International Journal of Computer Applications (0975 - 8887)
Volume 153 - No.5, November 2016

Geographic Routing in Wireless Sensor Networks based on a Partitioned Architecture

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ABSTRACT

Multiple sinks routing is envisioned as a possible solution to the bottleneck research problem in Wireless Sensor Networks (WSN). In addition to focusing on minimizing the energy consumption in a WSN, it is also equally important to design routing protocols that fairly and evenly distribute the network traffic; in order to prolong the network life time and improve its scalability.

In this paper we present an enhancement to the GRPW algorithm for wireless sensor networks. Performance of GRPW algorithm algorithm depends heavily on single sink position , we propose a protocol called GRPW-MuS(Geographic Routing to Multiple Sinks in connected wireless sensor networks) based on Multiple Static Sinks, we modified the existing sink location privacy protection scheme by dividing nodes in the network containing multiple sink into different levels in which real packets are forwarded to sink belong to corresponding logical levels and the intermediate node generating fake packets and sending it to fake sinks. Using OMNET++ simulation and the MiXiM framework, it is shown that proposed protocol significantly improves the robustness and adapts to rapid topological changes with multiple mobile sinks, while efficiently reducing the communication overhead and the energy consumption.

General Terms

Wireless Sensor Network (WSN), Routing , Multiple Sinks

Keywords

Wireless Sensor Network (WSN), Routing, Multiple Sink, Localization, Geographic Routing

1. INTRODUCTION

The evolution of low-cost camera hardware extended the capability of wireless sensor networks (WSNs) to support multimedia adaptations for the typical WSN applications such as surveillance, target tracking, battlefield intelligence and environmental monitoring. Due to the challenge of carrying high volume data over resource limited wireless sensors, multimedia sensor networks has become an active research area. The state of the art and the major research challenges in architectures, algorithms, and protocols for wireless multimedia sensor networks are discussed in [21]. There are several products in terms of sensor platforms [14, 28], camcamera functionalities [21] and academic research prototypes [27]. The ongoing research on prototypes of multimedia sensors and their integration into testbeds for experimental evaluation of algorithms and protocols for multimedia sensor networks are described in [31]. Congestion is a challenging problem for WSNs, due to the intrinsic characteristics of high node density, convergecast communication pattern and multi-hop network topology. Moreover, the necessity of providing a high Quality of Service (QoS) requirement for video traffic imposes extra difficulties besides carrying such traffic over a limitedbandwidth, error-prone wireless channel by the sensors with limited energy budget.

A Wireless Sensors Network (WSN) contains a set of sensors which communicate to transmit information about specific detections. A wide range of monitoring applications have already been identified such as risk detection on industrial sites, protected and reserve areas , intelligent transportation , and underwater monitoring [9, 11, 6] . Designing a WSN involves two main levels of decisions: operational and strategic. In the context of WSN, the operational level is usually related to protocols, network issues, communication policies, and traffic loads and their distribution; while the strategic level addresses decisions able to better cope with some issues like minimizing the energy consumption, reducing the traffic, balancing the network load, enhancing the reliability, maximizing the network lifetime, for instance. In this study, we focus on a strategic and theoretical optimization problem occurring in the design of WSN.

Data to the sink can be transmitted via single hop or multi hop communication. All the sensor nodes can use single hop communication but in long distance transmission, the energy consumption is much higher in transmission as compare to processing and sensing tasks. Transmission energy dominates the overall energy used in communication process. The requirement of energy goes on increasing with the increase of distance [10, 15]. Therefore, it becomes necessary to reduce the energy consumption and to enhance the network lifetime. Therefore, it is preferable to use short-range multihop communication. In multi hop communication, all nodes communicate with each other using wireless channels without need of any control structure and common infrastructure. Nodes cooperate with each other to forward the data and one or more nodes may play the role of relay nodes (RN) [35]. Multi hop communication is the promising solution to increase network coverage and throughput. Transmission power of the senor nodes can be reduced to transmit the data at the short distance and to reduce the interference among the signals. This is advantageous in terms of spatial reuse of frequency. But a node playing the role of RN can deplete its energy earlier than other nodes so this problem should be examined and tackled by the routing protocols. Many different technologies are under exploration like fixed relays (Relays that are not connected to the backbone of the network), movable relays (Relays, which agree to transmit the packets of each others) and hybrid relays (Relays, which are fixed but are situated on the body of mobile objects). The use of relay nodes is very beneficial in terms of scheduling, interference management, network lifetime, adaptive modulation etc. Due to advantages of multi hop communication, many researchers have developed relay based routing protocols and in future, it can be considered vital to give attention to short-range communication where power levels of nodes can be controlled. Many protocols falls under the category of multi hop communication.

Several works in the literature bury the optimization issues into simulations which are done to solve operational issues, with no formal definition of the corresponding optimization problem. As a consequence, the proposed solutions may not properly handle the core of the optimization problem since optimization is a desired feature and not the main focus. Investigating the optimization problems involved in WSN allows to understand its complexity and improve the control, the management and the design of WSN. Here, the bibliographical review mainly focuses on the works dedicated to optimization problems for WSN using multi-sink. Rather than being exhaustive, we describe works strongly related to our main concerns, i.e. to better understand the core of optimization problems involved in a WSN.

2. RELATED WORK AND BACKGROUND

Wireless sensor network (WSN) are utilized in a wide range of applications, including military applications and the monitoring of oceans and wildlife. WSN comprise many low-cost devices called sensors, which monitor the status of the environment and send sensing data to the sink node. Because of limitations on the energy supply, available storage space and the computational capacity of the sensor nodes, the data that are transmitted between a sensor node and the sink node must been forwarded by other sensor nodes. Multi-hop WSN with one sink has been developed over a long period, but possible architectures are limited by the need for robustness, scalability and reliability since large-scale WSN depend entirely on the single sink. Wireless sensor networks (WSNs) have received significant attention due to their potential use in several different real-world applications [7, 1, 8]. To increase the capabilities of such applications, the underlying WSNs are being enhanced with multiple sinks sensors that can to collect data from different sensor nodes, therefore data collection is important issue in wireless sensor network. This new form of WSNs is known as Routing Wireless Sensor Networks with Multiple Sink [17]. The most widely known proposal is [3][12], but several other geographic routing schemes have been proposed [20] One of the key challenges in geographic routing is how to deal with dead-ends, where greedy routing fails because a node has no neighbor closer to the destination; a variety of methods (such as perimeter routing in GPSR/GFG) have been proposed for this. More recently, GOAFR [16] proposes a method for routing approximately the voids that is some asymptotically worst case optimal as well as average case efficient. Geographic routing is scalable, as nodes exclusively maintain state for their neighbors, and supports a full general any-to-any communication pattern without explicit route establishment. However, geographic routing requires that nodes know their location. While this is a natural assumption in some settings (e.g., sensornet nodes with GPS devices), there are many circumstances where such position information isn't available.are most often require information about the position of their voisins to function effectively.Or, this assumption is far from the reality.The other, the localization of protocols, used as a preliminary step by geographical routing protocol are not necessarily precise. For example, in [22],the authors proposed localization methods with which sensors determine their positions with a rate of less than about 90% positioning in large scale. or, if a node that does not know its location, the node risk of never communicate with other node of networks,and no information will be transmitted to the user and the base station never knows that node.

As a general wireless communication principle, sensor nodes have a maximum transmission range. Therefore, to route data to the sink node, a multihop transmission strategy is adopted. In general, the energy consumption of sensor nodes next to the sink is higher compared to the one of other sensor nodes in the network. This is due to the fact that the network traffic is unevenly distributed. Considering their position next to the sink node, most of the network traffic passes through the sinks neighbour nodes. This effect considerably reduces the network lifetime as the energy of the sensor nodes next to the sink rapidly depletes resulting in no possibility to reach the sink2. This effect is referred to as the bottleneck problem and is accentuated as the networks scalability increases in terms of number of nodes. The bottleneck problem is accentuated in large-scale networks because of the many-toone network traffic pattern which increases the energy unbalance in WSNs with a single sink node.

To provide a longer lifetime while increasing multi-sensory data collection rates in WSNs, the research community has exploited the use of multiple sinks [13, 25, 2, 4]. multiple sinks can provide multiple alternative routes from a source node to one of the interconnected sink nodes. This can shorten transmission distances and therefore reduce the network energy cost. Since sensor nodes play the dual role of both event detectors and data routers, the larger the number of hops involved in the routing of data packets to the sink, the greater are the overheads experienced, leading to higher energy cost. However, there are still several challenging issues that need to be further investigated in the context of various applications of Routing Wireless Sensor Networks with Multiple Sink [18].

One important implied assumption behind the data collection mechanisms using mobile sinks is that the collected data must be delay-tolerant as the collection delay is bounded by the physical distances and the speed of the mobile sinks. Clearly, this whole approach would not be appropriate when we need to collect real-time data, for which new approaches need to be developed as we are currently investigating in a related work [26, 29]. For monitoring applications that are able to perform their expected functionalities as long as the data transmission is done within hours or minutes, then we can consider mobile sinks. In such applications, to make better analysis and decisions, we need to get almost all of the data from sensor nodes to the base station (i.e., provide a high delivery rate) while minimizing the collection delay as much as possible.

In dense networks, lifetime can be maximized by creating covers, i.e., groups of sensors that are active at the same time. This strategy has been proven to be efficient in several applications of WSN [5, 19]. Following this idea, decomposition approaches as column generation (CG) have been largely used to identify and create schedules for the covers. As well as in the classical implementation, CG decomposes the problem into a restricted master problem (RMP) and an auxiliary problem (AP). The former optimizes the lifetime using an incomplete set of columns, and the latter is used to identify profitable columns.

In this paper we propose an enhancement to the GRPW algorithm based on scheduling techniques that allow the sink node to send its position in a planned manner to support a multi sinks based on a logical partition. We propose a multi sinks with limit path in the edge of site which sensor nodes are scattered there.

2.1 Motivation

In this paper we present a new method for multiple sinks enhancement based on the previous GRPW algorithm (Geographic Routing Protocol Washbasin). as basis for an investigation on improving the deployment of a network. GRPW is a geographical routing protocol for Wireless Sensor Networks (WSN) ensures a load balancing, minimizing energy consumption and the rate of message delivery for very low power networks and uses a routing policy with logical levels, inspired from the water flow in a washbasin . GRPW requires knowledge the static single sink position which is considered as parameter for initialization of the network to construct the logical levels topology . By changing these parameter a trade off is made between an overhead in the number of transmissions used to setup routing information in the network and an overhead in the number of transmissions used for sending the queries. In order to set these parameter, the single sink node position has to be known before deployment. If GRPW is initialized with multiple sink parameter then it will not be efficient and can in some cases be outperformed by a simple protocol such as classic flooding. In many cases the number of events or queries cannot be expected to be known in advance. As a consequence, GRPW will not always be an attractive routing protocol.

2.2 Organization

We have organized this paper in the following way: Section II describes the previous work. In this section we will focus on GRPW which is the basis for our extension. In Section III we describe our algorithm and the implementation of it. Section IV describes the simulation details of our algorithm and the results obtained are presented in Section V. In Section VI results are discussed and conclusions presented.

3. GRPW ALGORITHM

Several papers have been published about routing in WSN. In this section we will focus on introducing the GRPW Routing approach as this is the foundation for our work. For a more elaborate description to GRPW please refer to [24].
GRPW that each node can get its own location information either by GPS or other location services [30][23]. Each node can get its one-hop neighbor list and their locations by beacon messages. We consider the topologies where the wireless sensor nodes are roughly in a plane.
Our approach involves three steps:

(1) **The distribution the immobile sink position to all sensors networks:** In the first step,The communications in this step are made in three steps:
  —When a node wants to transmit the sink position to its neighbors ,it first emits ADV message containing the location of sink.
  —A node receiving a message ADV. If interested by this information, it sends a message REQ to its neighbor.
  —In Receiving a message REQ, the transmitter transmitted to the node concerned the sink position in a DATA message.

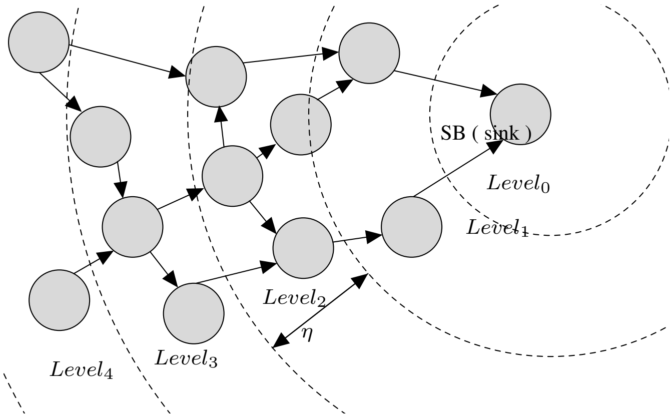

Fig. 1. Illustration of GRPW routing network levels

(2) **Construction of logical levels:** In this step the node networks determine its level of belonging through the sink node position,each node u well localized, calculate its level based on the received position of sink in the *Phase 1* ,with which u calculates the distance $d_{uS_{ink}}$ which separates him with the sink node .the levels is calculated so that the width level η be constant is less than and inversely proportional to the density of networks δ.
The level l of the node u defined by:

$$Level_u = \{l \in \mathbb{N} / \frac{d_{uS_{ink}}}{\eta} \leq l \leq \frac{d_{uS_{ink}}}{\eta} + 1\}$$

Set of the neighbor nodes that are well localized and which belongs to the same level as u :

$$L_{N_\Lambda(u)} = \{v \in N_\Lambda(u) / Level_u = Level_v\}$$

Set of the neighbor nodes that are well localized and which belongs to the higher level than u :

$$L^{+}_{N_\Lambda(u)} = \{v \in N_\Lambda(u) / Level_u = Level_v - 1\}$$

Set of the neighbor nodes that are well localized and which belongs to the lower level than u :

$$L^{-}_{N_\Lambda(u)} = \{v \in N_\Lambda(u) / Level_u - 1 = Level_v\}$$

(3) **Data forwarding :** The routing decision is done in our approach in three modes, depending on dispoinibilites neighboring nodes and of their level of belonging: the *Even Forwarding* , *Anterior Forwarding* and the *Rear Forwarding* (respectively called EF, AF and RF).
In the first mode AF ,GRPW constructs a route traversing the nodes of the source to the destination which each node receiving a packet DataPacket with the mode of transport `ANTERIOR_FORWORD`, will move toward the intermediate node in its coverage area what in before , the intermediate node select among the neighboring node using a lookup function. Lookup function is used by a node in order that he can determine the next hop to reach the next level, to determine the next hop function, lookup based on the principle of Round

Robin (RR). In the second mode EF, on account of the frequent failures of nodes, the mobility of nodes or policy scheduling of activities used, disconnections can occur in the network generates, so, what are called holes in this situation, GRPW will change the routing mode to `EVEN_FORWORD` to reroute the packet in EF mode and to overcome the void case. In the third mode RF, GRPW reroute the packet DataPacket, who was failed in AF and EF, RF fact sends a packet to the low level $L^{-}_{N_{\Lambda}()}$ by seeking the next hop among neighboring based on the lookup function. RF is leaning on same technique used in EF, for avoids the routing loop we safeguard the sets of node traversed by the packet DataPacket in a vector-type structure

4. GRPW-MS: ADAPTIVE ROUTING A MOBILE SINK IN WSNS

Let us now consider the use of GRPW in a sensor network with static nodes and a single static sink. If the sink moves, its virtual level will change, and the messages routed to the old coordinates will not reach the sink. A simple solution would be to notify each nodes about the sinks new coordinates. This solution, however is expensive in terms of the number of messages, and the corresponding energy consumption.

The GRPW-MS algorithm takes an idea which had been successfully applied to geographical routing to reduce the number of update messages necessary to maintain routability in context of multiple sinks . The general idea is that as long as the sink moves inside a limited local level area, the nodes outside that level area will not be notified about the sinks movement. The routing will rely on the nodes at the periphery of the level area to forward the messages to the the closest sink which belongs to its area.

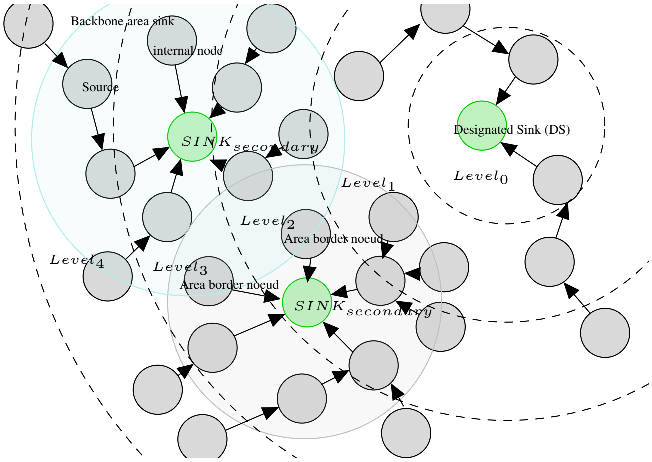

Fig. 2. Illustration of GRPW-MuS routing network levels

4.1 GRPW-MuS defines the following overlapping categories of nodes

In Figure 2 GRPW-MuS defines several special nodes and area types:

- An internal nodes has all its logical address belonging to the same area sink .
- An area border noeud is a noeud that connected at one or more areas sink . It is considered a member of all areas sink it is connected . An ABN keeps address of all sink where it belongs in memory, one for each area to which that node is connected.
- An area border noeud (ABN) is a noeud that connected at one or more areas sink . It is considered a member of all areas sink it is connected . An ABN keeps address of all sink where it belongs in memory, one for each area to which that node is connected.
- A backbone area sink has a link to the backbone area.
- Each node has an identifier. This identifier must be established in every GRPW-MuS instance. If not explicitly configured, the highest logical address will be duplicated as the router identifier. However, since the router identifier is not a logical address, it does not have to be a part of any area in the network, and often isn't to avoid confusion.

4.2 GRPW-MuS Algorithm

A designated Sink (DS) is the sink node elected among all nodes , generally assumed to be a multihop network. The basic neighbor discovery process (Hello), DS election (priority). The DR is elected based on the following default criteria:

- If the priority setting on an GRPW-MuS node is set to 0, that means it can NEVER become a DS When a DS fails and the BDS (Backup Designated Sink). takes over, there is another election to see who becomes the replacement BDS.
- The node sending the Hello packets with the highest priority wins the election. If two or more nodes tie with the highest priority setting, the router sending the Hello with the highest NID (node ID) wins.
- Usually the node with the second highest priority number becomes the BDS. The priority values range between 0 - 255,[14] with a higher value increasing its chances of becoming DS or BDS. If a higher priority GRPW node comes online after the election has taken place, it will not become DS or BDS until (at least) the DS and BDS fail.
- If the current DS 'goes down' the current BDS becomes the new DS and a new election takes place to find another BDS. If the new DS then 'goes down' and the original DS is now available, still previously chosen BDS will become DR.

In GRPW algorithm, SINK secondary cannot compute distances when a designated Sink (DS) sends a message by using distance estimation techniques SumDIST . This method is the most simple solution for estimating distances to DS . It adds ranges encountered at each hop during the network flood. Each DS sends a message including its identity, coordinates and path length initialized to zero. When a node receives this message, it calculates the range from the sender, adds it to the path length and broadcasts the message. Thus, each SS obtains a distance estimation and position of anchors. Of course, only the shortest distance will be conserved. Sum-dist is very simple and fast. Moreover, little computations is required. A drawback of Sum-dist is that range errors are accumulated when distance information is propagated over multiple hops. After this phase, Second calibration allows to convert distances into a radius of the area representing its size . This conversion consists to divide the estimated distance with the number of all sinks .

After this logical networks reconstruction ,each sink establishes its area based on the sink DS position. The routing of captured data be performed within each zone belonging to each node using the GRPW method for each Area Sink .

5. SIMULATION

The performance evaluations were conducted using the OMNET++ discrete event simulator and making use of the MiXiM framework. The obtained results are presented and compared to GRPW protocol in terms of network lifetime as well as the average remaining energy and the energy consumption. The behaviour of the network lifespan is also evaluated and analysed as the network scalability is increased in order to study its effect on the performance. The idea of using four interconnected sinks is also to allow much more distributed energy consumption throughout the network as a mechanism to facilitate energy balance.

5.1 Simulation Results

The evaluation of the performance of the three strategies is based on two concentration models that represent different data generation rates. The proposed scheme is found to be adaptable to various environments with different concentrations. The following metrics are used to compare the performance of GRPW and GRPW-Mus .

—Average hop count: The average hop count from source to sink is the number of forwarding times. A higher count corresponds to greater aggregate energy consumption. A large count also means a large data delay.

—Network lifetime: The lifetime is measured from deployment to the time when the first hotspot exhausts the battery. It is a good indicator of the expected lifetime of a network as it shows how effectively the load balancing scheme avoids the EISS problem.

5.2 the average lifetime against the number of sink

Fig. 9 plots the average lifetime against the number of sink nodes. The number of sensor nodes is 600. The NS scheme derives yields the shortest lifetime in both the linear and the complicated concentration models because it transmits sensing data to the nearest node. The Levels scheme has the longest lifetime in the linear model because all of the hotspots exhaust equal energy, but the lifetime is susceptible to the number of sink nodes in the complicated concentration model. The average lifetime in the GRPW-Mus scheme is close to that of the GRPW scheme but more stable than that of the GRPW scheme in the complicated concentration model. Hence, the GRPW-Mus scheme can balance the load for various traffic patterns.

5.3 Average lifetime vs. numbers of sink nodes

From Figure 4 , we see that GRPW-MuS outperforms other protocols significantly, with GRPW-MuS close to doubling or tripling the time to first sensor node failure in some cases. In GRPW, the first node dies quicker than the other protocols, because all packets are sent to only one sink and there is no multiple sink nodes levels reconstruction and path switching. The GRPW-MuS Algorithm decrease energy consumption which can improve the lifetime of sensor nodes and the GRPW-MuS Algorithm uses the multiple sink nodes which improve the load-balance of data which is sent to sink nodes. However, GRPW-MuS by combining multiple sink nodes, levels reconstruction and path switching, can best balance sensor energy consumption and prolong the duration for sensor network which is fully functional.

5.3.1 Average Energy Consumption . In Figure 5 and Figure 6, This can be seen where the hop count and distance decreases with time for most algorithms. GRPW, however, behaves a bit differently in that its average distance to sink does not decrease much over time, meaning that it is still able to keep some of the outlying sensors alive (and hence the higher average distance). Despite the longer actual distance from the sinks (which greatly affects the energy consumption of the packet), GRPW-MuS still maintains the best average energy consumption per packet, which is a tribute to the level maintenance and path switching mechanisms.

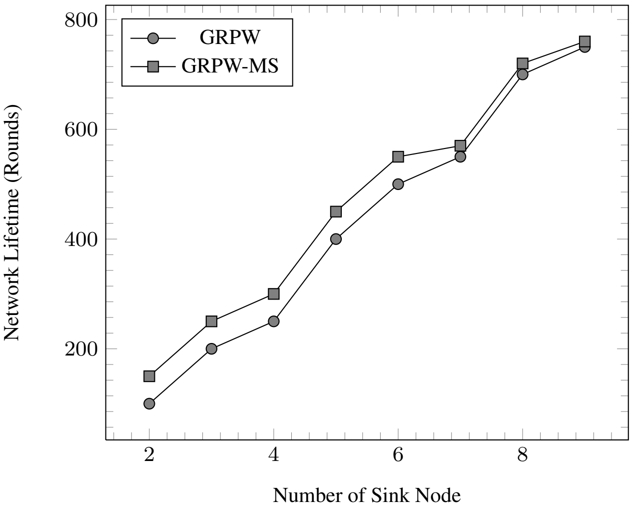

Fig. 3. Number of Dead Nodes

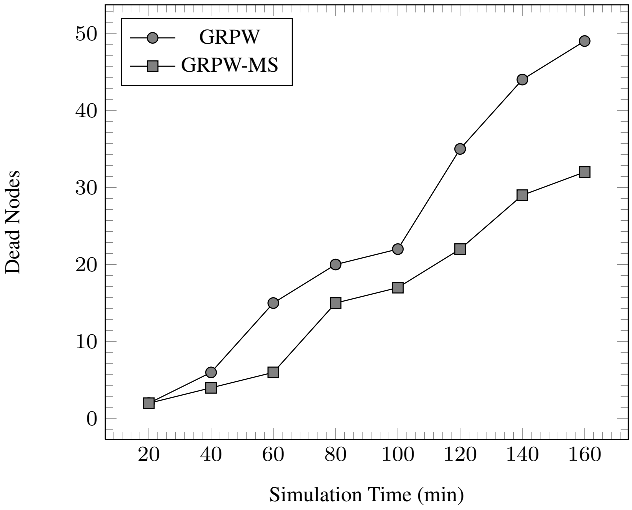

Fig. 4. Number of Dead Nodes

5.4 Safe time

Here the safe time is denoted as a number of hopes the adversary has to travel to find the location of the sink. The total number of hopes includes a number of hope at the fake path and number of hopes at the real path the adversary has to move to locate the sink. Figure 7 shows safe time as a function of a number of sinks. The safe time for GRPW-MuS and GRPW go on increasing the number of sink is increased. The performance of GRPW-MuS is better compared to GRPW as in GRPW-MuS the node are divided into the number of zones and hence multiple paths are generated simul-

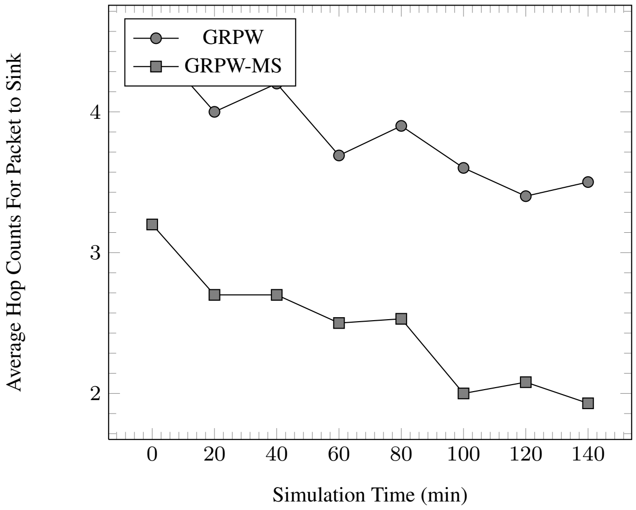

Fig. 5. Average Hop Count vs Time

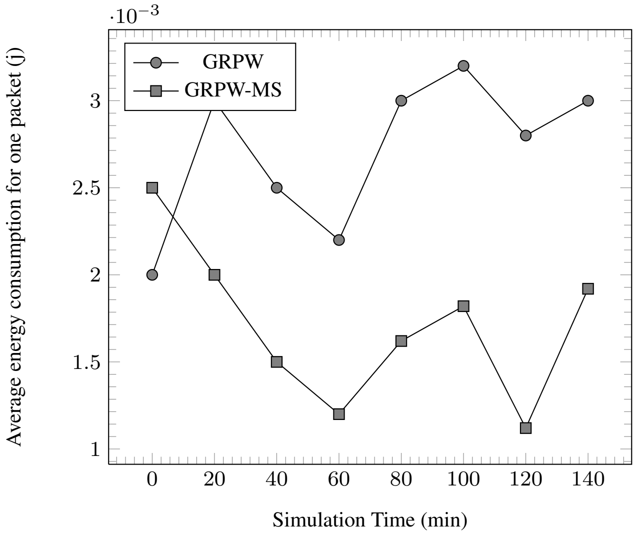

Fig. 6. Average Energy Consumption for packet

taneously in the network and hence safe time is more while using GRPW-MuS.

5.5 Packet Delivery Ratio

Figure 8 shows the packet delivery ratio as a function of a number of sinks. The packet delivery ratio in GRPW and GRPW-MuS initially decrease up to a number of sink 2, after which it increases with increasing number of sink. The packet delivery ratio for GRPW and GRPW-MuS almost remains identical as a function of number of sinks.

5.6 Average Throughput (kbps)

Figure 9 shows that performance of GRPW-MuS is slightly better for the average throughput as compared to GRPW. Performance GRPW and GRPW-MuS are increases in average throughput as a function of number of sinks. Due to zone partitioning done by GRPW-MuS, It increases performance for an average throughput.

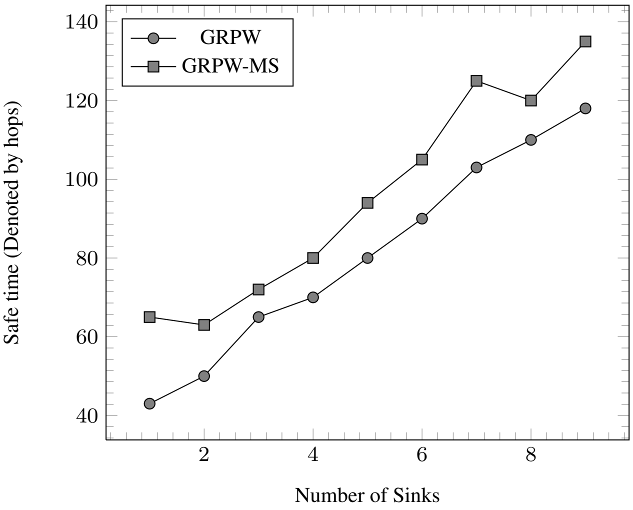

Fig. 7. Safe time as a function of number of sinks

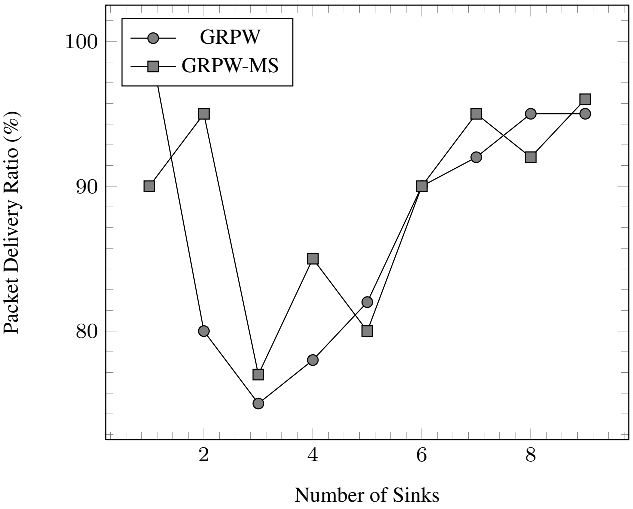

Fig. 8. Packet Delivery Ratio (%) as a function of number of sinks

5.7 Normalized Routing Load

Figure 10 shows that performance of GRPW is slightly better for normalized routing load as compared GRPW-MuS. The routing load drastically increases for both GRPW and GRPW-MuS up to a number of sink-2 and then decreases linearly with increasing number of sink.

6. CONCLUSION AND FUTURE WORK

Deployment of multiple sinks is a promising solution in VSNs in terms of reliability, latency and energy efficiency due to the alleviation of congestion around the sinks. The maximum gain from the deployment of multiple sinks can be achieved by an effective load balancing among the sinks. In applications such as target tracking where load creation is dynamic throughout the network, static

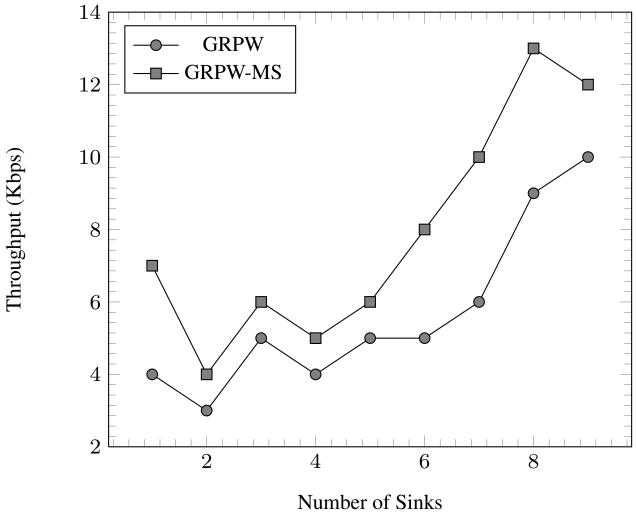

Fig. 9. Average Throughput (kbps) as a function of number of sinks

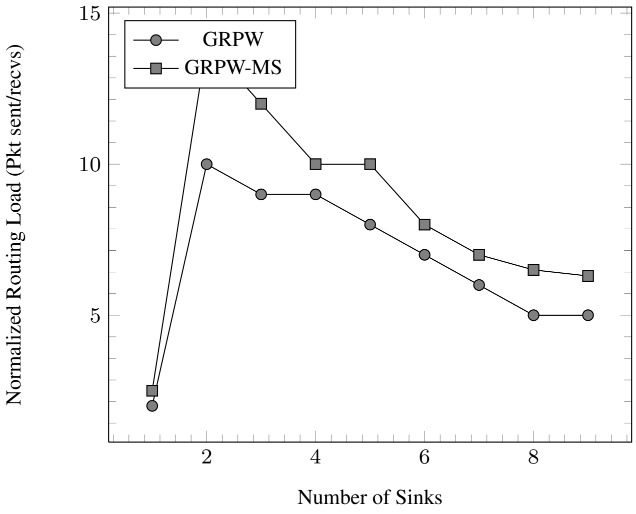

Fig. 10. Normalized Routing Load as a function of number of sinks

load balancing techniques could not effectively distribute the load to multiple sinks. A dynamic load balancing technique is the appropriate solution for the applications where data creation is triggered upon event detection. In this paper, we designed the new scheme to provide the Multiple Sink location privacy in WSNs. We use the GRPW-MuS routing protocol based on level partitioning without relying on geographical information about the sensors and the sinks. Using levels partitioning, the numbers of nodes are divided into several levels. The fake packet injection scheme is used to protect the location privacy in which the real traffic is routed through the shortest path. Moreover, The various fake paths are generated by generating fake packets to fake sinks. The performance of the fuzzy sink selection is evaluated using OMNET++ simulator and is compared with three different selection schemes. The multi-sink simulation results shows that although, deploying extra sinks into the environment increases the performance of the network, the breakpoint is the deployment of the second sink. Hence, the number of sinks to be deployed into the environment should be determined by the budget for the sensor network and the QoS requirements of the application. The comparative simulation results present a surprising outcome that even directing the load to randomly determined sinks without considering the distance is superior than directing the load to the closest sink. The comparative results also confirm the success of the fuzzy sink selection mechanism for achieving the best performance in terms of reliability, latency and energy efficiency for high video qualities. In the future, we want to improve the multi-sink forwarding scheme by employing a dynamic sink-switching mechanism along the way considering the decision history and the current load conditions towards each sink. In addition, we want to explore the benefits of applying load balanced forwarding to mobile sinks in terms of reliable and energy efficient data delivery.

The GRPW-Mus mechanism is currently based on geographic routing due to its low computational complexity and scalability since it does not require routing information exchange and does not need to maintain large routing tables. However, in the future we want to adapt our sink selection scheme to other routing algorithms using different set of parameters.

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