Journal of Theoretical and Applied Information Technology
31st July 2015. Vol.77. No.3

ISSN: **1992-8645** www.jatit.org E-ISSN: **1817-3195**

THE EFFECT OF ROUTING ON DATA TRAFFIC CONTROL IN ENVIRONMENTAL EVENT MONITORING USING WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensors networking is a promising technology for a wide range of useful applications in many areas including civilian and military areas. Thanks to the sensing capabilities of Wireless Sensor Networks (WSNs), they become a prominent choice for certain applications such as environmental monitoring. The distributed sensors collectively realize the evolution of physical and operational phenomenon and predict its effect on mission execution and then trigger control actions that perform high-level mission procedures. However, efficiency, reliability and performance are the main challenges in deploying and utilizing WSNs especially in harsh environments conditions. This paper studies, the event tracking issues and identifies the reasons behind the deficiency of reliable transfer of the data traffic under abnormal situations or scenarios where WSN characteristics and performance may differ significantly. It investigates the performance issues related to routing protocols in WSN such as Low-Energy Adaptation Clustering Hierarchy (LEACH) and Directed Diffusion by using a simulation model in which represents a variety of sensor networking environments and examine their suitability for the WSN environment in terms of data traffic control. It was found that LEACH routing protocol outperforms Directed Diffusion due to its hierarchical nature, but suffers from several issues such as scalability, adaptability, utilization, latency, and throughput.

Keywords*:* *Event Tracking, Wireless Sensor Networks (WSN), Routing Protocols, Traffic Control, LEACH, Directed Diffusion.*

1. INTRODUCTION

Sensor networks encompass a significant number of miniature processing machines, each by itself behaving independently and equipped with a specified and limited range of wireless communication [1] [2], processing capability and memory size as well as being prepped with sensing capability. Each decision will particularly be based on two important factors which are the accuracy and the availability of the required information. Sensor networks can significantly improve the quality as well as the ways of gathering the information [3]. The quality of the information and the way it is gathered can significantly be improved through the extensive implementation of sensor networks. An example of this would be in the favor of getting higher reliability of information, gathering of information in real time, acquiring information that is difficult to be obtained as well as the reduction in the cost of acquiring the information. Due this various benefits, it is inferred that many areas in the near future will have sensor networks being applied. Some of the areas that would benefit of using WSNs are production surveillance, management of traffic, super visioning environment, as well as in the medical area and military application [4].

WSN is defined as a combination or network of the sensor nodes that are used for the sensing an event and communication of the acquired or processed data. A WSN may consist of a few to thousands of sensor nodes responsible for data acquisition and communication. When the basic architecture of WSN is established, the sensor nodes will organize themselves according to the network infrastructure. This is done by using the multi-hop connection in the interactions of the sensor nodes, as described by [5], where sensor nodes responsible for collecting information from the environment, for instance, seismic, infrared, acoustic or magnetic information. Figure 1 shows how the end users enable to acquire the information from the sensor network. This is done via the internet routing from the base stations (sinks). A base station acts as an interface between the end user and sensor nodes [5].

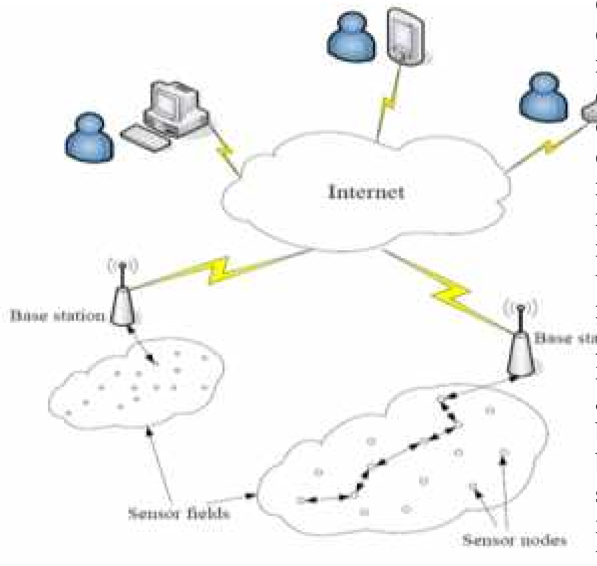


Figure1: End users access WSN via Internet (Adopted from Yu et al. [5])

1.1. Issues of wireless sensor networks

As stated in [6], the key characteristics of a WSN include ease of use, ability to withstand harsh environmental conditions, ability to cope with node failures, heterogeneity of nodes, mobility of nodes, scalability to large deployment of nodes, communication failures, and power consumption limitation. Several challenges can be encountered when building WSNs, which related to hardware design, wireless networking, and applications[7].In terms of hardware design, Microelectromechanical systems (MEMS) sensor technology plays an important role that comprises sensor networks. The main challenges related to hardware design are the interaction challenges that arise by virtue of scale [8]. These interaction challenges include interactions of network dynamics in widely distributed sensing networks in addition to functional, data, and timing interactions. The reason behind deploying distributed sensing network failures is due to unpredicted interactions among multiple components that bring about new delicate failure modes [9]. During the design time in sensor networks, it is difficult to discover the space of these interactions. Although many verification techniques have been developed, yet, they suffer scalability challenges that occur because of the massive concurrency and unreliable components, such as wireless [10].

In the presence of hardware limitations and environment where nodes should operate efficiently, according to application requirements, mechanisms and protocols should be designed to offer a reliable and energy efficient communications system. Robust methods for channel access should be developed and issues of routing and mobility management should be resolved. Promising applications for wireless sensor networks include applications that utilize sensors used by people in their homes, offices, cars, whose measurements could be shared for purposes of providing a range of services. These services include the use medical sensing networks that assess human biometrics and make them accessible by the corresponding medical repositories that will be available to care-givers [11]. It also can be shared with phones and cars that compute information of community concern, for example, pollution or traffic patterns [12-14]. For such applications, the main challenge is to have effective abilities for efficient abstraction, transmission and representation of data received from the sensor. In these applications, networked sensing systems may have a variety of functional components designed for event detection and data collection, data processing, data fusion, and notification [15]. Sensor networks can provide a natural platform for hierarchical information processing if sensing, signal processing, and communication functions are integrated [16].

1.2. Routing in wireless sensor networks

Network routing is responsible for delivering data from a source node to a sink node across a WSN. Typically, sink nodes require a type of data from a specific area and therefore are not concerned with a particular sensor. Routing is the most energy consuming operations in WSNs. Therefore, the more routing action is, the less remaining lifetime will be. The volume of traffic routed to the corresponding sink depends on the number of sensor nodes required to send their data. Routing protocols in the WSN are required to provide good quality of communication along with the energy consumption constraints. There are various techniques and algorithms developed for the wireless networks generally, according to the Zhang et al, [15] the important routing protocols which are made for wireless networks which are proposed for the WSN can be partitioned in seven classifications illustrated in Table 1. These protocols were supposed to offer good network performance and satisfactory network services for different WSN applications; taking into account energy efficiency, network scalability, adaptability to changes, delay, throughput, utilization, and fairness [12].

Table 1: Routing Protocols for WSN

CATEGORY	REPRESENTATIVE PROTOCOLS
Location-Based Protocols	MECN, SMECN, GAF, GEAR, Span, TBF, BVGF, GeRaf
Data-Centric Protocols	SPIN, Directed Diffusion, Romer Routing, COUGAR, ACQUIRE, EAD, Information-Directed Routing, Gradient-Based Routing, Energy-aware Routing, Information-Directed Routing, Quorum-Based Information Dissemination, Home Agent Based Information Dissemination
Hierarchical Protocols	LEACH, PEGASIS, HEED, TEEN, APTEEN
Mobility-based Protocols	SEAD, TTDD, Joint Mobility and Routing, Data MULES
Multipath-based Protocols	Sensor-Disjoint Multipath, Braided Multipath, N-to-1 Multipath Discovery
Heterogeneity-based Protocols	IDSQ, CADR, CHR
QoS-based Protocols	SAR, SPEED, Energy-aware routing

The sensing of physical environment is strongly established due to high potentials and usage of WSNs' applications. However, efficiency, reliability, and performance are the main challenges deploying and utilizing WSNs [6]. A lot of researchers have been interested in investigating the performance of WSN and many solutions were developed to improve the performance and to ensure reliable transfer of the data traffic [17]. Nevertheless, the nature of WSN in harsh environments conditions creates different situations or scenarios, in which WSN characteristics and performance may differ significantly. The aim of the research work presented in this paper is to examine the performance of the common existing routing protocols developed for WSNs to identify the key problem areas and come up with a solution to improve data traffic control in WSN. The rest of the paper is organized as follows; methods of gathering and reporting data are presented in Section 2. Section 3 presents the performance evaluation, including simulation scenario setup. Simulation results are discussed in Section 4. Recommendations to improve LEACH routing protocol is stated in Section 5. Finally, conclusions and future work are presented in Section 6.

2. DATA GATHERING AND REPORTING

Data gathering is the most important issue in WSNs. Protocols for reporting an event, once detecting it, can be considered as responses to an event-driven query. A single responsible sensor reports the sensed data after aggregation. Based on the purpose of the application that utilizes sensor networks, sensed data can be collected in different ways. In time-driven systems, such as environmental monitoring, sensors report their collected information periodically to their cluster head (CH), or to the sink. In event-driven systems, such as fire or temperature detection, sensors send their data only when events happen. Though, in query-driven systems, the sink (or CH) request data from sensors whenever needed. Our future interest in this research is to develop an application that requires monitoring of a crucial variable (say temperature) and send data only when an event has developed (reaches a certain threshold). Therefore, our focus will be on event-driven systems. We also investigate the possibilities of using query-driven data aggregation when the event under monitoring worsens.

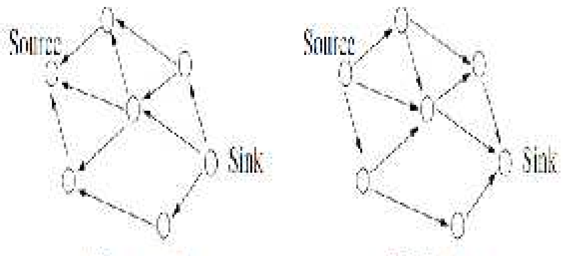
This section presents the most common protocols used in reporting to the sink node according to its position with and without local information derived by the sink node based on broadcasting and geocasting concepts where sensor nodes may memorize certain information that is used in reporting afterward.

2.1. Reporting with data-centric routing

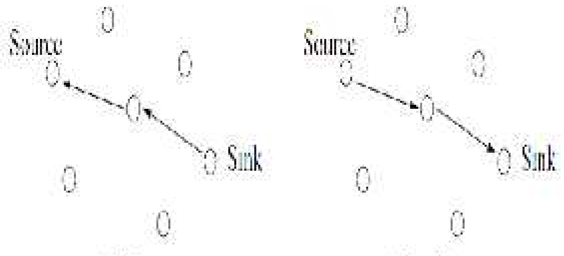
In this type of routing, the focus is on the retrieval and dissemination of data of a specific type or defined by certain attributes in flat-based WSNs where all sensors have same roles and collaborate to perform the routing tasks [18]. It is opposed to the data collection from certain sensors in hierarchical-based WSNs. The use of data-centric, results in a dynamic operation as it determines the endpoint in WSNs [19]. If the sensor condition changes, the routes of network will be adapted to these changes in order to satisfy the requests. Furthermore, a global node addressing scheme is not needed when using data-centric, which in turn offers energy efficiency as routes are established only when there is an interest. In addition, data-centric helps in decreasing energy consumption as routes are selected for a particular interest from the sink.

The directed diffusion data dissemination has been proposed to deal with the requirement where the CH (or the sink) demands certain information from the nodes in a WSN. Directed Diffusion protocol [20] is a data centric protocol, which is used queering, dissemination and processing from the sensors. The directed diffusion protocol is using data naming, interest and gradient, reinforcement and data propagation. This protocol is having the features of robustness, energy efficiency and scalability. At the initial stage of communication the sink defines a less data rate for the events which are incoming, after that the sink is able to use reinforce for the sending actions along with high rates of the usage of interest message.

Directed diffusion function in several phases in order to exchange information and deliver data between the sink and the nodes involved in response to the request sent by the sink. These phases include the propagation of interests, setup of gradients, reinforcement, and delivery of data. In the interest propagation stage, the sink floods the network with interest messages as shown in Figure 2(a).



(a) Interest propagation (b) Gradient setup



(c) Reinforcement (d) Data delivery

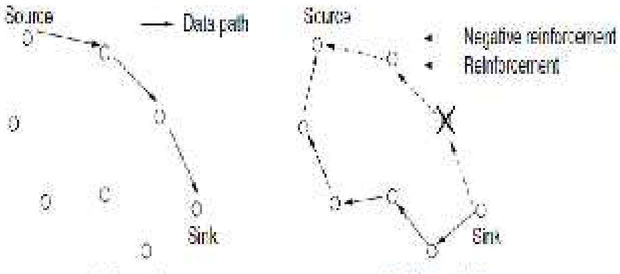
Figure 2: Reporting using Directed Diffusion Protocol

Sensors with matching data for these messages store the messages in their interest cache. The interest cache consists of many fields as follows:

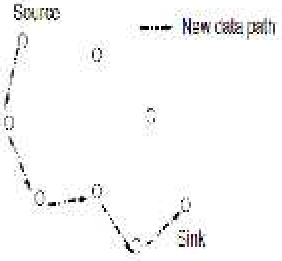
- Timestamp - specifies the local time of the interest message arrival.
- Gradient - specifies the sensor from which the interest message has received. It helps forming the reverse routes towards the sink.
- Duration - every interest message is kept at a particular time designated by the duration field.

Upon receiving a message of interest, the node will forward (or floods) the message to the neighbors except the one it received from. Once the interest message reaches the intended sensor, the gradients from that sensor to the sink will be set up. When the sensor has the data for the specific interest, it sends the data over the route of the interest's gradient, as depicted in Figure 2(b). The source sensor can have many gradients for the same interest as the gradients are not limited during the gradient setup phase; thus, data can be reported to the sink via multiple paths. In such case, the sink may reinforce a specific route by resending the interest through particular sensors in that route as illustrated in Figure 2(c). The route can be selected according to its quality or has the lowest delay among the other routes. When a particular sensor node is selected, the interest message is directed only to that sensor in order to reinforce the route that includes the selected sensor. Every sensor along this route has to forward the reinforcement to its next hop. Hence, a connection between the source and the sink is established as shown in Figure 2(d).

Furthermore, reinforcement helps in dynamically routing data in different routes whenever changes in the WSN occur. In such case, the sink node will send reinforcement via another route and negative reinforcement will be sent via the active route to block data transmission through that route as illustrated in Figure 3.



(a) Data path (b) Negative reinforcement



(c) New data path

Figure3: Negative Reinforcement in Directed Diffusion

The directed diffusion protocol achieves energy saving by choosing the most efficient routes. Nevertheless, directed diffusion is a query-driven data model, which usually consumes much more energy in monitoring environment that requires constant data delivery to the sink.

The design of data-centric routing protocols according to a flat topology network is the main disadvantage of these protocols, as it can bring about congestion among the nodes near the sink node as well as scalability problems. Data generated by nodes concentrated close to the sink makes data overload becomes an issue as the density increases. Thus, distributed aggregation schemes are required in order to decrease data flowing in every link of the network, and a matching procedure for data and inquiries cases considerable overhead at the sensor nodes. Furthermore, these protocols are appropriate to a certain application in WSNs, as the communication with sensors is established by queries sent by the sink. Hence, data-centric routing protocols, like directed diffusion, are not suitable for dynamic applications that highly require a constant data delivery. Also, for each application, the type of query, in addition to the interest matching processes should be defined. Likewise, the data-centric method results in application-dependent naming schemes that should be defined in advance in case of any change in the application.

The data-centric protocols in flat-architecture networks makes sensors located nearby the sink dies faster as route more data than others far from the sink. This may cause dis-connectivity between the sink and the rest of the network. Hence, uneven energy consumption throughout the network can take place that affect the scalability of the protocols. Forming a hierarchical architecture can overcome the problems with flat-architecture protocols. Nodes can be clustered where communications among cluster members are controlled by the CH.

2.2. Reporting with energy-efficient routing

Sensors are usually equipped with small batteries, and in most sensor network scenarios, it is impossible to recharge those sensors. Hence, the lifetime of a WSN is proportional to the energy consumption produced by the routing protocol in use. The basic method for reporting data is to send a packet with satisfactory power to reach the sink node (in case the sink in small-size WSN). If omnidirectional communication is used, there is no need for precise position of the sink node. In such networks, as sink node can have more power than sensors, it can inform its presence and location by sending a packet to all sensors. Sometimes, sensor nodes need to increase their transmission power to reach the sink node until they receive acknowledgements from the sink node regarding their reports. This direct communication with the sink can consume the power quickly if the communication is over a long distance. In medium and large-size WSN, clustering is used in achieving scalability, reducing the size of routing tables, and decreasing the management overhead.

The Low-Energy Adaptation Clustering Hierarchy (LEACH) [21] is used for reporting data to the sink.

It aims to balance the load of sensor nodes and achieve energy efficiency. LEACH is a two level clustering scheme where sensors are divided into clusters based on the received signal strength. Each node randomly volunteers to become a CH in round that all sensors will be a CH with certain probability. Once a node is willing to be a CH, it sends a packet to notify nearby sensor nodes. Each sensor then has to report to the CH which in turn sends aggregated data received from other nodes directly to the sink.

LEACH round has setup phase and steady phase. In the setup phase, each sensor chooses a random value between 0 and 1, which is the probability p to designate itself as CH. If p is less than a threshold T(m) for sensor m , then sensor m will become CH for this round R in the set of sensor nodes G that have not yet become cluster heads in the previous 1/p rounds. T(m) is computed equation 1 as follows:

$$T(m) = \begin{cases} \dfrac{p}{1 - p\left[R \bmod \left(\frac{1}{p}\right)\right]} & \textit{if sensor } m \in G, \\ 0 & \textit{otherwise,} \end{cases} \qquad (1)$$

Thus, initially all sensors have the same probability p to become CH. For the next round, T (m) parameter will be increased because there will be lesser number of sensors left that need to be CHs. After CHs announcement, the rest of sensors determine the cluster to join according to signal strength received from CHs. Then each sensor notifies the closest CH that it will be a member of that specific cluster, and therefore, the node clusters are formed. In the steady phase, the sensors start sensing and send their data to their CH.CH then aggregates and transmits these data to the corresponding sink. After some time spent in the steady phase, another round of selecting CHs will begin and so on. Figure 4 shows the operation of LEACH protocol.

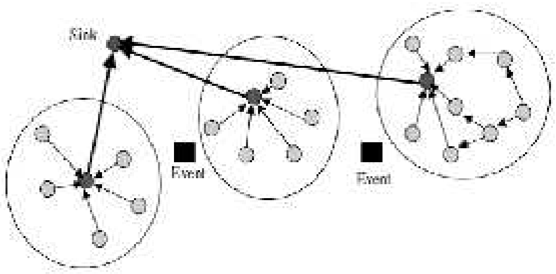


Figure 4: Direct Reporting to Sink using LEACH Protocol

LEACH supports node mobility; although this has negative effects such as unreliable communication and costly route maintenance. Sensor failures can cause problems as the number of potential CHs will be less than desired as P defines the proportion of the total number of sensors [22].

The main problem with LEACH is that CHs might be located far away from the sink node; hence direct reporting can consume much energy or even sometimes is impossible to reach the sink node. Also, CHs might not be distributed through the network uniformly. There will be a possibility that CHs are concentrated in an area of the network, resulting in having no CH for sensors in other areas. These sensors will be cut out of the communications. In addition LEACH clustering algorithm suffers from high overhead and complexity [23].

3. PERFORMANCE EVALUATION AND SIMULATION SETUP

In this research work, Mannasim module is utilized to investigate the performance of LEACH and Directed Diffusion routing protocols. Version 2.29 of NS-2 [24] was chosen for implementing the Mannasim module [25]. To compile the module into the network simulator, some of NS-2 files should be modified in order for the module to run correctly. These files are:

- ns-2.29/apps/udp.cc
- ns-2.29/common/ns-process.h

ns 2.29/common/packet.cc

- ns-2.29/common/packet.h
- ns-2.29/mac/mac-802_11.cc
- ns-2.29/tcl/lib/ns-lib.tcl
- ns-2.29/tcl/lib/ns-default.tcl
- ns-2.29/Makefile.in

3.1. Simulation scenarios

The simulation scenarios used for evaluating LEACH and Directed Diffusion are set according to the parameters shown in Table 2 below.

Table 2: Simulation Parameters for Evaluation Scenarios

Parameters	Value
Traffic type	Constant Bit Rate
Routing Protocols	LEACH / Directed Diffusion
Deployment Area	1000 * 1000 m2
Link Layer	Mac / 802_11
Number of Nodes	300,700,1000
Packet size	25 bytes
Initial battery power	IJ
Energy Dissipated in Tx , Rx	50 nJ/bit
Transmit Amplifier	120 pJ/bit/m2

3.2. Performance metrics

Performance metrics are the criteria, based on which, the performance of the network communication system is evaluated [26]. In this research work, after conducting simulation experiments, the acquired results are analyzed and compared statistically in terms of Packet delivery ratio (PDR), Routing Load (RL), and Average End-to-End Delay.

Packet delivery ratio (PDR)
Based on this performance metric the ratio of sent to the received data is calculated. Equation 2 below presents the formula for the PDR:

$$\text{Packet Delivery Ratio} = \frac{\sum Total\ Packet\ Recieved}{\sum Total\ Packet\ Sent} \quad (2)$$

Routing load (RL)
Routing operation consumes the most energy in WSNs. Therefore, the regularity of the routing in nodes is a serious issue in defining their residual lifetime. The total packets routed to the BS depend on the number of nodes willing to send their data in every round. Equation 3 below presents the formula for the RL:

$$RL = \sum_{\forall Si \in F} (1 - \mu)\lambda Si \quad (3)$$

Where λ s_i is the rate of sensed data generated by node s_i, F is the group of nodes that send their sensed data and μ ⩽ 1 is the percentage of data redundancy to the sensed data that had conveyed by s_i that is conditional upon the density of nodes and the interval sensed data reporting.

Average end-to-end delay
It presents delay occurred during the transmission of packets from source node to the destination node. All possible delays are included; such as processing delay, queuing delay, retransmission delay at the MAC, propagation delay, and transmission delay at every intermediate node. Equation 4 below presents the formula for the average end-to-end delay:

$$Average\ end - to - end\ delay = \left[\sum_{n=1}^{n} (R_i - S_i)\right] / n \quad (4)$$

4. RESULTS AND DISCUSSION

The simulation results illustrated in the following figures represent the performance of LEACH and Directed Diffusion protocols based on the evaluation metrics: Packet Delivery Ratio, Routing Load, and Average End-to-End Delay.

4.1. Packet delivery ratio

As shown in Figure 5 (based on the data values in Table 3), Directed Diffusion protocol produces a lower PDR than LEACH protocol. It is because the route adaptation mechanism that Directed Diffusion uses in responding to any topological changes. Directed Diffusion produces fewer throughputs compared to LEACH because of the path re-establishment process whenever a path is broken. On the other hand, LEACH performs much better as it builds cluster heads that help reducing overhead. As LEACH suffers from scalability and expandability issues, the packet delivery ratio decreases when the network size increases. There is more nodes failure near the sink due to have load.

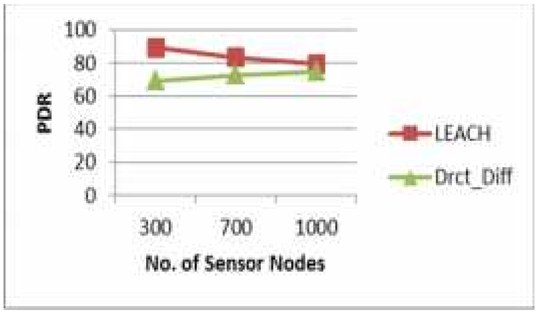


Figure 5: Comparison of LEACH and Directed Diffusion Protocols in terms of PDR

Table 3: Packet Delivery Ratio for LEACH and Directed Diffusion Protocols

No. of Nodes	300	700	1000
LEACH	89.38	83.4	79.5
Drct_Diff	69.3	72.8	74.9

4.2. Routing load

As shown in Figure 6 and Table 4, Directed Diffusion produces higher overhead because of its adaptive nature. It needs to re-trigger a route discovery when a link failure happens while LEACH characteristics of rotating cluster head duties among nodes present less overhead compared to Directed Diffusion protocol as the routing load area is divided between the several clusters. However, it produces slightly higher overhead for less number of nodes.

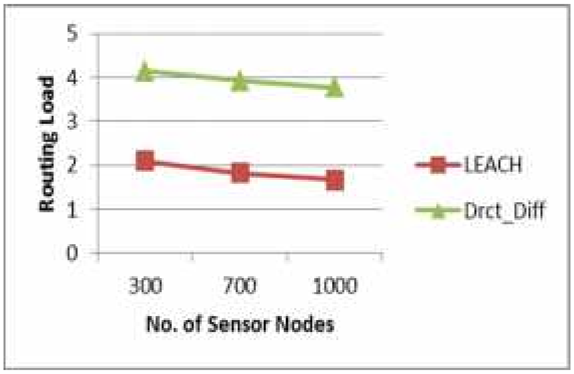


Figure 6: Comparison of LEACH and Directed Diffusion Protocols in terms of Routing Load

Table 4: Routing Load for LEACH and Directed Diffusion Protocols

No. of Nodes	300	700	1000
LEACH	2.1	1.82	1.67
Drct_Diff	4.14	3.92	3.77

4.3. Average end-to-end-delay

Figure 7 and Table 5 show that LEACH has a lower end-to-end delay as it is considered as a single-hop clustering routing protocol that aggregates data from a cluster head. Directed Diffusion has a higher delay as it is considered as a flat architecture routing protocol that does not use cluster based mechanism for routing.

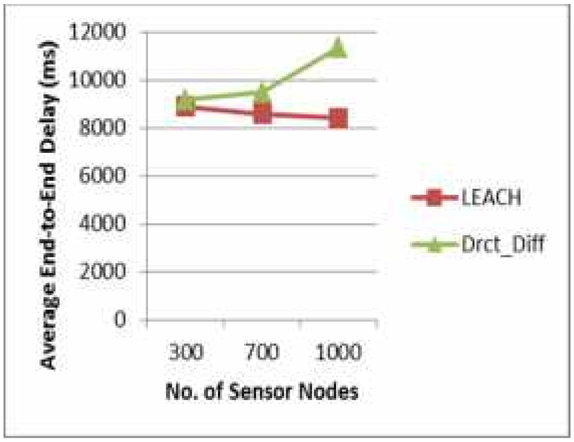


Figure 7: Comparison of LEACH and Directed Diffusion Protocols in terms of Average End-to-End Delay

Table 5: Average End-to-End Delay for LEACH and Directed Diffusion Protocols

No. of Nodes	300	700	1000
LEACH	8891	8577	8391
Drct_Diff	9178	9474	11361

The simulation results verify that LEACH protocol performs better overall compared to that of Directed Diffusion due to its a single-hop cluster based architecture. It confirms that utilizing a cluster-heads technique can help in a higher Packet Delivery Ratio (PDR), which in turn achieves better quality of services provided. For Directed Diffusion protocol, the network performance was degraded even though there seems to be a close competition between LEACH and Directed Diffusion for the case when 300 nodes were used.

5. RECOMMENDATIONS TO IMPROVE LEACH

As mentioned earlier, this research work is related to the potential event tracking system that we are going to develop for temperature detection where sensors are capable of detecting smoke and fire. Early detection of such event is important fast and immediate remedial measures. As in such application, the monitoring area can very large, hierarchical routing protocols are needed to cover such large area with right clustering topology to help reducing the amount of communication needed and in turn saving energy.

As it has been shown that LEACH protocol provide better performance than Directed Diffusion, LEACH will be considered for routing data in our system. However, due to several limitations of LEACH, it needs for enhancement in order to minimize energy consumption and reduce interference among sensors, which leads to maximizing the lifetime of WSNs.

As LEACH is a single-hop protocol, if the CH is located far away from the sink node, it consumes more energy and dies early causing serious reduction in the network performance. Mixing between direct sending and multi-hop communication between CHs and base station (sink) along with an efficient deployment strategy, where nodes are clustered in one-hop only (see Figure 8), can improve the overall network performance and lifetime. A strategy that ensures a minimal distance to neighbor nodes can reduce the possibility of message might be lost among nodes. In addition, efficient clustering reduces the radio interference, consequently reduces the time that sensors have to wait to transmit data. Furthermore, a good clustering strategy can help in making a network scalable and in facilitating data aggregation that leads to significant reduction in the amount of processing cycles and energy. This can provide a longer lifetime for WSNs.

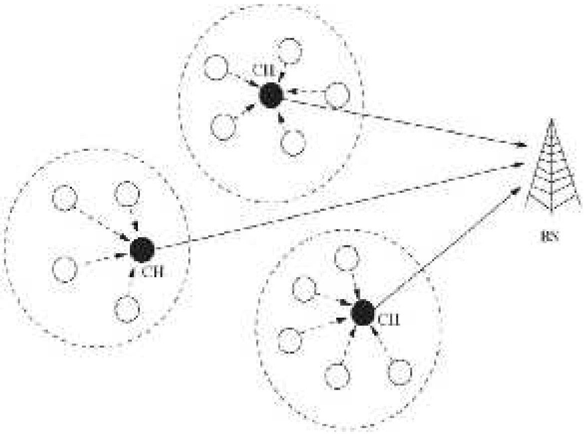


Figure 8: Nodes Clustered in One-hop Communications with BS

Avoiding the process of the periodical election of the cluster head can also be an advantage to the lifetime of the network. This can be done by the base station (as it has much more resources) in the setup phase by allocating specific time periods for nodes to be as CHs (according to their distance and energy) and advertises this information earlier to sensing and reporting data.

For data propagation in a WSN, the improved LEACH concerns energy-efficient and energy balance where it has to ensure that the average energy dispersion is equivalent in every node in the network. In developing the improved LEACH, it is assumed nodes placement and event generation in the network are random uniform. When a data message arrives at a node, it will be either propagated one-hop or multi-hops on the way (or recurrent way) to the BS (depends on the transmission rate announced by BS according to network condition), or sent straightly to the BS. The option of whether to send one-hop, multi-hops, or directly to BS should be performed locally at each node in a probabilistic fashion. Crucial events are assumed to take place at random uniform locations in the network area. Let n be the number of stationary sensor nodes deployed randomly uniformly, therefore, the number of nodes in a specific area is relative to the size of the area. The BS is the sink node that collects information about the developed event. The BS has very powerful resources such as energy and computing power. Sensor nodes are aware of their distance to the BS which is provided during the establishment stage when the BS broadcast control messages to all nodes in the network.

It is also assumed that nodes can have various transmission ranges (R and R‘ • R), where R‘ is the smallest integer not less than the fraction of the sensor’s distance from the BS (d) over R that set by operator. That is it, the ceiling (d/R).

LEACH assumes a robust network model, in which all sensors can reach the BS in one-hop. Nevertheless, with this strong assumption, LEACH then is not an energy balanced protocol. It is our believe that, considering a satisfactorily wide angle φ and/or by making several sets of hierarchical slices, the entire monitoring area can be covered without aggregating R` beyond the maximum acceptable transmission range.

As presented in Figure 9, from the BS perspective and according to the definitions below, the area is covered by a disk sector of angle φ. The sector is divided into m tires (or slices). The outer slice has a transmission range of R. Any other slice or tire Ti (2 ≤i ≤ m) is defined by two consecutive tires, one of transmission range R‘ • R and the other of transmission range R‘‘ • R (where R‘‘=i-1).

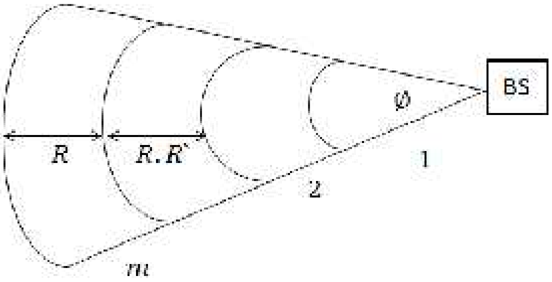


Figure 9: Network with Angle φ and m Slices of Different Transmission Ranges

Definition 1

The zone bounded by two successive disk sectors is called a Tire (or slice). The tire with center the BS, and range equal to R, is called T1. Thus, the ith tire of the network is Ti where $1 \le i \le m$.

Definition 2

The size of the tire Ti of the network is Si where $1 \le i \le m$.

Since the energy dissipation is of concern, it is assumed that one receipt for each transmission and that the energy consumption of a node when sending data is relative to the square of the distance to the BS. As the potential system concerns monitoring the temperature (constant value), the size of messages should be constant. It is also assumed that the event is sensed by several sensor nodes. In each tire, Ti, every node sensing the event generates data that need to be sent to the BS.

To achieve load balancing, each event data in Ti is propagated to another tire Ti-x, (where x present the next hop) in the direction of the BS with probability Pi. Nevertheless the event data are propagated directly to the BS when the probability is 1−Pi. Probability Pi for tire Ti is computed so that the average energy depletion per node is the same for the whole network. It is important to mention that, if Pi increases, more local transmissions will take place, therefore energy consumption is low. Though, nodes near the BS are going to be overused as all messages will pass over them. Conversely, if Pi decreases, more direct remote transmissions will happen that causes much energy consumption. Yet, propagation will be faster and nodes near the BS are bypassed. Scheming the proper probability Pi for each tire Ti and tackling issue of energy balance are crucial for efficient data propagation and better lifetime of WSNs.

In order for improved LEACH to ensure that only one “next-hop” node receives the propagated message, BS locates a “next” node to be transmitted to, and inform the corresponding CH of the ID of the next node. Since the powerful BS aware of the network resources, it is responsible of electing CHs and assigning time slot for them during the setup phase.

Thus, the improved version of LEACH protocol is considered a distributed protocol in the sense that each node selects the propagation probability independently based on local information as Pi depends on the distance from the BS only.

6. CONCLUSION AND FUTURE WORK

In spite of the fact that sensor networks have the ability to monitor real world status carefully, nevertheless, the deployment of such networks requires a lot of cost and work. It also can be a difficult task when the real world event causes bugs that degrades performance. Thus, it is important to investigate sensor networks in a simulated environment to identify the problems that might appear during deployment and provide suggestion to improve the performance of the network. Pre-deployment testing of wireless sensor networks in simulation, such as NS-2, can help detect problems that may occur during deployment. Therefore, in this paper two methods of gathering and reporting data of interest were discussed in addition to the common protocols used along with these methods, namely LEACH and Directed Diffusion. These protocols were investigated in terms of three performance metrics packet delivery ratio, routing load, and average end-to-end delay. It was found that LEACH presents better performance compared to Directed Diffusion for event tracking applications. Nevertheless, LEACH does not provide optimal solution when it comes to energy efficiency. The energy issue is important matter due to the nature of wireless sensor network deployment in the dense and scattered. Thus, an enhancement of LEACH was presented in this paper that supports scalability and can help to improve the efficiency of data aggregation and network lifetime.

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