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Internet of Things: Proposed System Architecture and Technologies forSmarter Public Places

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Abstract - The modern world is moving towards intelligent devices and automation of the existing systems. There are many innovations which are being employed in vibrant fields. Internet of Things (IoT) is one of the budding technologies that has turned many researchers towards it and fascinating the public with its wide applicability. Enhanced security and automation of devices are major scaffolds provided by the IoT to the modern world. Here in this paper we have discussed about the intelligent monitoring system with IoT enabled Wireless Sensor Network and IPv6 in Low Power Wireless Personal Area Network (6LowPAN) concepts in two application regions, a bus stand and a car parking area of a mall in developing countries like India. We have highlighted few similar works with the devices involved in IoT and proposed suitable system architecture for the bus stand and car parking area smart monitoring and automation with the sensor devices.
Keywords: IoT, 6LowPAN, WSN, RFID, Smart Parking

I. INTRODUCTION

The recent trends in computing technologies have brought much more changes in all the fields and made effortless usability with hidden technical exertions. Internet of Things (IoT) is one of the emerging platforms where the things communicate with each other without or less human intervention. It makes the things (embedded, non-phone devices) [1] to be smart with the presence of Internet and mainly makes use of sensors, actuators, Wireless Sensor Networks (WSN), smart cameras, RFID readers and tags. The state of the art technology has introduced a credit card sized on-board device Raspberry Pi, which is highly recommended for IoT projects (https://en.wikipedia.org/wiki/Raspberry_Pi). Updating with modernity is inevitable in almost all the areas including smaller applications like office automation, smart home and larger applications like health care, education, industry, banking etc. Updations include speedy actions with more intelligence, improved safety and security, energy efficiency, low cost, less man power, anytime anywhere availability, interoperability, long life, scalability, high throughput and easy accessibility. The emerging IoT and WSN play imperative roles in enhancing the smartness of the world in an intelligent manner. There was a debatable issue whether all the small devices are connected to the IoT. This induced the Internet Engineering Task Force (IETF) to introduce the new concept IEEE 802.15.4 6LoWPAN [2] which is a combination of the IPv6 and Low Power Wireless Personal Area Network for the smallest devices with limited specifications. With IPv6 addresses (128-bit address, hence 2^128 addresses), it is possible to address massive number of large and small devices. It is similar to ZigBee* but can provide heterogeneous network communication with a bridge device.

*ZigBee is an IEEE 802.15.4 standard based specification, a low cost, low power personal area network, designed for small scale projects which need wireless connection. (https://en.wikipedia.org/wiki/ZigBee)

With the aid of the above mentioned contemporary technologies, Intelligent Monitoring is becoming one of the major promising applications in diverse fields especially in the unman areas and remote areas. Many researches are being taken up in this aspect, but still the researchers are facing lots of challenges [3, 4] in terms of network connectivity and better localization. Since with 6LoWPAN, it is possible to provide IPv6 addresses [5, 6] for all the devices including sensors and RFID as well as integrate with existing network, guaranteed network connectivity can be assured, provided the changes for IPv6 in the device configuration. Localization is another major sector of WSN research [7] as it is application specific. In this paper, we have proposed an initiative for intelligent monitoring in the places where the human access is less and vehicle movements are frequent. Those places include port, mining area, go-downs, vehicle depot etc, from which we have considered two different application regions for the case study; a bus stand and a shopping centre parking area. Countries like India mostly depend on the buses for the transportation in both Government and private sectors. The bus stands in major cities are handling huge number of buses and their timing of entry and exit, route number, driver details are not clear for the new passengers, which can be intelligently handled by the emerging technologies. The second area is the parking sectors of any big shopping centres that are highly crowded during weekends and evenings, which can be made smarter. Providing better security [8] and maintenance are major issues in terms of cost and human resources. Our theme here is to incorporate better accessibility and ease of use in these aforementioned areas using the WSN and 6LoWPAN technologies. The paper is organized as follows. The following section discusses the related work, the next section explains the system model, followed by the system architecture and recommendations.

II. RELATED WORK

Many researches are being carried out in IoT and 6LowPAN, this section highlights some of the research work on different aspects.

2.1 Technology -

2.1.1 6LoWPAN -

J.Martinez [9] has experimented in real time with the 6LoWPAN WSN using ATAVRRZRAVEN 2.4 GHz Evaluation and Starter Kit and showed that the 6LoWPAN adaptation layer enables the deployment of IPv6 which provides better internet connectivity to low-powered devices and improves the efficiency and cost reduction in manufacturing process. He also mentioned that the accuracy of time of flight calculation was less and the service-enabled positioning system had to be built. In case of smart home, it has been tested and proved that [10] the 6LoWPAN based WSN has improved the home security, control of the home appliances and communication to the other 6LoWPAN subsystems like environmental monitoring. The authors of [11] have proposed a mobility protocol in hospital WSN using IPv6 and 6LoWPAN to reduce the amount of messages and overload and to avoid reconfiguring IP addresses when change of network occurs. They concluded that the proposed mobility protocol is very feasible with IPv6 except in few handovers. The 6LowPAN architecture is shown in the following figure 1.

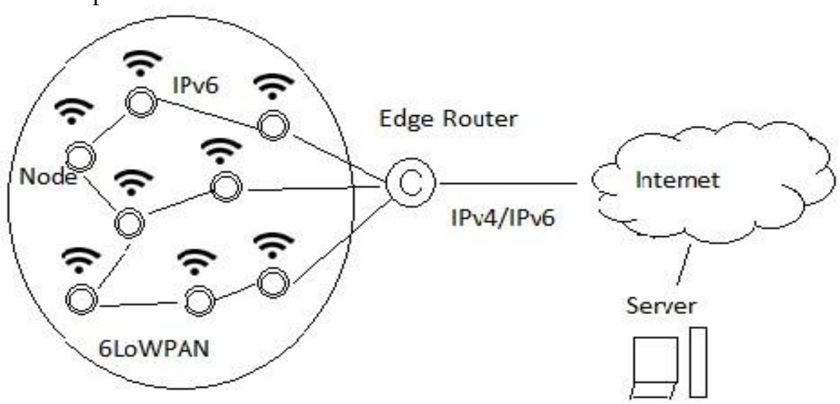
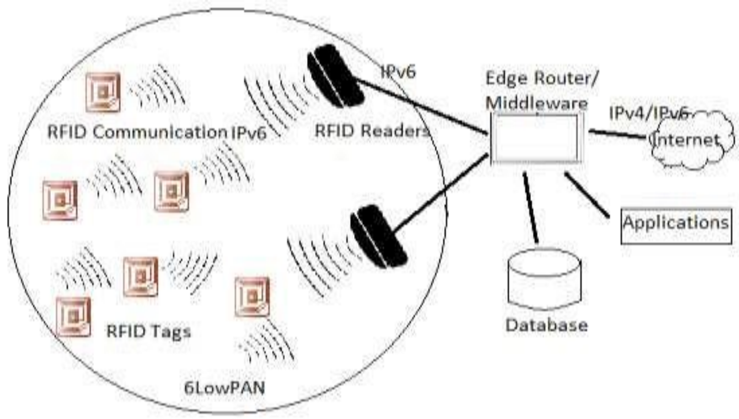


Figure 1. 6LowPAN Architecture

2.1.2 RFID-

Agarwal and Dive [12] have performed a small scale test on bus management system with RFID technology and GSM. The system enables communication among the buses and bus stop RFID reader modules. It may help in handling emergency situations, reduce the waiting time of the passengers, and improves the public transportation service effectively. Another bus monitoring system with RFID, GPS, GPRS and GIS is proposed theoretically with rule based algorithms and prototype is implemented by Hannan et.al [13]. The proposal has been shown in experiment that it can provide an intelligent bus monitoring system which will reduce human interventions and increase the productivity. In production, manufacturing and warehouse, the RFID based intelligent decision making system and monitoring system have been implemented by Guo [14] and Minbo [15]. The following figure 2 depicts the RFID with 6LowPAN architecture.



Edge Router - header compression

Middleware – EPC Allocation,

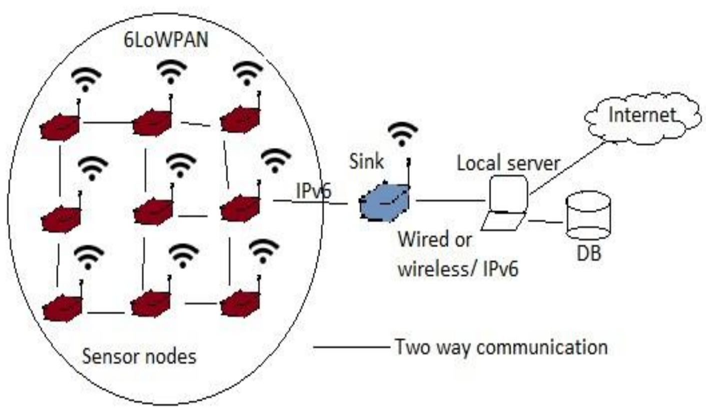
Data Collection, filter, integration and routing,

Track applications

Figure 2. RFID with 6LowPAN

2.1.3 WSN -

Wireless Sensor Network based intelligent monitoring of agricultural ecosystem has been proposed by [16] J.P.Kumar et al, in which special software programs named 'mobile software agents' have been embedded in the sensor nodes. In the real time agricultural field, the automated schedule for irrigation based on the soil wetness is achieved with the embedded software. This may reduce freshwater wastage and irrigation cost. Agent based architecture is conceived by S.Z. Erdogan [17] with WSN and RSS indicator for indoor monitoring that finds out the behaviour and physical activities of a person and the changes in the room. The WSN with 6LowPAN architecture is shown in the following figure 3.



Sink acts as edge router for bridging two IP networks.
Local Server is an intelligent device to process and react to the sensed information, as well as it acts as addressing device

Figure 3. WSN with 6LowPAN

2.2. Pertinent Concepts -

2.2.1 Multi-Target Scenario -

The authors of [18] have come up with a multiple target tracking algorithm 'Interacting Multiple Model (IMM)' for the military surveillance. The algorithm is described in a fusion node with Structured Branching- Multiple Hypotheses Tracking (SB-MHT) for improved data association. From the simulation results it is known that the proposed algorithm is able to track multiple targets efficiently except when the targets are close to each other. A scalable hierarchical multiple target tracking algorithm for WSN is developed in [19]. The algorithm is Markov Chain Monte Carlo Data association (MCMCDA) based and extended hierarchically. It shows a better performance than MHT in extreme conditions like more targets in a dense region. The simulation results show that the model is suited for autonomous surveillance using WSN.

2.2.2 Localization: WSN and RFID -

There are several methods proposed and still being researched for RFID and WSN node as well as target localizations, as it is purely application based. A self-localization algorithm for WSN is proposed based on the controlled power of the beacon nodes [20] which has been simulated to prove its performance. Another WSN

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localization algorithm based on fuzzy logic with RSS information is proposed [21] and the simulations show that the system gives certain accuracy in localizing the sensor nodes in any indoor area. For RFID indoor localization a Genetic Algorithm based solution has been given by [22]. The scheme uses the RSS value and GA which yields better localization despite more interference. This algorithm needs light of few pre-established data to figure out the estimated location in a better way. In [23], the indoor RFID localization is improved with cellular technologies (GSM, UMTS) at lower cost. Localization accuracy is enhanced in this scheme which is done in two phases. First phase is calibration phase where RSS values are quantified and RFID fingerprint model is generated and based on these quantified values the localization phase is carried out.

2.2.3 Multi-sink scenario in WSN -

In case of WSN, the multi-sink usage increases the network life. Chiara Buratti,et.al in [26] has stated that the multi-sink scenario in WSN decreases the probability of isolation of nodes or clusters and scalable when increasing the number of nodes in the network. For the nodes to decide which sink may be selected for communication, few measures are considered including minimum delay, maximum throughput and minimum number of hops. Thus the network performance increases with the multi-sink WSN but the communication protocols are complex. The WSN with multisink single hop topology is mentioned as star topology in [27], where the routing complexity due to multi hop is eliminated, life time increases and the sensor nodes can be simpler. First the best sink for the nodes is selected based on RSSI and the registration among nodes and sink is done. Ali Hammad [28] has proposed Gateway assisted Routing in 6LoWPAN network with the RREQ packet modification and has chosen multiple gateways which are responsible for merging two dissimilar networks. Multiple gateways as per the Region of Interest (RoI) is useful for better load balancing and the advertising message traffic is shallower which in turn increases the network performance.

III. SYSTEM MODEL

For the constancy, few appropriate assumptions are made before the systems are formalized.

Deployment model: Grid based deployment of sensors in the Region of Interest (RoI); Multi-sink scenario
Communication: Sink to nodes communication is made single hop, as many sinks operate.

Localization model: Distributed localization [29, 30] with beacon signals. Based on Received Signal Strength Indicator (RSSI) and Trilateration method, sensor node localization as well as the vehicle localization is done.

Homogeneous sensors are used and smart enough to localize in a distributed manner.

Sensing Model: Boolean deterministic sensing model [37] which provides better network coverage.

Routing Model: RPL with 6LoWPAN

Bus stands and car parking lot are Wi-Fi enabled.

3.1 6LoWPAN -

6LoWPAN is a protocol which defines the Adaptation layer (figure 4) to pack together the IEEE 802.15.4 at the MAC layer and IPv6 at the network layer, as the IPv6 packet is 1280 octets and MAC frame is only 127 octets. [24] There are many routing protocols [25] defined, one of the main protocols is Routing Protocol for Low Power (RPL). RPL constructs a Destination Oriented Directed Acyclic Graph (DODAG), through which each node transfers the sensing data to the sink. RPL is more advantageous as it consumes less power compared to AODV and OLSR and enables point to point communication in storing mode and non-storing mode. In storing mode, each node has a routing table to a destination node and in non-storing mode, DODAG root maintains the routing table. Storing mode acts in distributed manner.

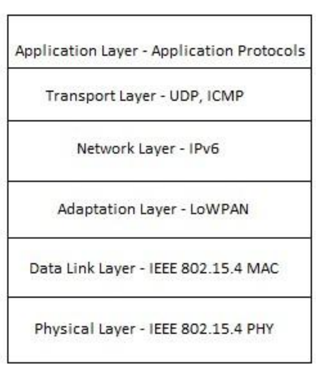

Figure 4. 6LoWPAN Protocol Stack

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IV. SYSTEM ARCHITECTURE

The RoI, we have assumed here, are enabled with 6LoWPAN and the Intelligent Monitoring Server (IMS) works both as bridge device and communication server. We mount 'n' number of sensor nodes in uniform grid. The vehicle identifications are known by a sensor fixed on each of the bus that uses the bus stand, whereas in parking area the car details (Car number plate is scanned) are taken while it enters the RoI. The multiple-sink scenario is adapted and the fixed nodes register with the corresponding sink based on the minimum delay value. The assumed deployment models for both the case studies we have considered are shown in the figure 5a and 5b. When there are multiple sinks, same sensor node may connect to more than one sink, if it is located in the transmission range of the sinks and minimum delay in receiving signals. Based on the initial assumption, we consider single hop, so when a sensor node takes more than a hop to the sink, then the sink –to- node connection can be forbidden [31, 32 and 33]. Even with single hop a sensor node may connect to more than one sink, this problem is handled by the smart sensors by comparing the RSSI from the sinks and connect to the better RSSI sink and ignore the others. Another issue is when many nodes connect to the same sink as the previous criteria are satisfied. In that case, the sinks are observed for the amount of energy consumed; the sinks with more energy consumptions are considered to be victims and the nodes connected to those sinks are identified. The nodes are compared for minimum delay and those have comparatively maximum delay in receiving signals are released from the current victim sink and made to connect with next nearby sink. This process repeats until all the sinks have energy consumption less than the maximum allowable threshold value [32] and all the sensor nodes are connected.Since the sensors are stationary except those fixed on the vehicles, the frequent shifting of nodes among sinks is negligible. Even though the sink to node communication and node localization are different issues to be handled, both are slightly related in terms of signal propagation. In case of sensor node localization, three neighbour nodes locations are manually fixed and these nodes act as beacon nodes [36] to localize other nodes in the network. It is being assumed that all the nodes are fixed in the same height, so 2D localization is carried out; otherwise it is good to use 3D localization. With the beacon signals from the three nodes, the Received Signal Strength (RSS) values are calculated and the neighbour non localized nodes distances are known. The other measures like Angle of Arrival (AoA), Time of Arrival (TOA) need additional hardware to calculate distance, so to be cost effective RSS value is predominantly considered. The RSSI and distance are related measures [34] and with the known distance, the trilateration method is used to calculate the locations of the nodes. If x1,y1; x2,y2; x3,y3 are the known location coordinates of three anchor nodes and d1, d2 and d3 are the distances calculated to a non-localized node, the location of that node (xn, yn) is calculated as below [35].

$$2\begin{pmatrix} x_3-x_1 & y_3-y_1 \\ x_3-x_2 & y_3-y_2 \end{pmatrix} \begin{pmatrix} x_n \\ y_n \end{pmatrix} = \begin{pmatrix} (d_1^2-d_3^2)-(x_1^2-x_3^2)-(y_1^2-y_3^2) \\ (d_2^2-d_3^2)-(x_2^2-x_3^2)-(y_2^2-y_3^2) \end{pmatrix}$$

Once a node is localized, it may involve in localizing other nodes in turn. The process is iterated until all the nodes are localized. When the beacon nodes find the repetitive RSS signals, the localization is completed and the nodes start working normally for sensing. In particular time interval, the beacon signals are recursively circulated to check for the activeness of the sensor nodes. The nodes talk to each other as well as to their corresponding sinks in the 6LoWPAN network. To handle many buses / cars simultaneously, the multiple target tracking is employed by the Markov Chain Monte Carlo Data Association [19, 38] algorithm which can initiate and conclude tracking autonomously and is robust against transmission failures. MCMCDA provides better accuracy of estimates compared to other methods like Multiple Hypothesis Tracker (MHT). When the time of parking exceeds a maximal allowable time limit for any bus(s) /car(s) is (are) reported to the corresponding sink and taken to the Intelligent Monitoring Server for further actions. This reduces over crowdedness of the bus stand and slot occupancy in the car parking area.

4.1 Bus station automation-

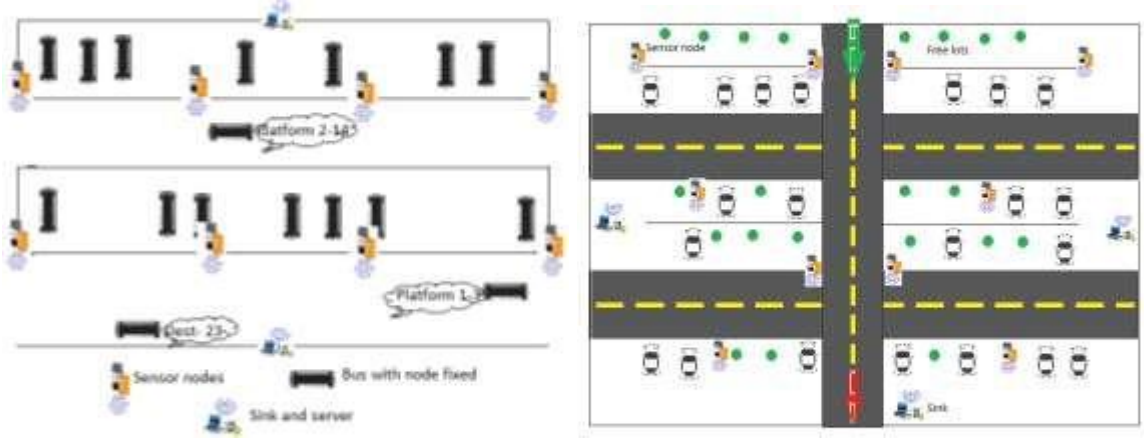

Figure 5. (a) Proposed System Architecture for the bus stand and (b) the car parking area

The Indian city bus stands are highly crowded and during festival times, the situation is worse. The people who visit the city newly are not able to find the right platform for their destination. There are inquiry offices but that is not always informative due to non-availability of the real time information about the buses in the bus station. With the IoT technologies, the bus stand system can be automated with one-time implementation cost. The system architecture is explained in the last section; here we see the design paradigm. The platform details, flow of buses and bus details are stored in the server database. The buses which are fixed with sensor nodes and RFID are allowed to enter the bus stand, which get activated immediately after entering the RoI.The need of sensors in the buses is to know the details of them as well as the drivers. The buses which go to the same destination or go in that same route are parked in nearby platforms and the buses are allowed to park there only for half an hour. When the next bus comes in, the platform has to be freed for it. This half an hour is for shifting drivers and for some maintenance work. If the bus doesn't have a next trip, it will directly go to the bus depot after leaving the passengers. The buses are not allowed to park anywhere inside the bus stand except the allotted platforms. When the bus comes in, the sensor node gets localized with the fixed nodes. Immediately the driver is notified with his “bus-unit” about the free platform availability. The notice boards show the details of the bus, platform number, destination and the timing. Similarly, when the bus exits the bus stand, the details are recorded and the corresponding platform is made available for the next bus which is going to the same destination. This is repeatedly done for all the buses which enter and exit. At the same time, the driver is intimated with his next schedule and the route. The sensor nodes on the buses can be effectively used if the bus-stops they move through, have sensors and communication facilities. The time the bus is reaching the particular bus-stop can be known which decides the speed of the bus. In turn, it will help for maintaining the smooth traffic as well as in reducing accident rates.

4.2 Automation of Car Parking -

In recent days, some of the innovative technologies are being used for day to day activities in many countries [39]. Since plenty of two wheelers used in India, car parking is not given much important. Here we concentrate on parking of car automation in India, but the same is applicable for two wheelers with less or no modification. Even though in countries like Dubai, the malls have facilities including green light on free slots and red light on occupied slots, location identification of the car parked; there is no facility for identifying the free slot while entering the parking lot. This steals most of the time of the shoppers. Sometimes shoppers park their car far away from the shopping area. Since there are lot of area allotted for the car parking, shoppers spent considerable time to locate their car after their shopping as got over. Our proposed system senses the entry of a car into the parking lot, and gets the shopping priority of the customers, and via sink, intelligent system displays the free slots and directions in the display unit which is preferably nearer to the shopping area. This helps the customer not to waste his time in searching for parking, he can choose and directly park wherever is comfortable for him. This makes the occupied entry to be added by one, the display unit would show the updated list of free parking slots. The parking lot details will be sent to the customer’s mobile with the parked date and time. This also helps the shopping mall management to vigilantly monitor the miss use of the parking area. The details of the customer who parked the car and their purchase details can be linked and provide some privileges to the customer who are making more purchase in that mall, in future. Parking area also can be designed with various sizes so that parking allotment can be provided based on the car type and this creates more space for cars in the mall. The system will also look for the proper parking of the cars in the slot. If the parking is overlapping the slots it will give beep sound as well as message to the customer to park the car properly. If the customer leaves the car as such then message will be given to the guard's office for further action. Even if the customer misses their parking details from their phone with the help of the special devices at the exit doors, customer can track where they have parked their car by entering the car plate number. Shopping malls may provide "parking valet" for their premium customers or for others at minimum charges.

V. CONCLUSION AND RECOMMENDATIONS

IoT is becoming a part of our life and it keeps changing our life style. The main advantage of IoT is collecting details of each person through different devices and sending to the cloud environment. In the cloud environment it can be analysed and action can be taken according to the situation. The intelligence of this system makes it more popular. The cost of the IoT devices and applications are also drastically reduced and their limitations are almost eradicated by the researchers. The above mentioned application region case studies can be handled with one-timeinstallation cost and minimum maintenance. We have presented these two case studies as a sample. But IoT may dominate every walk of one's life in sooner future. When IoT comes into implementation it may change the scenarios of our activities entirely like minimizing the people visit to the shopping malls through automated online business models. Hence the case studies here may be taken as solutions for the current problems in particular regions with the help of IoT.

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