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Direct Line Routing Protocol to Reduce Delay for Chain Based Technique in Wireless Sensor Network

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Direct Line Routing Protocol to Reduce Delay for Chain Based Technique in Wireless Sensor Network

Abstract

The main objective of routing protocol is to select the next-hop connection node for packets traveling from source to destination. Greedy algorithm depends on the distance only to select the next-hop connection and it is building one chain only. Delay is considering the main drawback in all chain based routing protocols in the wireless sensor network. Direct Line Routing Protocol (DLRP) is a proposed protocol in this scientific research and it has three phases which are intraconnection, interconnection and chain head selection. DLRP connects all sensor nodes in the same line (column) in one chain then selects one node as the chain head (CH) to connecting directly with the base station (BS). CHs in DLRP have lower responsibility for data delivery than other protocols that make energy saving and avoid data redundancy. Network simulator 3 (ns-3) is used to evaluate the performance of DLRP including all phases with close routing protocols DCBRP and CCM since they are for deterministic node deployment and in the same experimental environment. The results show the superiority of DLRP based on related performance metrics which average end-to-end delay, power consumption, CHs power consumption, and delay*energy metrics. Furthermore, DLRP can adopt to another deployment method to increase the stability and prolong the lifetime of the Network.

Keywords

WSN; Routing Protocol; Deterministic node Deployment; DLRP; CCM; DCBRP

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1. Introduction

Wireless Sensor Networks (WSNs) consist of a number of sensor nodes (devices), which are connected to each other wirelessly. WSNs applications are used in deferent areas, such as military, industrial, environmental, habitat monitoring and disaster management [1]. Sensor node considers the main part of WSNs however, it has many important limitations in a characteristic which include computational capability, power resource, memory and bandwidth [2]. These nodes have the capability to connect each other and with nodes called chain heads, which can connect to the base station node. Every node has a sensor device to play a specific task (one or more). These nodes also have a radio module for sending packets by a wireless medium, a microcontroller for processing, and a power supply for providing energy for all parts [3]. Usually, the battery is the main energy source in all nodes, as a result of its deployment method, and consequently recharging consider an impossible task. WNSs nodes also have a particular level of intelligence algorithms to send data to BS [4].

Routing is one of the most pertinent perplexing matters that straight affect the performance of WSNs. The main aim of the routing protocols in WSN is delivering all sensing data to the base station with lower energy consumption to extend the lifetime of the network's nodes. Different factors related to routing protocols affect the performance of WSNs. Which are include energy consumption, scalability, redundancy, bandwidth, data aggregation, multipath, localization, and the end to end delay [5].

Base on the network's construction, the routing protocols in WSNs are dividing into three categories: *hierarchical*, *location-based*, and *Flat* protocols. Location-based protocols are typically used in real-time applications. This is also called position-based depending on the geographical positions. In the Flat protocols, all nodes have same duty in the network, therefore it is normally using the flooding method to deliver data to BS. Hence the Flat topology is active in the small scale networks [5,6].

In the hierarchical routing protocols, the sensor nodes perform many tasks. There are one or more cluster heads in each cluster. The main functions of the chain head are to collect data from the output environment, aggregate data from the normal nodes, and to send packets between CHs, or with the BS. The other

nodes are called the Member Node (MN) or Ordinary Node (ON) that perform the sensing and transmitting its data to CH only [7,8].

Tree-based, chain-based and cluster-based are the main types of hierarchical routing protocols [9]. Fig. 1 explains routing types in WSNs. In cluster-based protocols, one or more nodes are nominated to be CH(s). The rest nodes are connected to nearby CH as normal nodes. Low-energy adaptive clustering hierarchy (LEACH) [10] is one of cluster-based protocols for example. The main idea in tree-based is that all sensing packets are sent from children (normal node) to their parents only [11]. Data Routing for In-Network Aggregation (DRINA) [12] consider a tree-based routing protocol example. All nodes in the chain base technique are connected as chain and select one node as CH to deliver chain data to the BS. Although many types of routing protocols in WSN are discussed in the literature review, chain-based protocols seem most promising than others in terms of energy consumption and network lifetime [13–15].

Furthermore, node deployment is extremely application dependent and is related to energy consumption and network lifetime for all nodes. Typically, there are two famous methods for nodes deployment in WSNs. The first one is *deterministic*, which deploys the nodes manually in predetermined areas to meet the requirements of applications. The second strategy is randomly deployed for all nodes which are used in the areas where manually installation is not applicable [16,17].

This research addresses the delay problem in the chain based routing protocols and propose DLRP protocol to reduce the end to end delay.

2. Chain-based routing protocols

The underlying idea in chain based routing protocols is to connect all nodes like a chain(s) to reduce the power consumption in the transmission part of sensors devices by minimizing the radio power coverage. This idea is successful because of its objective to keep the unnecessary power consumption for a wide area. While nodes need to connect and transmit their data to the closest node only. Then, chain head(s) collect data from all chain members using a multi-hop method to delivers data to the base station with a single-hop method. Mamun in Refs. [14] did comprehensive comparisons between deferent logical

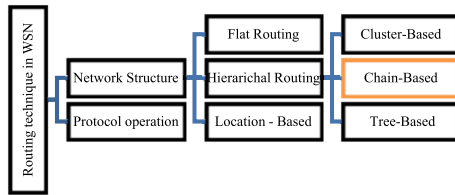


Fig. 1. Routing technique in WSN.

topologies in WSNs. Cluster-based, tree-based, flat and chain-based topologies use common performance metrics such as energy dissipation and balancing, network lifetime, resource expends per message delivery and others. This study shows that chain-based topology outperforms other topology in terms of total energy consumption, energy distribution, load distribution, network lifetime, and topology management overhead.

Based on the fact that “energy is the main consideration in analysing routing protocols in WSNs” [18], chain-based routing protocols are considered to be more promising than other routing protocols approach due to its primary ability and feature in power saving and extending network lifetime [13,19].

3. Chain based routing protocols for deterministic node deployment

The chain-based protocols are considered as the best among all other techniques in WSNs [20,21] and the deterministic nodes deployment can decrease the node redundancy, minimize the overall network cost, extend the lifetime of networks, decrease the difficulty of data fusing and make the network topology more controllable [22–24].

So, several protocols use the chain-based approach with unifying node deployment in WSN. This approach achieves efficient energy consumption and extends the network lifetime such as Deterministic Chain-Based Routing Protocol (DCBRP) [20] and Chain-Cluster based Mixed (CCM) [25].

4. Chain-Cluster based mixed routing protocol

CCM routing protocol builds the horizontal chain in each row by connecting every node with its neighbour only to save energy consumption by transmitting distance. Each row will select a chain head node by sequence way to forwarding the data of these row's nodes data to the main node directly, which is selected by the maximum energy factor.

5. Direct Line Routing Protocol

Routing protocols in WSN contents number of phases helps to explain all steps of protocol behavior. Each phase performs a specific task respectively which is considered a part of the routing protocol. Fig. 2 explain the main steps in DLRP sequences.

5.1. Intra connection method

Direct Line Routing Protocol has one method to connect all nodes which is the same for all lines also, each node of DLRP connects with the next node directly until reaching the BS. This method makes all nodes saving its energy as long as possible because of the little constant distance between the nodes which is 10 m in this scenario and this is a very important factor for all routing protocols in the wireless sensor network.

5.2. Interconnection method

Chain heads connection with the BS is a very hot topic for all researchers because of its direct relation with delay and power consumption metrics in the WSN areas. DLRP has an advantage in this phase, the cluster base method is the direct connection with the base station for each chain head so, this method makes this protocol delivering all packets without any delay. Therefore, DLRP should have the same number for lines of nodes and interconnections with the BS. Fig. 3 shows the first and second phases in DLRP routing protocols.

5.3. Chain head selection

There are a lot of methods of chain head selection and each one has advantages and disadvantages,

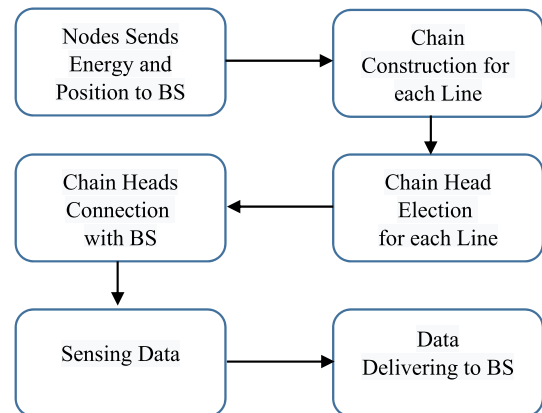


Fig. 2. The main steps in DLRP.

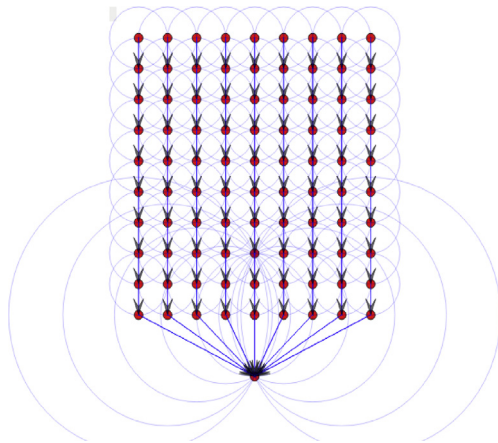


Fig. 3. Phases in DLRP as shows in the first round (FR).

DCBRP routing protocol has a powerful algorithm for this phase, therefore DLRP adopts the same algorithm to ensure the fair distribution of chain heads load for all nodes. CHS mechanism uses Equation (1) Which is adopt from in Ref. [20] to select one chain head for each line. The result of this equation will perform for all nodes and calculate the minimum value to select its node as CH for this line. This CH plays an important task by delivering all nodes in the same line packets to the base station.

$$CHSfactor = \frac{Eelec * k + Eamp * k * d2}{Einitial - \sum_0^{current\ round} Econsum} \quad (1)$$

6. Performance evaluations of DLRP

Network Simulator 3 (ns-3) used to implement and evaluate DLRP routing protocol as a result of its reliability and used by many researchers [26,27]. ns-3 simulator used by many researchers in the WSN area based on its powerful, adaptive and scalability. Evaluation of DLRP achieved by comparing with closest routing protocols in WSN which are DCBRP and CCM because of their characteristics in deterministic deployment for sensor nodes. Table 1 explains the experimental parameters which are commonly used to evaluate the protocols as applied in many protocols such as [28]. There are four performance metrics used in this evaluation depending on the main goal of the DLRP routing protocol.

6.1. Average end-to-end delay

The main goal of this research to develop delay aware routing protocol for WSN so, the end to end

Table 1
Experimental parameters.

Parameters	Value
Area	100*100 m
Number of nodes	90
BS Location	(50,120)
Initial Energy	2.0 J
Packet's length	2 Kbit
Deployment Method	Deterministic
Distance between nodes	10 m
EC model	First Order Radio Model
Send/Receive Energy spending	50nJ/bit
Routing Protocol	DLRP; CCM; DCBRP
Mac	802.15.11

delay considers important metric for all routing protocols. Moreover, the delay can evaluate the performance of any routing protocol in this area. Equation (2) determines the average end to end delay until the first node dies.

$$Avg. End\ to\ End\ Delay = \frac{\sum_{n=1}^{n=FND} Packets\ Delay}{FND} \quad (2)$$

The above Equation calculates the packets delivering delay for source to destination (BS). Each node has different position therefore variant value will have obtained for different nodes in particular round. In addition, the average value gives a clear performance evaluation for any routing protocol in WSN.

Fig. 4 illustrates the end to end delay for DLRP, DCBRP, and CCM routing protocols, as shown in this figure, DLRP has reliable mechanisms to get better result in delay metric. DLRP has number of CHs equal to the number of lines while, DCBRP has on CHs for every three lines of nodes, also CCM has one CHs but

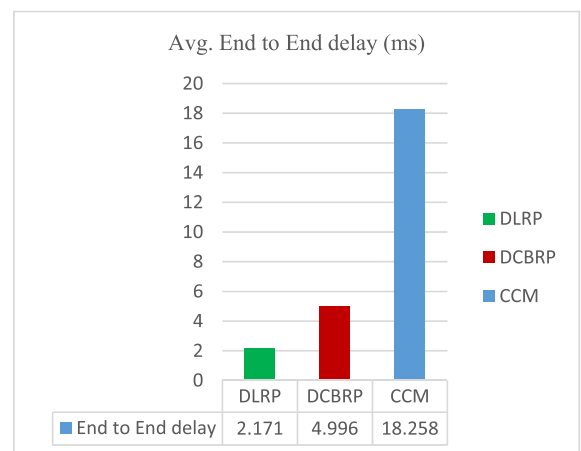


Fig. 4. End to End delay for DLRP, DCBRP and CCM.

for all sensing nodes. As the result, DLRP outperforms DCBRP and CCM on the average end to end delay.

6.2. Average power consumption

This metric measures the power consumption by all nodes in the sensing area to delivering data to the BS. As all nodes have limitations in energy (normally is battery) so, the efficient routing protocols will reduce the power consumption and prolong the network lifetime. Equation (3) calculates the average power consumption to delivering all packets in rounds until FND.

$$Avg. Po. Consu. = \frac{\sum_{n=1}^{n=FND} All\ Nodes\ Po. Cons.}{FND} \quad (3)$$

Fig. 5 shows that DLRP outperforms DCBRP protocol in the power consumption metric because each CHs DCBRP's responsible for delivering all cluster packets which are equal to a number of line's node multiply by three. CCM has an advantage by using one CH only but this highly effects the delay metric as clearly appeared in Fig. 4.

6.3. Average CHs power consumption

Chain Heads Selection has played an important role to save the energy of all nodes in the network based on its energy, position, and reliability to delivering node's packets to BS. DLRP and DCBRP have the same CHs selection mechanism but a deferent number of nodes in the specific cluster so, this deference gives DLRP advantage in the CHs energy consumption. While CCM has one CH for all nodes in the network

therefore, CCM's CH spends a lot of its energy quickly to play as a unique gateway in the network. Equation (4) calculates the average CHs power consumption until FND to show the routing protocol's efficiency based on the results.

$$Avg. CHs Po. Cons. = \frac{\sum_{n=1}^{n=FND} CHs\ Po. Cons.}{FND} \quad (4)$$

Fig. 6 Explains that DLRP outperforms DCBRP and CCM routing protocols in the CHs energy consumption. Results show DLRP spends 0.02130 mj as average CH's power consumption while DCBRP and CCM spend 0.03893 and 0.16646 mj respectively until FND in the same deterministic node deployment.

6.4. Delay * Energy metric

Delay * Energy metric suggested and used the first time by Lindsey [29] to the chain based protocols researchers in the wireless sensor networks. Delay is the main side effect of chain base routing protocols while, the energy is important benefits of this type of protocol so, this metric combines the effects of energy and delay. Delay * Energy calculated by Equation (5).

$$Del. * Ene. = Avg. End\ to\ End\ De. * Avg. Po. Cons. \quad (5)$$

Fig. 7 shows the Delay * Energy metric for DLRP, DCBRP and CCM routing protocols, this fair comparison is very important for all routing protocols evaluation in deferent nodes deployments methods. DLRP has an advantage in the delay metric based on it intraconnection method (every line consider build one

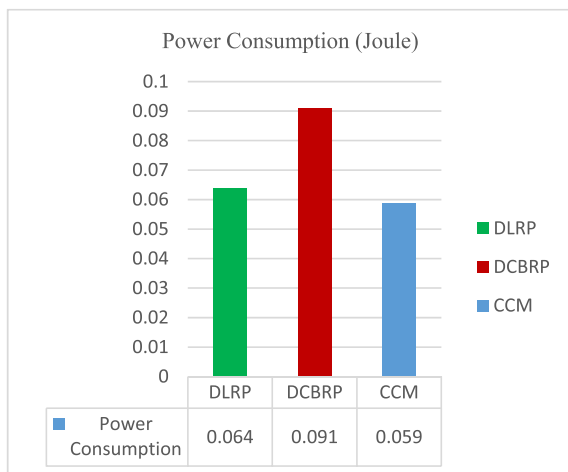


Fig. 5. Power consumption for DLRP, DCBRP and CCM

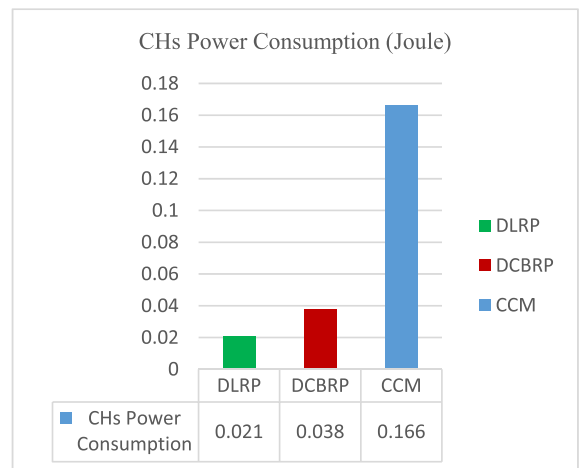


Fig. 6. Av. CHs Po. Cons. for DLRP, DCBRP and CCM

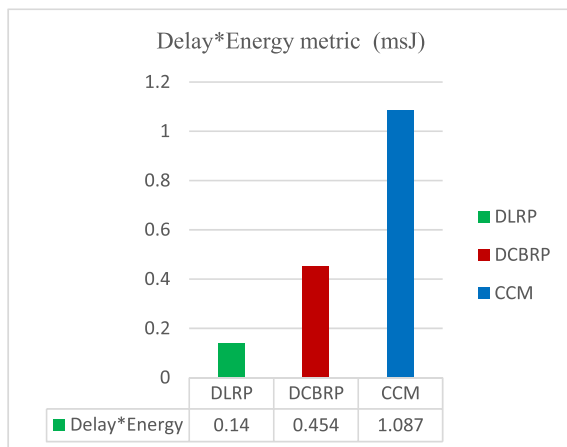


Fig. 7. Delay * Energy metric for DLRP, DCBRP and CCM.

chain only) so, it is outperforming other protocol. DCBRP has a better result than CCM because of its behavior for the number of CHs in the networks.

7. Conclusion

Chain based routing protocols are promising in the WSN however, the delay is considering the main problem for data delivery and redundancy. In this research, DLRP routing protocol is proposed, and it is successfully reducing the delay and power consumption for CHs nodes during reducing the number of nodes in the same chain (line). Delay * Energy metric can be breaking the trade-off between energy and delay performance in the chain base routing protocol so, DLRP has good performance than DCBRP and CCM in this metrics. As a future research work, DLRP can be applied and tested with heterogeneous nodes, deferent environments and nodes deployments method (random deployments).

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