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A Framework for Energy Management in Smart City through Internet of Things

Dr. Ashwini K. B.
R V College of Engineering, Master of Computer Applications, Bangalore, India,

Prashanth K.
R V College of Engineering, Master of Computer Applications, Bangalore, India,

Abstract--Increasing population density demands adequate provision of services and infrastructure in urban centers to meet the needs of city inhabitants, encompassing residents, visitors and workers. The utilization of information and communications technologies to achieve this objective presents an opportunity for the development of smart cities through the Internet of Things (IoT). Since all services of IOT depend on energy, energy management becomes the most important part of smart city. This paper presents a framework for energy efficient automatic street lighting system based on low cost microcontroller. The main objective is to design energy efficient based controller for controlling street light using appropriate controllers, light sensor, zigbee, motion sensor, and ultrasonic sensor. The system is programmed to automatically turn off the street lights during daylight and only operate during the night. Around 45%-50% reduction in power consumption can be achieved through this proposed automatic street lighting system.

Keywords--Internet of Things (IoT), Wireless Sensor Networks (WSN), Information and Communications Technologies (ICTs), Street Light.

I. INTRODUCTION

The Internet of Things envisions a near future, in which day to day requirements will be equipped with WSNs as the arm of sensing actuation for IoT, and a protocol stack which is suitable that will make them able to communicate with one another becoming an integral part of the internet [1]. In future, by enabling easy access and interaction with a wide variety of devices such as home appliances, surveillance cameras, monitoring sensors and so on, the IoT will foster the development of numerous applications that make use of the potentially enormous amount and variety of data generated by such objects to provide new services to citizens, companies and public administrations [2]. This paradigm finds application in many domains smart city [3] [4] is one of them. Cities need to be smart, to survive as platforms that enable economic, social, and environmental well-being. Smart city is one that uses ICTs to make the city services and monitoring more aware, interactive and efficient [5]. IoT is a radical evolution of the current Internet into a ubiquitous network of interconnected objects that not only harvests information from the sensing and interacts with the physical world but also uses existing internet standards to provide services for information transfer, analytics, and applications [6]. With advanced sensing and computation capabilities, data are gathered and evaluated in real time to extract the

information, which is further converted to usable knowledge. This will enhance the decision making of city management and citizens to turn the city smart.

II. MOTIVATION

It is estimated, about 70% of the world's population, over six billion people, will live in cities and surrounding regions by 2050. To accommodate this massive urbanization, cities needs to find smarter ways to manage complexities, reduce expenses, increase efficiency and improve the quality of life. So, cities need to be smart, if only to survive as platforms that enable economic, social, and environmental well-being. Smart city systems not only offer improvements in the Quality of Life (QoL) of the inhabitants, but also greatly improve efficiency regarding asset management, including intelligent transportation systems, smart grids, street lighting management, traffic lights management, waste management, environmental monitoring, water management and many more. The citizens at large use smart phones, wearable and sensors to collect and forward a variety of visual, signal, and environmental data for data aggregation. In short smart cities spans six key areas: Governance, Mobility, Energy, Utilities, Water and Environment [7][8][9][10][11].

Since all services of IoT depend on energy, energy management becomes the most important area of smart city. IoT provides a service to monitor the energy consumption of the whole city, which enables authorities and citizens to get a clear view of the amount of energy required by the different services like public lighting, transport, traffic lights control, cameras and so on. This in turn will identify the main energy consumption sources and to set priorities in order to optimize their behaviour.

III. Street Light Application of IoT

Energy efficiency is driven mainly by social responsibility for green operations. Smart city in general and IoT-based environments, in particular, go a long way in addressing this need. Larger facilities can realize higher relative efficiency gains, based on the idea that the more energy one is already wasting, the more the opportunity they have to save. Smart city should have a centralized system that monitor, control and record the functions of smart city services systems, such as mechanical systems, elevators, electrical systems, lighting, plumbing, security/surveillance, and contingency alarms. In order to increase in the quality of life, long-term strategic planning for the city is required. Among many issues, street light management is of critical concern. The optimization for street lighting is an important feature using which we can optimize the street light intensity according to the time of the day, on weather condition and movement of the people. It is the basic step in changing from static energy consumption modes to distributed and dynamic energy control.

IV. Energy Monitoring

Existing street light consume 40W power per/hour. Usually the lights are on by 6:00pm till 6:00am, which may not be needed during bright days. Street lights consume enormous electric energy. Table 4.1 depicts on an average 10 lamps in a row consume 480 Watts for 12 hrs.

Table 4.1 Electricity consumption by street lights

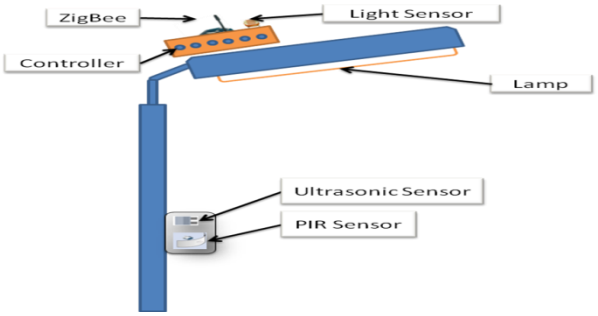
No of lights	Watts consumed per hour / lamp	No of hours (Avg)	Total watt consumtion
10	40 Watt	12	480 Watt

On the streets, maximum movement of the vehicles and pedestrians will be reduced as the time passes. Based on which an architecture is proposed, by implementing it at the worst case streets lights will be switched on continuously till 11:00pm. Therefore, the total consumption will come to as shown in Table 4.2. Comparing the power, on an average 40% to 50% power can be saved.

Table 4.1 Electricity consumption by street lights

No of lamps	Watts consumed per hour / lamp	No of hours (Avg)	Total watt consumption
10	40 Watt	6	240 Watt

V. Design Architecture



The proposed architecture for the system is to achieve the proper power utilization during the late night hours where there is no movement of vehicles and pedestrians on the streets. Components used in the proposed system

5.1 Street Light Unit

This unit consists of the tube light, light sensor, motion sensor, zigbee, ultrasonic sensor and controller. The light will be switched on when the luminous of sunlight is reduced and continues to be switched on till midnight constantly. A timer is used to keep the street light on continuously. After the time elapsed the street lights will be switched on only when the motion is detected on the streets based on the distance and motion detection.

5.2 Motion Sensor

Since there will be very less movement during late night hours, the circuit will be switched off which results in activating the motion sensor. This sensor will be active until it finds any movement on the streets. When the sensor finds the movement immediately sends signal to controller for next set of instructions for switching on street light.

5.3 Ultrasonic Sensor

Ultrasonic sensor is used to check the distance at which the object is identified. This will also solve the problem of when the light should be switched on during the early hours. Sensor will work in the combination of the motion sensor and timer.

5.4 Light Sensor

Street light should be switched on during night so this sensor will detect the luminous of sunlight. It sends signal to the controller to switch on the street light and circuit. Timer will start from the time the light is switched on. This sensor will switch off the circuit when the luminous of sunlight is preferably high.

5.5 Controller

The factors that controller will take care is keeping the light usage minimum, efficient, communicate with set of connected light units and cloud. Controller takes care of sensing the sunlight intensity and various combinations of data from different sensor. The number of the different steps in controlling are one is with light intensity during the day. Controller has a timer to keep the street light continuously on till 11 PM and automatically switch off after post time. Two is during the post time, controller will switch to movement sensing unit. If the movement in the street is not detected light will be continue in the same state. Once the motion sensor detects any movement it captures the data and passes it on to the controller. This results in switching on the light and the timer is started automatically. As timer completes the task controller will switch to motion sensor again. This process of switching on and off will continue till morning.

5.6 Zigbee

ZigBee provides self-organized, multi-hop, and reliable mesh networking with long battery lifetime. [12] The state of light should also be communicated to the nearest posts to change the state of the light.

VI. Network Architecture

The Fig 6.1 shows the proposed architecture which contains fixed infrastructure. The WSN platform facilitates deployment flexibility to incorporate diverse sensing modalities for continuous monitoring, providing baseline reference data. The three-tier IoT architecture for street lights consists of

Level 1: The street lights at the road junction include motion sensor, zigbee and ultrasonic sensors mounted on it. Controller will keep track of the timer where lamp will be switched on continuously till the midnight. As timer completes the task controller will switch to motion sensor and ultrasonic sensor, the light will be switched automatically once a movement is detected within the range.

Level 2: Depending on movement and distance of object, the zigbee communicates the adjacent street light to switch on eventually, all the lights will be switched on for that particular road. This process will continue till the luminous of sunlight is high. Relay nodes will collect signal from zigbee and forward the signal across multiple hops to a gateway.

Level 3: Controller will collect data from the relay node and send them via the Internet to the Cloud. Concentrating on the user requirements for sensing and smartness in analysis with any IoT interconnected sensors for future analysis. Cloud computing is a promising solution for IoT based applications. Upcoming models for interacting with wireless sensors such as Internet of Things and Sensor-Cloud aim to efficiently utilize resource and overcome restrictions on it. Sensor-Cloud enables different networks, spread in a huge geographical area, to connect and be employed simultaneously by multiple users on demand. [12] Sensor-Cloud is a flexible, reconfigurable and popular platform for proper monitoring and controlling applications. [13]

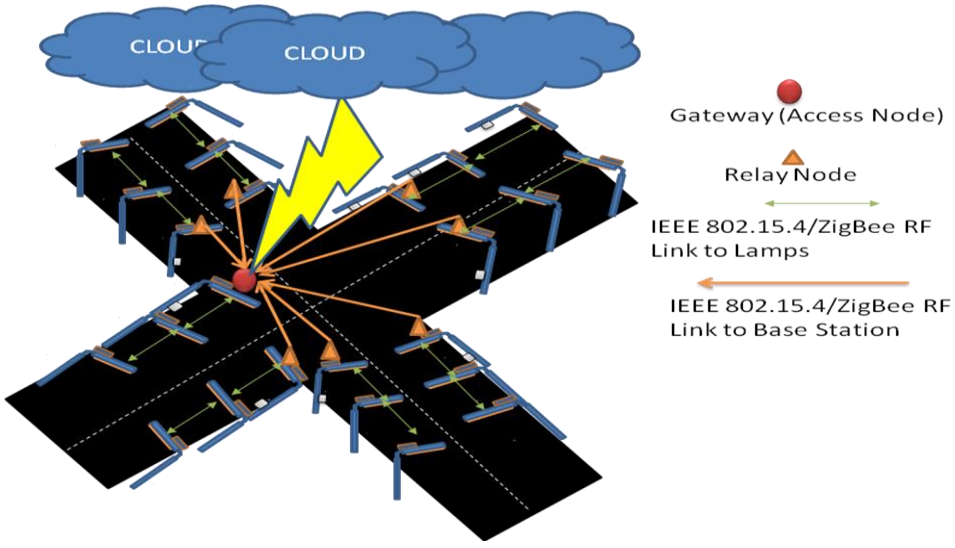


Fig 6.1 IoT architecture for street lights

VII. Conclusion

With rapid development in the emerging IoT technology, key services of IoT are identified. All these services depend on energy, because of which energy management becomes the most important part of smart city. The paper presents the automatic street lighting system based on internet of Things architecture. The current system relies on environmental and traffic indicators to estimate the needs for street light intensity. It then controls the luminaries accordingly. Around 45%-50% reduction in power consumption can be achieved through this proposed automatic street lighting system.

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