Application of LoRa WAN Sensor and IoT for Environmental Monitoring in Riau Province Indonesia

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Abstract — **Land and forest fires especially in Riau Province, Indonesia, have affected the length and breadth of Indonesia. The fires are normally hampered by seasonal dry conditions such as El Nino effect. In addition, the haze has affected the neighboring countries such as Malaysia, Singapore and south of Thailand. The effects of haze on human health as reported in that particular year were about 20 million people have suffered from respiratory problems and serious deterioration in overall health. There were other effects on environment, economy, flora and fauna in Southeast Asia region due to this disaster. This research proposes to develop a smart monitoring system using Long Range Wide Area Network (LoRa WAN) with low power wireless data communication and Internet of Things (IoT) technology. With LoRa technology, data can be transmitted up to 30 miles which is worthwhile to cover some of Riau Province that have been badly impacted by this disaster. In this article propose to develop sensors system that capable of detecting land and forest fire. The sensors will be located at several locations that has badly impacted previously. LoRa IoT Technology will be deployed to provide a platform for connecting the sensors. An early indication of land or forest fires is vital for quick prevention before they become uncontrollable and overwhelming. The design and development of LoRa sensors give high feasibility to overcome current issues in Riau Province because of land and forest fire.**

***Index Terms* — LoRa WAN, IoT, Sensors, Monitoring**

I. INTRODUCTION

Indonesian suffer from badly haze due to land and forest fires that happen almost every year. The location of Indonesia at equatorial causes this country to have longer dry season spans from April to October. Riau province is one of the state that has high threat to land and forest fire due to peatland, particularly in industrial forest areas. Most of the fires occurring in peat forests are serious due to the characteristics of peat which is easily flamed due to continuous dry season. It has been reported that the total economic loss for Riau province in year 2015 due to this disaster was about USD1.65 billion. More worst when it has huge impact on local environment, flora, fauna and human health. Elderly people and children are severely affected due to haze. Furthermore, the impact of this land forest fire is not only in Indonesia or Riau Province but also has caused deterioration in air quality and human health problem in others countries like Malaysia and Singapore. Current detection method is using satellite to detect any hotspot of land and forest fires. Such data however may not sufficient as the satellite cannot provide fine hotspots detection at other potential areas. The local authorities are normally depending on the satellite imagery to make a decision or report from local community and company that operation exploiting the lands [1, 2].

Rapid development and evolution in wireless network technology has dramatically changed and improved the natural environmental monitoring system from satellite to ground level detection methods such as Wireless Sensor Network (WSN) [3, 4]. New data for environmental applications and vital hazard warning such as land and forest detection and flood detection can be provided by such systems. The advantages of ground level detection can be categories in three aspects [5-7]: Sensor Nodes; low-cost, low power, robust, low pollution and environmental disturbance; Communication; low data rate, long range and error detection and correction; Computing; small OS for nodes, microcontrollers and low power system. With the emergence of IoT and Long Range (LoRa) Technology [8-10], the wireless sensor network and connectivity become more reliable, robust and quicker. With these technologies, a smart monitoring system for land and forest fire detection can be developed [11-13].

Therefore, in this research focus on developing ground level smart monitoring system to detect and monitor the environmental behavior in term of temperature, humidity and gasses. Proposing a new technology for monitoring system using low power wireless data communication with LoRa-IoT technology. The integration of sensors with LoRa technology would have an effect to local community where people could access the information through developed real-time database in anytime. This ground level detection method will be deployed in other areas, regions and states in Indonesia. It is anticipated to be quicker and cheaper solution than to satellite data acquisition and this would definitely be beneficial to social welfare and economy development. In addition, the development of real-time database would also require some support from them as a policy maker to understand how the system works and also understand the pattern of the results so that an appropriate action can be taken.

II. LoRa WAN Monitoring System Development

Monitoring system is widely use in detection of object or parameters that require continuous in time. Nowadays, many kind of monitoring system based on aim and objective as well as parameters to be monitor. Environmental monitoring for fire detection is implemented in some of institution or agency to monitor latest status of environmental. Current technology using is mostly from satellite data to detect hotspot of fire, this technology has some weakness and limitation such as only detect when fire already happen and in some case for example in bad weather or cloudy then satellite unable to penetration of cloud and image will not update. New method proposes in this system is use LoRa wireless sensor and IoT. LoRa sensor deploy in the area with high risk of fire to collect data such smoke detection, temperature, particle changing, etc. All the information collected by sensors send to sensor base station as gateway to transfer data collected from monitoring system (data center) because the distance between sensor base station to monitoring system very far away up to 200 km in some area to monitor. To achieve accurate data large number of LoRa sensors will deploy around the area because long range sensor be able to transmit data up to 15 km, mean a base station covering 15 km radius. LoRa sensor based on IoT technology that recently many industries introduced because of advantage long range and low power. Beside LoRa sensor, in every base station attached with high definition camera to analyze sky (environmental) image before and after fire then training data to analyze any changing of environmental image.

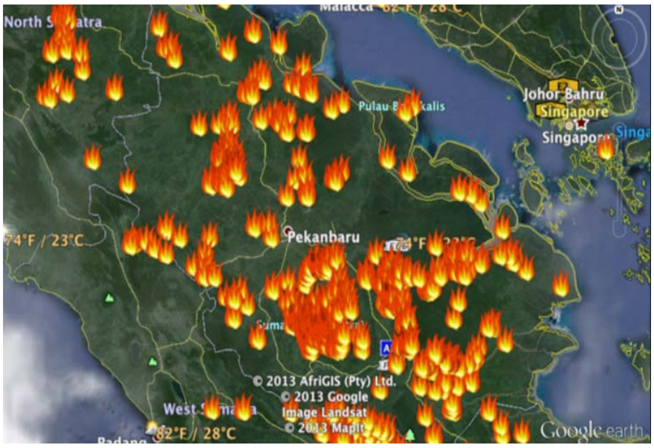

Fig. 1. Riau map and number of hotspots based on satellite image [4].

The selected sites which is high potential for forest fire decided as shows in Fig. 1, where the systems will be installed were chosen by previously obtained the approval of the local authorities such as Riau Local Council and the Ministry of Environment and Forestry Indonesia. Again, the established links between Islamic University of Riau with local authorities is necessary for integrating them into decision making process, facilitating the access for installation, monitoring, data analysis and reporting. Developing ground level smart monitoring land and forest fires using LoRa-IoT technology, an early indication can be obtained which improve the decision making in preventing the disaster. This design acquires new design and development with latest wireless LoRa-IoT technology and signal propagation study.

The setup of sensor base stations at difference area to collect information from LoRA sensor and IoT network deploy surrounding. Fig. 2 shows a proposed LoRa WAN sensor deploy and data network diagram for environmental monitoring. Information collected by sensor base station will keep in internal database then send to monitoring system (data center), because of sensor base station locate in rural area that far away up to 200 km then solar panel system will use as power supply for system. Latest technology of communication system also proposes such as 4G technology or even 5G technology for future in order to achieve real-time data to display to monitoring system.

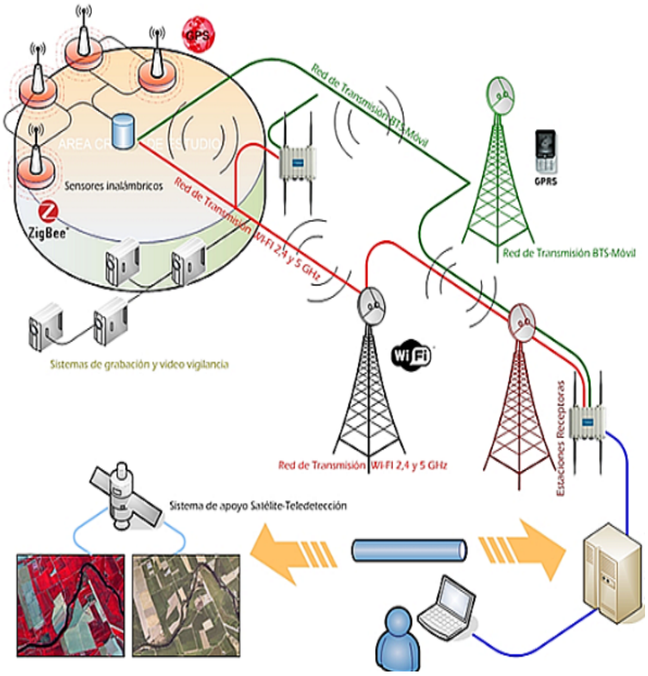

Fig. 2. Proposed LoRa WAN sensor for environmental monitoring.

The sensors be able to detect and gives early warning before fire is happen to authority for prevention action. Next step more sensors and sensor base station setup to cover entire of Riau Province and this project as prototype system to setup in others province in Indonesia. The proposed scenarios of LoRa sensors also opens to analyze behavior and changing of environmental before and after fire by image processing, analyze particle detection, sensor data's and new method of data communication system.

III. LoRa WAN Solution for Monitoring System

Proposed solution for LoRa WAN networks employ the robust LoRa modulation by Semtech technology in order to get long range operation. There is standardize by the LoRa alliance, which has defined frame formats, provisioning, medium access, management messages and security mechanisms, device management. Fig. 3. shows illustrates that LoRa WAN networks form a star topologies around gateways, which act as packet forwarders between end devices and a central network server (NS). The NS is responsible for handling MAC layer processing and acts as a portal between applications running on end devices and application servers (APs). The LoRa WAN standard defines three classes for end devices of networking topology in order to cater to a number of different scenarios which are A, B, and C [14].

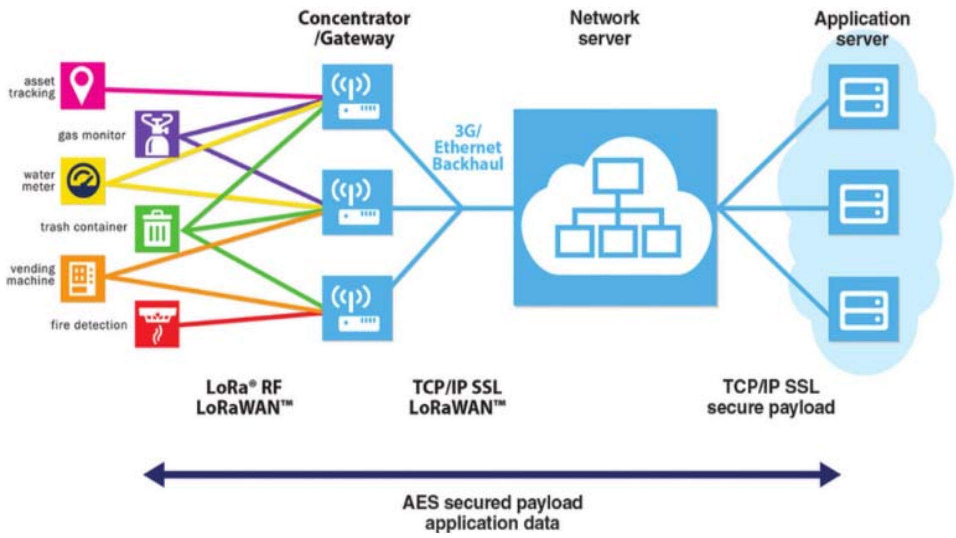

Fig. 3. Overview of the LoRa WAN hierarchical architecture based on Semtech proposal

The A class of end devices have their own transceivers in deep sleep for the majority of the time and wake up infrequently to transmit data toward the NS. The wireless medium access in LoRa WAN network follows an ALOHA scheme, which does not employ listen before talk, and is therefore subject to restrictions in most areas in the world while use it. For example, in Europe, the 868-MHz band consists of a number of sub-bands where Radio Duty Cycle (RDC) restrictions range from 0.1% to 10% with 1% being most common [15].

A. LoRa WAN Sensor Node

Solution for the LoRa node as point to collect data of environmental from the sensors installed and the protocol stack of the backbone network to transfer data from the node is shows in Fig. 4. Currently, most of commercially LoRA node (sensor) that available solutions follow by many of system is based on Semtech application notes, whose architecture and block diagram of the system as graphically depicted in Fig. 4. In this case the network backbone use is the internet or at least an intranet network. In this proposed environmental system proposed network is by radio communication which 4G or 5G technology.

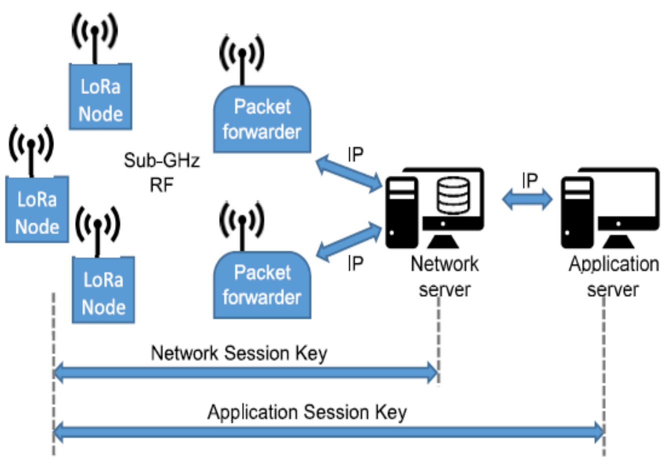

Fig. 4. Overview of the LoRa WAN hierarchical architecture based on Semtech proposal

The network gateway forward from LoRa WAN message based on data collected from LoRa node toward network servers can be one or more. The network server authenticates the received message and further forward the user payload to a single or several application servers to make sure all the data collected from the sensors node is stored in database. The application server used is for in charge of admitting nodes to the network and takes care of encrypting or decrypting user data sent and received to or from the end device. In the end, the application server forward node data from the sensors to a user server that actually implements the final user application. Additional to this scenario of proposed network is a network controller, whose aim is collecting reports related to the network status and be able to modify the LoRa WAN network accordingly for example changing the data rate supported by end devices and implementing an Adaptive Data Rate (ADR) scheme as well as can complement the network servers [16].

B. LoRa WAN Networking Architecture

Proposed scenarios of networking architecture in this LoRa WAN as stated in previous section is a network level architecture compatible with regular internet standards for example Internet Protocol version 6 (IPv6), would be highly desirable for a quick integration of the whole LoRa WAN system and its single end nodes within the fast and heterogeneous IoT ecosystem. However, LoRa WAN technologies are highly constrained regarding their transmission capabilities as limited bitrate and reduced packet size. Hence, the straight integration of IPv6 datagrams into LoRa WAN packets is not trivial and compression mechanisms are necessary. Based on this proposed solution is providing IPv6 connectivity to LoRa node by using an LoRa WAN link, but using a Multi-Access Edge Computing (MEC) based architecture to allow this integration by using LoRa technology as accessing network as shows in Fig. 5. The MEC node performs the packet translation tasks for the compression or decompression in order to interconnect the LoRa and IPv6 network segments the bidirectional flows can be established between LoRa WAN and IPv6 nodes [17].

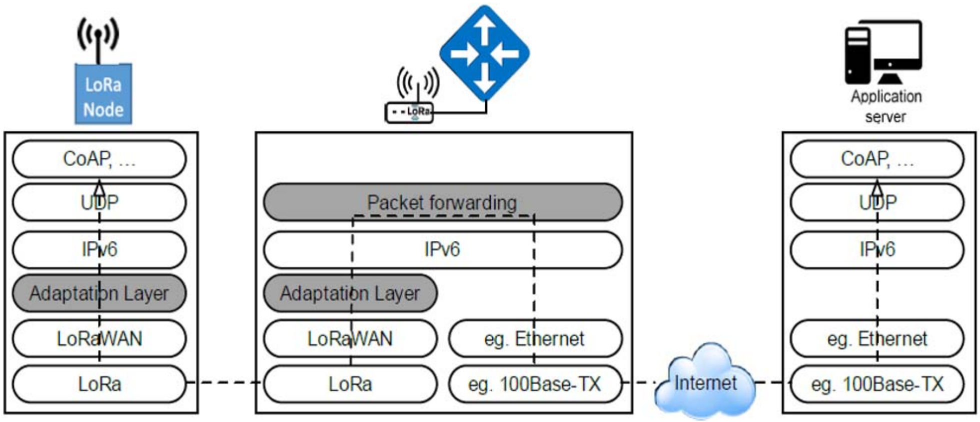

Fig. 5. Architecture of the IPv6 over LoRa WAN networking solution

The proposed solution can contribute of this LoRa WAN network such as:

- A real implementation of IPv6 over LoRa is developed and tested.
- A LoRa node test bench is deployed for providing environmental datas with IPv6 connectivity through LoRa WAN links.
- A base IoT environment for smart environmental data services are setup, which is ready for user to use it.

The other proposed solution for a LoRa WAN network is based on a star-of-stars topology composed of three basic elements in end of devices, a gateways and central network server as shows in Fig. 6 is end-devices, which may correspond to any input such as LoRa node sensors or actuators, communicate with the network server through one or more gateways, while the network server sends LoRa data to end-devices through a specific gateway. End-devices use the LoRa physical layer to exchange data with the gateway, while the gateway and the network server communicate over an IP-based protocol stack [18].

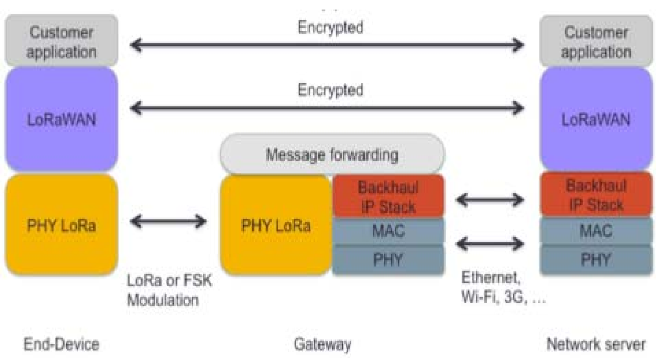

Fig. 6. LoRaWAN (a) system and (b) protocol architecture

C. LoRa Physical error model

After LoRa Physical (PHY) error model the interleave, the output data are whitened in order to boost the entropy of the information source. Note that in the Bit Error Rate (BER) in simulations the information bits are drawn from a uniform distribution, therefore the entropy of the information source is already at its maximum. Before passing the whitened bit stream to the modulator, it is reverse gray mapped first. This produces a sequence of integers, which are fed to the LoRa WAN sensor node. At the LoRa sensor node, a sequence of N time-shifted complex baseband up-chirp samples is generated via a phase accumulator as given by (1), where N, the number of samples data per baseband symbol, is equal to $2^{SF}(f_s/BW)$. The input integer determines the time-shift of the up-chirp [14].

$$m(i) = \begin{cases} \exp(-j\pi), & \text{if } i = 0 \\ m(i-1)\exp(jf(i)), & \text{if } i = 1, \ldots, N-1 \end{cases} \quad (1)$$

where the instantaneous frequency $f(i)$ is given by

$$f(i) = -\pi + \frac{i}{N}2\pi, \text{ for } i = 1, \ldots, N-1. \quad (2)$$

Next, the samples of the LoRa WAN symbol are sent over the Additive White Gaussian Noise (AWGN) channel for a given signal to noise ratio (SNR) as per

$$c(i) = m(i) + \sqrt{\frac{E_s}{2\text{SNR}}}[\mathcal{N}(0;1) + j\mathcal{N}(0;1)], \quad \text{for } i = 0, \ldots, N-1 \quad (3)$$

where $\mathcal{N}(0;1)$ is the standard normal distribution and SNR $= 10^{\text{SNR}_{\text{dB}}/10}$. Note that the energy per symbol is equal to one for the LoRa WAN sensor node.

In the end at the receiver, the LoRa demodulator employs correlation based on demodulation where the received symbol is correlated to all known LoRa symbols. The decision on which symbol was sent, is made by selecting the LoRa symbol with the maximum correlation value. After demodulation, the receiver chain is the reverse of the sender chain. The error rate is measured in the information bits, after error correction of the data demodulation.

IV. Conclusion

LoRa WAN system is developed for the environmental monitoring system because applicable for long range sensing up to several miles. Proposed solution for development of the LoRa WAN application in environmental monitoring system as discussed, LoRa node and point to collect data from the sensors installed sent the data to the application server through the IPv6 networking with physical layer used 4G or 5G technology. With the proposed system environmental data can be sent to the application server in minimum time to achieve real time monitoring system.

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