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A Wireless Smart Sensor Network for Flood Management Optimization

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Abstract- Recent development in the sensing technologies and wireless sensor networks has encouraged many innovative applications in disaster management and forecasting. Flood is one of the most dangerous natural disasters that occurs frequently in south Asia. Therefore, water level monitoring and flood early prediction, play an important role in lives and properties saving. In this paper, an optimized Flood Warning System (FWS) is presented. The system is based on multi parameters Wireless Smart Sensor Network (WSSN) for early flood warning. WSSN performs pre-processing procedures at sensor level before sending the data to a base data analyzing station. This pre-processing step is to improve the reliability, data quality and transmission quality. For the purpose of validation, the proposed method is applied using two parameters: The water level (L) and streamflow of water (R) in rivers. The proposed system provides early flood detection by continuously measuring R and L in real-time. The collected data is to be used to predict flood time and place. Data is exchanged among sensors in real-time. Pre-analyzing is performed and reports are sent to the base station only if the analysis gave a high risk level. The main purpose is to cut down the data size. Analysis and simulation showed that the data size is improved significantly using this method. Calculations considers real cases on a part of Pahang River (Sungai Pahang).

Index Terms- Flood Forecasting, Wireless Smart Sensor Network, Artificial intelligence.

I. INTRODUCTION

Malaysia climate is classified as equatorial with constant high temperatures and high humidity. This climate cause heavy rains between November and February every year. The precipitation may reach 600 mm in 24 hours in some extreme cases, [1]. Several major floods have been experienced in the last few decades. Such floods have severe effects on communities and economy because of the damages in properties and crops. Usually Flood Warning Systems (FWS) are used to take measures and send information to a base station, the transmitted data size depends on the number of parameters to be measured, the number of sensors and the size of the area covered. Reducing the data size is one of the vital optimizations needed to guarantee real-time sensing and early warning. Wireless Smart Sensor Networks (WSSN) supports data collection in changeable environment based on their applicability in a variety of fields. In this paper an optimized flood warning system (FWS) is proposed to generate early warnings for floods by collecting and processing data in each sensor before sending them to a base station. The main target of the proposed system is to reduce the data size to guarantee real-time sensing and early warning.

Using WSSN for flood warning is not a new method. Recently, many researchers from different countries are adopting wireless sensing techniques to carry out instantaneous flood prediction and monitoring. For example: A flood monitor has been modeled and simulated by Manal Abdullah in [2] for Jeddah area, Saudi Arabia. Direct diffusion routing protocol has been used to control and monitor flood case. A best sensor network configuration for the area of deployment under consideration has been suggested. Moreover, Md Asraful Islam in [3] designed and implemented a water monitoring system to remotely monitor water levels in Bangladesh. The proposed system is capable of sending early warnings while sensing critical water levels. The sensed data is made available at a website for remote access. Nevertheless, flood monitoring and detection systems based on WSN have been proposed for floods in India in [4], [5]. The proposed models have been designed and implemented in various geographical locations in India. Moreover, in [6] the flood/drought monitoring and detection

in Pakistan is proposed in an alarming situation. They proposed a low-cost and reliable flood/drought forecasting system that may help in extreme situations of natural disasters.
Most of the discussed above works are trying to optimize the flood warning systems by improving connections links, routing protocols, network topology or sensing algorithms. The data size in not discussed. In this paper, processing algorithm is approved to decrease the size of the transmitted data through network. The main target is achieving a real-time system.

The rest of the paper is organized as follows: Section II presents the details of the proposed system, Simulation results are discussed in Section III. Finally, Section IV is for conclusion.

II. FLOOD WARNING SYSTEM BASED ON WSSN

Every node in the proposed WSSN, acts as data acquisition device, data router, data aggregator and data pre-processor. In addition, WSSN nodes communicate with neighboring nodes to reduce the transmission power. This is done to avoid long distance transmission, expensive transmitters and repeaters which are commonly used in traditional remote systems [7]. Additionally, this method allows WSSN to provide information from locations that are difficult to communicate directly with the base stations.
The main benefit of this topology is to minimize the data size which is sent to the base station. To explain the proposed Flood Warning System (FWS) more clearly, a case study is to be applied on Pahang river (Sungai Pahang) in Malaysia. The river is shown in Figure 1.

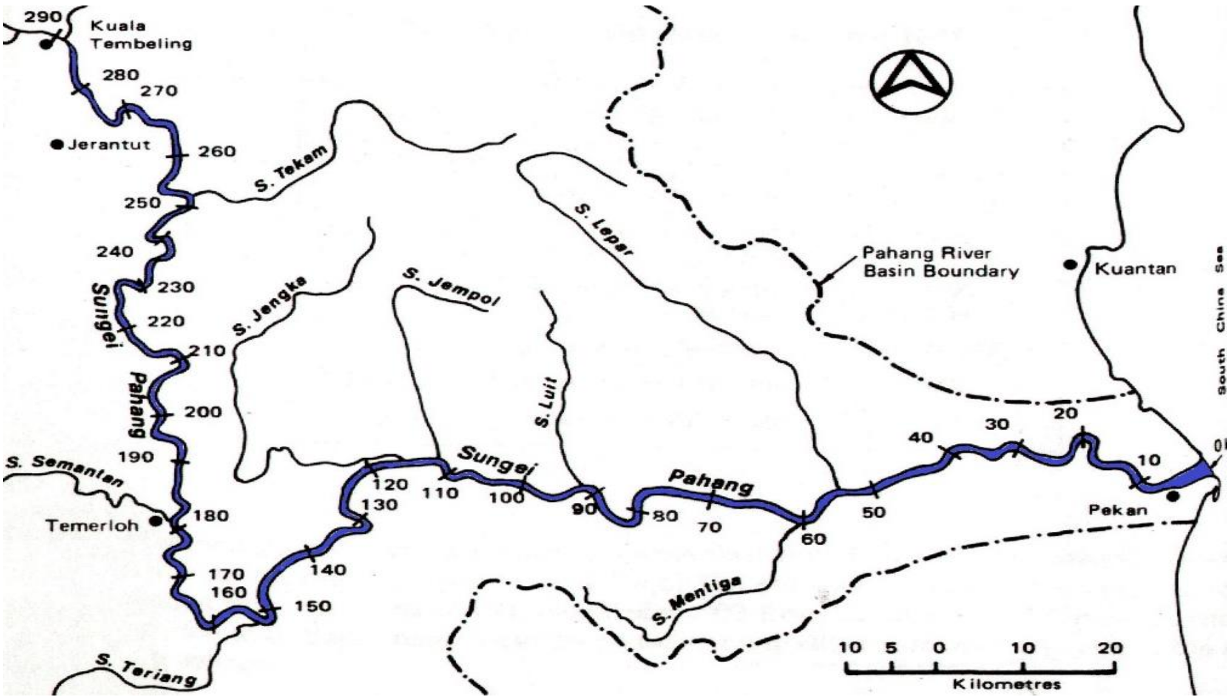


Figure 1. Sungai Pahang (Pahang River).

In this study, FWS is composed of 17 smart sensor nodes distributed along the main stream points of Pahang river. The points are located over a course of 50 km along the river as shown in Figure 2. The diagram in Figure 2 illustrates the suggested distribution of sensors along the study area of Pahang River.

Figure 2. The distribution of sensors along the study area.

Each smart sensor is used to monitor water streamflow (R) and water-level (L) continuously. Ultrasonic Sensor (HC-SR04) is used to measure water- level (L). While, water flow sensor (YF-S201) is used for streamflow (R) measuring. Both sensors are shown in Figure 3.a and 3.b respectively.

(a) **(b)**

Figure 3. (a) Ultrasonic sensor, (b) Streamflow sensor.

The pre-processing flowchart is shown in Figure 4. Sensor node (i) acquires the real-time data of the water-level (L_i) and the streamflow (R_i) where i: 1 – 17. Each node includes an Embedded microcontroller. Each sensor is connected the embedded microcontroller which compare the measured values with a database of thresholds. If the result of comparison is positive, that means the flood risk is high in node area (i). Thresholds are decided according to statistical information. When the level exceeds the specified threshold, the node sends a message to the base station, this message contains information on the expected flood location.

Wireless transceiver sends the converted data to the base station, communication link between the sensor and base station is suggested to be via Bluetooth or ZigBee which are similar. Bluetooth prove the ability for emergency real-time applications like the emergency system in [8]. However, ZigBee is considered an ideal communication standard for WSNs because it is built on the power efficient IEEE 802.15.4 specification. Moreover, it has a multi-hop routing algorithm capable of adapting to link failures while minimizing communication power consumption [9].

The base station collects the sensed data alarm from sensors that evaluate and set the flood warning with the help of predefined data ranges. The pre-processing procedure of data in sensors significantly reduces the amount of data sent to the base station.

This thereby reduces the energy consumed in the continuous transmission as in other systems as well as it reduces the time of data processing in the base station, which means that we have developed a system which able to work in real-time.

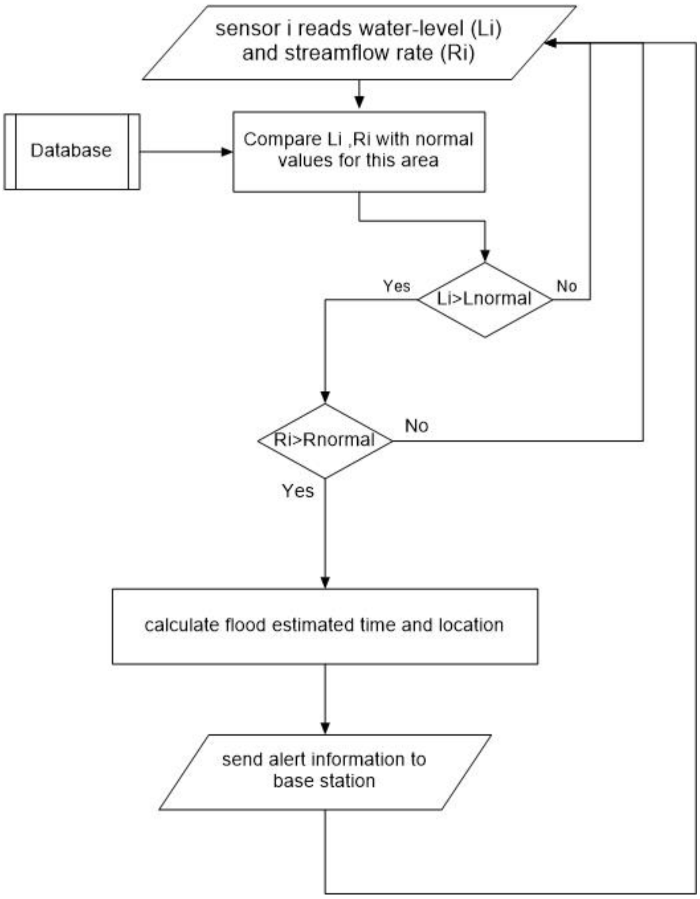


Figure 4. Pre-processing flow chart for smart sensor nodes.

III. SIMULATION AND RESULTS

To evaluate the proposed system, a simple simulation and analysis is presented in this section. The size of the data sent to the base station is considered an important factor in alleviating instant size on the network, which reduces the energy consumed and the time required to issue a flood warning. Therefore, in this section a comparison between our suggested system and a conventional wireless sensor system in term of size of data is presented.

Table 1 summarizes the comparison of the two systems. Each sensor uses 10 bits for one reading. This is because the used microcontroller includes 10-bit Analog to Digital convertor (ADC). Zigbee bit-rate speed is fixed to 40 Kbit/s between Sensor and main station and 20 between two neighboring sensors Kbit/s. The actual data throughput will be less than the maximum specified bit rate due to the packet overhead and processing delays. However, we neglect this lost in this study. Since two parameters (L, R) only are used, data generated in each sensor for all parameters is 2 x 10 = 20 bits per one reading. Increasing the number of sensors will increase the data size of course. The micro controlling unit have a built in ADC which accepts up to 8 sensors without any hardware addition. However, in the smart system, the usage of the pre-processing will combine the sensor values to be one comparison result value. The comparison results are actually flags of 1 or 0 for each parameter. If the result of comparison for a parameter is True (1), that means this parameter is reaching a risky value which might lead to a flood. One byte i.e. 8 bits are used to send the comparison results to give a capacity up to 8 sensors. Therefore, for comparison aspect 4: “Data generated in each sensor for all parameters”, the smart sensor network is always using 8 bit while the conventional sensor network needs 20 bits for two sensors only.

To save power in conventional sensor network, the frequency of sending data to base station is set to be every 5 seconds. On the other hand, smart sensors send data every 5 second in case of Flood Alarm. However, in normal case they send data every 1 minutes (i.e. 60 seconds) for the purpose of general monitoring only. The Flood Alarm is decided on sensors level before sending data to base station, Communication with main base is done throw one sensor only which is the closest to base station. Therefore, smart sensors reading frequency is set to 1 reading per second, and consequently the frequency of data transfer between neighbor sensors is also set to be every 1second as shown in Table 1, comparison aspect 6: "Frequency of data sending between sensors and base Station". This paper is focusing on the size of data transferred to base station. Another simulation on power is needed for evaluating the power consumption in sensor nodes. Power consumption simulation is to be ready in the soon coming future.

Table 1. Comparison between the conventional and the smart wireless network system

	Comparison aspect	Conventional Sensor Network	Smart sensor Network	Remarks
1	Bitrate between Sensors	None	20 Kbit/S	Zigbee Speed …
2	Bitrate between Sensor and Main Station	40 Kbit/s	40 Kbit/s	
3	Data generated in each sensor for each Parameters	10 bits/ 1 reading	10 bits/ 1 reading	Using 10 bit resolution ADC
4	Data generated in each sensor reading for all Parameters	20 bits	8 bits	Because of the pre-processing procedure
5	Frequency of data sending between Sensors	Not Available	Every 1 second	
6	Frequency of data sending between sensors and base Station	Every 5 seconds f = 1/5 = 0.2Hz	Every 60 seconds f = 1/60 = 0.016Hz Or Every 5 seconds in case of emergency f = 1/5 = 0.2Hz	Smart sensors sends data every 5 seconds in case of Flood Alarm but in normal cases, it sends every 1 minutes for the purpose of general monitoring
7	Data Transfer with Main Station per hour	14.4 (Kbit/Hour)	0.48 (Kbit/Hour) Or 5.7 (Kbit/Hour)	

To compare the size of data for our system with a conventional system the size of data transmitted per hour is considered. Different cases were considered as following:

1. For conventional sensor network:

Data transfer with main station per hour $=$ Data generated in each sensor for all Parameters $\times$ Frequency of data sending between sensors and base Station $\times 3600 second = 20 \times 0.2 \times 3600 = 14400\ bit/hour = 14.4\ Kbit/hour$

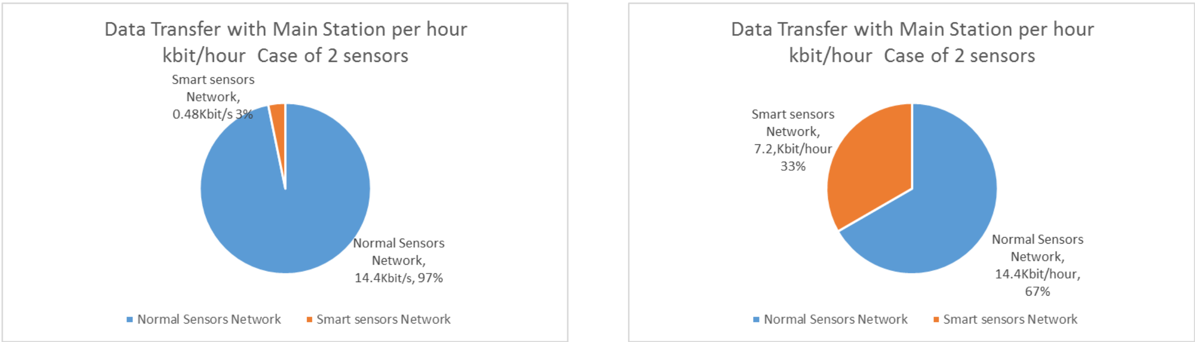
2. For smart sensor network:
   a. Normal operating case:

Data transfer with main station per hour $=$ Data generated in each sensor for all Parameters $\times$ Frequency of data sending between sensors and base Station $\times 3600 = 8 \times 0.016 \times 3600 = 479.9\ bit/hour = 0.48\ Kbit/hour$

b. In case of Flood Alarm

Data transfer with main station per hour = $\text{Data generated in each sensor for all Parameters} \times \text{Frequency of data sending between sensors and base Station} \times 3600 = 8 \times 0.2 \times 3600 = 5760\ bit/hour = 5.7\ Kbit/hour$

Figure 5 shows the plot of data size transferred to base station for both conventional sensor network and smart sensor network for 2 sensors case. It is clear from the figures that smart wireless sensors system reduces data size significantly.



a b

Figure 5. Comparison between conventional sensor network and smart sensor network in term of data size transferred to base station for 2 sensors case. a: Comparison during normal operating case, b: In case of flood alarm.

The system can accept up to 8 sensors for each node without any hardware addition as mentioned above. For more investigation on the efficiency of the proposed method, the case of 8 sensors can be discussed as following:

1. For conventional sensor network:

Data transfer with main station per hour = $\text{Data generated in each sensor for all Parameters} \times \text{Frequency of data sending between sensors and base Station} \times 3600 = 80 \times 0.2 \times 3600 = 57600\ bit/hour = 57.6\ Kbit/hour$

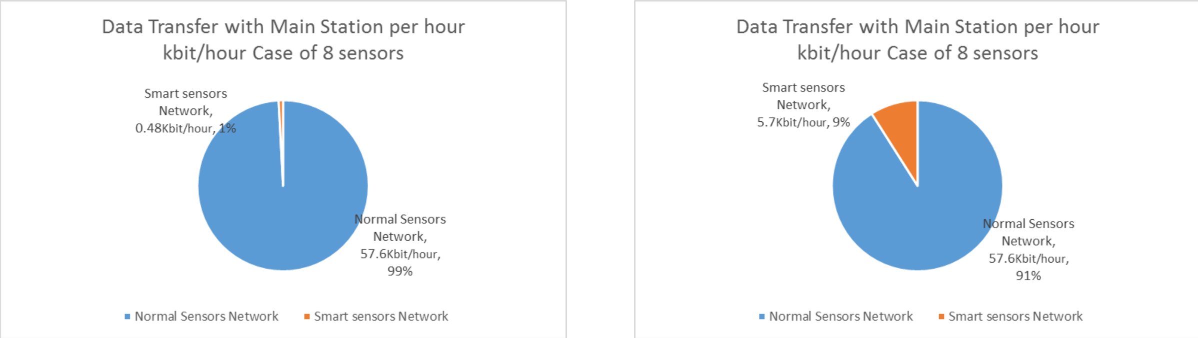
2. For smart sensor network, there will be no change:
   a. Normal operating case:

Data transfer with main station per hour = $\text{Data generated in each sensor for all Parameters} \times \text{Frequency of data sending between sensors and base Station} \times 3600 = 8 \times 0.016 \times 3600 = 479.9\ bit/hour = 0.48\ Kbit/hour$

   b. In case of Flood Alarm

Data transfer with main station per hour = $\text{Data generated in each sensor for all Parameters} \times \text{Frequency of data sending between sensors and base Station} \times 3600 = 8 \times 0.2 \times 3600 = 5760\ bit/hour = 5.7\ Kbit/hour$

Figure 6 shows the plot of data size transferred to base station for both conventional sensor network and smart sensor network for 8 sensors case. It is clear from the figures that smart wireless sensors system reduces data size more significantly when the number of sensors increases.



a b

Figure 6. Comparison between conventional sensor network and smart sensor network in term of data size transferred to base station for 8 sensors case. a: Comparison during normal operating case, b: In case of flood alarm.

IV. CONCLUSIONS

In this paper we proposed a general idea about a wireless smart sensor network which is designed for flood management optimization. The main optimization discussed in this paper is reducing the size of data to be transferred to base station. The proposed system is targeted for real-time early flood detection. The collected data of two sensors is subject to pre-analyzing procedure. The system is still in its early designing steps. Preliminary analysis and simulations showed that the data size improves significantly using this method. The system is subject to more comprehensive study and simulation to evaluate it is efficiency in early flood prediction in real-time. This paper is only focusing on the size of data transferred to base station. Another simulation on power is needed to evaluate the power consumption in sensor nodes. Power consumption simulation is to be ready in the soon coming future.

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