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TOWARDS AN IP-BASED, ENERGY EFFICIENT AND ADAPTABLE RIVERINE FLOOD MONITORING SYSTEM

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Abstract

Riverineflooding has been a critical environmental problem faced by most developing countries around the world today due to the lack of adequate and efficient flood monitoring systems. Such flooding claimsseveral lives annually anddestroysfarmlands and other properties. However few systems that exists to monitor flood in the developing countries are either expensive, require high energy, inadequate, inefficient or totally depends on complex middleware to connect with existing internet infrastructure for wider public informationoutreach. Power consumption, complexity, coverage, correctness and adaptability are the key parameters that define the efficiency of any real-time flood monitoring system. In this paper, we proposedanarchitecture for the development of a real-time,energy efficient, adaptable, simple and globally accessible riverine flood monitoring system using 6loWPAN based Wireless Sensor Network (WSN). Our proposed evaluation is to useOMnet++ and TinyOSSIMulator (TOSSIM) WSN simulators based on energy utilization per packet, throughput and response time.Large scale implementation of the proposed system will provide relatively cheaper and affordable flood monitoring system for use in developing countries.

Key words: Flood Monitoring System, 6loWPAN, WSN, TOSSIM, OMnet++

1. Introduction

One of the major disasters faced by many countries especially the developing ones as Nigeria today is riverine flooding. According to the United Nations Educational Scientific and Cultural Organizations (UNESCO), fifty percent of water related natural disasters world-wide between 1990 and 2001 are caused by flood [14]. Riverine flooding is the overflowing by water above the normal confines of a river.There are other kinds of flood such as: flash flood, single and multiple event flood, seasonal flood, coastal flood, urban flood etc. [14].

Flood is mostly a natural disaster caused by the changing weather conditions recently attributed to global warming resulting into heavy rainfall, highly accelerated snowmelt, severe winds over water, unusual high tides or tsunamis. It can also be caused by the failure of dams, levees, retention ponds or other structures retaining water [2]. Flooding can have significant effect on long term economic growth of the affected regions and their environments [1]. It leads to loss of lives, displaces hundreds of people from their homes, washes away farmlands, destroys social amenities such as hospitals, schools, markets, poles carrying electric cables etc. flood affects over half a billion people every year worldwide. This figure may increase to two billion by 2050 [5]

Report from Nigeria has shown that in 2012 at Lokoja, Kogi state, not fewer than 332 communities in nine of their twenty one Local Government areas were affected; **rendering close to two million persons homeless. According to the National Emergency Management Agency (NEMA), about 70 per cent of Kogi State population were affected [3].**Flooding also caused some health problems to the affected persons. Most of the people around a river depend on that river for drinking water, after flooding the water becomes contaminated causing cholera and typhoid fever among other diseases. Riverine flood monitoring is the continuous process of observing the situation of a river mainly to identify anomalies that could result to flood.

Despite the annual damages in Nigeria and its counterpart developing countries, few systems exists to monitor riverine flood and the few are either expensive, require high energy, inadequate, inefficient or totally depends on complex middleware to connect with existing internet infrastructure for wider public information outreach. This research is intended to provide mechanism to monitor riverine flood employing IPV6 over low power Wireless Personal Area Network (6loWPAN) technology to create a Wireless Sensor Network (WSN).

This paper is organized into five sections. Section one provides the general introduction, section two highlights the related works in flood monitoring, in section three we present the proposed method, section four is the conclusion and finally section fivewhich are the references

2. Related Works

Riverine flooding has been studied under various considerations and technologies such as WSN, embedded system with a middleware; internet based real-time data acquisition, flood modelling and forecasting [13]. WSN was identified as the most appropriate and reliable system used in recent years for monitoring applications where a number of sensors are planted to read and transmit wirelessly the hydro/metrological parameters to be used in analysing flood.

In literature, the existing riverine flood monitoring systems that employed WSN used one of the existing wireless communication technologies such as GPRS, Zigbee, Wi-Fi, UWB etc.; hence their limitations are inherent in these technologies they employed. For instance GPRS is known to consume high energy and is faced with transmission delay making it unsuitable for real-time sensor network applications. Zigbee has issues with standardization and scalability in addition to interoperability, Wi-Fi was not intended for Wireless Personal Area Networks it is expensive and energy demanding hence unsuitable for use in sensor network and so on. Before 6loWPAN, the existing proprietary technologies posed some challenges in connecting to each other or even the internet. 6loWPANwas introduced by the Internet Engineering Task Force (IETF) in 2005; it was based on IEEE802.15.4 standard of 2003. It introduced an extra layer called 'Adaptation layer' which stands in between IEEE802.15.4 MAC layer and the IPV6 network layer (Figure 1) mainly to provide some header compression functionality allowing the two layers to be compatible. With this layer tiny sensors can connect and send data directly from their field to the internet through a router called 'edge router' that is always at the edge of the loWPAN sensing field.

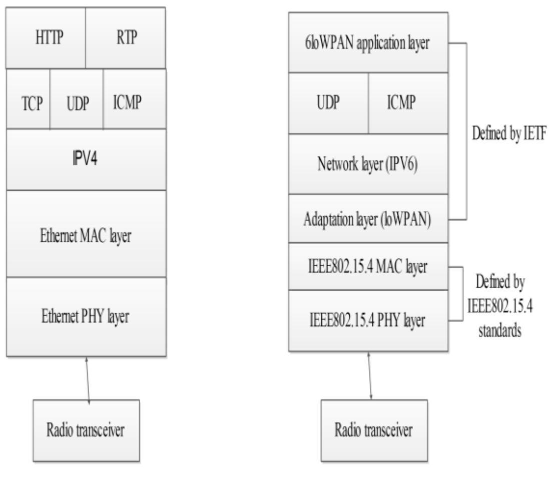

Figure 1: Comparison between Ethernet (IP) Protocol Stack and 6loWPAN Protocol Stack (Source: 12).

Some flood monitoring systems that employed wireless technology are presented below with their strengths and weaknesses:

Authors in [8], [13], [11] and [9] employed GPRS technology in designing a WSN for relaying water related data to the place where flood computation is to be carried out (Figures 2&3). In their work [13], Incorporated a middleware called VitualCOMto support the GPRS communication. The systems have their independent capabilities ranging from wider information coverage, cost efficiency and simplicity. However, the GPRS technology they employed made them to consume high amount of energy than other existing low power technologies like Zigbee and 6loWPAN. Again they are faced with transmission delay that leads to untimely information which could cause distrust on the part of its potential users. Finally, they require a gateway or proxies to connect with the existing internet infrastructure.

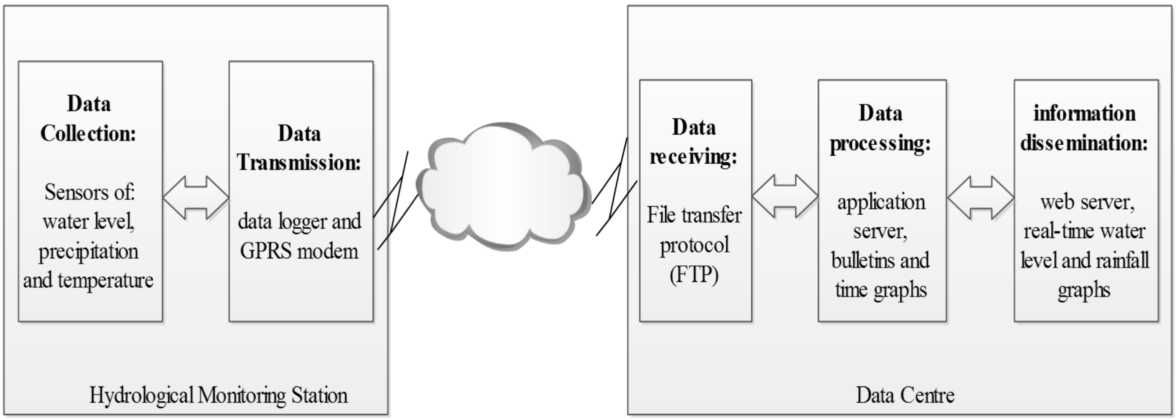

Figure 2: The high level architecture of flood monitoring system. (Source: [8])

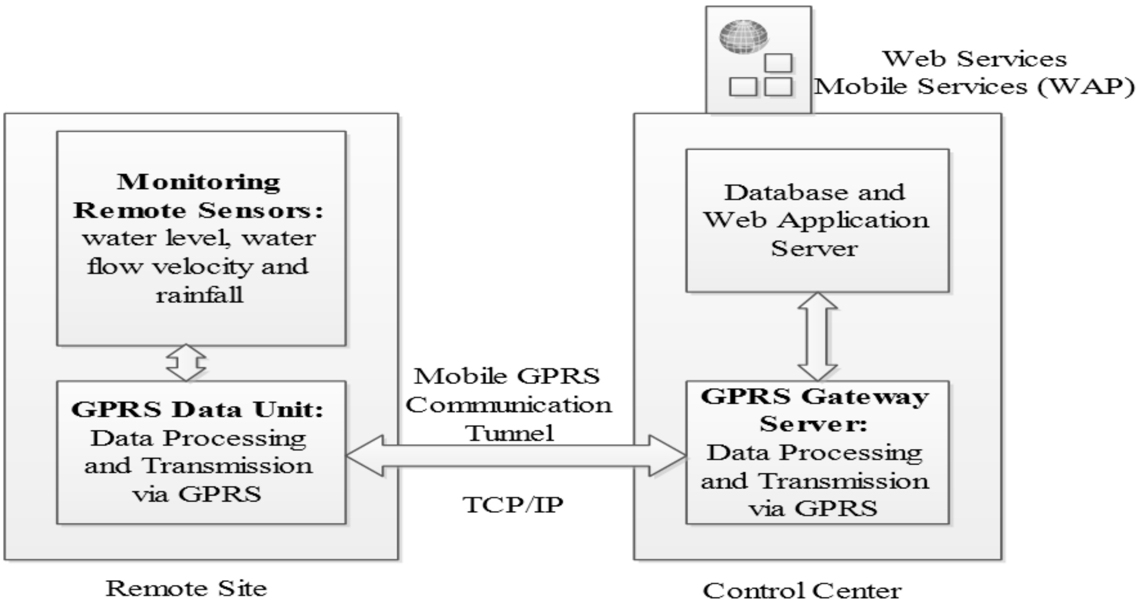

Figure 3: The Highest Level System Architecture of the real-time flood monitoring and warning system [13]

Authors in [15] Developed a WSN for weather and disaster alarm systems. The system utilizes Zigbee technology for sending weather information and used decision tree technique to alert the system administrators each time the read data exceeds a given threshold. The system is power efficient and covered a large area. However, the information is restricted to only the system administrators; hence there is no internet integration. In [4] similar system was developed employing Zigbee radio for flood monitoring and detection

(Figure 4). The author utilized a wireless gateway to connect the sensing module with the surveillance module where flood computation is carried out. The system is robust and gives timely alert of flood. However, it required gateway to connect with the existing internet infrastructure and a middleware for efficiency.

In their work, [6]presented an intelligent and adaptable grid-based flood monitoring and warning system. A system that employed a 'Gridstix' sensor platform to develop Grid-based, adaptable WSN capable of performing both on-site and off-site flood modelling; the Gridstix platform utilizes heterogeneous wireless networking technologies of Bluetooth, GPRS and 802.11b in addition to a next generation Grid middleware.The system is adaptable, support diverse sensors and provides timely warning to stake holders. However, it is complex and lacks appropriate power management strategy; also the adaptation policy employed is manual hence require human intervention.

The authors in [7] proposed a difference image based Joint Photographic Expert Group (JPEG) communication scheme using sparsely sampled images in time domain. The system comprised of a master system and a slave system (Figure 5). The slave system consists of two subsystems: the image acquisition subsystem with storage and the image encoding and transmission subsystem. The image acquisition subsystem comprised of a camera that captures the water images with the size 640×840 and stores them in the memory to be used in finding the difference image when compared with the a reference image initially captured when the camera is been calibrated. The image encoding system encodes the difference using JPEG encoder; this reduced the image to about 10 Kbits to be sent through a narrowband Ultra High Frequency (UHF) modem with a speed of 9600bps. The master system provides control to the remote slave system; it also receives the transmitted data from the slave system. It first receives the reference image then followed by the difference JPEG image. The difference image is decomposed using a JPEG decoder. The decoded reference image is added to the reference image to reconstruct the original field image and then passed through a low pass filter to remove noise due to light reflection and ripple on the water surface during capturing. The image is finally used by an algorithm developed to measure the water level. The system shows some remarkable accuracy level as compared to ultrasonic sensor and can be used to monitor not only the river but the surrounding situation of the river. However, the system is complex and lacks power management strategy; the medium of communication used can also lead to transmission delay due to its narrowness.

In their work [10], described an experiment through the deployment of two GPS buoys simultaneously near two tide gauges in a river; using the tide gauge to verify the efficacy of GPS buoy and to test the accuracy to which a tidal datum can be transferred based on water levels estimated by the buoy. The GPS buoy used was of wave rider style designed to operate autonomously and it consists of a GPS receiver with an antenna and a battery. Though the system's data deviates as compared with other methods involving tide gauge and it also lacks power management ability but it can be able to utilize typical existing GPS surveying equipments and hence cheap and simple to construct.

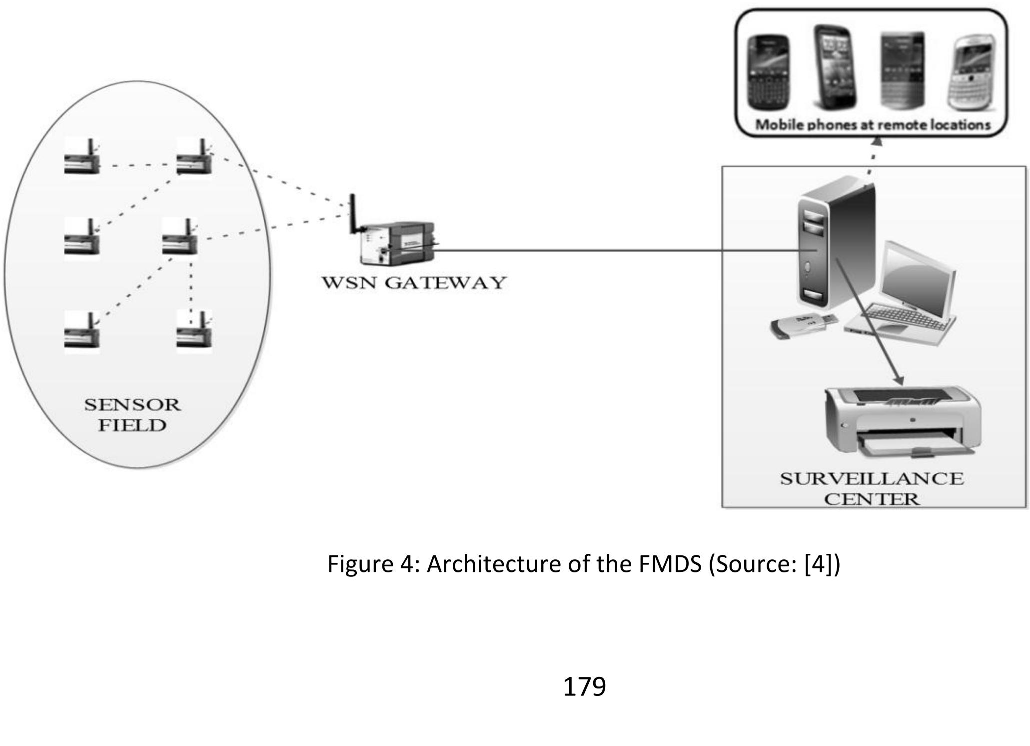

Figure 4: Architecture of the FMDS (Source: [4])

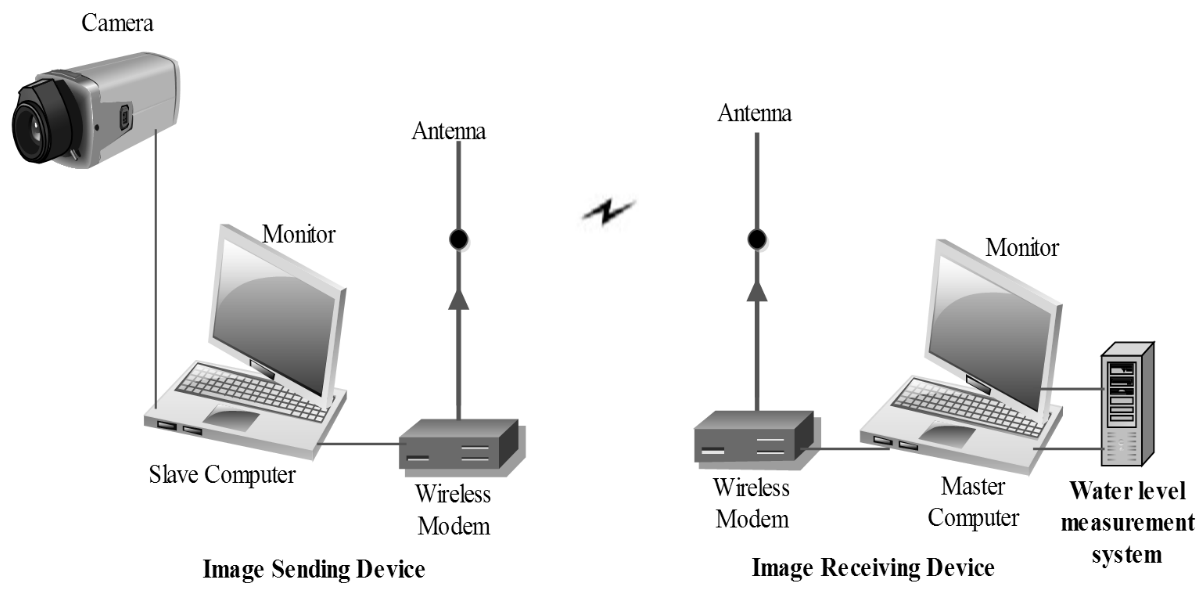

Figure 5: System configuration of remote detection and monitoring of water level

(Source: [7]

3. Proposed Method

The aim of this research is to develop a simple, cost effective, energy efficient, adaptable and globally accessible flood monitoring system that will solve the problems posed by other existing systems.

To achieve this, we proposed a 6loWPAN based WSN to be used in sensing and transmitting temperature, humidity, water level and rainfall information. The proposed block diagram and system architecture are shown in Figure 6 and 7 respectively.

It comprised of four units namely: the sensing unit, the transmission unit, the database/web server unit and the users unit.

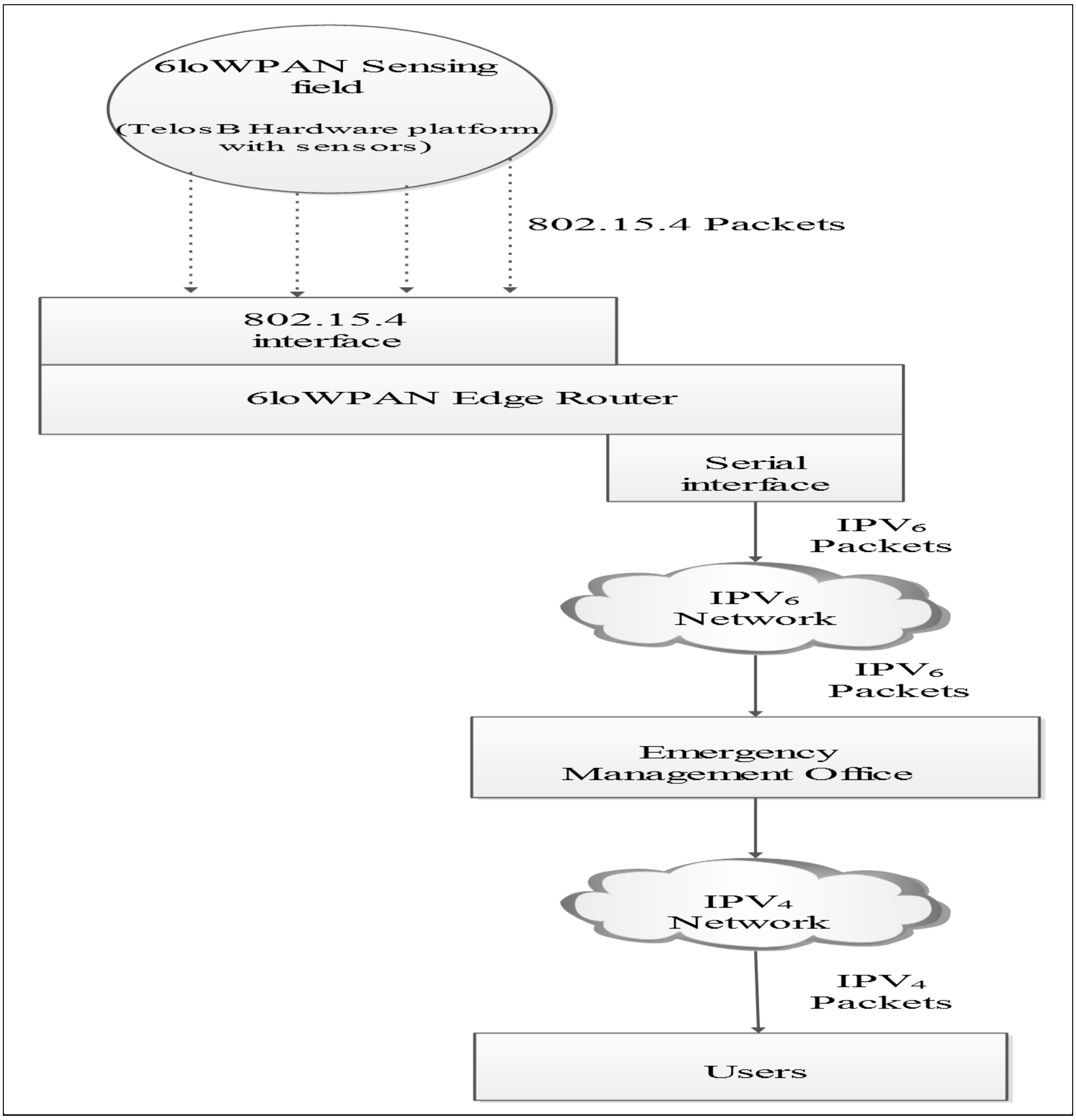

Figure 6: Proposed block diagram of the IP-based riverine flood monitoring system

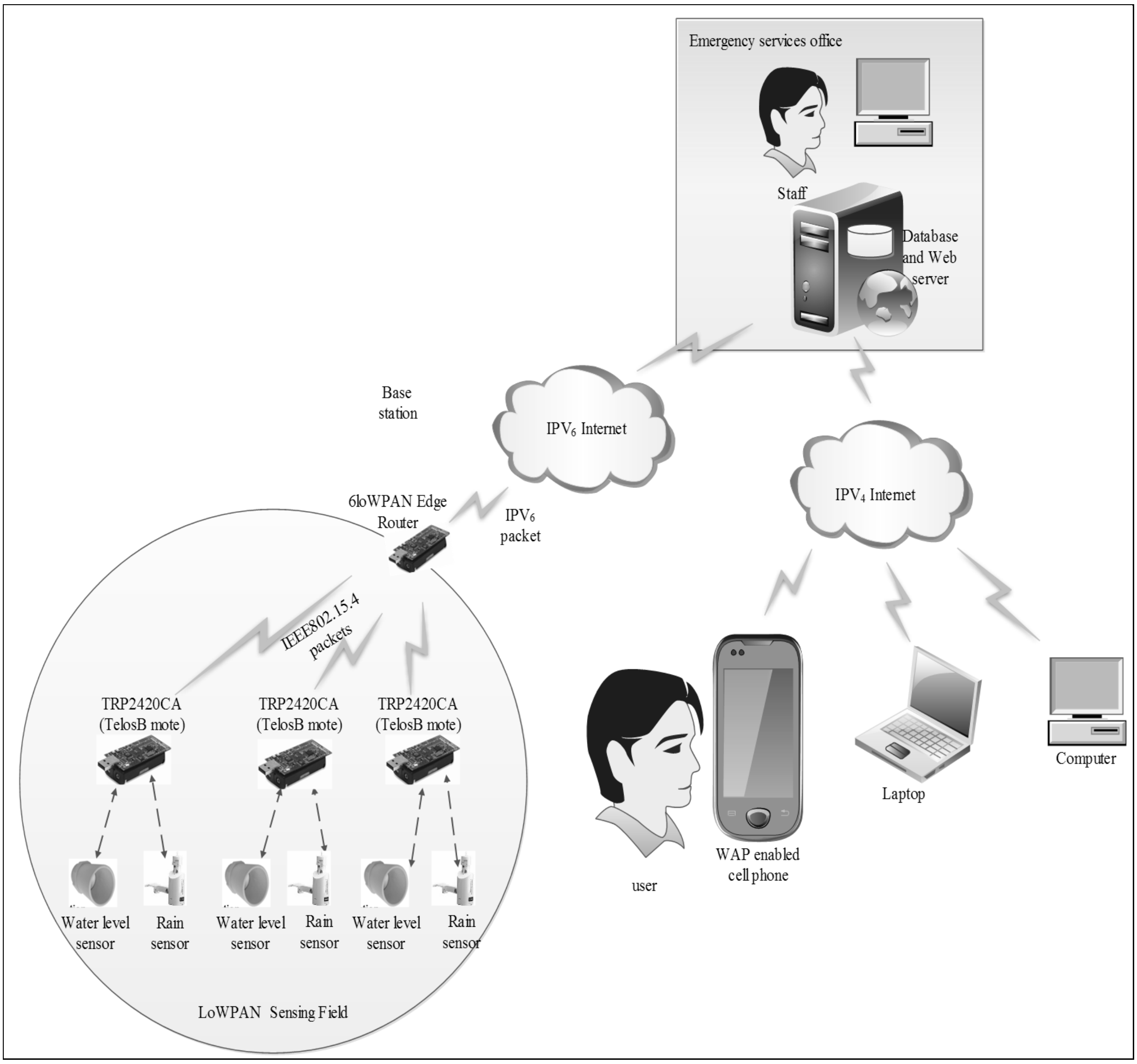

Figure 7: Architecture of the proposed IP-based riverine flood monitoring system

The sensing unit forms the 6loWPAN sensing field and comprised of a TelosB sensor motes (TPR2420CA)withon-board temperature and humidity sensors, expanded with additional water level and rain sensors. These motes will be positioned some distances apart across a 50×50 meter fieldaround a river to form a star network with the edge router (TPR2400CA). The individual motes will run on tiny operating system (TinyOS) and will be configured to appropriately interface with the sensors to read and sleep when not reading to preserve energy. The edge router will also be configured to provide interface to both the IPV6 internet and the 6loWPAN sensing field and some computation capabilities to the received data.

The transmission of data from the sensing unit to the database server at the emergency services office will be in the following sequence: first, data moves from the sensing unit to the edge router in 802.15.4 packet format, then to the IPV_6 internet and finally received at the emergency services building for storage. The information is stored in a database server and can be queried by interested persons using any internet enabled device by logging to the provided web site where the database is hosted. The information can be in tabular or chart form depending on the users query.

The database/web server unit is located at the Emergency services office. The components of this unit include: a database that will store the received data from the sensing unit and a Web server for hosting the information in the IPV4 internet for public access.

Users of the system are expected to use any internet enabled device to access the Web address where the information about that particular river would be uploaded, the information is viewed via a standard Web-based graphical user interface (GUI).

3.1 Proposed Plan for Performance Evaluation

The proposed system will be evaluated based on the following metrics: energy utilization per packet, throughput and packet delay of the 6loWPAN based WSN created as compared to a corresponding Zigbee network.

Energy utilization per packet is the amount of energy the network utilized in send a single packet from the source node to the base station (Edge router).

Packet delay also known as response time will provide a test in the performance of the network. It is the duration between when a packet is sent until the entire packet is received at the base station.

Throughput is the measure of the amount of data received within a defined period of time. This depends on the baud rate and the packet size. Thus it is calculated as packet size divided by the transmission time: mathematically:

$$Throughput = \frac{(8 \times number\ of\ bytes)}{total\ transmission\ time\ (secs)}$$

The created 6lowpan network will be benchmarked with a corresponding Zigbee network (a popular low power wireless technology) in terms of the aforementioned metrics;this is to prove the energy efficiency and the quick response capability of the created 6lowpan network.

While Omnet++ with Castalia extension will provide the simulation environment and the tools for evaluating the mentioned metrics, TinyOS Simulator (TOSSIM) will provide debugging functionalities during configuration.

4. Conclusion

Riverine flooding is a serious natural disaster affecting the world. To curtail its effects we require an adequate and efficient monitoring system. The proposed architecture of IP-based riverine flood monitoring system leverages on the energy management, internet based (IP-based) and flexibility of 6loWPAN technology.OMnet++ with Castalia extension and TOSSIM WSN simulators will provide the tools for evaluating the system based on energy utilization per packet, throughput and packet delay and benchmarked with a corresponding Zigbee network.Large scale implementation of the proposed system will provide relatively cheaper and affordable flood monitoring system for use in developing countries.

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