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An Integrative Comparison of Energy Efficient Routing Protocols in Wireless Sensor Network

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ABSTRACT

Many advances have been made in sensor technologies which are as varied as the applications; and many more are in progress. It has been reasonable to design and develop small size sensor nodes of low cost and low power. In this work, we have explored some energy-efficient routing protocols (LEACH, Directed Diffusion, Gossiping and EESR) and their expansions (enhancements), and furthermore, their tactics specific to wireless sensor network, such as data aggregation and in-network processing, clustering, different node role assignment, and data-centric methods. After that we have compared these explored routing protocols based on different metrics that affect the specific application requirements and WSN in general.

Keywords: Wireless Sensor Network; Routing Protocol; Energy Consumption; LEACH; Directed Diffusion; Gossiping; EESR

1. Introduction

Wireless Sensor Networks consist of tiny sensor nodes that, in turn, consist of sensors (temperature, light, humidity, radiation, and more), microprocessor, memory, transceiver, and power supply. In order to realise the existing and potential applications for WSNs, advanced and extremely efficient communication protocols are required. WSNs are application-specific, so the design requirements of WSNs change according to the application. Hence, routing protocols' requirements are changed from one application to another. For instance, the requirements of a routing protocol designed for environmental applications is different from that designed for military or health applications in many aspects. As a result, routing protocols' requirements are as diverse as applications'. Some of these are: Scalability, Latency, Throughput, Recourse Awareness, Data Aggregation, Optimal Route, over-head, and other metrics. Some applications need some of these metrics to be provided and other applications need others to be provided. However, routing protocols of all Wireless Sensor networks, regardless of the application, must try to maximise the network life time and minimise the energy consumption of the overall network. For these reasons, the energy consumption parameter has higher priority than other factors.

2. Routing Protocols in Wireless Sensor Network

Due to these differences, many new algorithms have been proposed for the routing problem in WSNs, taking into account the inherent specification of WSNs along with the application and architecture requirements.

2.1. LEACH Protocol

Low-Energy Adaptive Clustering Hierarchy (LEACH) is a clustering based protocol that uses a randomised rotation of local cluster base stations. The nodes in LEACH are divided into clusters and each cluster consists of members called Cluster Members and a coordinator node called the Cluster Head, CH. The cluster heads are not selected in the static manner that leads to quick die of sensor nodes in the network. However, the randomised protocol has been used in order to balance the energy consumption among the nodes by distributing the CH's role to the other nodes in the network. Furthermore, LEACH uses Time Division Multiple Access (TDMA) protocol in order to regulate the channel access within a cluster [1].

It is the responsibility of the CHs to assign TDMA slots to the cluster members. The peer to peer communication between the CH and a member is done just during the time slot that assigned to that member, and the other members will be in their sleep state. Hence, it decreases the energy dissipation; see **Figure 1**. Moreover, LEACH uses the TDMA communication protocol to decrease the interference between the clusters.

LEACH has been produced to overcome the disadvantages of the Flat-Architecture Protocols that consume

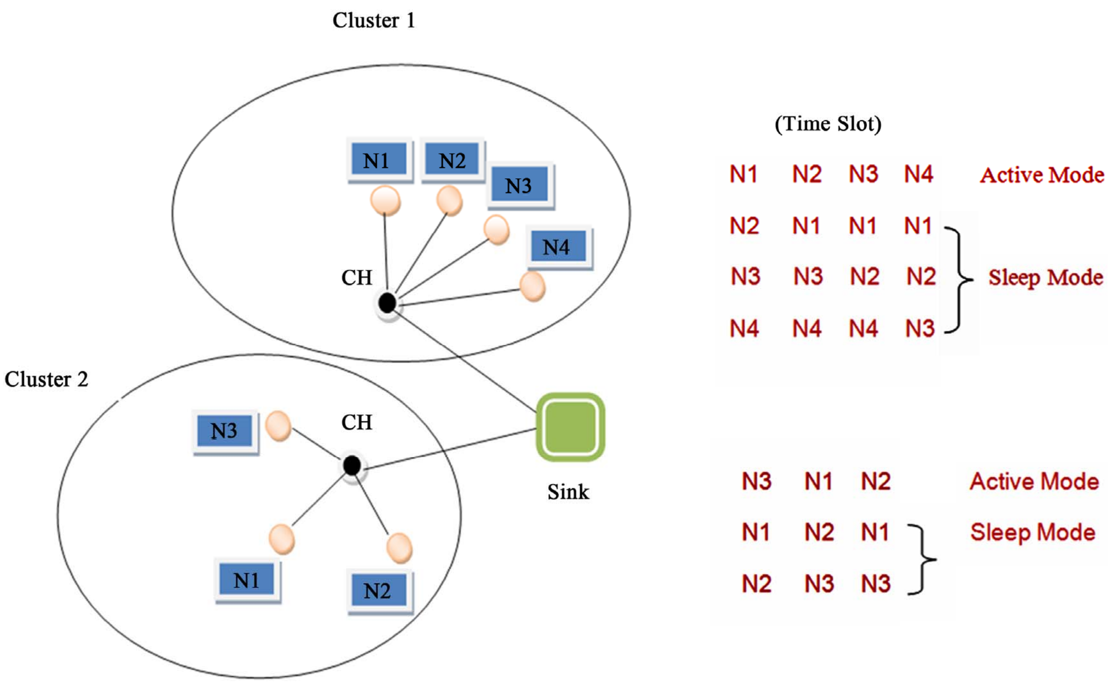

Figure 1. LEACH protocol and TDMA schedules

more energy [2]. The CH aggregates/combines the collected data by the nodes to the smaller size and meaningful data, and then sends the aggregated data to the sink consuming less energy. LEACH tries to send the data over short distances and reduce number of the transmissions, where the energy consumptions depend on the distance and data size. As a result, the main problem with LEACH is the direct sending of CH to the sink, especially when these CHs are located far away from the sink. However, allowing the multi-hop transmission to the sink through other CHs will solve this issue, where the CH just forwards the data to others until it reaches the sink and does not have to re-aggregate the data come from other CHs.

LEACH, compared to the direct communication and other minimum energy routing protocols, achieves a significant reduction in energy dissipation. Finally, the main properties (advantages and disadvantages) of LEACH include [1,2].

2.2. Advantages of LEACH

- It limits most of the communication inside the clusters, and hence provides scalability in the network.
- The CHs aggregates the data collected by the nodes and this leads to a limit on the traffic generated in the network. Hence, a large-scale network without traffic overload could be deployed and better energy efficiency compared to the flat-topology could be achieved.
- Single-hop routing from node to cluster head, hence saving energy.
- Distributiveness, where it distributes the role of CH to the other nodes.
- It increases network lifetime in three ways. Firstly, distributing the role of CH (consumes more energy than normal nodes) to the other nodes. Secondly, aggregating the data by the CHs. Finally, TDMA, which, assigned by the CH to its members, puts most of the sensor in sleep mode, especially in event-based applications. Hence, it is able to increase the network lifetime and achieve a more than 7-fold reduction in energy dissipation compared to direct communication [1].
- It does not require location information of the nodes to create the clusters. So, it is powerful and simple.
- Finally, it is dynamic clustering and well-suited for applications where constant monitoring is needed and data collection occurs periodically to a centralised location.

2.3. Disadvantages of LEACH

- It significantly relies on cluster heads and face robustness issues such as failure of the cluster heads.
- Additional overheads due to cluster head changes and calculations leading to energy inefficiency for dynamic clustering in large networks.
- CHs directly communicate with sink—there is no inter cluster communication, and this needs high transmission power. Hence, it does not work well in large-scale networks that need single-hop communication with sink.

- CHs are not uniformly distributed; CHs could be located at the edges of the cluster.
- CH selection is random, which does not take into account energy consumption.
- Finally, it does not work well in the applications that cover a large area that requires multi-hop inter cluster communication.

2.4. Improvements of LEACH

Due to some drawbacks of LEACH, much research has been done to make this protocol perform better. Some of these pieces of research are: E-LEACH, TL-LEACH, M-LEACH, LEACH-C and V-LEACH [3].

2.4.1. E-LEACH

Energy-LEACH protocol improves the CH selection procedure. Like LEACH, it divided into rounds, where in the first round all nodes have the same probability to be CH. However, after the first round the remaining energy of each node is different and the node with high residual energy will be chosen as CH rather than those with less energy [4].

2.4.2. TL-LEACH

in LEACH, the CH sends the data to the base station in one hop. However, in Two-Level LEACH, the CH collects data from the cluster members and relays the data to the base station through a CH that lies between the CH and the base station [5].

2.4.3. M-LEACH

As mentioned above, in LEACH, the CH sends the data to the base station in one hop. In Multi-hop-LEACH protocol, the CH sends the data to the sink using the other CHs as relay stations [6]. In this protocol, the problem with CHs that are away from the base station, where they were consuming huge amounts of energy during data transmissions, has been solved.

2.4.4. V-LEACH

In the new Version of LEACH protocol, in addition to having a CH in the cluster, there is a vice-CH that takes the role of the CH when the CH dies [7]. When a CH dies, the cluster become useless, because the information collected by the node members will not reach the sink.

2.4.5. LEACH-C

LEACH has no knowledge about the CHs places. However, Centralised LEACH protocol can produce better performance by distributing the cluster heads throughout the network. During the set-up phase, each node sends to the sink its remaining energy and location. The sink then runs a centralised cluster formation algorithm to determine the clusters for that round. However, since this protocol requires location information for all sensors in the network (normally provided by GPS), it is not robust [8].

2.5. Directed Diffusion

Directed diffusion is data-centric routing protocol for collecting and publishing the information in WSNs. It has been developed to address the requirement of data flowing from the sink toward the sensors, *i.e*., when the sink requests particular information from these sensors [9]. Its main objective is extending the network life time by realising essential energy saving. In order to fulfil this objective, it has to keep the interactions among the nodes within a limited environment by message exchanging. Localised interaction that provides multi-path delivery is a unique feature of this protocol. This unique feature, with the ability of the nodes to respond to the queries of the sink, results in considerable energy savings [10].

In order to construct the route between the sink (inquirer) and the sensors that interest to the sink's request, there are four stages; (A) interest propagation, (B) gradient setup, (C) reinforcement, and (D) data delivery. Below is a detailed description for each stage:

1) *Interest propagation*: when a sink detects an event, it initiates the *interest messages* and floods them to all nodes in the network. These messages are exploratory messages indicating the nodes with matching data for the specific task. During this stage, the sink periodically broadcasts the interest message. Once the interest message is received, each sensor node saves it in an interest cache. After that, the nodes flood this message to the other nodes until the node that is interested in this interest message; see **Figure 2(a)**.

2) *Gradient setup*: based on local rules, different techniques are used in gradient setup. For example, the nodes with highest remaining energy could be chosen when setting up the gradient. During the interest propagation through the network, the gradients from source back to sink will be setup. A node becomes a source node if its observation matches the interest message and sends its data through the gradient path back to the sink as shown in **Figure 2(b)**.

3) *Reinforcement*: during the gradient setup phase, many paths have formed from the source to the sink. This means the source can send the data to the sink through multiple routes. However, as shown in **Figure 2(c)**, the sink reinforces one specific path by resending the same interest through the specified path, which is chosen based on many rules, like the best link quality, number of packets received from a neighbour, or lowest delay. Along this path, each node just forwards the reinforcement to its next hop [10]. Finally, during this phase, the sink could select multiple paths in order to provide multi-path delivery.

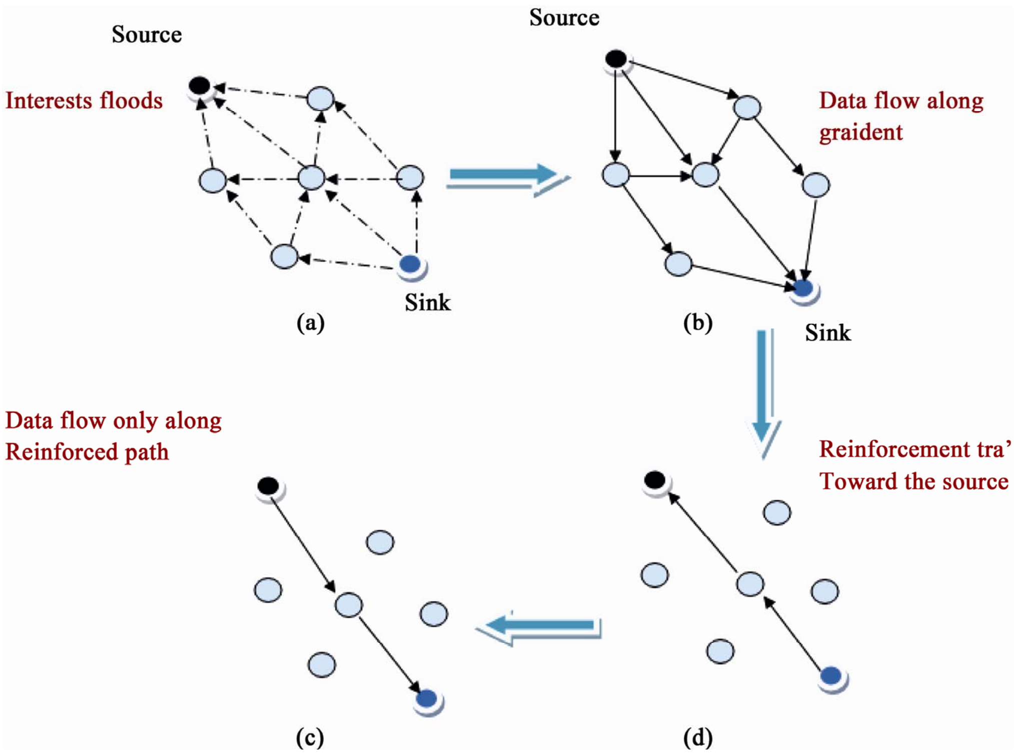

Figure 2. Operation of the directed diffusion protocol.

4) ***Data delivery*****:** after the reinforcement phase, as shown in **Figure 2(d)**, the route between the source and the sink has been constructed and the data is ready for transmission. As a result, we can say the Directed Diffusion is characterised by these following specifications [11,12]:

2.5.1. Advantages of Directed Diffusion

- It is designed to retrieve data aggregates from a single node.
- Data is named by attributed-value pairs.
- It works well in multipurpose wireless sensor networks and in sensor networks that query, for example, "GIVE ME THE TEMPERATURE IN PARTICULAR AREA" or "WHO CAN SEE THE BLACK COW".
- Unlike other routing algorithms, in Directed Diffusion more than one sink can make queries and receive data at the same time; hence, simultaneous queries could be handled inside a single network.
- The interests/queries are issued by the sink not by the sources, and only when there is a request. Moreover, all communication is neighbour-to-neighbour, which removes the need for addressing and permits each node to aggregate data. As a result, both points contribute to reduce energy consumption.
- It provides application-dependent routes based on the interests of the user.
- It requires neither a global node addressing mechanism nor a global network topology. Moreover, the routes are formed only when there is an interest. As a result, it achieves energy efficiency.
- In order to satisfy the user's requests, network routes are changed according to sensor reading changes.
- The nodes that have matching information are only the nodes that involved in the information generation.
- It mostly selects a specific route for the interest. Hence, it decreases the energy consumption in the network.

2.5.2. Disadvantages of Directed Diffusion

- It is, generally, based on a flat topology. Hence, scalability and congestion (especially in the nodes that near to the sink) problems exist.
- An overhead problem occurs at the sensors during the matching process for data and queries.
- In Directed Diffusion, the initial interest contains a low data rate. However, an important overhead is caused during flooding operation of interest propagation phase.
- Due to the flooding required to propagate the interest on each node, it is not optimised for energy efficiency and need high amounts of memory to store interest gradients and received messages.
- It mostly selects the shortest path between the source and the destination, which leads to quick death of

nodes on that path [12].
- Finally, Directed Diffusion is a query-based protocol. It may be not work well in applications where continuous data transfers are required (dynamic applications); for instance, environmental monitoring applications.

2.6 Gossiping Protocol

Gossiping is data-relay protocol, and, like Flooding protocol, does not need routing tables and topology maintenance. It was produced as an enhancement for Flooding and to overcome the drawbacks of Flooding, *i.e.*, implosion. In Flooding, a node broadcasts the data to the all of its neighbours even if the received node has just received the same data from another node. The broadcasting will continue until the data is received by the destination [11]. However, in Gossiping, a node randomly chooses one of its neighbours to forward the packet to, and once the selected neighbour node receives the packet, it chooses, in turn, another random neighbour and forwards the packet to them. This process will continue until the destination or number of hops has been exceeded. As a result, only the selected nodes/neighbours will forward the received packet to the sink. Unlike Flooding, Gossiping serves well at one-to-one communication scenarios but it does not at one-to-many. Packet forwarding mechanisms for both Flooding and Gossiping are shown in **Figure 3** [13].

The main objective of Gossiping was reducing the power consumption and keeping the routing system as simple as possible. However, it suffers from the latency caused by the data propagation. The power consumed by Gossiping [14], is approximately equal to

$$O\ (K^L)$$

K: *Number of nodes that forward the packet.*
L: *Number of hops before the forwarding stops*.

The most considerable feature of Gossiping is the ability of controlling the power consumption by selecting appropriate K and L.

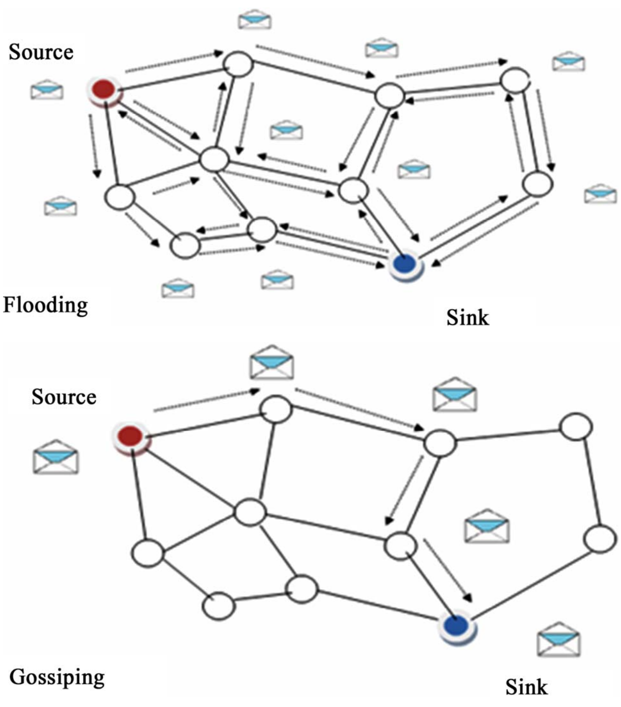

Figure 3. Forwarding mechanisms of both flooding and gossiping.

2.6.1. Advantages of Gossiping
- It is very simple and does not need any routing table and topology maintenance. So, it consumes little energy.
- It appeared as an enhancement to overcome the implosion that exists in Flooding.
- In Gossiping, only the selected nodes contribute in forwarding the data to the sink.
- It works well in applications that need one-to-one communication but it does not in one-to-many.

2.6.2. Disadvantages of Gossiping
- The next hop neighbour is randomly chosen, which means it may include the source itself.
- The packet will travel through these selected neighbours until it reaches the sink or number of hops exceeds
- It suffers from packet loss.
- The remarkable disadvantage of Gossiping is suffering from latency caused by data propagation.

2.6.3. Improvements in Gossiping
Finally, in order to enhance the Gossiping protocol, many protocols have been produced as an extension. For example FLOSSIPING, SGDF, LGOSSIPING and EL-GOSSIPING.

2.6.3.1. FLOSSIPING Protocol
It combines the approaches of both flooding and the gossiping routing protocols. When a node has a packet to send, it decides a threshold and saves it in the packet header, then randomly selects a neighbour to send the packet to in Gossiping mode, while the other neighbour nodes listen to this packet and generate a random number. The neighbours whose generated random numbers are smaller than the threshold will broadcast the packet in Flooding mode. As a result, Flossiping improves the packet overhead in Flooding and the delay issue in the Gossiping [13].

2.6.3.2. SGDF Protocol
Single Gossiping with Directional Flooding routing protocol divided into two phases; Network Topology Initialisation and Routing Scheme. In the first phase, each

node generates a *gradient* (shows number of hops to the sink). In the second phase, in order to deliver the packet, SGDF uses single gossiping and directional flooding routing schemes. As a result in **Figure 4**, SGDF achieves high packet delivery ratio, low message complexity, and short packet delay [13].

2.6.3.3. LGOSSIPING Protocol [15]

In Location based Gossiping protocol, when a node has an event to send, it randomly chooses a neighbour node in its transmission radius. Once the neighbour node receives this event, it, in turn, randomly chooses another node within its transmission radius and sends it. This process will continue until the sink. As a result, the delay problem has been solved to some extent. **Figure 5** shows the main objective of LGOSSIPING.

2.6.3.4 ELGOSSIPING Protocol [16]

In ELGOSSIPING protocol, when a node detects an event and want to send, it selects a neighbour node within its transmission radius and the lowest distance to the base station/sink. Once the neighbour node receives the event, it, in turn, selects another neighbour node within its transmission radius and also the lowest distance to the sink. The event will travel in the same way until the sink. As a result, the problem of the latency and situation of non-reaching packets has been solved to some extent. See **Figure 6**.

2.7. Energy Efficient Sensor Routing Protocol

Energy-Efficient Sensor Routing (EESR) is a flat routing algorithm [17] proposed especially to reduce the energy consumption and data latency, and to provide scalability in the WSN. Mainly, it consists of *Gateway*, *Base Station*, *Manager Nodes*, and *Sensor Nodes* [18]. Their duties are:

- ***Gateway***: Deliver messages from Manager Nodes or form other networks to the Base Station.

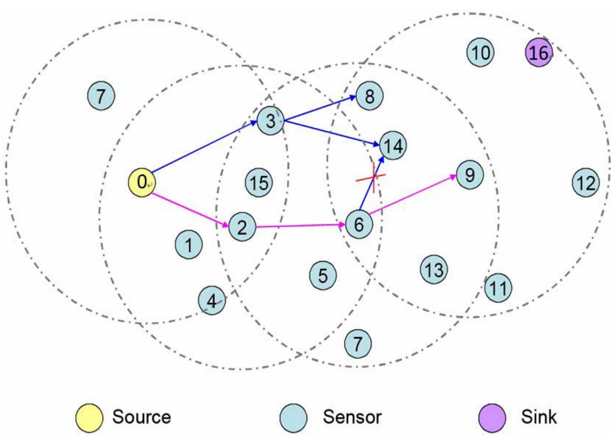

Figure 4. Routing scenario in SGDF.

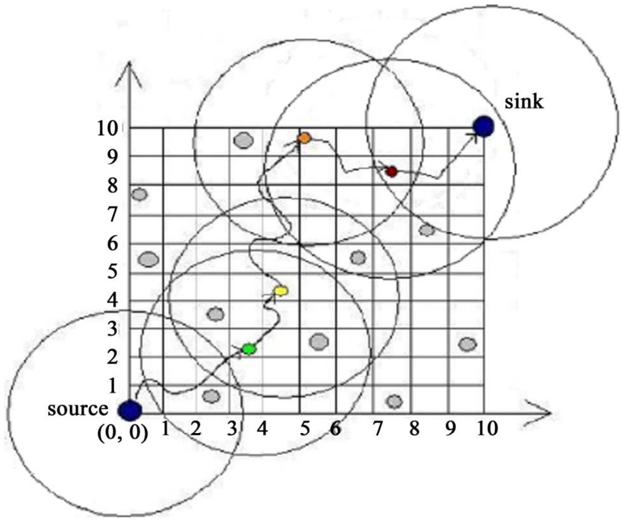

Figure 5. Schematic of data routing in LGOSSIPING.

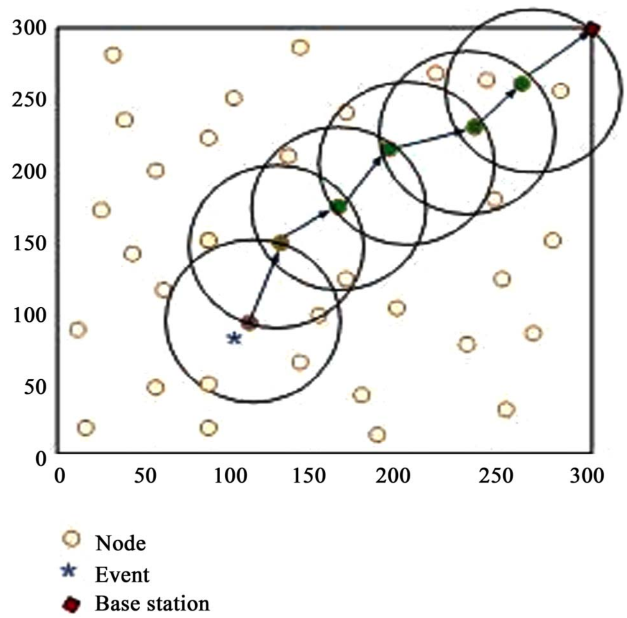

Figure 6. Routing in ELGOSSIPING.

- ***Base Station***: Has extra specifications compared to normal sensor nodes. It sends and receives messages to/from the Gateway. Moreover, it sends queries and collect data to/from sensor nodes.
- ***Manager Nodes and Sensor Nodes***: Collect data from the environment and send it to each other in 1-Hop distance until the Base Station.

Application area is divided based on the 2-dimensional (x, y) coordinates into four quadrants; (+ +), (+ –), (– –), and (– +), and the Base Station is located in the centre (at coordinate). Furthermore, each quadrant, in turn, is divided into sectors, locating the Base Station in the middle, their numbers determined by minimum hops required to deliver a message from the base station to the farthest position in the quadrant. Manager Nodes are located (predetermined) in the centre of each sector on the diagonal line of the quadrant with 1-hop distance between each other. Finally, the other nodes are randomly distributed in the application area; see **Figure 7** [17].

As shown in **Figure 7**, each quadrant has three sectors because the Base Station can communicate with the furthest node in a minimum of 3-hops. Each sector has its own ID, gathered it from Base Station, determined by the quadrant name and the distance from the base station. For example, 1-hop distance sectors names are (+1 +1) sector, (+1 –1) sector, (–1 –1) sector, and (–1 +1) sector.

Each sensor node constructs its EESR table, as shown in **Table 1**, by broadcasting a "HELLO" message within 1-hop neighbour. The table contains distance from the base station, Quadrant Names, Sector ID and Manager Node Names.

2.7.1. The Algorithm

After the nodes are deployed, the Base Station sends the relative direction information and sector ID of each node, then each node constructs its EESR table. Once a node detects an event, in order to select the next node to deliver the event, it investigates the sector ID of all neighbour nodes within 1-hop in its EESR table. The node selects its next node in one of these three procedures:

- If a Manager node is within 1-hop distance, it will be the next hop.

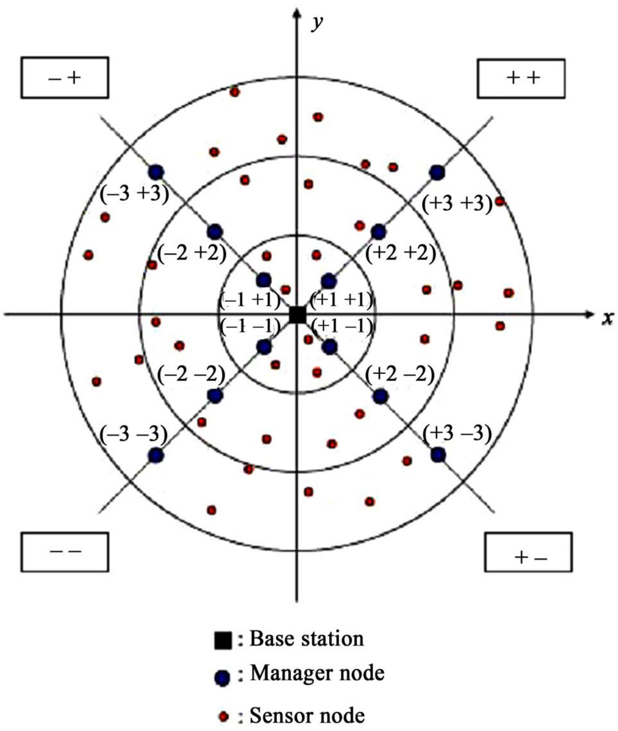

Figure 7. Locations of the nodes based on 2-dimensional (x, y) Coordinates.

Table 1. Quadrant names, sector ID, and manager node names.

Distance from the base station	Quadrant name	Sector ID	Manager Node name
1 hop	(+ +)	(+1+1)sector	+1 +1M.N
	(+ –)	(+1 –1)sector	+1 –1M.N
	(– –)	(–1 –1)sector	–1 –1M.N
	(– +)	(–1 +1)sector	–1 +1M.N
2 hop	(+ +)	(+2 +2)sector	+2 +2M.N
	(+ –)	(+2 –2)sector	+2 –2M.N
	(– –)	(–2 –2)sector	–2 –2M.N
	(– +)	(–2 +2)sector	–2 +2M.N
3 hop	(+ +)	(+3 +3)sector	+3 +3M.N
	(+ –)	(+3 –3)sector	+3 –3M.N
	(– –)	(–3 –3)sector	–3 –3M.N
	(– +)	(–3 +3)sector	–3 +3M.N

- If there is no Manager node, it will check for a normal 1-hop distance node that exists on the same sector to be the next hop.
- Otherwise it will look to another node that lies out of its sector but close to the Base Station to be the next hop. The nodes that lie on the same quadrant are the preferred ones

After selecting its next neighbour node, the first node will send the event only to this selected node. Once the selected node receives the event, it, in turn, repeats the same procedure to select its next 1-hop and send the event. This process will continue until the Base Station receives the event. However, if a Manager Node receives the event, the event will transmit from manager-manager until the Base Station [17].

2.7.2. Advantages of EESR

- It divides the application area into sectors; hence, it is scalable.
- It energy-efficient and achieves this feature in three ways: firstly, it sends the event to the just one node and does not flood it; secondly, Manager Nodes relay the data in a predefined shortest path; and finally, after sending the first event, normal nodes will easily select the next node by using their EESR tables. As a result, it consumes little energy and prolongs the network life time.
- It uses one-one communication. Moreover, after sending the first event, the next hop will be found easily. As a result, it is low latency.
- In order not to send the data through a same route and exhaust energy of these nodes, sometimes, it chooses other routes to deliver the data.

2.7.3. Disadvantages of EESR

- All 1-hop nodes of the event detected node could be out of it transmission range. So, it has no specific criterion to select the next node [19].

- If a node located in the furthest sector detects an event and the next hop is located in the lower sector, the data will be lost in the case where the lower node's energy has had finished.
- If the normal nodes that are located in the furthest sector detect an event and accidently every time their next hop is a Manager Node, the energy of these Manager Nodes will exhaust earlier, because they will send the event manager-manager until the Base Station.
- There is no balance in energy consumption, *i.e.*, some nodes consume their energy before other nodes.

2.7.4. Improvement of EESR

Due to these drawbacks, I proposed a new optimal routing algorithm in EESR by creating concentric sectors.

Our first Solution: is increasing number of the *Highways* (diagonals) in each quadrant as shown in **Figure 8**. In this solution, the second and the third problems (mentioned above in the disadvantages of EESR) have been solved. However, the first problem is the most important issue that needs to be solved.

Our second Solution: is fairly determining a number of *relay nodes* (Manager Nodes) in each secto regardless of the highways, as shown in **Figure 8**. In this solution, the first and the last problems have been solved [19].

The routing process of this enhancement protocol is as shown in the following flow chat in **Figure 9**.

3. Comparison of Explored Routing Protocols

During this research, many differences have been observed, generally between flat and hierarchical routing protocols and, precisely, among these researched routing protocols. When compared to the other protocols, Gossiping is very simple and does not need any routing table

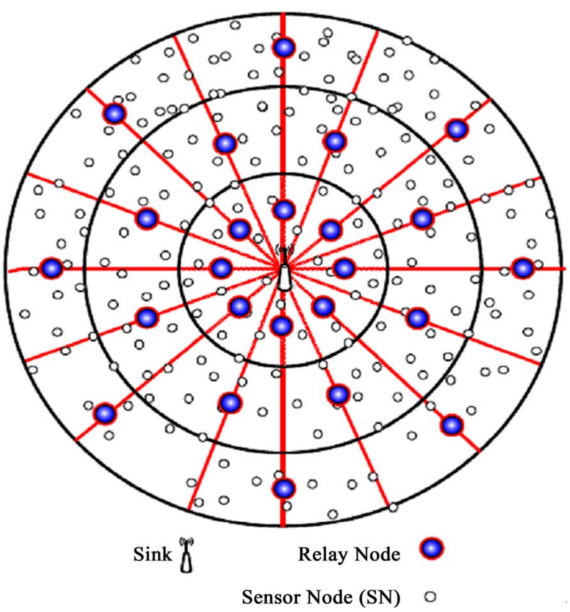

Figure 8. Network with 16 highways.

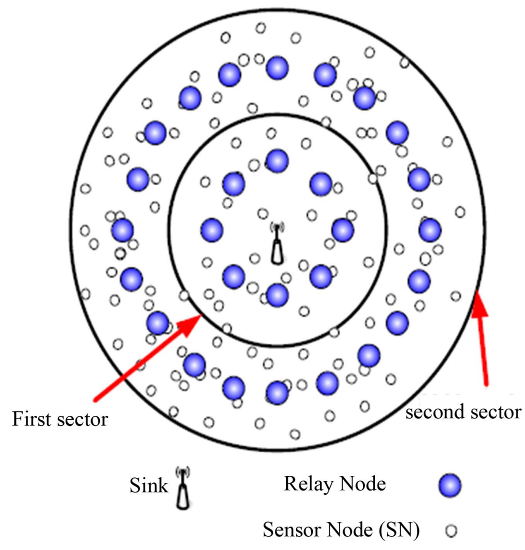

Figure 9. Rely nodes in each sector.

or topology management. It provides very high connectivity, where as soon as a node becomes aware of its neighbours it is able to send and forward packets. Gossiping protocol is based on the flooding protocol. Instead of broadcasting each packet to all neighbours, the packet is sent randomly to a single neighbour, meaning only one copy of a packet is in transit at any one time. Having received the packet, the neighbour chooses another random node to send it to. However, this can include the node which sent the packet itself. This process continues until the packet reaches its destination or the maximum hop count of the packet is exceeded. As a result, compared to LEACH, Directed Diffusion nor EESR Protocols, Gossiping uses a medium amount of power and it appears to evaluate the improvements over Flooding, not over LEACH, Directed Diffusion and EESR. Gossiping, compared to other Protocols, suffers from quite high latency because of the data propagation through network (one to one communication) and the hop count could become quite large due to the random nature of the protocol. As the number of nodes in a network increases, the number of paths that a packet can follow increases. On average, the number of hops taken to traverse the network increases. Hence, packets are dropped when the packets hop count reaches a maximum value. In larger networks it is more likely that a packet's hop count will reach this value and so more packets are dropped. In smaller networks, roughly half of the packets sent are lost, and in larger networks the loss rate increases drastically. As a result, the Gossiping protocol is the worst protocol in terms of loss of data packets. Hence, Gossiping is not Scalable like LEACH, Directed Diffusion and EESR. As a result, we summarised all that was mentioned above in two tables; **Table 2** [20], shows a general comparison of different routing approaches for flat and hierarchical sensor networks, and **Table 3** shows how

Table 2. General comparison between flat and hierarchical routing protocols.

Hierarchical Routing	Flat Routing
Reservation-based scheduling	Contention-based scheduling
Collisions avoided	Collision overhead present
Reduced duty cycle due to periodic sleeping	Variable duty cycle by controlling sleep time of nodes
Data aggregation by cluster-head	Node on multi-hop path aggregates incoming data from neighbours
Simple but non-optimal routing	Routing can be made optimal but with an added complexity.
Requires global and local synchronisation	Links formed on the fly without synchronisation
Overhead of cluster formation throughout the network	Routes formed only in regions that have data for transmission
Lower latency as multiple hops network formed by cluster—heads always available	Latency in waking up intermediate nodes and setting up the multipath
Energy dissipation is uniform	Energy dissipation depends on traffic patterns
Energy dissipation cannot be controlled	Energy dissipation adapts to traffic pattern
Fair channel allocation	Fairness not guaranteed

Table 3. Comparison between LEACH, directed diffusion and gossiping routing protocols.

	LEACH	Directed Diffusion	Gossiping	EESR
Class	Hierarchical	Flat	Flat	Flat
Scalability	High (Divides the nodes into clusters)	Limited (Due to flat topology nature)	Limited (Due to flat topology nature)	High (Divides application area to sectors)
Life Time	Very Good (Due to TDMA, most of the sensors are in sleep mode and distributing the role of CH to other nodes)	Good (Demand-based andneighbour-neighbour Communication)	Medium (It suffers from high latency)	Very Good (Due to predetermined allocation of M.N. and using sectors)
Energy efficient	YES (Single-hop routing from node to cluster head)	YES (mostly selects a specific route for the interest and routes are formed only when there is an interest)	Medium (Not like LEACH or EESR. However, no routing table and topology maintenance)	YES (It sends only to 1-hop neighbours and chooses different routes to deliver data)
Data aggregation	YES (data aggregated by CHs)	YES (each node aggregate data then relay it to the next hop)	NO (The nodes that participate in data delivery are just relay stations)	YES
Negotiation-based	NO (According to signal strength)	YES (Negotiation is done during Gradient setup phase)	NO (A node randomly selects a neighbour node to send)	YES (constructing EESR table finding the optimum route)
Recourse Awareness	YES	YES	NO	NO
Hop Comm.	Single-Hop (Member-CH and CH-BS)	Multi- Hop (From source to BS through other nodes)	Multi-Hop (From source to BS through other nodes)	Multi-Hop (Each time 1-hop till B.S.)
Optimal Route	NO (Member has one chance relay to CH)	YES (Reinforcement phase)	NO (Randomly select)	YES (Every time checks its EESR table to find better Sector ID)
Latency	Little (Node directly sends its data to CH)	High (due to the flooding during interest propagation)	Very High (Due to data propagation)	Little (No overhead, and after the first event, the next hop will be found easily)
Throughput	Very high (No delay and only one node accesses the channel at a time)	Acceptable	Low (Due to the high delay)	High (Select optimum path, no delay, no overhead)
Overhead	NO (CH aggregates the data of many nodes)	YES (Overhead during the matching process for data and queries)	NO (it sends to a neighbour node directly)	NO (One to one communication)

Continued

-based	Event-based (Only when an event occurs does the sensor detect it)	Query-based (The queries are issued by the user only when there is a request)	Event-based (only when an event occur the sensor detect it)	Event-based (Only when an event occur the sensor detect it)
Applications	Monitoring app. (Dynamic app. -If an event occurs a node detect it)	Multi-purposes Applications (more than one sink can make queries and receive data at the same time)	Application need (one-to-one communication)	Monitoring app. (Dynamic app.)
App. Type	Health monitoring (artificial Retina)	Environmental monitoring (PODS Hawaii)	Environmental monitoring or during deployment phase and network initialisation	Environmental monitoring, *i.e.*, Agricultural application

these researched routing protocols (LEACH, Directed Diffusion, Gossiping and EESR) fit under different categories and also compares these routing techniques according to many metrics.

With some changes in Gossiping Protocol, we can decrease the energy consumption and also increase Network lifetime. Therefore, in order to enhance the drawbacks of Gossiping Protocol, many new protocols have been proposed as an extension for Gossiping: for example, Flossiping, SGDF, LGossiping and ELGossiping:

Flossiping combines the two protocols of Flooding and Gossiping. In this protocol, the overheads that exist in the flooding and the delays that exist in gossiping have been improved. However, the power consumption and packet delay time in this protocol are the same as the flooding and the gossiping routing protocols.

(*SGDF*) Single Gossiping with Directional Flooding routing protocol achieves high packet delivery ratio, low message complexity, and short packet delay. However, the ill side effect of this protocol is that the amount of packets becomes larger during packet delivery because of the directional flooding.

LGossiping Although in this protocol the delay problem has been solved to some extent, there is still the problem of non-reaching of many events to the main station. Moreover, this protocol uses GPS to determine the location of each node. Hence, additional hardware means extra money.

ELGossiping is proposed to improve the LGossiping protocol. It has improved the network life time and has solved the delay of delivering the packets to the Base Station and non-reaching packets to some extent, but not completely. In this protocol, two important metrics have been exploited: energy and distance to the base station; and in this way, when a node detects an event within its transmission range, it sends the data to a neighbour node that has lower distance to the sink.

4. Conclusion

Wireless Sensor Networks are powered by a limited capacity of batteries. Because of the power management activities of these sensor nodes, the network topology dynamically changes. These essential properties pose additional challenges to the communication protocols. In this article we studied the operation of routing protocols with safe energy consumption and discussed impact factors in energy optimisation. With a little care in Gossiping protocol we can find that by making some changes in choosing of the next hop, the network lifetime can be increased.

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