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Improving fault tolerance and network lifetime using relays assisted data forwarding in WSN

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ABSTRACT

Wireless sensor network plays a pivotal role in gathering useful data through sensor nodes and using this information for efficient information processing. The supervision of these nodes, therefore, requires optimized algorithms for efficient data capture, data processing and information retrieval. To amplify the lifespan of the nodes, the researchers in the past have adopted for the clustering-based approaches. In this paper, the route maintenance mechanism has been defined where each sensor node and CHs locally select new disjoint routing paths/routes in the presence of node/link failures. This technique proposes a modification to an existing scheme by selecting the cluster heads in advance before the start of a new round of data gathering. This helps to avoid the broadcasting of ADV packets in the network. In addition, MDEEHC also allows the parent cluster heads to choose relay nodes from their clusters. These relay nodes are used to transmit the data of the child CH to the base station, thus reducing the load over the parent CH. we have implemented DEEHC and modification to existing DEEHC clustering algorithm. DEEHC defines the formation of k-vertex disjoint paths from cluster members to cluster heads and from CHs to sink node or base station. This procedure selects cluster heads considering the remaining energy of the nodes as a prime factor. M-DEEHC modifies the cluster formation of DEEHC algorithm as well as modifies the way the data is communicated from child cluster heads to the BS. The performance of the network was analyzed based on throughput, remaining energy, and packet delivery ratio.

Keywords— *DEEHC, Relay, ADV, LEACH Network, CH, Sensors*

1. INTRODUCTION

The basic motive as to why the WSNs are installed in the unfriendly surroundings is the gathering of useful information by the sensors and getting them transferred to the base station for useful interpretation. The prime concern here is how long actually the nodes can continue to collecting information and keep sending it to the BS. The answer lies in the fact that these nodes are battery-driven, so lesser the batteries used more efficient will be the network [3]. To increase the lifespan of the nodes, the researchers in the past have adopted for the clustering-based approaches. These approaches allow the nodes to work for a longer duration of time thus leading to lesser node failures occurring because of battery drainage. At this moment in time, maximum available sensor devices are significantly appreciated to the degree that computational power, memory, productivity and communication capabilities are concerned [11]. The vast majority of the examination on sensor networks has concentrated on the configuration of battery and computationally productive protocols. In addition, the application zone has been bound to basic data situated examination. In the event, that nodes are entirely extra capable of battery-powered devices in the area, it is helpful to habit their control and communication properties for difficult calculations and as entries to dissimilar methods [1].

The advancement of minimal effort, low-control, a multipurpose node has acquired scalating attention from diverse commercial ventures [4]. Sensors in the wireless system are tiny and are fit for sensing, accumulating and supervising data despite the fact that they are in communication with other connected sensors, by means of radio. The sensor network can be comprehensively perceived as devices starting from moveable workstations, PDAs or cell phones to the extremely little and basic sensing device.

2. LEACH PROTOCOL

LEACH is Low-energy adaptive clustering hierarchy, a clustering protocol that reduces dissipation of energy in sensor networks. LEACH is required because a network node is of no use after its battery is dead [2]. This protocol enhances the life of the nodes; it makes a node to work less during data transmission. The main aim of leach is to select random sensor nodes and set them as cluster head, so high-energy dissipation at the time of communication with the base station is given to every sensor node in the sensor network. LEACH network consists of nodes, some of them are known as cluster heads. The cluster head is used to accumulate data from its surrounding nodes and give it to the base station [7]. As the job of cluster head rotates, hence leach is dynamic in nature. The working of the leach protocol works in two phases:

- Set-up Phase - In LEACH we expect that each node starts with equally distributed energy. So arbitrarily, one node turns into the CH which has not already been CH previously and remaining hubs turn into the member nodes of the cluster [5]. To become CH is an energy concentrated function. In the event, if there are k nodes display in the system, at that point for the following round k-1 nodes have the likelihood to become the next CH node.
- Steady State Phase-In this stage transmission of data starts. The member nodes of the cluster transmit their detected data to the CH node in its TDMA slot [7]. After the calculation and data accumulation, the cluster head transmits it to the base station.

3. IMPLEMENTATION

The authors in "Energy-Aware Distributed Routing Algorithm to Tolerate Network Failure in Wireless Sensor Networks" have described clustering approach combined with k-vertex disjoint path routing procedure to increase the lifespan of the system. The defined clustering algorithm chooses the CHs to arrange an attached support system in which sensors create native conclusions if they should connect as a cluster head or member in the support system [10]. The result in an individual node is built on the basis of its present remaining battery. The kVDPR procedure in clustered sensor networks is described to select *k* separate paths amongst the cluster leaders and the base station. This is a disseminated method in which respective head independently chooses *k*-vertex separate paths agreeing to the remaining battery of their parent heads and amount of prevailing paths amongst them [8]. Lastly, Route maintenance mechanism has been defined in which respective sensor and heads choose novel separate routing pathways in the existence of sensor/connection faults.

In the first phase of the existing scheme, it talks about CH advertisement process in which every eligible node will transmit an announcement packet for the election of CH. In addition, after the expiration of the timer, the node broadcasts selection message again to inform others of its election as CH. This process will consume a large amount of energy, as so many nodes will be involved in the broadcasting process. In the existing scheme, the authors have described k-VDPR algorithm, which helps CHs to forward the data to the BS via other CHs. Since CHs already consume more energy (first in broadcasting the advertisement and selection messages and second in relaying the data of its member nodes to the BS), therefore, the focus must be given on alternate or modifying the current data relaying scheme.

3.1 Algorithm

1. Suppose 'N' is the number of the nodes in the network
2. For i=1: N
    a. If Remaining Energy(i) > Threshold
        i. Broadcast ADV packet in the communication range
    b. Else
        i. Do not opt for broadcasting
    c. End if
    d. If Remaining energy < Energy received in the ADV packet
        i. Withdraw from advertisement
    e. Else
        i. Continue with the broadcasting process
    f. End if
3. End for
4. suppose' be the number of nodes which received ADV packet
5. For i=1: M
    a. If ADV packet is received from multiple CHs
        i. Form k-vertex paths with them
        ii. Choose highest energy CH as parent CH
    b. Else
        i. Keep cluster head in the parent CH list
    c. End if
6. Form cluster with the selected parent CH
7. Send Join packet to the CH
8. End for
9. For each CH, do
    a. Arrange members in increasing order of residual energy and least distance from BS
    b. Choose node at top of the list to be CH for the next round
10. End for
11. Base station broadcasts L-ADVE packets to CH
12. Each CH re-broadcasts L-ADVE packet to child CHs
13. Suppose 'k' is the number of disjoint paths from CH to BS
14. For i=1:k
    a. Each CH chooses relay node from its member nodes
15. End for
16. If any node goes fault
    a. CH chooses the next member as a relay node for child CH
17. End if

In this work, we have simulated two techniques namely DEEHC and second was a modification to DEEHC, which we named Modified-DEEHC or MDEEHC. Both the techniques are simulated in Network Simulator 2.35. This is an open-source simulator, which can be used to simulate networks in different kinds of real-time environments. The advantage of using the network simulator over MATLAB is that it provides with various inbuilt routing protocols, propagation models, mobility models and energy model as well. Thus, it becomes fairly easy to simulate the networks using NS2.35. In this technique, every sensor node sends an update message to its neighbours inside a set time c language. Then the neighbour detects the existence of the node and sends the popularity to the fusion centre. The following set of input parameters were considered while creating a wireless sensor network:

Table 1: Simulation Parameters

Parameter	Value
Channel	Wireless
Mac	802.11
Propagation Model	Two Ray Ground
Antenna	Omni Directional
Number of nodes	100
Network Area	700 * 750 sq meters
Initial Energy	20 Joules
Queue	CMUPriqueue
Queue Length	500

4. RESULTS

The performance of the network was measured based on throughput, packet delivery ratio and energy remaining in the network.

(a) Throughput: It is well-defined as the amount of data acknowledged at sink node per unit of time. In this work, throughput is computed at the Base Station. Its formula is:

i. Throughput = Amount of data received in bits / Time

(b) Packet delivery ratio: This is the proportion of the amount of data packets acknowledged/received to the amount of packets transmitted in the network:

i. PDR = amount of packets received / amount of packets transmitted

(c) Remaining Energy: This signifies the amount of battery expended in the WSN and is a measure of network lifespan.

(d) Below are the snapshots of the graphs obtained after simulation of both the techniques.

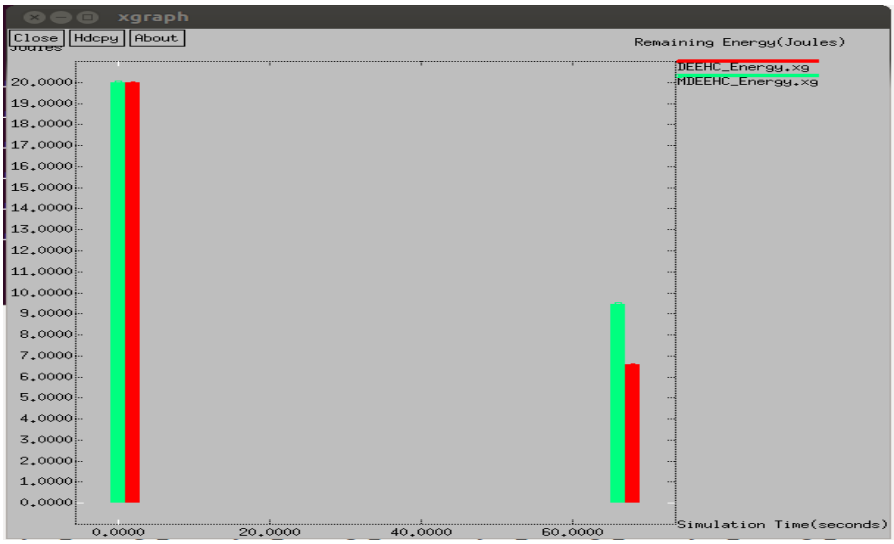

Fig. 1: Remaining energy

The initial average energy of the network was 20 Joules. At the end of the simulation, the remaining energy was approx. 9.44 Joules for M-DEEHC and 6.60 Joules for DEEHC. The amount of remaining energy is highest for the proposed technique. The reason is attributed to the following two facts:

(a) Initially, both the schemes opt for the cluster formation process. This process requires a substantial amount of broadcasting leading to consumption of energy sources of the sensors. This process is run every time at the start of a new round for the cluster head selection process.

(b) The proposed scheme, however, avoids successive runs of this process by electing the cluster heads for the subsequent rounds in the current round itself. Thus, nodes do not need to advertise themselves for the cluster head election process.

(c) The proposed scheme proposes that cluster heads do not take on a load of forwarding the data of the child cluster heads. Instead, the parent cluster heads choose a relay node from their clusters to forward the information from child CH to BS. Thus, these two reasons when combined leads to the lesser energy consumption of the network as well as increased lifetime.

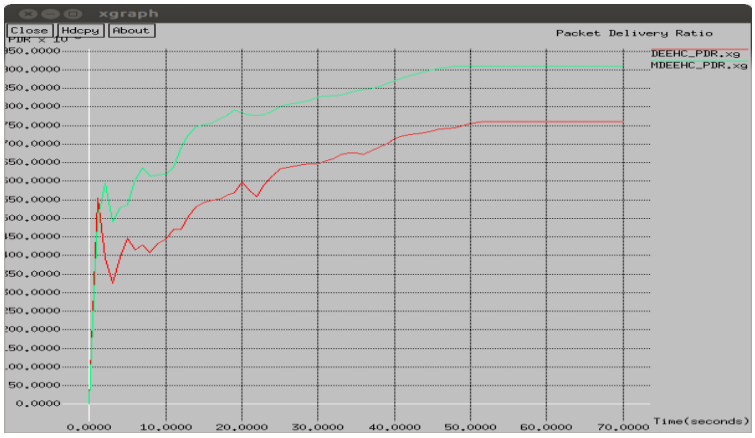

Fig. 2: Packet Delivery Ratio

The value of PDR initially was down at the starting of the simulation for the two schemes. This is because in the process of cluster formation the eligible nodes, which can become cluster head, broadcast many ADV messages. This broadcasting leads to congestion in the network, leading to packet drops. In DEEHC, during the advertisement process, the nodes send their residual energy value along with ADV packet. The receiving nodes withdraw themselves from the process of broadcasting if their residual energy is less than the value received in the packet.

In M-DEEHC, the CHs for the succeeding rounds are nominated in the previous round which avoids broadcasting of ADV packets in consecutive rounds. Thus, the least amount of broadcasting results in the best value for the packet delivery ratio for M-DEEHC. Consequently, the value of PDR increases during data packet transmission in the network. The value for PDR is 0.90 for M-DEEHC and 0.76 for DEEHC.

Thus, it becomes fairly easy to simulate the networks using NS2.35. In this technique, every sensor node sends an update message to its neighbours inside a set time c language. Then the neighbour detects the existence of the node and sends the popularity to the fusion centre.

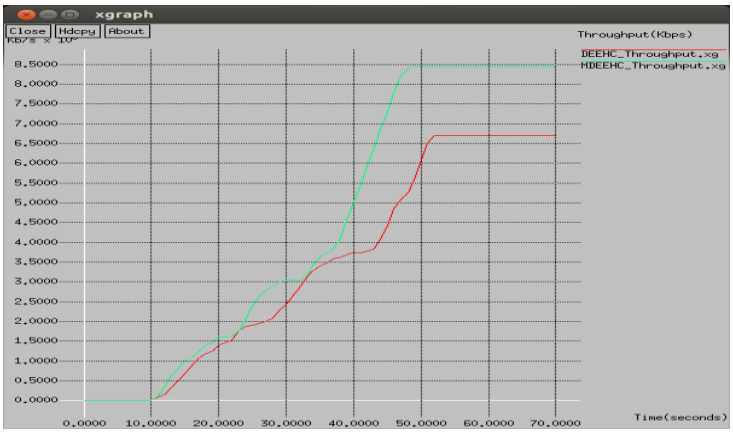

Fig. 3: Throughput

This indicates the quantity of information received at the destination node for each unit of time. As explained earlier, the amount of broadcasting is least for Modified-DEEHC as it avoids the advertisement phase in the consecutive rounds. This leads to quick cluster formation and early start of data gathering and data transmission process. Thus, more data can be communicated to the base station. Also, lesser packet drops lead to increased throughput of the network. The value of throughput is in line with the value obtained for PDR as well. For M-DEEHC, the value of throughput was around 8450 Kbps, for DEECH this value was around 6713 Kbps.

Table 2: Comparison

Parameter/Technique	DEEHC	MDEEHC
Remaining energy	6.60 Joules	9.44 Joules
PDR	0.76	0.90
Throughput	6713 Kbps	8450 Kbps
Number of Packet Drops	1480	252

5. CONCLUSION

In this study, we have implemented DEEHC and modification to existing DEEHC clustering algorithm. DEEHC defines the formation of k-vertex disjoint paths from cluster members to cluster heads and from CHs to sink node or base station. This procedure selects cluster heads considering the remaining energy of the nodes as a prime factor. M-DEEHC modifies the cluster formation of DEEHC algorithm as well as modifies the way the data is communicated from child cluster heads to the BS. The

performance of the network was analyzed based on throughput, remaining energy, and packet delivery ratio. The initial average energy of the network was 20 Joules. At the end of the simulation, the remaining energy was approx. 9 Joules for M-DEEHC, 6.5 Joules for DEEHC. The amount of remaining energy is highest for the proposed technique. The reason is attributed to two facts.

Initially, both the schemes opt for the cluster formation process. This process requires a substantial amount of broadcasting leading to consumption of energy sources of the sensors. This process is run every time at the start of a new round for the cluster head selection process. The proposed scheme, however, avoids successive runs of this process by electing the cluster heads for the subsequent rounds in the current round itself. Thus, nodes do not need to advertise themselves for the cluster head election process. Secondly, the proposed scheme proposes that cluster heads do not take on a load of forwarding the data of the child cluster heads. Instead, the parent cluster heads choose a relay node from their clusters to forward the information from child CH to BS. Thus, these two reasons when combined leads to lesser energy depletion of the system in addition to increased lifetime.

The value of PDR initially was down at the starting of the simulation for both the schemes. This is because in the process of cluster formation the eligible nodes, which can become cluster head, broadcast many ADV messages. This broadcasting leads to congestion in the network, leading to packet drops. In DEEHC, during the advertisement process, the nodes send their residual energy value along with ADV packet. The receiving nodes withdraw themselves from the process of broadcasting if their residual energy is less than the value received in the packet.

In M-DEEHC, the CHs for the succeeding rounds are nominated in the previous round, which avoids broadcasting of ADV packets in consecutive rounds. Thus, the least amount of broadcasting results in the best value for the packet delivery ratio for M-DEEHC. Consequently, the value of PDR increases during data packet transmission in the network. The value for PDR is 0.91 for M-DEEHC, 0.76 for DEEHC. As explained earlier, the amount of broadcasting is least for Modified-DEEHC as it avoids the advertisement phase in the consecutive rounds. This leads to quick cluster formation and early start of data gathering and data transmission process. Thus, more data can be communicated to the BS. Also, lesser packet drops lead to increased throughput of the network. The value of throughput is in line with the value obtained for PDR as well. For M-DEEHC, the value of throughput was around 8500 Kbps, for DEECH this value was around 6800 Kbps. Thus, it can be concluded that our proposed scheme outperforms the other scheme.

In future, other parameters such as delay, jitter etc. can be analyzed for the proposed scheme. In addition, the work can be equated to other algorithms such as LEACH and other variants of LEACH. These days, the concept of the Internet of Things is in high demand. This work can also be explored for an application of IoT such as military investigation, forest fire discovery etc. Internet of Things combines sensor networks along with other networks such as MANETs, VANETs or FANETs. M-DEEHC can be explored for the same.

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