevent any external or malware attacks.

7.3Addressing Scheme

The ability to uniquely identify 'Things' is critical for the success of IoT. This will not only allow us to uniquely identify billions of devices but also to control remote devices through the Internet. The few most critical features of creating a unique address are: uniqueness, reliability, persistence and scalability. Every element that is already connected and those that are going to be connected must be identified by their unique identification, location and functionalities. The current IPv4 may support to an extent where a group of cohabiting sensor devices can be identified geographically, but not individually. The Internet Mobility attributes in the IPV6 may alleviate some of the device identification problems; however, the heterogeneous nature of wireless nodes, variable data types, concurrent operations and confluence of data from devices exacerbates the problem further. Persistent network functioning to channel the data traffic ubiquitously and relentlessly is another aspect of IoT. Although, the TCP/IP takes care of this mechanism by routing in a more reliable and efficient way, from source to destination, the IoT faces a bottleneck at the interface between the gateway and wireless sensor devices. Furthermore, the scalability of the device address of the existing network must be sustainable. The addition of networks and devices must not hamper the performance of the network, the functioning of the devices, the reliability of the data over the network or the effective use of the devices from the user interface. To address these issues, the Uniform Resource Name (URN) system is considered fundamental for the development of IoT. URN creates replicas of the resources that can be accessed through the URL. With large amounts of spatial data being gathered, it is often quite important to take advantage of the benefits of metadata for transferring the information from a database to the user via the Internet. IPv6 also gives a very good option to access the resources uniquely and remotely. Another critical development in addressing is the development of a lightweight IPv6 that will enable addressing home appliances uniquely. Wireless sensor networks (considering them as building blocks of IoT), which run on a different stack compared to the Internet, cannot possess IPv6 stack to address individually and hence a subnet with a gateway having a URN will be required. With this in mind, we then need a layer for addressing sensor devices by the relevant gateway. At the subnet level, the URN for the sensor devices could be the unique IDs rather than humanfriendly names as in the www, and a lookup table at the gateway to address this device. Further, at the node level each sensor will have a URN (as numbers) for sensors to be addressed by the gateway. The 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 URC).

7.4 Data Storage and Analytics

One of the most important outcomes of this emerging field is the creation of an unprecedented amount of data. Storage, ownership and expiry of the data become critical issues. The internet consumes up to 5% of the total energy generated today and with these types of demands, it is sure to go up even further. Hence, data centers that run on harvested energy and are centralized will ensure energy efficiency as well as reliability. The data have to be stored and used intelligently for smart monitoring and actuation. It is important to develop artificial intelligence algorithms which could be centralized or distributed based on the need. Novel fusion algorithms need to be developed to make sense of the data collected. State-of-the-art non-linear, temporal machine learning methods based on evolutionary algorithms, genetic algorithms, neural networks, and other artificial intelligence techniques are necessary to achieve automated decision making. These systems show characteristics such as interoperability, integration and adaptive communications. They also have a modular architecture both in terms of hardware system design as well as software development and are usually very well-suited for IoT applications. More importantly, a centralized infrastructure to support storage and analytics is required. This forms the IoT middleware layer and there are numerous challenges involved which are discussed in future sections. As of 2012, Cloud based storage solutions are becoming increasingly popular and in the years ahead, Cloud based analytics and visualization platforms are foreseen.

7.5Visualisation

Visualization is critical for an IoT application as this allows the interaction of the user with the environment. With recent advances in touch screen technologies, use of smart tablets and phones has become very intuitive. For a lay person to fully benefit from the IoT revolution, attractive and easy to understand visualization has to be created. As we move from 2D to 3D screens, more information can be provided in meaningful ways for consumers. This will also enable policy makers to convert data into knowledge, which is critical in fast decision making. Extraction of meaningful information from raw data is non-trivial. This encompasses both event detection and visualization of the associated raw and modeled data, with information represented according to the needs of the end-user.

8. APPLICATIONS

There are several application domains which will be impacted by the emerging Internet of Things. The applications can be classified based on the type of network availability, coverage, scale, heterogeneity, repeatability, user involvement and impact. We categorize the applications into four application domains: (1) Personal and Home; (2) Enterprise; (3) Utilities; and (4) Mobile. There is a huge crossover in applications and the use of data between domains. For instance, the Personal and Home IoT produces electricity usage data in the house and makes it available to the electricity (utility) company which can in turn optimize the supply and demand in the Utility IoT. The internet enables sharing of data between different service providers in a seamless manner creating multiple business opportunities. Some of the applications of IoT in various fields are represented below in figure 2.

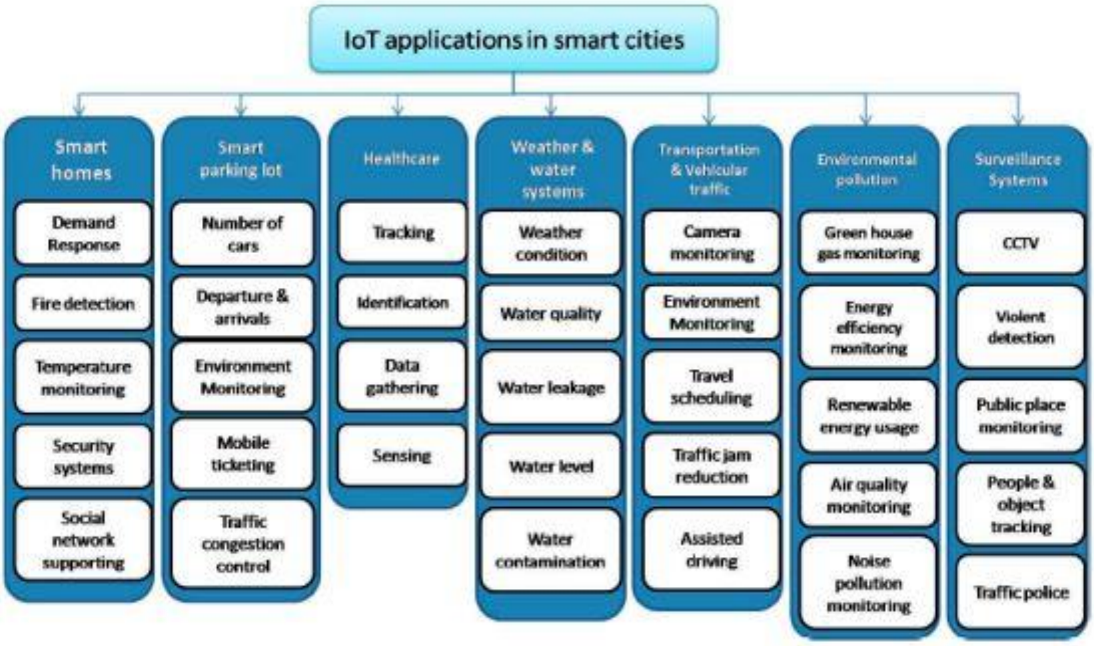


Figure 2.The main applications of the IoT

9. HYDROPONICS

Internet of Things is a new type of computing system where small electronic devices equipped with sensors are used to detect the operating environment of the system and, together with data from other sources, determine the actions that should be taken on behalf of users to increase values or create new features for the system. Automation is usually one of the goals for deploying Internet of Things either in home or workplace. Smart agriculture or smart farming is the application of Internet of Things to growing crops with the potential of saving labor and resources, more fine-grained control in watering and fertilization, and more accurate gathering of information about planting environment. Hydroponics is a method of growing plant without soil, using instead liquid nutrient solution. One benefits of hydroponics farm is reduced labor cost because the farmer does not have to prepare the soil, and watering and fertilization are usually automatically build into the hydroponics farm. Since hydroponics farm is usually partly automated, it is much easier to integrate Internet of Things to get better and more accurate data and fully automate the farm. In this research, we plan to evaluate the cost effectiveness of Smart Hydroponic farm using Internet of Things technology when compared to a regular hydroponic farm. Of course, the Smart Farm should produce better crops, but we intend to find out how much better, and whether the improvement merit the usually high cost of installation.

10. IMPLIMENTATION

Hydroponics is a method in growing plant in nutrient solution. It helps produce more crops than planting in the soil. It can also be seen from tomatoes grown in a building using the planting material that the yield increases by 20-25%.The three most popular hydroponic plantings are Nutrient Film Technique (NFT), Deep Flow Technique (DFT), and Dynamic Root Floating Technique (DRFT). The first one, NFT, is a method that makes nutrient flow along a one-to three-millimeter-thin film and this gives roots opportunity to be exposed to air. The second one, which is DFT, is a method in which plant is floated in water and there has to be a 3-5 cm gap between nutrient solution and planting sheet to let one part of the root be exposed to air and another is in the solution. The last method, DRFT, is quite similar to the second method; however, a nutrient circulatory system is added.

11. MATERIAL LIST

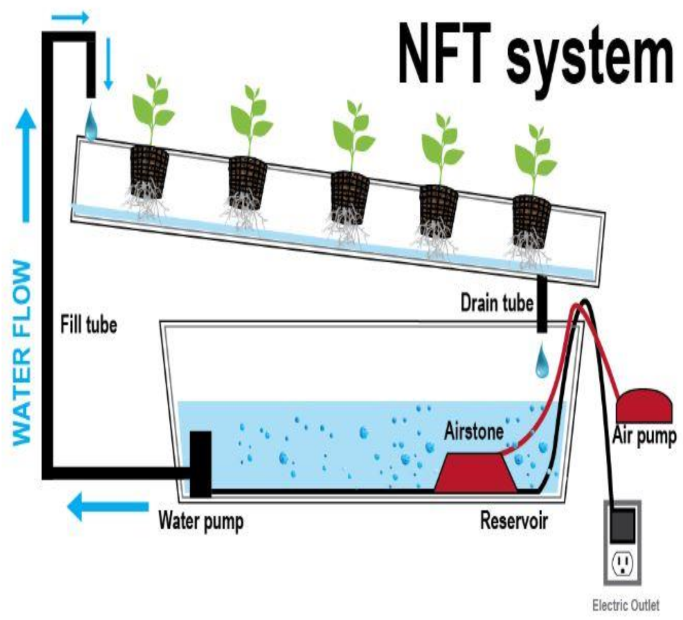
1) Five 2-to-3-millimeter-thick and 3-meters-long film rails.

2) A table (1.6 meters width, 3 meters length) 3) A 50-liter nutrient solution container (61” width x 41” length x 30” height)

4) 3/5-mm and 25-mm HDPE pipes.

5) Sonic AP 3500 water pump which can pump 2,800 liters of water per hour. The electrical power consumption is 60W and the water can go up to 2.8 meters high.

6) Four plastic buckets with cross-section area measured.
7) Arduino Mega 2560 Rev 3, a main microcontroller device.
8) Ultrasonic Sensor was used to measure water height.
9) Water Pumps DC 12V.
10) A pH sensor
11) A EC (Electrical Conductivity) sensor used to sensor concentration of nutrient solutions.
12) Water Temperature Sensor.
13) Temperature & Relative Humidity Sensor.
14) Light Sensor.



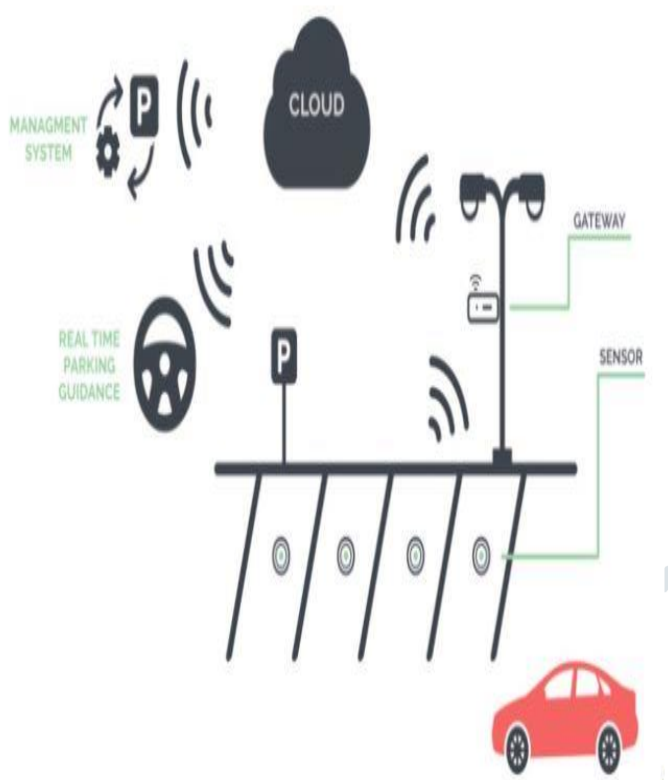
12. PARKING SYSTEM

Here we propose a Smart Parking system which provides an optimal solution for parking problem in metropolitan cities. Due to rapid increase in vehicle density especially during the peak hours of the day, it is a difficult task for the drivers to find a parking space to park their vehicles. The target here is to resolve the above mentioned issue which provides the Smart Parking system. This system uses cloud computing and Internet of Things (IOT) technology. In this paper we introduce the usage of android application using smart phone for the interaction between the Smart Parking system and the user. RFID technology is used in this system to avoid the human intervention which minimizes the cost further we propose a cloud based smart parking system which uses Internet of Things (IoT). In this system, all the physical objects like Smartphone, GPS location and cloud based servers and all car parks are connected to form network architecture and it is an automatic system where we use a Radio Frequency Identification (RFID) technology. We use RFID reader which is a sensor that reads the RFID tag and authenticates the user information. All the car parks in the intended area are connected to form a parking network. The user books the parking slot using the android application by specifying his destination and the type of vehicle which is updated to the cloud. The cloud finds the shortest path which is the distance between the car park and the vehicle and allocates the parking space and this information is sent to the user. When the user starts from his place to destination, the GPS location is updated to cloud server periodically. Then, when the user reaches the car park the RFID tag is read and authenticated by the RFID reader after which the user is allowed to use the parking space. This information is updated to the cloud and to the neighbor car park. When the user exits the car park the RFID tag is read again by the RFID reader which is further updated to the cloud. Then billing process will take place in the cloud server and this information is sent to the user.

Advantages:
1. Better performance.
2. Low Cost.
3. Includes resource allocation mechanism.
4. Provides large scale parking system.

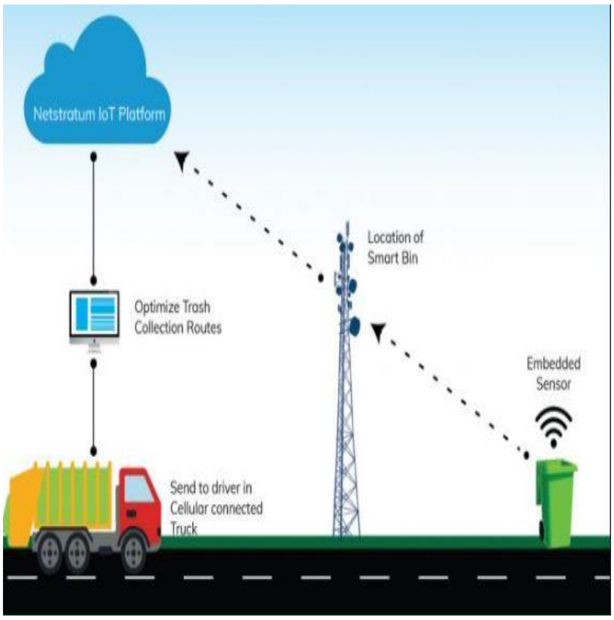
Disadvantage:
1. Car park should be registered in the smart parking system to provide service.
2. The service cannot be provided if there is no Smartphone.

12.1 ILLUSTRATION



13. Waste Management

Due to rapid population growth, disorganization of city governments, a lack of public awareness and limited funding for programs, garbage management is becoming a global problem. Due to the lack of care and attention by the authorities the garbage bins are mostly seem to be overflowing. The details of each bin are monitored by the authority with the help of GUI. Effective actions will be taken if the corresponding authority is not concerned regarding the cleaning of bins. The implementation of smart garbage management system using sensors, microcontrollers and GSM module assures the cleaning of dustbins soon when the garbage level reaches its maximum. If the dustbin is not cleaned in specific time, then the record is sent to the higher authority who can take appropriate action against the concerned contractor. Smart collection bin works with the sensors which will show us the various levels of garbage in the dustbins and also the weight sensor gets activated to send its output ahead when its threshold level is crossed.



14. Conclusion

With rapid development in the emerging Internet of Things technology, we give in this paper a comprehensive blueprint of developing a smart city using IoT, which is actually motivated and strongly demanded from city councils as they seek to ensure the provision of necessary services and quality of life for city populations. In this context, we identify the key IoT building blocks of smart cities, as well as provide the approaches and resolutions to meet the irrespective communications, computing and computation necessities.

In this paper, the implementation of cloud based smart parking system using Internet of Things is discussed. This system includes RFID technology with Android application which provides user interface for control system and vehicles. The average waiting time of users for parking their vehicles is effectively reduced in this system. The optimal solution is provided by the proposed system, where most of the vehicles find a free parking space successfully. This smart parking system provides better performance, low cost and efficient large scale parking system. Security measure to ensure that the users do not misuse the parking system can be implemented.

The smart waste management system ensures that the surrounding stays clean and disposal of garbage is done suitably from time to time, it is a much more efficient method of waste disposal.

The hydroponics cultivation not only supports greenery but also enriches the beauty the surrounding it provides clean and positive environment and hence must be promoted more and more.

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