Journal of Korea Multimedia Society Vol. 22, No. 6, June 2019(pp. 676-683)
https://doi.org/10.9717/kmms.2019.22.6.676

Multiple Sink Nodes to Improve Performance in WSN

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ABSTRACT

Wireless Sensor Networks (WSNs) consist of multiple tiny and power constrained sensors which use radio frequencies to carry out sensing in a designated sensor area. To effectively design and implement reliable WSN, it is critical to consider models, protocols, and algorithms that can optimize energy consumption of all the sensor nodes with optimal amount of packet delivery. It has been observed that deploying a single sink node comes with numerous challenges especially in a situation with high node density and congestion. Sensor nodes close to a single sink node receive more transmission traffic load compared to other sensors, thus causing quick depletion of energy which finally leads to an energy hole and sink hole problems. In this paper, we proposed the use of multiple energy efficient sink nodes with brute force technique under optimized parameters to improve on the number of packets delivered within a given time. Simulation results not only depict that, deploying N sink nodes in a sensor area has a maximum limit to offer a justifiable improvement in terms of packet delivery ratio but also offers a reduction in End to End delay and reliability in case of failure of a single sink node, and an improvement in the network lifetime rather than deploying a single static sink node.

Key words: Wireless Sensor Network (WSN), Sink Nodes, Cluster Head (CH), LEACH Protocol

1. INTRODUCTION

Wireless sensor networks (WSNs) consists of hundreds and thousands of wireless sensors which are either randomly or deterministically deployed in a target area (commonly harsh environment) for surveillance, monitoring and controlling [1]. Sensor nodes are resource constrained in terms of energy, processor, memory, low range communication and bandwidth [2]. Wireless sensor nodes collect data in an application field periodically or continuously and forward it to the base station (BS). Some sensor nodes, namely cluster heads, might have the ability to also process, aggregate data and forward it to the base station [3]. All sensor nodes need not to transfer at an identical time and they may transfer solitary with neighboring nodes and in so going various approaches have been proposed to enhance the network lifetime and packet delivery. Cluster based design of WSNs is a widely used technique to preserve sensor node energy and enhance network lifetime. Each cluster consists of a set of sensor nodes and has a representative node that is known as cluster head (CH). A CH aggregates data from it's member nodes (i.e Intra-cluster communication) and can cooperate with other CHs to report the data to the BS(i.e inter cluster communication) [4, 5, 6]. In previous works, many researchers have improved single sink node scheme and multi sink schemes to enhance whole

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Receipt date : Apr. 1, 2019, Revision date : May 13, 2019
Approval date : May 14, 2019

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※ This work was supported by research fund of Chungnam National University

network lifetime in terms of energy hole, low delay in packet delivery and reduced packet loss. But there has not been consideration upon multiple base stations environment. As a first step, this paper compared the performance of throughput of packet transmission in single sink environment with multi sink environment. NS2 simulation shows that multi sink scheme is better than single sink scheme even upon the possibility of heavy energy consumption of multiple sink nodes.

In this paper we have addressed the concept of deploying of multi-sink nodes with brute force technique under optimized parameter in a monitored field with N sensors, this approach ponders the optimal deployment of N sink nodes, parameter optimization and location positions for the sink nodes in a WSN. We also analyzed the effect of adding new sink nodes by use of brute force technique, thus evaluating and substantiating the performance of the design idea in terms of Packet delivery ratio, packet delay and PDR as a function of the number of base stations.

The rest of this paper is organized as follows: Section II presents the related work and protocols deployed, section III consists of the proposed methods and simulation environment, section IV shows the simulation results and analysis. finally, in section V we have the conclusion and future work.

2. LEACH AND DSDV PROTOCOL OVERVIEW

2.1 LEACH protocol and Architecture

In [6, 16], the authors proposed Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. It is one of the most popular hierarchical routing algorithms for sensor networks. It employs localized control for data transfers; Randomized, Adaptive and Self-organizing techniques for cluster formation and cluster head selection. The algorithm saves energy since the transmissions are only done by cluster heads rather than all sensor nodes. An optimal number of cluster heads is estimated to be 5% of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \bullet (r \bmod 1/p)}, & \text{if } n \in G \\ 0 & , \mathit{otherwise} \end{cases} \quad (1)$$

Where p represents the desired percentage of cluster heads (e.g. 0.05), r denotes the current round and G is the set of nodes that have not been cluster heads in the last 1/p rounds. Each node should support both TDMA (Time Division Multiple Access) and CDMA (Carrier Sense Multiple Access). However, failure of cluster head is a problem to the entire network and cluster head selection is a difficult problem to optimize.

This protocol basically chooses cluster heads based on random probability and sensor nodes make autonomous decision for dynamic cluster formation. Clustering in WSN is defined as the process of dividing the nodes of the WSN in to groups, where each group agrees on a central node, referred to as cluster head (CH), with the primary role of gathering and aggregating sensed data of the group members, and sending them to BS. CH also coordinates the communication among the cluster members as shown in fig 1 [1, 8].

The operation of LEACH is divided into rounds, each round begins with a set-up phase and followed by a steady-state phase where several frames of data are transferred from the nodes to the cluster head and on the BS [7].

2.2 Single sink node WSN

In single sink node deployment in WSN, the nodes need to send the data through multi-hop. The

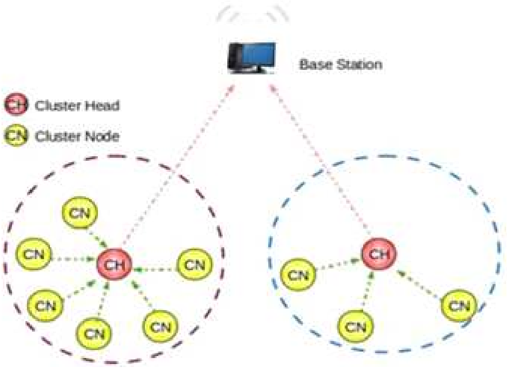

Fig. 1. Cluster-based architecture of LEACH Protocol in WSN.

nodes close to the sink node forward the total traffic to the sink node. Hence, they exhaust their energy faster and energy-holes are formed near the sink node, which reduces the lifetime of the network. In addition, with a large WSN, it becomes quite inefficient in terms of power consumption while gathering all information in a single sink [19].

A single sink node can be categorized into: static sink node and mobile sink node. A static sink node is positioned in a particular area either within the sensor area or out side a sensor area for data collection from the sensors and a mobile sink node travels in a sensor area randomly with a purpose of also collecting sensor data. Studies show that the data collection based on the mobile sink node is better than the data collection by using static sink node. Deploying a mobile sink node is similar to using several static sinks. However using several static sinks requires additional global communication for collecting all data at single final point. A mobile sink can follow different types of mobility patterns in the sensor field, such as a random mobility, predictable, fixed path mobility or controlled mobility [19, 20].

2.3 Multiple sink nodes WSN

Multiple sinks are placed in the network with each being used to gather sensed data of the sensors in a limited number of hops, which results in decreasing the relay workload in intermediate nodes, and lowering the latency. The smaller the hop-count is, the lesser energy is consumed and the longer the network lifetime [18, 19].

Energy is the most critical resource in the life of a wireless sensor node. Therefore, its usage must be optimized to maximize the network life. Besides using power adjustable transmitter circuitry, usage of multi-hop communication links should be considered to save energy. Moreover, in large-scale networks with a large number of sensor nodes, multiple sink nodes should be deployed, not only to increase the manageability of the network and congestion control in terms of (node level congestion and link level congestion) but also to reduce the energy dissipation at each node [10, 11].

Furthermore, multiple sinks in a sensor area decreases the probability of isolated clusters of nodes that cannot deliver their data owing to unfortunate signal propagation condition. And multi sink WSN can be more scalable [12, 13].

According to [16], the authors pointed out that the amount and exact locations of the sink nodes directly affects the lifetime of the sensor network. Therefore, they recommended that for economically feasible investment, the designer should focus on correct placement of the sink nodes.

However, the existing algorithms downplay some important issues in multiple sink nodes such as; minimum number of sink nodes, location information for each sensors, congestion control mechanisms and delay factor. Therefore, in the proposed algorithm these challenges were investigated leading to profound results.

2.4 DSDV (Destination Sequence Distance Vector)

As for routing protocol, we applied DSDV for effective routing and forwarding of data packets. This is a proactive and table-driven routing scheme for ad-hoc mobile networks based on the Bellman-Ford to calculate paths [9].

In this protocol each node maintains a routing table. Thus, the routing information must be periodically updated. The cost metric used is hop count, which is the number of hops it takes for the packet to reach its destination. Therefore, the changes are propagated through periodic and trigger update mechanisms used by DSDV. Due to these updates, there is a chance of having routing loops within the network. To eliminate routing loops, each update from the node is tagged with a sequence number. The sequence number from each node is independently chosen but it must be incremented each time a periodic update is made by a node. The sequence number of normal update must be an even number, each time a periodic update is made, the node increments its sequence number by 2 and adds its update to the routing message it transmits. The node cannot change the sequence number of other nodes [14].

In addition, the DSDV protocol guarantees loop-free path to each destination, operation of DSDV algorithm ensures that at every instant G(x) is loop-free, rather, it is a set of disjoint directed trees. Each such tree is rooted either at x or at a node whose next-hop is nil. Since this property holds with respect to each destination x, all paths induced by routing tables of DSDV algorithm are indeed loop free at all instants [15].

3. THE PROPOSED METHOD

3.1 Multi-sink nodes with brute force technique under optimized parameters

The proposed algorithm deploys the concept of multi-sink nodes with existing models under specific parameters; with reduced range for clusters (20 meters), lowest possible CH probability (0.05), variable size of data packets, minimum communication energy, Receive Signal Strength (RSS) dynamic range of the advertisement from each CH (-50 to - 60 dBm) and also used an efficient MAC (Media Access Control) flow control, congestion control and also offer a high one hop reliability of the network to ensure retransmission.

In the simulation, we used the brute force technique for determining the exact number of sink nodes suitable for a particular network setup thereby deployment started with a single sink node located at the center of the monitored area. We carried out evaluations at every increment of the sink node in a bid to establish the maximum number of deployable and placement locations of sink nodes in a specific monitored area.

Brute force is a technique that verifies all possible candidates for solution of a problem to check whether each candidate can be a solution or not [21]. Our multi-sink nodes with brute force approach is to find out an multiple sink node location set Λ, through iterating all possible candidate locations denoted by a finite set $Loc = \{loc_1, loc_2, \ldots, loc_n\}$ in a sensor field. First, we generate one candidate location $loc_1(x_1, y_1)$ among 2-dimensional axis values in a sensor field and add it to the set Λ which is initially empty. Then we take the second candidate $loc_2(x_{1+dx}, y_{1+dy})$ and add it to the set Λ until the number of elements in the set Λ reaches to the number of sink nodes to select, namely n_{goal}. As the number of elements in the set Λ reaches to n_{goal}, new candidate loc_j is replaced with the worst location loc_k in the set Λ only when the performance of loc_j yields better performance of existing element loc_k. In this way, whole candidate locations are examined to make optimal sink node location set. Here, dx, dy and n_{goal} are variable parameters to run and they decide the granularity of the brute force technique. This algorithm is described again in fig 2.

With due diligence, we observed the impact of the proposed algorithm with respect to; the maximum number of sink nodes that can be deployable, packet delivery, delay factor as a function of the respective number of nodes in the monitored area and packet delivery ratio as a function of the number of base stations. Therefore, the proposed algorithm registered a tremendous improvement as

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Select $loc_1(x_1, y_1)$ and add to $\Lambda$;
for all the candidate $loc$ in the sensor field
    Select $loc_j(x_{(j-1)+dx}, y_{(j-1)+dy})$;
    if (the number of elements in $\Lambda < n_{goal}$ )
        add $loc_j$ to $\Lambda$;
    else
        if ($loc_j$ is better than the worst element $loc_k$
           in $\Lambda$)
           replace $loc_k$ with $loc_j$ in $\Lambda$;
end for
```

Fig. 2. Brute force multi-sink node selection algorithm.

compared to existing algorithms in terms of performance.

3.2 Simulation Environment

We used NS2 as a network simulator with a deployment of 56 sensors in random way and sink nodes in a deterministic manner in a sensor field of 100 × 100 square meters and other parameters as shown in table 1.

We compared two different scenarios: The first one was to use a single sink located at the center of the sensor field as shown in fig 3 and the other was use of multiple sink nodes in exactly the same simulation environment as shown in fig 4. In this simulation the researchers simulated a model to best describe the actual system with less abstraction. Among the software requirements we deployed Ubuntu 16.04, TCL (Tool Command Language), Network Simulator Version 2, NAM (Animation), Xgraph (plotting) and the hardware requirements included System: Core i7- Processor 3.4GHz, Hard drive: 1TB, RAM: 8GB.

We analyzed the effect of randomly adding sinks into a sensor field, this comes with challenges of establishing the best sink location and also identifying an effective clustering of the sensor nodes for optimal performance. Therefore by knowing the

Table 1. Simulation Parameters

No	Parameter	Value
1	Deployment field (M)	100 × 100
2	Data packet size (Bytes)	50
3	Number of nodes	56
4	Sink positions (X, Y)	Sink 1(-12.695, 296.741) Sink 2 (67.5875, 235.265) Sink 3(-19.9441, 334.262) Sink 4(89.5302, 334.262)
5	Initial Energy(J)	2
6	Routing Protocol	DSDV
7	Sensor Deployment	Random
8	Simulation Time (S)	40
9	Antenna	Omni Directional
10	Transmission Energy (J)	0.001
11	Receiving Energy(J)	0.0005
12	Idle Power(J)	0.5
13	Mac Type	802.11 (Wireless)

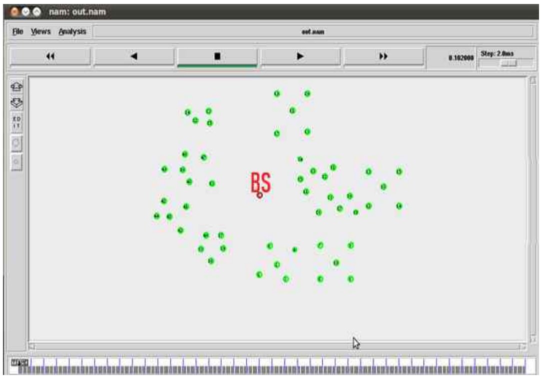

Fig. 3. Sensor field with single base station at the center used in simulation.

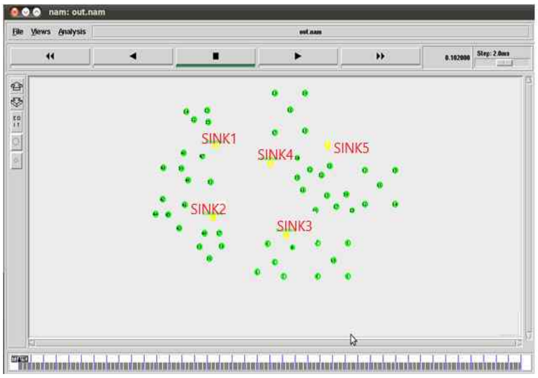

Fig. 4. Sensor field with multiple sinks used in simulation.

number of sink nodes to be deployed will represent the number of the cluster in the network. However the major problem with multiple static sinks is that one has to decide where to deploy them inside the monitored region so that the data relaying load can be balanced amongst the nodes.

4. SIMULATION RESULTS

4.1 Multiple sink deployment results

Simulation result with optimized ranges and number of cluster, lowest possible CH probability, short frames and minimum communication energy ratify that multiple sink nodes environment lightens congestion with quality of services. Thus offering a better performance than single sink environment as also indicated on the number of packets delivered by 16.7% as shown in fig 5.

Multiple sink nodes were used in data collection process from sensors and stored collected data on the base station (BS) in the database. In such a situation when one of the sink nodes fails, another sink node is available as a backup one. Contrary, a single sink node was also used to collect data in WSN by use of multi-hop, through forwarding and relaying of data. This leads to less packet delivery and more energy consumption among the nearby nodes around the BS, which finally leads to an energy hole problem.

The proposed algorithm also exhibited a decrease of 12.65% in terms of packet gathering delay(ms), where a single sink node is consequently suffering from a lot of delay in terms of packet delivery to the sink as a result of congestion, overhead and other factors whereas with the deployment of multiple sinks, there was a faster delivery of packets onto the respective sink nodes as shown in fig 6. In addition, it was also observed that there is a direct proportionality between the number of sensor nodes and delay that is to say, as the number of nodes increases in the sensor field, delay in packet delivery also increases simultaneously.

It was observed that as the number of Base stations increased in the monitored area the PDR also significantly increased by 15.76 % with the four base stations deployment as shown in fig 7. In ad-

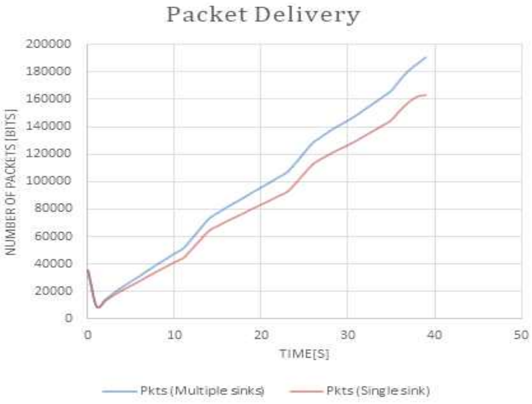

Fig. 5. Packet delivery ratio with single sink node and multi sink nodes.

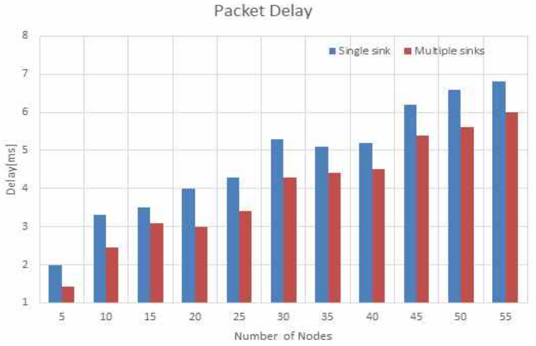

Fig. 6. Packet delivery delay(PDR) with single sink and multi sinks.

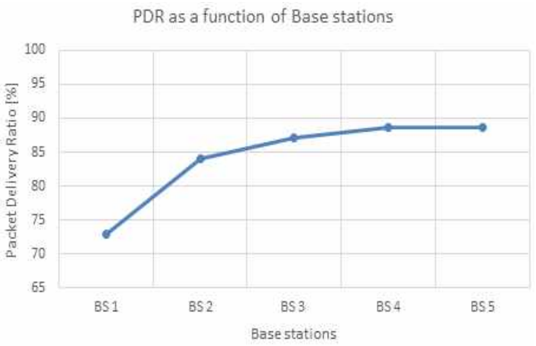

Fig. 7. Packet Delivery Ratio as a function of number of Base stations.

dition, we noticed that as the number of base stations increased, we ascertained an increase in the delivery of data packets and a reduction in congestion. However, as the number of base stations exceeded two, the PDR started to increase with a smaller magnitude.

5. CONCLUSION AND FUTURE WORK

Deploying multiple sink nodes with brute force technique under optimized parameters not only ascertains that in a monitored area with N sensors, there is always a limit at which the number of sink nodes seizes to offer a significant improvement in performance in terms of packet delivery ratio, but we also found substantial evidence to better performance on the number of packets delivery, reduction in terms of End to End delay, solution to the energy sink hole problem in WSN and congestion control as shown in the simulation results compared to that of a single sink node in WSN. On the future work, we plan to extend the multi sink scheme with multiple base stations in a large sensor field.

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