Hardware Based Data Aggregation Routing Protocol for Forest Preventive Fire System

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Abstract. A hardware based Data Aggregation (DA) routing protocol to achieve energy efficiency in Wireless Sensor Network (WSN) is presented in this paper. There are 4 stages of scenarios involved in this hardware operational design i.e. the user node broadcast the interest messages, the coordinator node performs storing and transmitting the gradient information, the user node perform storing the gradient information in the interest cache and the target node to respond the interest message through the gradient flow. The hardware design testing shows the operational of Directed Diffusion is successfully implemented for all of 4 stages. Each of nodes is connected through their individual address.

1. Introduction
Several forest fire cases have been triggered by the long dry season in the last decade in Riau Province. In this province mostly forest fire cases exposed to peat land and this become problematic to handle it [13]. Base on record of Riau Province Natural Resource Conservation Agency, Pelalawan Residency with Tesso Nilo National Park (TNNP) has contributed the most hotspot among others Residency in Riau Province. Also, according to this agency, almost every year there are several forest fire cases at TNNP. According to these facts, it is necessary to provide a preventive forest fire system instead of handling a fire case.

The recent technology of preventive forest fire system using of Wireless Sensor Network (WSN) [1,2]. A Wireless Sensor Network (WSN) consists of many sensor nodes. Those sensors are equipped by communication system that makes them able to communicate among them directly or indirectly through a base-station (BS). A huge number of sensors have capability to perform sensing across a wider geographical zone with higher accuracy. Individually, every sensor node equipped by sensing instrument, processing instrument, transmission instrument, moveable system, position tracking system, and power system.

Regardless of the numerous applications of WSNs, the networks in WSNs has several limitations, e.g., inadequate energy supply, restricted computing power, and restricted communication channel of the wireless connections among sensor nodes. One of the primary challenge in the design of WSNs is to deliver the data communication with a little bit longer network life time and try to avoid connectivity loss by deploying some tricky energy management approaches. These approaches are known as routing protocol [3].

There are progressive works on routing protocol [4,5,6,7,8,9,14]. Data Aggregation (DA) approach [3] is one of them. The basic idea of DA is to gather the incoming data from individual sensor node through avoiding severance, optimizing the transmissions number; hence lead to network energy saving.
and it will extend its lifetime. Unlike old-style node to node routing, DA manage to traces tracks from many sources to a sole destination that gathers a solid in-network from reappearance data.

Directed Diffusion is one of popular Data Aggregation methods which proposed by [10]. This method proposes a data-centric and application aware pattern in the perception that all data produced by sensor nodes is labeled by attribute-value pairs. Practically, sensors quantify events and generate gradients of evidence in their surrounding regions. Data is requested by base station through spreading interests. A task required to be performed by the network is described by interest. The network will absorb the interest hop-by-hop, and will be distributed by each node to its regions. Gradients will prepare to retrieve data matching the enquiry towards the demanding node while the interest is distributed all over the network, i.e., a Base Station may look for data thru broadcasting interests and these interests are propagated by intermediate nodes. Once a sensor receives the interest from a particular sensor node, this sensor prepares a gradient to that sensor nodes. This procedure remains until gradients are built between sources and Base Station. Basically, a gradient composed by a direction and attribute value. Each individual neighbour has different gradient strength and also reflects to vary of data flow capacity. Generally, the procedure of Directed Diffusion involves the following stages: interest delivery, gradient developing, and data broadcasting. The best track among multi tracks will be reinforced when the interests is matched to the gradients to anticipate flooding condition. Aggregation of data is performed in the middle of process to minimize cost of communication.

The objective of hardware implementation for Directed Diffusion (DD) routing protocol is to create prototype model of DD. Then, its protocol routing mechanism will able to demonstrate. The DD protocol routing mechanism is extracted from previous works [11]. This method proposes a data-centric and application aware pattern in the perception that all data produced by sensor nodes is labelled by attribute-value pairs. Practically, sensors quantify events and generate gradients of evidence in their surrounding regions. Data is requested by base station through spreading interests. A task required to be performed by the network is described by interest. The network will absorb the interest hop-by-hop, and will be distributed by each node to its regions. Gradients will prepare to retrieve data matching the enquiry towards the demanding node while the interest is distributed all over the network, i.e., a Base Station may look for data thru broadcasting interests and these interests are propagated by intermediate nodes. Once a sensor receives the interest from a particular sensor node, this sensor prepares a gradient route to the sensor nodes. This procedure remains until gradients are built between sources and Base Station. Basically, a gradient composed by a direction and attribute value. Each individual neighbour has different gradient strength and also reflects to vary of data flow capacity. Generally, the procedure of Directed Diffusion involves the following stages: interest delivery, gradient developing, and data broadcasting. The best track among multi tracks will be reinforced when the interests is matched to the gradients to anticipate flooding condition. Aggregation of data is performed in the middle of process to minimize cost of communication.

2. Methodology
Some procedures have to perform during implementation of Directed Diffusion (DD) routing protocol into the hardware target.

Firstly, the design requirement must be determined. The detail of design requirement refers to the minimum of DD routing protocol mechanism. Its mechanism covers the following scenarios i.e. the user node broadcast the interest messages, the coordinator node perform storing and transmitting the gradient information, the user node perform storing the gradient information in the interest cache and the target node to respond the interest message through the gradient routing. The detail of scenarios is illustrated in Figure 1.

The next procedure is determining the suitable sets of the hardware which able to accommodate the design requirement. The minimum mechanism of Directed Diffusion routing protocol which covers above scenarios is represented by 4 sensor nodes. Two of these sensor nodes will perform as transit gradient nodes. While the rest of two nodes are perform as coordinator and target nodes, respectively. The detail role of each node is illustrated in Figure 2. The node hardware specification is fulfilled by nRF24L01. The nRF24L01 has feature of baseband logic Enhanced Shock Burst which developed by
Nordic Semiconductor. The baseband logic Enhanced Shock Burst is data packet based layer which include packet assembly, automatic time setting and re-sending packet if necessary. The feature of baseband logic Enhanced Shock Burst able to improve power efficiency in one direction system. The processing unit is represented by Arduino Uno. The Arduino Uno is attached to nRF24L01 unit for a whole utilized node.

The last procedure is hardware design testing. The testing procedure is divided into two categories i.e. Directed Diffusion Protocol Routing function and Routing effectiveness base on energy efficiency.

![Directed Diffusion Routing Protocol mechanism.](image1)

**Figure 1.** Directed Diffusion Routing Protocol mechanism.

When the process is started then followed by the user node broadcast the interest messages. The interest messages is the information that required by the user i.e. temperature information. The next process is the coordinator node performs storing and transmitting the gradient information. In this process, the coordinator receives interest messages from the user node and performs two tasks i.e. storing the interest messages and transmits it. Then the process is continued by the user node perform storing the gradient information in the interest cache. The user node is performing storing the gradient information in the cache in order to speed up in the recalling of interest information. And the last process is the target node to respond the interest message through the gradient routing. The target node provides the required information that sent by the user node and transmit it through the gradient routing.

![Directed Diffusion nodes in the operation mode](image2)

**Figure 2.** Directed Diffusion nodes in the operation mode
The minimum operational of Directed Diffusion (DD) routing protocol involves four nodes i.e. coordinator node, target node and two transit gradient nodes. They work in the close loop.

3. Result and Discussions
The result is presented according to the described scenarios in section II. First category is to perform hardware design testing. The purpose of this testing is to ensure the hardware is work according to the minimum Directed Diffusion (DD) routing protocol mechanism. The result of this test category is successfully operated as shown in Figure 3.

Figure 3 shows the target node has responded to the interest message of fire case interest. The second scenario testing is routing effectiveness base on energy efficiency. In this case the several of distance among of nodes have been tested i.e. 10 m, 12m, 14m, 16m, 18m, and 20m. The illustration for this scenario has showed in Figure 4.

Figure 4 shows the various distances among coordinator node (yellow), router node (blue) and target node (black).
Figure 5 shows real set up in the field. As shown in the figure, certain distance position among coordinator node, 2 router nodes and target node. Base on the last test category the summary of key performance indicator has indicated as shown in the Table 1.

Table 1. Key performance indicator.

| Distances (meter) | Delay rates (ms) | Throughput rates (kb/s) | Packet Loss (%) |
|-------------------|------------------|-------------------------|-----------------|
| 10                | 265              | 2.43                    | 0%              |
| 12                | 186.4            | 3.53                    | 0%              |
| 14                | 592.5            | 1.10                    | 0%              |
| 16                | 155              | 4.13                    | 0%              |
| 18                | 189.9            | 3.54                    | 0%              |
| 20                | 249.4            | 2.80                    | 0%              |
| 22                | 414.6            | 1.58                    | 0%              |
| 24                | 243              | 2.64                    | 0%              |
| 26                | 204.8            | 3.45                    | 0%              |
| 28                | 220.9            | 3.15                    | 0%              |
| 30                | 711.2            | 0.93                    | 26%             |

4. Conclusions
The Directed Diffusion (DD) routing protocol has been implemented successfully on the Arduino Uno processing unit using of nRF24L01 module. The testing result shows this hardware design system able to operate on the minimum mechanism of DD routing protocol. Meanwhile the various node distances testing has indicated that 16 m distance is the most effective routing with the most efficient energy.
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