A NOVEL DISJOINT MULTIPATH ROUTING ALGORITHM FOR HETEROGENEOUS WIRELESS SENSOR NETWORK

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ABSTRACT

This paper describes disjoint multipath network algorithm (DHN) for the heterogeneous wireless sensor network. The algorithm calculates a disjoint path with minimum energy cost function among many paths available in the network which includes sensor node with minimum transmission range and processing capability and also super nodes with maximum transmission range and processing capability. Simulation results show that the disjoint path selected by the DHN algorithm are more reliable when compared to other existing protocols providing good throughput, packet delivery ratio and also it increases network life time.

Keywords: wireless sensor network, MAC overheads, throughput, packet delivery ratio, jitter, reactive routing protocols.

1. INTRODUCTION

In the last few decades, the growth in the field of wireless communication devices [2] [3] is increased drastically. This considerably increases the usage of senor nodes in many applications like industries to monitor the status of the device or a controlled test, remote sensing applications, surveillance, to check the energy reserves and also to track the natural habitat of rare animals. This increases the usage of a number of sensors in the application areas and also requires constant coordination between these sensors to gather the required information from the sender to the receiver.

Since the sensor nodes considered in most of the traditional protocols [4] are battery operated, the life time of the sensor nodes is reducing the continuous transmission of data. This raises the likelihood of failure of the node in the network path. Hence, there is a necessity of source node to initiate route request packets (RREQ) to be flooded over the entire network for finding a redundant path towards the destination node. This broadcasting of RREQ packets in the WSN network which increases the network overheads and also the network become congested with overhead packets which slowly increase the packet delay to the destination node. Hence, there is the necessity of considering heterogeneous network [1] which includes super nodes along with ordinary sensor nodes. The super nodes are directly connected to the main supply and hence these nodes can transmit data over long transmission range when compared to sensor nodes. Thereby the load of the sensor node is considerably shared by the super nodes which reduce the rate of consumption of energy of the sensor node. This increases the life time of battery operated sensor node and also the life span of the sensor network.

The reliability of the network is once again a key parameter in the WSN network. In the traditional protocols like sleep and awake protocols, on-demand protocols and scheduling algorithm, the nodes in the path selected are not disjoint. Hence, the nodes involve more transmission of data in short period of time and the energy in the node slowly reducing transmission of data. This increases the probability of failure of a node and the path becomes less reliable for data transmission for a longer time. To overcome this, the proposed DHN algorithm considers the disjoint path in which none of the nodes are being shared by any of the paths available in the network. This considerable increase the reliability and also the network life time.

This paper introduces a novel disjoint multipath network (DHN) algorithm, which selects the more energy cost efficient path among many paths available in the heterogeneous network for improving the reliability and lifetime of the network. Simulation results show that the DHN algorithm provides good throughput and packet delivery ratio along with decreased packet delay when compared to other existing protocols[6][8] and thus makes it ideal for this algorithm to use in a high traffic density application areas like cloud computing, Internet of Things etc.

2. RELATED WORK

Energy optimization algorithms [1] [3] have been developed in the last few decades in order to conserve available energy resources in the network. One of energy optimization algorithm is a selection of disjoint paths in the network. Disjoint paths are paths that have nodes or links which are not shared by nodes or links from any other available path sets. This ensures that the nodes are dedicated to the entire path between source and destination. Disjoint-path selection is classified into node disjoint and link disjoint. In node disjoint algorithm, the nodes in the path are not shared by any other path, whereas in link disjoint, the entire link is dedicated to the path. One more energy optimization protocol is controlling topology of the network by adjusting the transmission power of the sensor nodes in that network [5] [13]. In [5], the transmission power is adjusted to control the neighbor set in the network. In [13], a graph model is constructed to form a backbone network. Redundant nodes in the backbone go to sleep mode, thus maintaining a k-vertex connection in the network. This algorithm also maintains fair rotation among active and sleep nodes in order to maintain a k-vertex connection at any time and thereby allows the system to work even if (k-1) node fails. In [9],

the problem of energy optimization and fault tolerant is addressed by considering heterogeneous network which has two layers. In bottom layer ordinary sensor nodes are present and top layer super nodes are deployed. The algorithm proposed in [9] is based on Minimum Weight-Based Anycast Topology Control where there are a k-vertex disjoint path between a given vertex and any other vertex in the sub graph and the sum of the weight of the selected edges is minimized. Here the edge between sensor nodes is replaced with a bidirectional edge of same weights whereas the edge between the sensor and super nodes are replaced with the unidirectional edge pointing towards the super nodes. This algorithm assumes that the path between sensor nodes is less reliable when compared to the path between super nodes. Thus, a lot of researches is going on to improve path reliability between sensor nodes [15] [16] [17]. The algorithm proposed in [16] [17], does not maintain K-Connectivity and thus less reliable when k-1 nodes fail in the network. And also in [17] does not consider energy efficient techniques to improve network lifetime. In [14], Clustering algorithm is used to control topology where nodes which performs similar operations are grouped and a cluster head is selected based on the polling technique. The groups are so selected in order to balance the load among different groups in the network.

Our algorithm differs from existing available algorithms proposed by considering optimal heterogeneous network and selecting node disjoint path among various available paths available in the network. The number of super nodes deployed is based on the geographical coverage area and data traffic required during peak hours. The node disjoint path is selected based on the residual available in the network and also depends on the reliability of the path selected. This is determined based on calculating node disjointed matrix for given path set available for a node. During path discovery phase, nodes are operated with increased power in order to maintain maximum likelihood in path selection.

3. PROBLEM STATEMENT

We aim to select node disjoint path among multiple paths available in a given path set given in model in section 4. The path selected should be reliable and are cost-effective in terms of energy efficient path. This can be achieved by creating disjointedness matrix and from this optimal disjoint path is selected. This ensures k-disjoint paths available in the network even after k-1 nodes failed in that network. The problem of energy conservation is addressed by selecting the disjoint path which mitigates link failure to a considerable amount and ensures the reliability of data transmission. Prolonged usage of network drains the network energy and hence reduces the overall network lifetime exponentially. This is addresses by using a two-tier architecture which includes super nodes. The optimal selection of a number of super nodes provides a good tradeoff between network energy resource utilization and network lifetime. Thus, our main objective to maintain path reliability even after k-1 node failure and

also to improve the lifetime of the network with a little tradeoff in utilizing additional network resource.

4. DISJOINT MULTIPATH NETWORK ALGORITHM

The proposed algorithm starts with finding a fresh path to the receiver node. This is done by broadcasting Route request (RREQ) packets over the entire network. Upon receiving RREQ packets, the destination node replies with Route reply (RRPLY) packets. From the RRPLY packets, the routing table is updated by all the intermediate nodes in the network. After finding various paths in the network towards the destination node, the disjoint path is calculated by the source node. The disjoint path is calculated using the following equation (1) given below.

$$Node\ Disjoint = \begin{cases} 0 & if\ node\ is\ shared\ with\ other\ path \\ 1 & otherwise \end{cases} \quad (1)$$

Using the above equation, the disjointedness matrix is constructed. The diagonal elements of the disjointedness matrix are always given zero. From the matrix, the rows with maximum zero elements are considered to be optimum disjoint path among many another available path in the network. An algorithm to calculate disjoint path set is given below

Algorithm Selection of disjoint path set
Inputs:i
Outputs:Pathset
$Pathset_i \leftarrow 0; i \leftarrow 0$
While ($node_{i+1} \neq 0$;
If($node_i \cap node_{i+1} = 1$)
$Pathset_i \leftarrow node_i$;
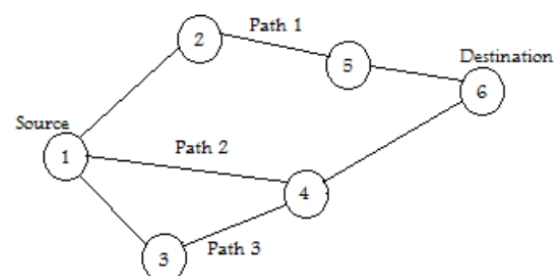$i \leftarrow i+1$;
end

Figure-1. Example scenario.

Figure-1 Shows a model network scenario which consists of a sender node and a receiver node. Between sender node and receiver node three paths are available. Among three paths, path 1 is considered to be a disjoint path. Since none of the nodes are not shared by any other paths. However in path 2 and path 3 the node 4 is shared and hence node energy drains very fast which makes both the nodes unreliable when compared to path 1. The disjointedness matrix is calculated using equation (1) is given by

$ND =$ 0 0 0
        0 0 1. Here in row one, all elements are zero
        0 1 0
and hence considers being optimal path for data transmission.

5. NETWORK TOPOLOGY

The proposed algorithm considers a heterogeneous network where the sensor nodes and super nodes are arbitrarily scattered over the entirely geographical region. Let n and m be the total number of nodes. In this DHN algorithm, it is assumed that $m \geq n$ for the optimal energy cost of the network. Thus the network topology consists of undirected weighted graph G={V,E} where V ={v1,v2,v3,…, vn+m} total number of nodes in the network and E= {(vi,vj) $\leq$ dist(vi,vj) $\leq$ Rmax} total number of edges in the network as shown in the Figure-2. The network assumes 5 mJ initial energy. Since the network is randomly distributed, the probability of scarcely populated node region is minimum in the heterogeneous wireless network.
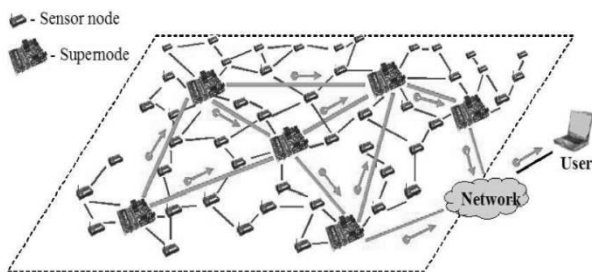

Figure-2. Network topology.

6. RESULTS AND DISCUSSIONS

A. Network parameters

The network parameters use in Proposed DHN algorithm is given in Table-1.

Table-1. Network parameters.

Parameter	Value
Channel type	Wireless channel
Propagation model	Two Ray Ground Model
Simulation area	1600 x 1000 m^2
Number of mobile nodes	61
Transmission range	250m
Node moving speed	15m/ s
Movement model	Random way point
MAC type	IEEE 802.11
Pause time	0s
Pmax	1.0 watt
Pmin	0.3 watt
Training execution time	900 s

The general network scenario is shown in the Figure-3. Here the sensor nodes and the super nodes are deployed randomly with in a geographical region of 1600 x 1000 m^2.
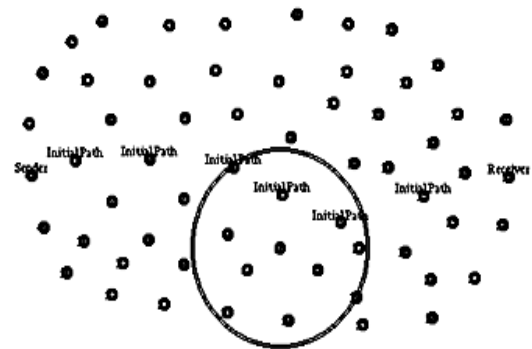

Figure-3. Network scenario.

B. Simulation results

The DHN algorithm proposed is simulated using network simulator - 2.34 in linux environment. The simulation carried under assumptions like the initial energy of sensor node is around 5 mJ, sensor nodes are randomly deployed such that the probability of scarcely populated node region is minimum etc.

The result obtained is compared with other existing protocols like sleep and awake protocols, on-demand protocols and scheduling algorithm and proves to be a better algorithm when compared to these protocols. Figure-4 shows the network life span of the heterogeneous network which purely depends on the remaining energy and lifetime of total number nodes present in the network. As the data transmission increases with time, the remaining energy of the transmission node keeps on decreasing with time. Thus, the node dies with time in a homogenous network. Since we consider heterogeneous network having super nodes, the long distance data transmission is carried by the neighboring super node and saving the residual energy of the sensor node for further data transmission. This increases the overall network lifespan as shown.
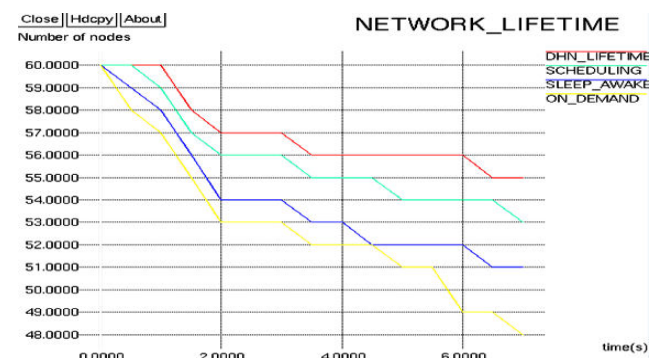

Figure-4. Network lifetime.

Figure-5 shows that the delay is increased as the data traffic time increased. Since the amount of data

increases from time to time the network gets congested. However, this delay is comparatively low when compared to other protocols.
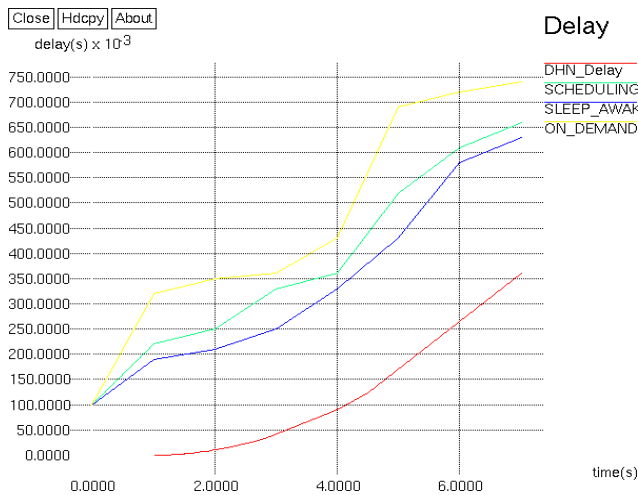

Figure-5. Network path delay.

Figure-6 shows the amount of jitter in the proposed heterogeneous network at different times. For a good algorithm, the jitter must be constant. However, it is normally not constant due to unpredicted congestion occurring due to heavy data traffic. From the Figure-6, the proposed algorithm considers disjoint path and hence gives more constant jitter when to compare with other algorithms.
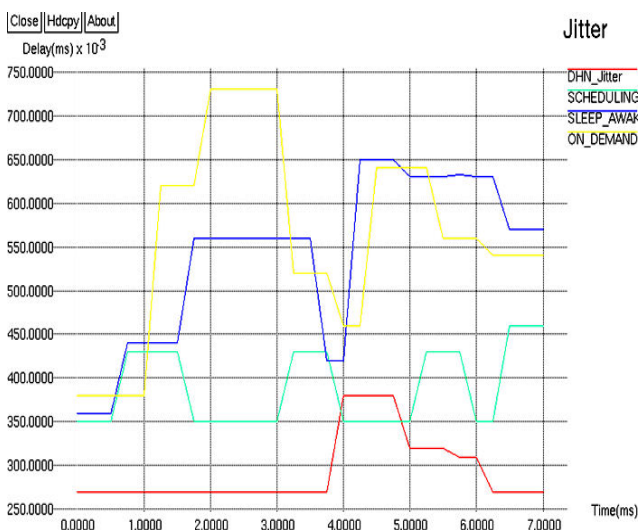

Figure-6. Jitter.

Figure-7 shows Normalized MAC overhead which is defined as a number of control packets to the overall data transmitted in a network. The overhead packets include a request to send packets, Clear to send packets, synchronization packets, Route request and route reply packets and other handshake packets. Since the proposed algorithm considers the disjoint link between transmission and receiver which is stable and the necessity

of routing overhead due to finding a new path is reduced considerably when compared to other protocols.
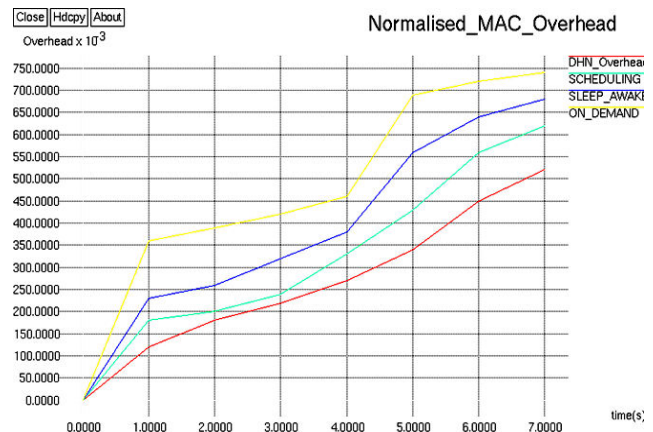

Figure-7. Normalized MAC overhead.

Figure-8 shows the packet delivery ratio of the proposed algorithm. As the data transmission increases with time, the network starts congestion with increases data packets in the queue. When the queue is full, the packets arrived starts drop and hence results in packet loss. Since the proposed algorithm considers disjoint path which is more dedicated for a particular transmission and hence the probability of congestion is lower and thus increases packet delivery ratio compared to other protocols.
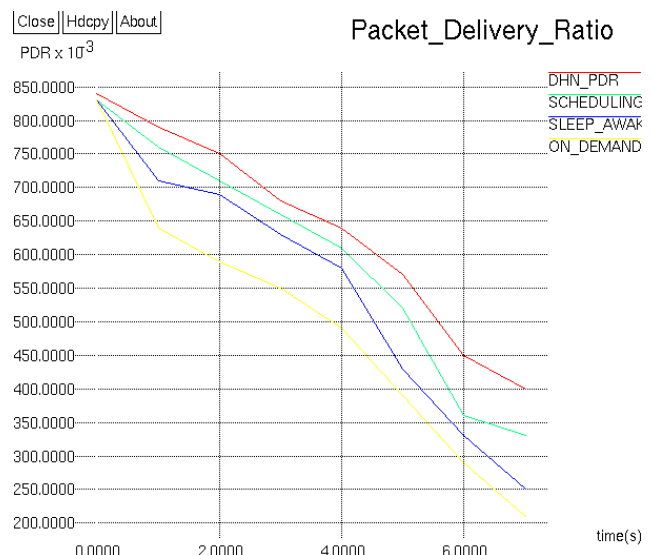

Figure-8. Packet delivery ratio.

Figure-9 shows the throughput of the DHN algorithm. As the packet delivery ratio and network lifetime increases, the throughput of the network also increases by comparing with other routing protocols. Hence, the proposed algorithm is very much suited to a worse environment with a large number of sensor nodes interconnected and is coordinated to do multiple tasks. Since the energy of the network is conserved by means of selecting a disjoint path, the throughput is higher

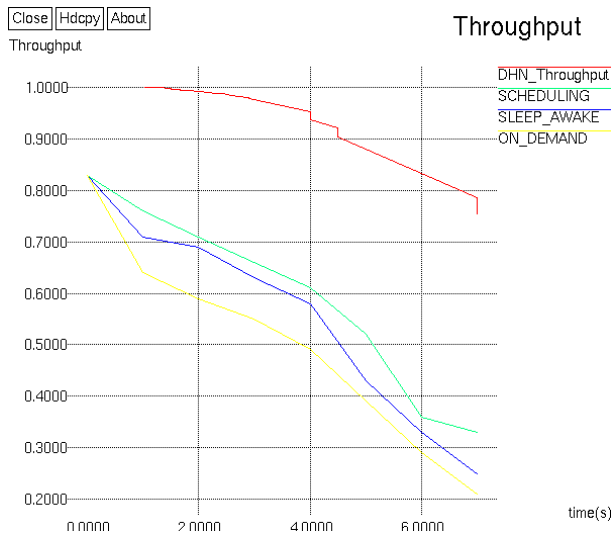compared to other algorithms and is maintained even in peak data traffic hours.

Figure-9. Throughput.

7. PERFORMANCE ANALYSIS

Table-2 gives performance comparison of proposed algorithm with existing algorithms. The simulation is measured by considering a total of 61 nodes transmitting data packets (1800 packets/s) from source to destination for the duration of about 7 minutes. Sensor nodes are assigned are assigned with an initial power of about 1 watt.

Table-2. Performance analysis.

	DHN Algorithm	**Scheduling**	**Sleep and awake**	**On demand**
Network lifetime	90.16 %	86.8 %	83.6 %	78.6 %
MAC Overhead	13 %	18 %	24%	27%
Jitter	52 %	23 %	36 %	17 %
Throughput	77 %	33 %	28 %	22 %
Delay	36ms	74ms	83ms	145ms
Packet delivery	83%	78%	73%	64%

From the above Table-2, the proposed algorithm out performed existing algorithms in terms of Lifetime, Overheads, Jitter, and throughput and thus makes it more ideal for sensor network with congested environment operating at peak traffic time.

8. CONCLUSIONS

In this paper, a novel disjoint multipath network algorithm is introduced for heterogeneous WSN network. The most important contribution of this study is a reduction in network energy consumption and network congestion which improves the performance of the system considerably. The algorithm selects disjoint path among many available paths which improves the reliability of the network path. Our algorithm shows better network life time, Packet delivery ratio and throughput by comparing with another existing algorithm. It also reduces network packet delay and MAC overheads over time. The algorithm gives constant jitter for prolonged time which is ideal for many applications like cloud computing, Internet of things etc.

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