European Journal of Applied Sciences 9 (3): 118-123, 2017
ISSN 2079-2077

DOI: 10.5829/idosi.ejas.2017.118.123

Hierarchical Routing Protocol for Data Broadcasting in Wireless Sensor Network

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Abstract: In Wireless Sensor Network (WSN) energy efficiency is the main issue. Because the nodes near the mobile sink are reduce faster than the other nodes. The reason is all the requests are transferred towards the same node near to the mobile sink. To overcome this problem there are many approaches are already established which aims to decrease the overload of advertising the sink's position to the network by implementing a virtual hierarchy of nodes which imposes different dynamic roles on the sensor nodes. To enhance the efficient way of routing to exhaust the energy used by WSN nodes, introducing Ring Routing is a hierarchical mobile sink routing protocol based on a virtual ring structure which is designed to be easily accessible and easily reconfigurable. In this first ring structure is constructed based on the location of the sink. The results show that Ring Routing is an energy-efficient protocol which extends the network lifetime.

Key words: Wireless Sensor Network · Mobile sink · Energy efficiency · Routing protocol

INTRODUCTION

In Wireless Sensor Network there are many approaches to the problem of routing in WSNs with mobile sinks. The most important and the most widely adopted one being are the hierarchical routing [1] protocols. In a typical wireless sensor network, the energy of the nodes near to the sink reduces faster than the other nodes due to the data transmission using the same path to the sink. In wireless sensor networks (WSNs), energy efficiency [2] is considered to be a crucial issue due to the limited battery capacity of the sensor nodes. This problem generally affects the trustworthy nodes in the network. It may also deplete the whole wireless sensor network within a short time. Hence this is important to overcome the energy drain of battery reduction.

To overcome the Wireless Sensor Network problem many approaches are already established. This may include the routing protocols [3] like flat routing and hierarchical routing. Flat routing protocol is only useful for small scale systems but not for large scale systems. Flat routing protocols include Sensor Protocol for Information via Navigation(SPIN), Directed Diffusion, Rumor routing, Minimum Cost Forwarding Algorithm(MCFA), Gradient-Based Routing, etc. Hierarchical routing protocols include Low Energy Adaptive Clustering Hierarchy (LEACH), Threshold-sensitive Energy-efficient protocols (TEEN), Small Minimum Energy Communication Network (MECN), Sensors Aggregates Routing, etc.

In this paper we focus on the hierarchy routing protocol. The main reason is that the hierarchical routing is used in large scale systems. Hierarchical routing protocol structure includes rectangular, cluster, quad tree, line, rail and ring. These structures are having different kind of protocols and benefits [4].

System Model: In this section we consider the existing system design and the proposed system.

Existing System: The existing design approaches are Sink Trail, Line Based Data Dissemination(LBDD), Two-Tier Data Dissemination (TTDD), Grid-Based Energy-Efficient Routing (GBEER).

Sink Trail: Sink Trail establishes a logical coordinate system for routing and forwarding data packets, making it suitable for diverse application scenarios. This technique aim to decrease the load of advertising the sink's position to the network by establishing a virtual hierarchy of nodes which imposes different dynamic roles on the sensor nodes.

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Line Based Data Dissemination (LBDD): It defines a vertical strip of nodes horizontally centered on the area of development. The nodes on this strip are referred to as in-line nodes. Sensor data are sent to the line and then the first in-line node encountered stores the data. The nodes can access the line by straight forward mechanism [5].

Two-Tier Data Dissemination (TTDD): It is a virtual grid based approach where each source node with sensor data proactively constructs a rectangular grid around itself and becomes a crossing point of this grid. Whenever sinks require data, they query the network by local flooding within a grid cell and these queries are relayed to the source node. Data is then forwarded to the sink using the reverse of the path taken by the data request [6].

Grid-Based Energy-efficient Routing (GBEER): Data announcements are propagated horizontally along the shared grid while data requests are propagated vertically, ensuring that these packets intersect at a crossing point. The position of the sink is then delivered to the source node and data is delivered directly to the sink. Grid-based protocols are advantageous for the easy accessibility of the grid structure [7].

Problem Identified:

- TTDD suffers from the high overhead of constructing a separate grid for each source node especially in applications where numerous sensor nodes generate data.
- GBEER eliminates the high overhead of constructing separate grids for each source, the nodes residing on the grid are likely to become hotspots and deplete their energy quicker than other nodes.
- GBEER requires more cost for implementing the mobile sink.

Proposed System: Ring Routing is a hierarchical routing protocol for large scale WSNs organized outside with static sensor nodes and a mobile sink. Ring Routing protocol first construct a virtual ring structure that allows the fresh sink position to be easily delivered to the ring and sink nodes to obtain the sink position from the ring with minimal overhead whenever needed[8].

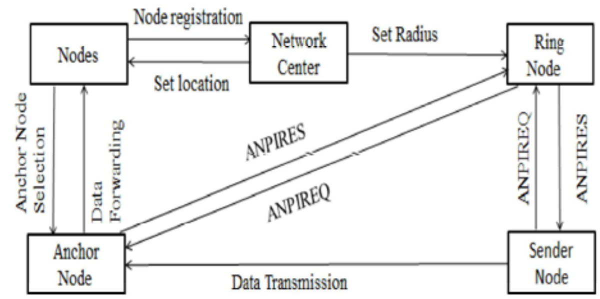

Fig. 1: Ring Routing System Design

The ring structure can be easily changed. The ring nodes are able to change roles with regular nodes by a direct and well-organized mechanism, thus modifying the hotspot difficult.

Benefits:

- Dynamic changing of ring structure will provide the efficient accuracy.
- Moderate cost for implementing mobile sink.
- Most secure and efficient communication.

Design Construction: This Section consists of the following module design to form the ring routing protocol. These are to be explained in this section [9].

Ring Configuration: Ring Configuration is dependent on the location information of the nodes, which is known to contain some incorrectness based on the developed technology. Monte-Carlo analysis to determine the successful ring construction likelihood under varying degrees of localization error. Network Center set the Radius for forming the closed loop containing several nodes. These nodes are called “Ring Nodes”.

Ring nodes are selected based on the distance of the node from the network authority. Monte-Carlo analysis is used for successful ring construction.

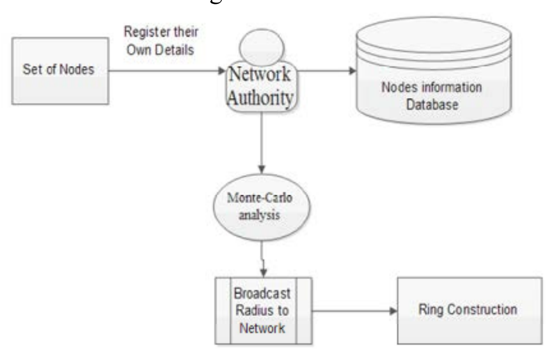

Fig. 2: Ring Configuration

Mobile Sink Position: Initially, the sink selects the contiguous node as it's AN and advertises an AN Selection (ANS) packet. Before the sink leaves the consultation range of the AN, it selects a new AN and informs the old AN of the position. Since now the old AN knows about the new AN, it can relay any data which is designed for it to the new AN.

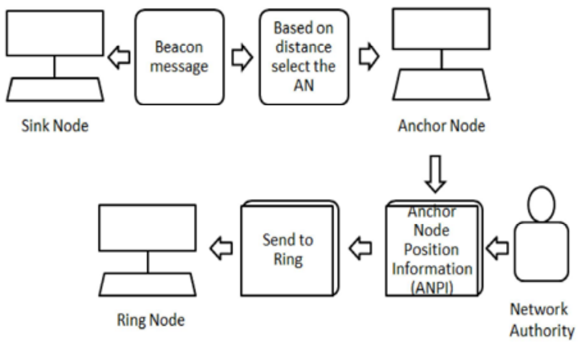

Fig. 3: Mobile Sink Position

The current AN relays data packets directly to the sink. After a ring node receives an ANPI packet, it shares this information by sending an AN Position Information Share (ANPIS) packet to its clockwise and counter-clockwise ring neighbors.

Each ring node receiving an ANPIS packet relays it to the neighbor ring node in the respective direction until the two ANPIS packets sent in the clockwise and counterclockwise directions arrive at the same ring node [10].

Anchor Node Position Information: Upon selection of a new AN, it sends an AN Position Information (ANPI) packet in the direction of the ring. If the AN is exterior to the ring, it sends the ANPI packet to the network center and if it is internal to the ring, it sends it data towards a point which be inherent in the opposite direction of the network center. The source node sends an AN Position Information Request (ANPIREQ) packet in the direction of the ring. The ring node receiving the ANPIREQ packet generates an AN Position Information Response (ANPIRESP) packet which include the current AN's position and sends the data to the source node.

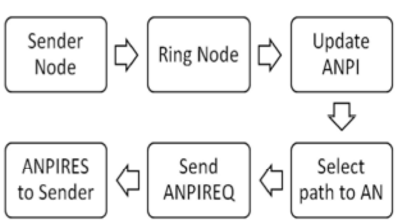

Fig. 4: Anchor Node Position Information

Data Transformation: In this module source node receives the response from the ANPIREQ. If the source node get the response from the anchor node it knows the position of the AN and can now send its message directly to it by geographic forwarding. If data reaches an old AN, that means that the AN has already changed by the time data has arrived at the destined AN, the follow-up mechanism is used to transmit data to the current AN [11].

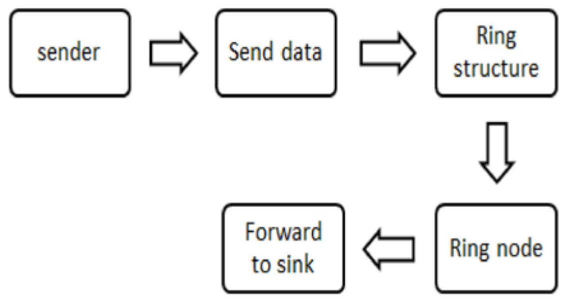

Fig. 5: Data Transformation

Performance Evaluation: Ring Routing has the best performance in all cases. LBDD performs better than Railroad for sink speed. LBDD's average energy consumption tends to increase monotonically. LBDD employs broadcasts along the line structure to share AN position information, thus increased rate of AN changes caused by increased sink speed leads to increased number of broadcast and thus elevated energy consumptions. Railroad limits the number of broadcasts along the rail by constructing localized stations in which the broadcasts are confined. The AN position information is shared by unicasts along the rail until a station constructed by broadcasts is reached. Therefore, Railroad performs better than LBDD for faster sink speed values.

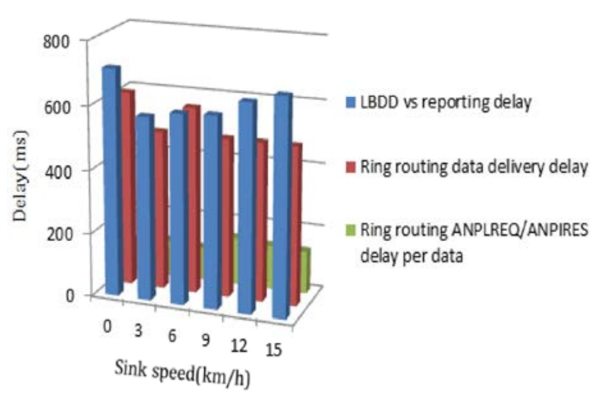

Chart 1: Delay breakdown of Ring Routing data delivery compared to LBDD.

In order to investigate the delay cost of the ANPI request/response mechanism employed by Ring Routing, we provide the delay breakdown of the data delivery process in Chart-1. The total delay for data deliveries are broken down into two components. The ANPI request/response delay per data component is the time until a response to the ANPI request is received by a source node. The second component is the actual data dissemination delay of the path from the source to the sink. The two components of Ring Routing's data delivery delays are compared with LBDD's average reporting delays. The delay cost of the request/ response mechanism is apparent. The actual data dissemination delays of Ring Routing are lower than LBDD's reporting delays [12].

Even though, discarding the request/response mechanism of Ring Routing and employing a direct data sending approach similar to LBDD would enhance the delay performance of Ring Routing, the energy advantages of the request/response mechanism outweighs such a delay reduction benefit.

Since the delay values of Ring Routing close to LBDD's and they are in reasonable limits to support time-sensitive applications, the energy consumption performance is favored [13].

Even though the average energy consumption metric provides an insight to the projected longevity of the WSN operation, the lifetime metric is the clearer indicator. We initially define the lifetime of a WSN to be the time until the first node in the network dies [14].

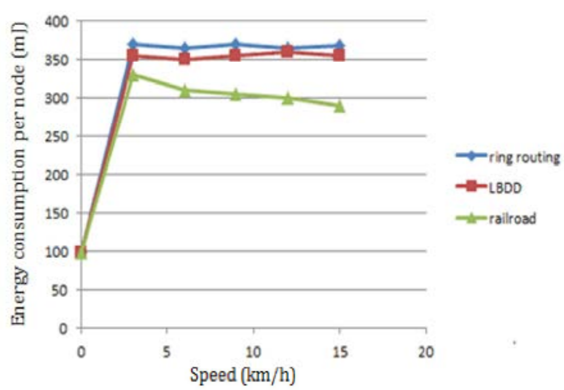

Chart 2: Energy consumption

Chart-2 shows the lifetimes of Ring Routing, LBDD and Railroad for varying sink speed values. LBDD, as expected, has the worst lifetime performance among the three protocols due to the decreased degree of the energy consumption uniformity caused by all the data traffic being handled by the line nodes. The lifetimes of Railroad are close to but slightly worse than Ring Routing. Railroad employs a request/response mechanism similar to Ring Routing; however, broadcasts along the second-tier structure are not entirely avoided, thus enabling Ring Routing to stand out in terms of the network lifetimes. The static sink case is also provided to show the huge advantage of mobile sinks in terms of lifetime elongation. The definition used for the network lifetime is reasonable but not enough to accurately assess the longevity of the WSN operation. The death of the first node might disrupt the topology and cause disconnectedness of some portions of the network, depending on the criticality of the dying node's position. However, these problems are implicitly mitigated by the usage of a mobile sink, since the sink is expected to eventually visit the disconnected areas in the network, thus providing stronger reliability and data delivery performance [15].

In Chart-3, the distribution of the node death times until 25 percent (50 nodes) of the 200 node network dies is provided. The death of 25 percent of the network, which is a significant portion, hinders the WSN operation greatly, in terms of both the imminent topological disruptions and the decrease of the sensor field's coverage.

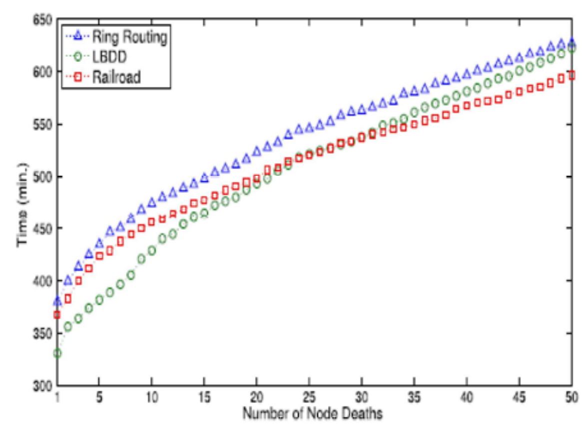

Chart 3: Death times

The constant sink speed value of 3 km/h is used for this set of simulations since the lifetime performances of the three protocols are observed to be the closest in the 3 km/h sink mobility case. Fig.3 emphasizes the strength of Ring Routing's lifetime performance. The deaths of the first 50 nodes in Ring Routing occur later than LBDD and Railroad on average. Moreover, for Railroad, the nodes die quicker than Ring Routing even though the first node death times are similar. LBDD's first node death times are much lower than Ring Routing and Railroad; however, the first 50 nodes death times distribution shows that LBDD's rate of node deaths decrease as more nodes die. LBDD performs better than Railroad after the death of _12 percent of the network, due to the later node death times beyond this instance. LBDD nearly catches up with Ring Routing as the 25 percent of the network dies; however, evaluating beyond this value is irrational since the successful operation of the WSN is very likely to be already interrupted. The sink speed is not the only parameter affecting the WSN performance. The network size in terms of the number of deployed sensor nodes also affects the WSN performance significantly since the density of the network and the total traffic loads depend on the network size [16].

CONCLUSION

Ring Routing relies on minimal amount of broadcasts. Therefore, it is applicable to be used for sensors utilizing asynchronous low-power MAC protocols designed for WSNs. Ring Routing does not have any MAC layer requirements except the support for broadcasts. It can operate with any energy-aware, duty cycling MAC protocol (synchronized or asynchronized). Ring Routing is suitable for both event-driven and periodic data reporting applications. It is not query based so that data are disseminated reliably as they are generated. Ring Routing provides fast data delivery due to the quick accessibility of the proposed ring structure, which allows the protocol to be used for time sensitive applications. No information about the motion of the sink is required for Ring Routing to operate. It does not rely on predicting the sink's trajectory and is suitable for the random sink mobility scenarios. Hence this is the optimal solution for avoiding the sink node energy depletion attack.

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