INTERNET OF THINGS FOR SMART CITIES

Krishna Priya R[1], Kalyani Subha M[2]

[1]Krishna Priya R, St. Joseph's College of Engineering, Chennai – 600119
[2]Kalyani M Kalyani Subha, St. Joseph's College of Engineering, Chennai – 600119

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Abstract - *The expeditious population growth has resulted in the demand for advanced embedded devices to meet the needs of city inhabitants. Thus, Internet of Things (IoT) shall be able to connect a large number of remote devices with the Internet in a transparent and seamless manner. This paper focuses on Urban IoT, which supports the Smart City concept. In this paper, an open source operating system, Contiki 3.0, is used to realize the smart street lighting and waste management system using Cooja simulator. Furthermore, this paper provides a comprehensive study of the various topologies that are used to realise the smart city concepts with minimum power consumption and delay.*

Key Words: Constrained Application Protocol (CoAP), Contiki, Cooja, ipv6, sensors.

1. INTRODUCTION

The Internet of Things is a recent prototype that is growing rapidly in the scenario of wireless communication. There are many domains in which IoT can help improve the standard of living of citizens. This concept finds application in health care, home automation, industrial automation, automotive and traffic management, etc. Using this paradigm, a large amount of data can be collected from remote devices that can be used for providing services to citizens, industries and public management. The Internet of Things transforms normal devices by making the Internet ubiquitous to enhance human life.

The application of IoT to an urban context results in the Smart City concept. The goal of smart city concept is to obtain information at a faster rate in order to aid the citizens more quickly. Though Internet of Things is an emerging concept, there are various concerns regarding the practical application of this prototype. One such concern is the amount of power consumed during the implementation of this concept and the rate at which the information can be transmitted and received. The economic and political aspect of the city also play a key role in the effectiveness of this paradigm. On the positive side, it increases employment opportunities for denizens.

This paper has two objectives. The first one is to discuss the various topologies available in Contiki OS such that the topology which results in minimum power consumption and reduced end-to-end delay is implemented for the required application. The second objective is to design smart street lighting and waste management systems using Constrained Application Protocol (CoAP). For this purpose, Contiki OS is used which is a lightweight operating system with support for dynamic loading and unloading, and replacement of individual programs and services.

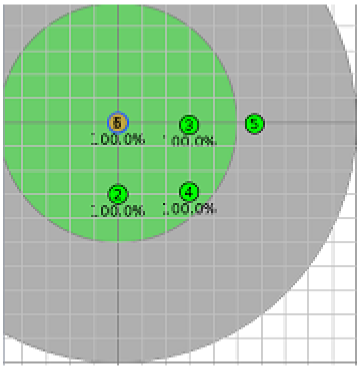
2. CONTIKI

Contiki has been the go-to operating system for implementing Internet of Things, since its inception in the year 2002, because it is an open source operating system which is lightweight and mature. It allows rapid prototyping and easy shift between different hardware platforms. This OS is preferred mainly because the developer need not design the underlying operating system for the internet-connected devices. Using this platform, almost any device can be connected to the internet even when the device is placed underground or in an enclosed space. The inventor of Contiki has managed to fit an entire operating system, including a graphical user interface, networking software and web browser into less than 30 kilobytes of space, which makes it easier to run on small, low-powered chips. Devices with limited memory, power, processing power and communication bandwidth can be run using Contiki.

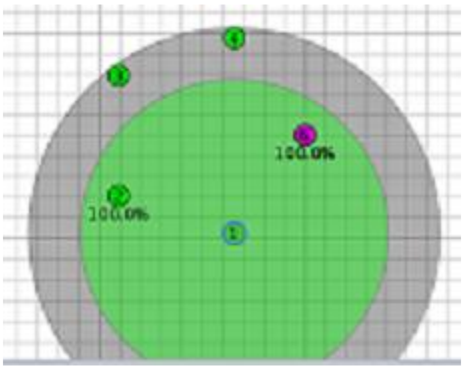
The Contiki system includes a network simulator called Cooja, which simulates networks of Contiki motes (sensors). Contiki provides IPv6 networking for relaying datagrams across network boundaries. It contains the Routing Protocol for Low power and Lossy Networks (RPL), an Internet Protocol (IP) optimized for wireless sensor networks. Contiki is implemented in the C language and can be ported to a number of micro controllers such as MSP430, Atmel AVR, Arduino, CC2430, etc. The applications are implemented using Constrained Application Protocol (CoAP) which is an application layer protocol that provides power efficient operation through low radio duty cycling mechanism. CoAP adopts patterns from HTTP but unlike the latter, CoAP uses UDP.

3. COMPARISON OF TOPOLOGIES

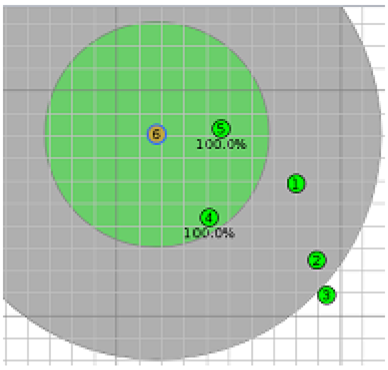
The remote sensors (motes) can be arranged in a number of topologies according to the required application. The mote type determines the type of sensor hardware and which Contiki applications are to be simulated. In the case of Smart City concept, the major concern would be power consumption and the transmission-reception delay. To determine the topology in which power consumption is minimum, motes were placed in different topologies with different transmission ranges and payload. The three major topologies are linear, ellipse and random. In this example, IPv6 routing with RPL is considered. Therefore, a rpl-border-router with three clients and servers are simulated using Cooja simulator. Figure-1 shows the various topologies.



(a) Linear



(b) Ellipse



(c) Random

Figure-1: Topologies

To evaluate the power consumption, Tmote Sky mote was used in different topologies and the following graph (Figure-2) was obtained from the average power values of each topology. From Figure-2 we can infer that power consumed during transmission and reception between motes is less in random topology.

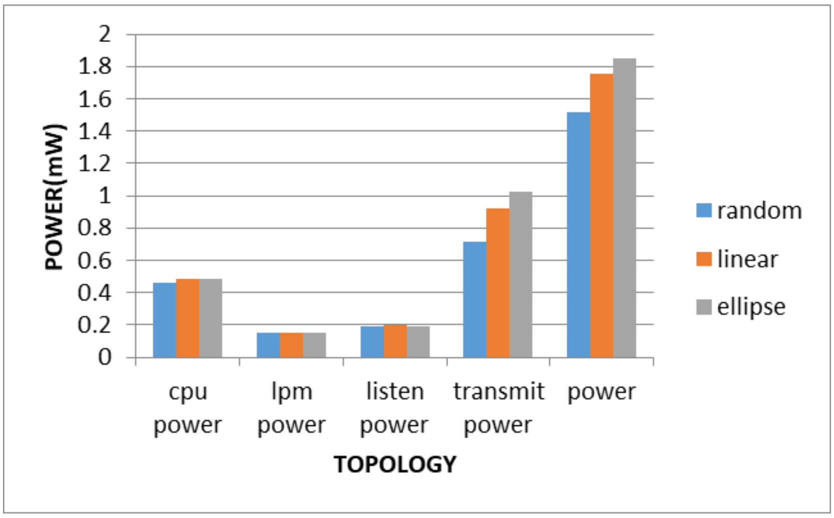
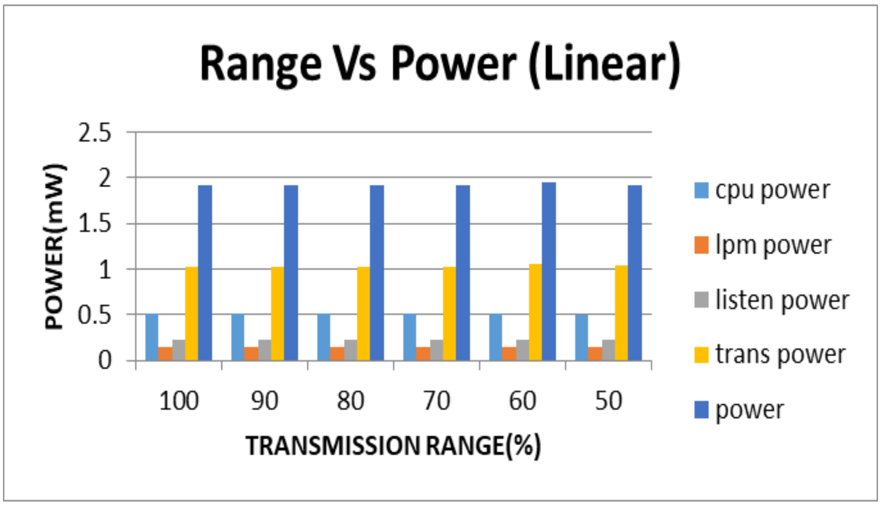
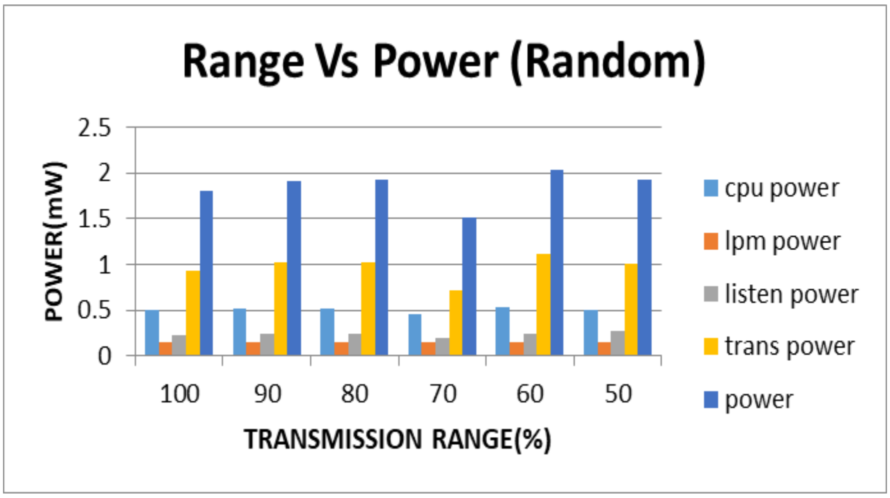


Figure -2: Power for various topologies

Transmission range of the various motes also affect the amount of power consumed. Therefore, we increase the transmission as well as interference ranges of the motes to examine the power consumption. From Figure-3 it can be observed that for various transmission ranges, the motes in random topology has consumed less power over its counterparts.





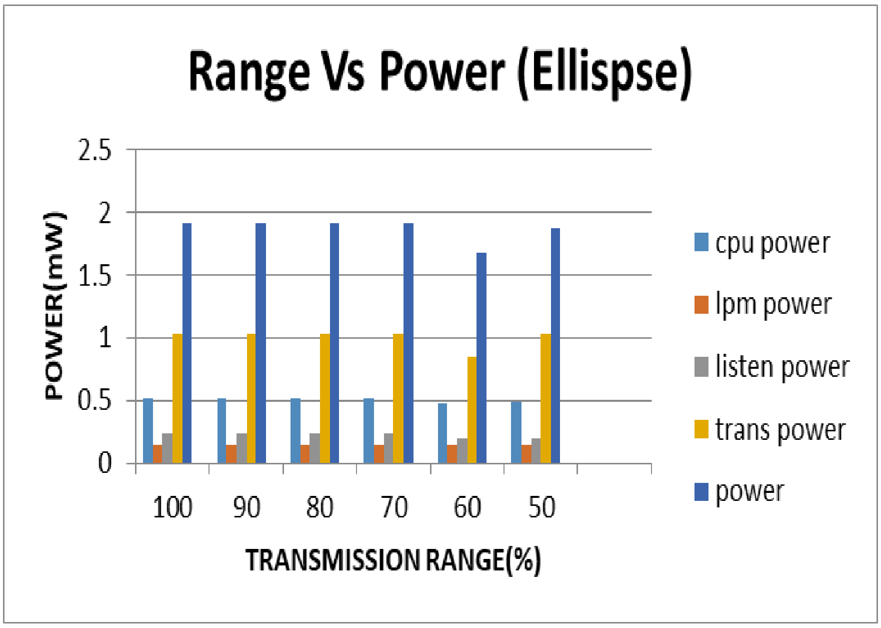


Figure-3: Range vs Power

The next concern is the amount of data, i.e., payload, sent by the servers during transmission of signals. Figure-4 plots the power consumed by the nodes with increasing payload. It can be seen that for random topology, the power consumed decreases drastically with increase in payload. Therefore, random topology can be used even when large amount of server data has to be transmitted.

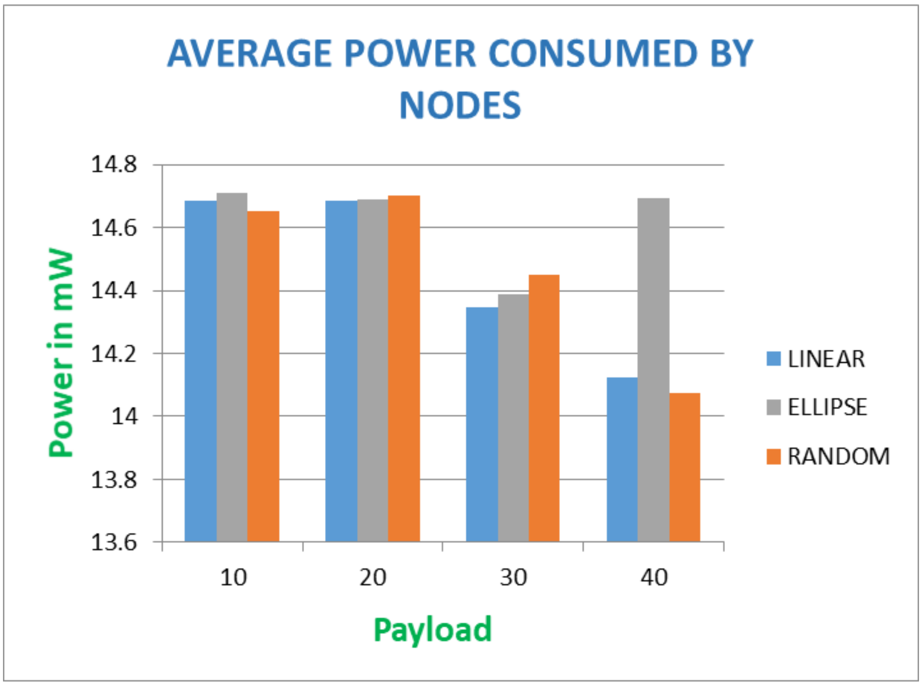


Figure-4: Payload variation

The payload also affects the end-to-end delay of the nodes. Hence, an experiment is conducted by increasing the payload and determining the corresponding power changes. From Figure-5, it can be inferred that as the payload increases, transmission-reception delay also increases. When the topologies are compared, linear topology has been found to have lesser delay.

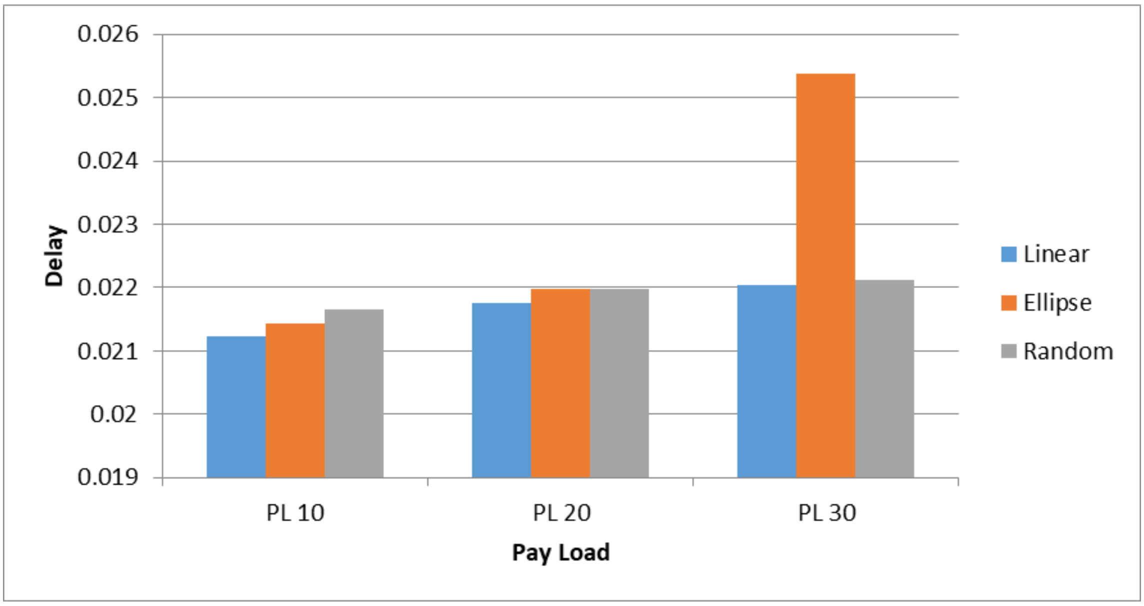


Figure-5: Payload vs Delay

From all the above comparisons, it can be observed that random topology can be used for practical applications.

4. SMART CITY SERVICES

According to Moser, M. A., the Smart Communities movement started in 1990's with the intention of expanding the base of users involved in Information Technology. The Smart City concept utilises Information and Communication Technology (ICT) and Internet of Things (IoT) to extend help to citizen with limited resources in an efficient way. Since IoT is considered as the future technology, many developing countries have also shown interest in Smart City solutions. Many countries like South Korea, Sweden, Canada, Taiwan, Japan, Scotland, UK and USA have been recognised for their efforts in this domain. Israel and China are the leading countries in establishing numerous smart city solutions. In this paper, two smart city services, viz., smart street lighting and waste management systems are discussed.

4.1 Smart Street Lighting System

This service is one of the technologies that support the green environment and energy conservation initiatives. The smart street lighting is the basic technology that is considered as the groundwork for development of Smart Cities. The existing lighting system stays ON throughout the night even when there is no use for it. Smart lighting system entails turning on the street light or increasing its intensity only when an obstacle is detected within the threshold distance. The light is turned OFF or dimmed when there is no obstacle within the range. A Passive Infra-red (PIR) sensor is mounted on the lamp for this purpose. These sensors are widely used in motion detection applications. It works by comparing change in temperature within a certain region of space to ambient temperature. When the obstacle is stationary for more than 10 minutes, the light is programmed to be dimmed or turned off. This feature allows the smart lighting system to be energy efficient with less maintenance.

4.2 Smart Waste Management System

Waste management is a principal issue in urban areas due to overfill of garbage bins which causes unsanitary conditions. The use of smart bins can help in efficient disposal of garbage with the timely intervention of collection trucks. To conceive this service, the garbage bins located on the roads are connected to a control center. When the waste in a bin reaches the threshold limit, an ultrasonic sensor senses the situation and sends a signal to the client via a router. The authorities can then give order for a truck to empty the bin. This concept results in effective garbage disposal because the collection route, truck size and various other factors can be prioritized according to the requirement. An ultrasonic sensor has high accuracy, low cost with safe and reliable operation.

5. HARDWARE IMPLEMENTATION

In this section, the practical implementation of Smart Waste Management System is discussed. This application is extremely helpful in public administration, making the collection of garbage and managing the collection truck routes efficient. This framework has already been executed but the use of Contiki for programming reduces the power consumption and the programming is easier. The target application consists of garbage bins placed at regular intervals throughout the city with sensors attached to them along with a micro-controller and connected to the Internet through gateway units.

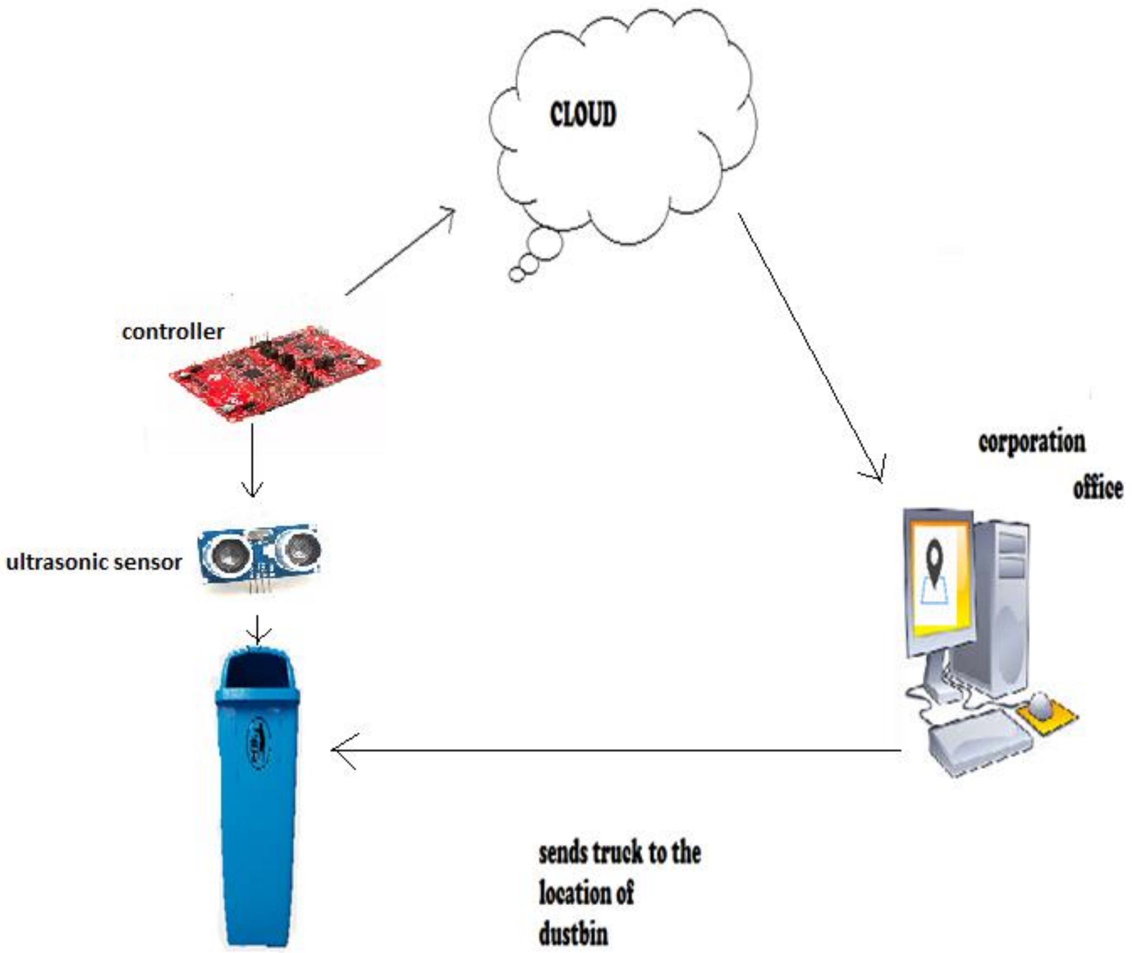


Figure-6: Block diagram of smart waste management system

Smart Waste Management Components: A conceptual block diagram of the Smart Waste Management System is given in Figure-6 In the following, the different hardware and software components of the system are discussed.

5.1 Contiki OS: A C program is written such that the sensor detects the analog value of distance in the garbage bin and sends a signal to the microcontroller when the garbage level reaches the threshold limit. The concept is simulated in Cooja using various motes placed in random topology along with a border router.

5.2 Ultrasonic Sensor: An ultrasonic sensor is placed at the top of each bin to detect the level of garbage inside it. An ultrasonic sensor has high accuracy, low cost with safe and reliable operation. The sensor transmits a burst of ultrasonic sound waves towards the object and then receives the corresponding echo. In this case, an HC-SR04 ultrasonic module is used for level detection. The time taken by the ultrasonic waves to reach the level of material and back to the sensor is accurately measured. This time is sent as a signal to the micro-controller.

5.3 MSP430 controller: The controller is placed in the bin along with the ultrasonic sensor. This controller is best suited for low cost and low power consumption embedded applications. The Contiki server program is flashed into this controller, which controls the ultrasonic sensor to detect the level of material in the garbage bin. The MSP430 has built-in Wi-Fi module that makes it a better choice for IoT applications. Analog-to-Digital Conversion (ADC) is also possible to convert the level value into a digital signal. This signal is then sent to the router.

5.4 Wireless router: A wireless router collects the information from the various bins and acts a gateway to send the information to the client. In the smart waste management application, this router can be placed on street lamp posts such that it can act as gateway to two or more garbage bins. The router provides access to the Internet or a private computer network. It can function as a wired Local Area Network (LAN) or as a wireless-only LAN (WLAN) depending on the location of the router.

5.5 Client System: The information from the server is sent to the client via gateway. When the garbage can level reaches the threshold limit, a signal is sent to the client which can make a LED light glow or activate an alarm depending on the Contiki client program. Here, the client is corporation personnel who then alerts a garbage truck collector to empty the bin in a particular locality.

6. CONCLUSION

In this paper, we analyzed the different topologies for the smart devices and concluded that random topology is best suited for practical application because it is power efficient in respect to transmission range and payload variations. Even though linear topology has lesser delay, it is not always feasible to have remote sensor devices arranged in a linear fashion. Then the application of Internet of Things to Waste Management system was also discussed. The use of Contiki can minimize power consumption and enable real-time implementation of Smart City concept in developing countries.

REFERENCES

[1] Zanella, N. Bui, A. Castellani, L. Vangelista, and M. Zorzi, "Internet of Things for Smart Cities," IEEE Internet of Things Journal, vol: 1 (1) pp: 22-32, 2014.

[2] L. Atzori, A. Iera, and G. Morabito, "The internet of things: A survey," Comput. Netw., vol. 54, no. 15, pp. 2787–2805, 2010.

[3] A. Dunkels, B. Gronvall, and T. Voigt, "Contiki – a Lightweight and Flexible Operating Sytem for Tiny Networked Sensors," IEEE International Conference, Local Computer Networks, 2004.

[4] F. Osterlind, A. Dunkels, J. Eriksson, N. Finne, and T. Voigt, "Cross-Level Sensor Network Simulation with COOJA," Proceedings- Conference on Local Computer Networks, LCN, pp: 641-648, 2006.

[5] Y.M. Yusoff, R. Rosli, M.U. Kamaluddin, and M. Samad, "Towards Smart Street Lighting System in Malaysia," IEEE Symposium on Wireless Technology and Applications, ISWTA, pp: 301-305, 2013.

[6] M. Shankar, J.B. Burchett, Q. Hao, B.D. Guenther, and D.J. Brady, "Human Tracking Systems using Pyroelectric Infrared Detectors," Optical Engineering, vol: 45(10) pp: 106401, 2006.

[7] A. Medvedev, P. Fedchenkov, A. Zaslavsky, T. Anagnostopoulos, S. Khoruzhnikov, "Waste Management as an IoT-enabled service in smart cities," Lecture Notes in Computer Science, vol: 9247, pp: 104-115, 2015.

[8] G. Ren, H. Guo, Y. Yang, and Z. Yang, "Ultrasonic sensor based material level and liquid level measurement technology," Lecture Notes in Electrical Engineering, vol: 132 LNEE (VOL. 1) pp: 25-30, 2011.

[9] N. Tsiftes, J. Erikkson, A. Dunkels, "Poster Abstract: Low-Power Wireless IPv6 Routing with ContikiRPL," North, vol: 3(3.5) pp: 4-5, 2010.

[10] M. Kovatsch, S. Duquennoy, A. Dunkels, "A low-power CoAP for Contiki," Proceedings- 8th IEEE International Conference on Mobile Ad-hoc and Sensor Systems, MAS, pp: 855-860, 2011.