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A New Multipath Protocol for Path Stability in Wireless Sensor Networks

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Abstract

Energy efficiency is a major issue in Wireless Sensor Networks. Due to path failure, sensor nodes consume high energy. So, the performance of the networks is totally degraded. To overcome this issue, we proposed New Adaptive Reporting Protocol (NARP). It attains both throughput and network connectivity while keeping the nodes moving in dynamic manner. The scheme consists of two phases. In fist phase, we proposed multipath routing to provide load balancing to improve the throughput. The proposed multipath contains the route discovery process and route maintenance process. During route selection, the minimum power consumption route is chosen to set the maximum power efficiency. In second phase, the path stability is determined to improve the network connectivity and reduce the packet losses. Here the sensor nodes are assigned with the constant codewords and different time slots. By using the extensive simulation results using the discrete event simulator, the proposed NARP achieves higher packet delivery ratio, network lifetime, less energy consumption, overhead and delay than the existing scheme GSTEB.

Keywords – WSN, NARP, Energy Consumption, Path stability, Scheduling priority, multipath routing, Network lifetime, overhead and end to end delay

I. INTRODUCTION

A. Wireless Sensor Networks

Wireless sensor network (WSN) is a group of sensor nodes (SNs) working in uncontrolled areas and organized into cooperative network. It is composed of huge number of sensor nodes which can monitor the environment by collecting, processing as well as transmitting collected data to the remote sink node through direct or multi hop transmission. WSNs have attracted lots of attention in recent years due to their wide applications such as battlefield surveillance, inventory and wildlife monitoring, smart home and healthcare etc. Each node has processing capability, a radio, sensors, memory and a battery. Since the sensor nodes are usually operated by a limited battery power which may not be replaceable once deployed, it is therefore, vital that the sensor network is energy balanced in order to ensure an extended network lifetime and efficient data gathering.

To minimize the energy consumption, there is a need of path stability in sensor nodes. For that we proposed multipath routing based path stability to make a balance between the network connectivity and energy efficiency.

II. PREVIOUS WORK

Tian et.al [1] proposed a node-scheduling scheme, which can reduce system overall energy consumption, therefore increasing system lifetime, by turning off some redundant nodes. The coverage-based off duty eligibility rule and backoff-based node-scheduling scheme guarantees that the original sensing coverage is maintained after turning off redundant nodes. Eligible nodes turn off their communication unit and sensing unit to save energy. Non-eligible nodes perform sensing tasks during the sensing phase. To minimize the energy consumed in the self scheduling phase, the sensing phase should be long compared to the self-scheduling phase.

Jing deng et.al [2] proposed the Balanced-energy Scheduling (BS) scheme in the context of cluster-based sensor networks. The BS scheme aims to evenly distribute the energy load of the sensing and communication tasks among all the nodes in the cluster, thereby extending the time until the cluster can no longer provide adequate sensing coverage. Two related sleep scheduling schemes, the Distance-based Scheduling (DS) scheme and the Randomized Scheduling (RS) scheme were also studied in terms of the coefficient of variation of their energy consumption.

Ram Kumar Singh and Akanksha Balyan [3] mainly focussed on the energy efficient communication with the help of Adjacency Matrix in the Wireless Sensor Networks. The energy efficient scheduling can be done by putting the idle node in to sleep node so energy at the idle node can be saved. The proposed model in this work first forms the adjacency matrix and broadcasts the information about the total number of existing nodes with depths to the other nodes in the same cluster from controller node.

Mohamed Lehsaini et.al [4] proposed a cluster-based efficient-energy coverage scheme Virtual Sensor (CSA_VS) to ensure the full coverage of a monitored area while saving energy. CSA_VS uses a novel sensor-scheduling scheme based on the k-density and the remaining energy of each sensor to determine the state of all the deployed sensors to be either active or sleep as well as the state durations. In this work, it is addressed that the k-coverage problem because in some applications, it is possible that some locations called sensitive regions in the monitored area are more important than others and need to be covered by more sensors to achieve fault tolerance and to deal with erroneous measurements collected by the sensors..

Babar Nazir et.al [5] presented a sleep/wake schedule protocol for minimizing end-to-end delay for event driven multi-hop wireless sensor networks. In contrast to generic sleep/wake scheduling schemes, the proposed algorithm performs scheduling that is dependent on traffic loads. Nodes adapt their sleep/wake schedule based on traffic loads in response to three important factors like the distance of the node from the sink node, the importance of the node's location from connectivity's perspective and if the node is in the proximity where an event occurs.

Dimitrios J. Vergados et.al [6] proposed a Scheduling Scheme for Energy Efficiency in Wireless Sensor networks. The basic concept of this scheme is to try to maximize the time each sensor node remains in sleep mode, and to minimize the time spent in idle mode, taking into account not only the consumed power, but also the end-to-end transmission delay. This is accomplished through the synchronization of the wake up times of all the nodes in the sensor network. More specifically, the gateway gathers the available connectivity information between all the nodes in the network, and uses existing energy-efficient routing algorithms to calculate the paths from each node to the gateway. Then, the gateway constructs a TDMA frame which ensures the collision avoidance. This schedule is broadcasted back to the sensor nodes, allowing every sensor to know when it can transmit and when it should expect to receive a packet.

Rakhi Khedikar et.al [7] explored the lifetime of wireless sensor network. The research of the network lifetime for wireless sensor network is analyzed to introduce some scheduling the methods of the researchers' uses. The proposed work is focussed on increasing the lifetime by scheduling. Depletion of these finite energy batteries can result in a change in network topology or in the end of network life itself. Hence, prolonging the life of wireless sensor networks is important.

Sounak Paul and Naveen Kumar Sao [8] proposed the work which is based on hierarchical cluster based homogeneous wireless sensor network model. The sensor nodes are virtually grouped into clusters and cluster head may be chosen according to some pre defined algorithm. Clustering architecture provides a convenient framework for resource management, such as channel access for cluster member, data aggregation, power control, routing, code separation, and local decision making.

Jungeun Choi et.al [9] proposed the Fault-tolerant Adaptive Node Scheduling (FANS) which gives an efficient way to handle the degradation of the sensing level caused by sensor node failures, which has not been considered in the existing sensor node scheduling algorithms. For this purpose, the proposed FANS algorithm designates a set of backup nodes for each active node in advance. If an active sensor node fails, the set of backup nodes pre-designated for the active node will activate themselves to replace it, enabling to restore the lowered sensing level for the coverage of the failed node.

Ming Liu et.al [10] proposed a mathematical method for calculating the coverage fraction in WSNs. According to the method, each active node can evaluate its sensing area whether covered by its active neighbors. It is assumed that the network is sufficiently dense and the deployed nodes can cover the whole monitored area. In this scenario, if a node's sensing area is covered by its active neighbor nodes, it can be treated as a redundant node. Based on this idea, it is proposed a lightweight node scheduling (LNS) algorithm that prolongs the network lifetime of the sensor network by turning off redundant nodes without using location information. The performance of LNS is independent of the location information of the sensor node. As a result, it can not only save considerably energy for obtaining and maintaining the location information, but also reduce the cost of sensor node. According to the desired coverage fraction required by application, LNS can dynamically adjust the density of active sensor nodes so that it will significant prolong the network lifetime.

Shan-shan Ma and Jian-sheng Qian [11] proposed a method to determine some boundary nodes only using the minimum cost of nodes and the neighbors. The inequality sleep problems were studied in location-unaware networks. To solve the problem that the boundary nodes may run out of their energy faster than other sensors, it is proposed a method to determine some boundary nodes only using the minimum cost value of each node and the neighbors' distance without any location information.

Gaurav Bathla et.al [12] developed proposed algorithm with data aggregation & fusion which is used to minimize reduction in system energy by first generating Minimum Spanning Tree between all sensor nodes so as to minimize their transmission energy with in network and after that a node of highest energy among the top tier will transmit the aggregated data of whole network to base station. They have kept network topology same till any node of network dies another highest energy node from top most rank tier is chosen to communicate with Base Station.

Yuping Dong et.al [13] proposed energy efficient routing algorithm for WSN. In this algorithm, they have divided the sensor nodes into several scheduling sets and let them work alternatively. In this way, the sensors do not have to be active all the time which saves a lot of energy. When choosing the next sensor to forward the information to, they considered both the distance from the base station to the sensor and its current energy level. So the network power consumption will be distributed among the sensors. When the network does not have enough sensors that have sufficient energy to run, it generates new scheduling sets automatically.

K. Vanaja and R. Umarani [14] deals with the fault management to resolve the mobility induced link break. The proposed protocol is the adaptive fault tolerant multipath routing (AFTMR) protocol which reduces the packet loss due to mobility induced link break. In this fault tolerant protocol, battery power and residual energy are taken into account to determine multiple disjoint routes to every active destination. When there is link break in the existing path, CBMRP initiates Local Route Recovery Process.

Zhao han et.al [15] proposed the self organized tree based energy balance routing to enhance the energy efficiency and radio interference to preserve the global connectivity. General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) builds a routing tree using a process where, for each round, Base Station assigns a root node and broadcasts this selection to all sensor nodes. Subsequently, each node selects its parent by considering only itself and its neighbors' information, thus making a dynamic protocol.

The paper is organized as follows. The Section 1 describes introduction about Wireless Sensor Networks (WSNs), need for scheduling in WSNs. Section 2 deals with the previous work which is related to the scheduling algorithms for energy consumption. Section 3 describes the implementation of proposed scheduling based energy efficient scheme. Section 4 describes the simulation results and settings and the last section concludes the work.

III. IMPLEMENTATION OF MAS ALGORITHM

In our proposed protocol multipath routing based path stability is used to provide energy optimization. The schemes are explained below.

A. Multipath Routing

Node supports with number of sensor nodes in its neighbourhood without relying on a single node to forward a message. If any failure of message arrival, it can be sent on alternative path or on multipath in parallel. So the impact of isolated failures is reduced. In the proposed scheme, multipath routing has been used mostly for fault tolerance and load balancing, and for failure recovery. The communication between sensor node and its neighbor node happens either through a direct communication path or through at most one neighbor. This guarantees that on any communication path between two nodes, there exist two disjoint authentication paths. The following procedure is for message forwarding in multipath routing. Consider a message travelling a path A_0; $A_{1,}$ A2…….A_k is authenticated twice before it is forwarded. A_0 creates Message Authentication Code (MAC) intended for nodes A_1 and A_2. A_0 can only reach A_1 directly and relies on S1 to transmit the MAC intended for S2. Before S1 forwards the message, it creates two new authentication codes itself for A_2 and A_3. It is continued until the message reaches its final destination. Before a node forwards a message, it checks the authentication codes from the two preceding nodes.

The main aim of proposed scheme is to discover the minimum power-limitation route. The power limitation of a route is decided by the node which has the minimum energy in that route. So compared with the minimum node energy in any other route, the minimum node energy in the minimum power-limitation route has more energy. In other words, the value of that node’s energy is the maximum of all minimum node energy in all selectable routes.

In routing Process of proposed adapting reporting protocol, The following assumptions are made:

1. A node can find the value of its current energy.
2. Links are bidirectional.

A. Route Discovery

In NARP, nodes that are not on a selected path do not maintain routing information or participate in routing table exchanges.

Step1:

When the source node wants to send a message to the destination node and does not already have a valid route to that destination, it initiates a path discovery process to locate the other node. The source node disseminates a route request (RREQ) to its neighbors. The RREQ includes such information as destination Internet ID, power boundary (the minimum energy of all nodes in the current found route), destination sequence number, hop count, lifetime, Message Authentication Code (MAC) is for providing certificate authority to the nodes and Cyclic Redundancy Code (CRC) for error detection and correction. The destination sequence number field in the RREQ message is the last-known destination sequence number for this destination and is copied from the destination sequence number field in the routing table. If no sequence number is known, the unknown sequence number flag must be set. The power boundary is equal to the source's energy. The hop count field is set to zero. When the neighbor node receives the packet, it will forward the packet if it matches.

Step 2:
When a node receives the RREQ from its neighbors, it first increases the hop count value in the RREQ by one, to account for the new hop through the intermediate node. The creator sequence number contained in the RREQ must be compared to the corresponding destination sequence number in the route table entry. If the creator sequence number of the RREQ is not less than the existing value, the node compares the power boundary contained in the RREQ to its current energy to get the minimum. If the creator sequence number contained in the RREQ is greater than the existing value in its route table, the relay node creates a new entry with the sequence number of the RREQ If the creator sequence number contained in the RREQ is equal to the existing value in its route table, the power boundary of the RREQ must be compared to the corresponding power boundary in the route table entry. If the power boundary contained in the RREQ is greater than the power boundary in the route table entry, the node updates the entry with the information contained in the RREQ.

During the process of forwarding the RREQ, intermediate nodes record in their route tables the addresses of neighbors from which the first copy of the broadcast packet was received, so establishing a reserve path. If the same RREQs are later received, these packets are silently discarded.

Step 3:
Once the RREQ has arrived at the destination node or an intermediate node with an active route to the destination, the destination or intermediate node generates a route reply (RREP) packet. If the generating node is an intermediate node, it has an active route to the destination; the destination sequence number in the node's existing route table entry for the destination is not less than the destination sequence number of the RREQ. If the generating node is the destination itself, it must update its own sequence number to the maximum of its current sequence number and the destination sequence number in the RREQ packet immediately. When generating an RREP message, a node smears the destination IP address, creator sequence number, and power boundary from the RREQ message into the corresponding fields in the RREP message.

Step 4:
When a node receives the RREP from its neighbors, it first increases the hop count value in the RREP by one like,

$$\text{Hop count} = \text{Hop count} + 1$$

When the RREP reaches the source, the hop count represents the distance, in hops, of the destination node from the source node. The creator sequence number enclosed in the RREP must be compared to the corresponding destination sequence number in the route table entry. If the originator sequence number of the RREP is not less than the existing value, the node compares the power boundary contained in the RREP to its current energy to get the minimum, and then updates the power boundary of the RREP with the minimum. The power boundary field in the route table entry is set to the power boundary contained in the RREP.

B. Route Maintenance

A node uses a Hello message, which is a periodic local broadcast by a node to inform each sensor node in its neighbourhood to maintain the local connectivity. A node should use Hello messages if it is part of an active route. If, within the past delete period, it has received a Hello message from a neighbor and then does not receive any packets from that neighbor for more than allowed-Hello-loss Hello-interval milliseconds, the node should assume that the link to this neighbor is currently lost. The node should send a route error (RERR) message to all precursors indicating which link is failed. Then the source initiates another route search process to find a new path to the destination or start the local repair.

C. Determination of Path Stability

In order to reduce the effect of DoS attacks, Data tampering and Eavesdropping, the stability of path is undertaken here.

Path stability includes the link cost, link quality and bandwidth of the link. The link cost function is used by the node to select the next hop during the path search phase. Let N_b denote the neighbor set of node b, node b will choose the next hop by following the criterion.

$$L_{ct} = \arg\min_{l \in N_b} \left\{ (1 - \frac{e_{j,remaining}}{e_{j,init}})^{[\delta(1 - \frac{(\Delta dh+1)}{d_{oe}})]} \right\} \quad (1)$$

where d_{oe} is the distance in hops between node *o* and sink e; d_{ke} is the distance in hops between node *k* and sink e; Δdh is the difference between d_{oe} and d_{ke}; $e_{j,init}$ is the initial energy level of node *j*; $e_{j,remaining}$ is the remaining energy level of node *j*; and δ is the weight factor and $\delta > 1$. Note that $(\Delta dh+1) \in \{0, 1, 2\}$ and $(1-e_{j,remaining}/e_{j,init}) \in [0, 1]$. The link cost function takes both the node energy level and hop distance into account. Suppose $e_{j,remaining}$ remains constant. In this case, the link cost increases when $(\Delta dh+1)$ increases. On the other hand, suppose $(\Delta dh + 1)$ remains constant. In this case, the link cost increases as $e_{j,remaining}$ decreases. The weight factor δ adjusts the priority. A large δ gives more weight to the node energy than to the hop distance.

Link quality is determined from received signal strength value and signal to noise ratio value. Signal to Noise Ratio influences the bit error rate that a packet is successfully transferred. Here we include the packet dropping ratio for determining the path quality. It is defined as the number of packets dropped to the total number of packets received in the particular link. Bit Error Rate is inversely proportional to the SNR. The SNR is derived as

$$SNR = \frac{S_R}{\sum_{i \neq R} P_u + N_K} \tag{2}$$

In case if the disjoint network occurs, the load balancing is required. Here, there are M disjoint paths between a source node S and a sink node D. The requested data rate to be arrived at the sink node D via all these multipaths is R bits/sec. Let f_j be the data rate allocated to path j. For a path j, the product of the path cost p_j and the data rate allocated f_j gives the path cost rate w_j.

$$\Phi(\overline{f}) = \frac{\left(\sum_{j=1}^{M} f_j p_j\right)^2}{M \sum_{j=1}^{N} (f_j p_j)^2} \tag{3}$$

where the vector denotes the traffic rates allocated to all available routes and f_j is the traffic flow allocated to path j.

The idle period of the wireless channel is a key parameter to determine the average bandwidth which is determined by the traffic travelling along the sensor nodes as well as their neighbor nodes. During that period the sensor nodes can successfully transmit data packets.

$$Avg_{bw} = Max_{bw} \otimes \left(\frac{Idle_t}{Initial_t} \right) \otimes \; L_q \tag{4}$$

Where L_q is the link quality.

B. Proposed packet format

Source ID	Destination ID	Scheduling Status	Network Connectivity Status	Energy Conservation Ratio	CRC
2	2	4	4	4	2

Figure 1.Proposed Packet format

In fig 1. the proposed packet format is shown. Here the source and destination node ID carries 2 bytes. Third one is scheduling status of the node. The scheduling status induces the whether the transmission of packets are travelled with highest link priority and least hop distance. In fourth field, the network connectivity status is indicated. It determines how much of the connection status between various clusters with the current cluster. It also determines whether packet is assigned with correct time slot. In fifth, the energy conservation ratio is allotted to ensure minimum energy consumption. The last filed CRC i.e. Cyclic Redundancy Check which is for error correction and detection in the packet while transmission and reception.

IV. PERFORMANCE ANALYSIS

We use Network Simulator (NS 2.34) to simulate our proposed NSEES algorithm. Network Simulator-2(NS2.34) is used in this work for simulation.NS2 is one of the best simulation tools available for Wireless sensor Networks. We can easily implement the designed protocols either by using the oTCL (Tool command Language) coding or by writing the C++ Program. In either way, the tool helps to prove our theory analytically.

In our simulation, 200 sensor nodes move in a 1300 meter x 1300 meter square region for 60 seconds simulation time. All nodes have the same transmission range of 500 meters. Our simulation settings and parameters are summarized in table 2.

A. Performance Metrics

We evaluate mainly the performance according to the following metrics.

End-to-end delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Packet Delivery Ratio: It is defined as the ratio of packet received with respect to the packet sent.

Throughput: It is defined as the number of packets received at a particular point of time.

The simulation results are presented. We compare our proposed algorithm MAS with existing schemes like GSTEB [15] and our previously proposed scheme NARP achieves better performance in the presence of energy consumption.

Table1. Simulation settings and parameters of proposed algorithm.

No. of Nodes	200
Area Size	1200 X 1200
Mac	802.11
Radio Range	500m
Simulation Time	60 sec
Traffic Source	CBR
Packet Size	512 bytes
Mobility Model	Random Way Point
Protocol	LEACH

Table2. Analysis of Proposed Method and Existing Methods in terms of different parameters

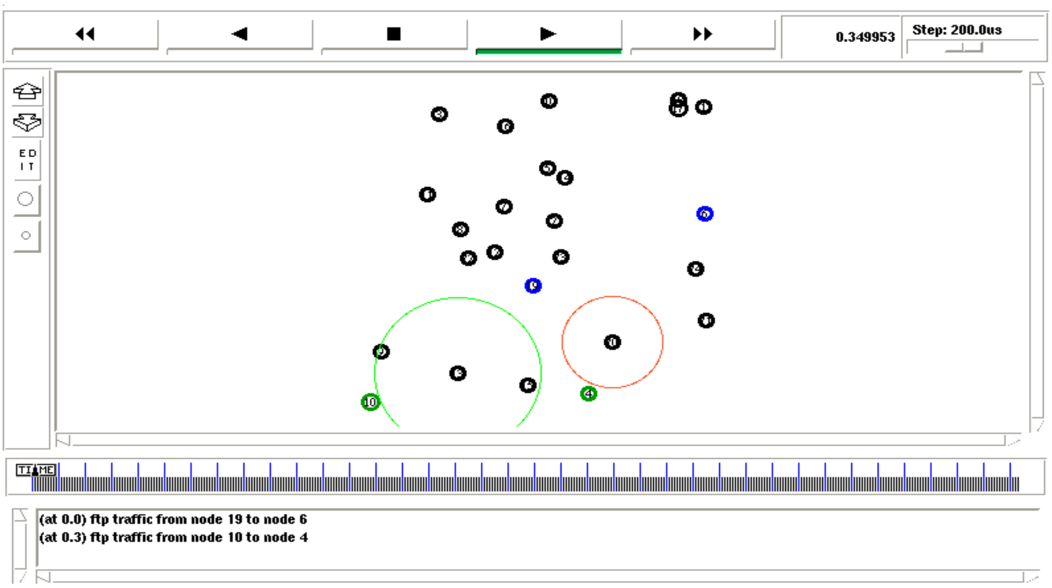

Figure 2. Topology of the proposed scheme

Figure 2 shows that the proposed scheme topology for ensuring the multipath routing. Source node sends the packet to destination node via intermediate nodes. In case if the node failure occurs, the node choose the alternative path to reach correct delivery of packets.

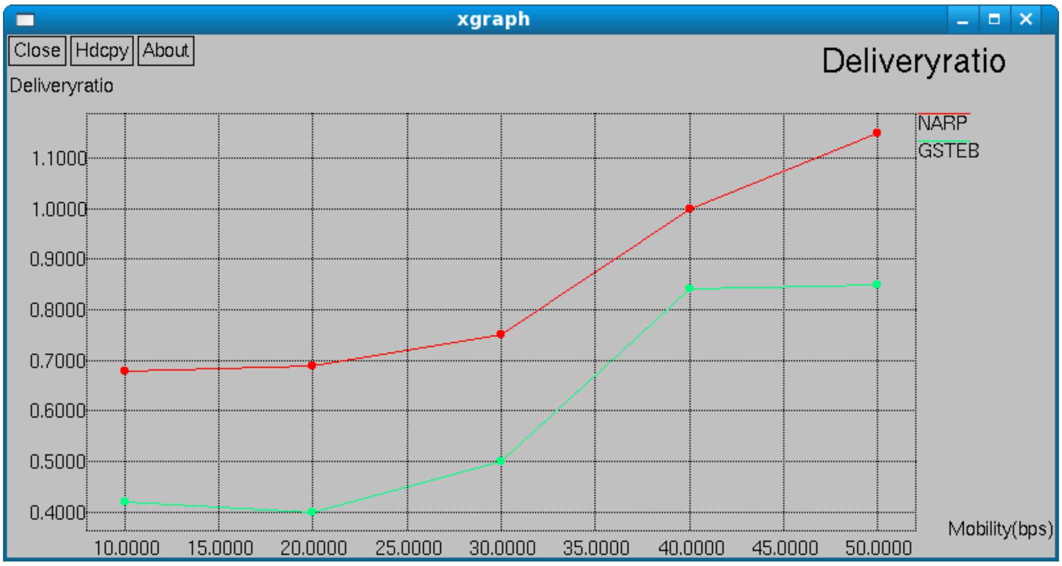

Figure 3. Mobility Vs Delivery Ratio

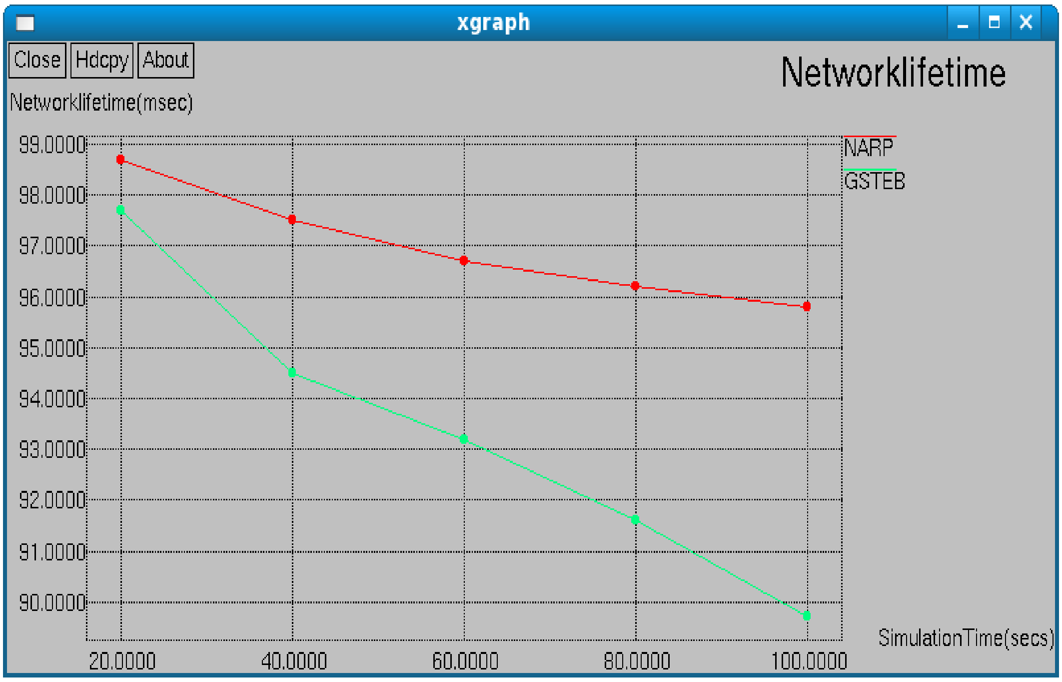

Figure 4. Simulation time Vs Network Lifetime

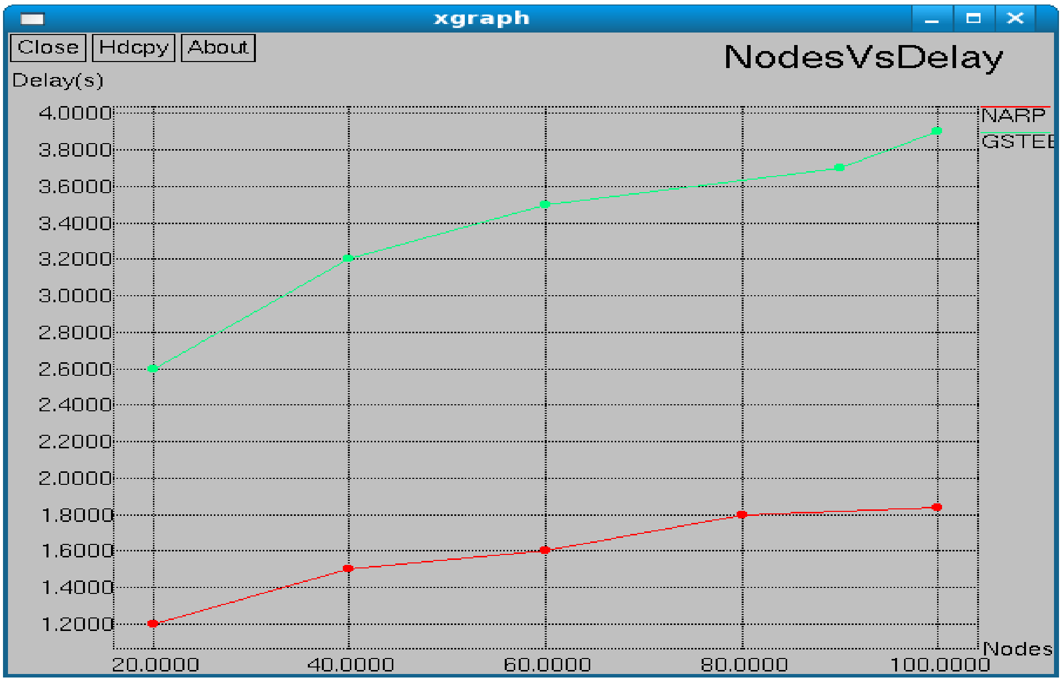

Figure 5. No.of Nodes Vs Delay

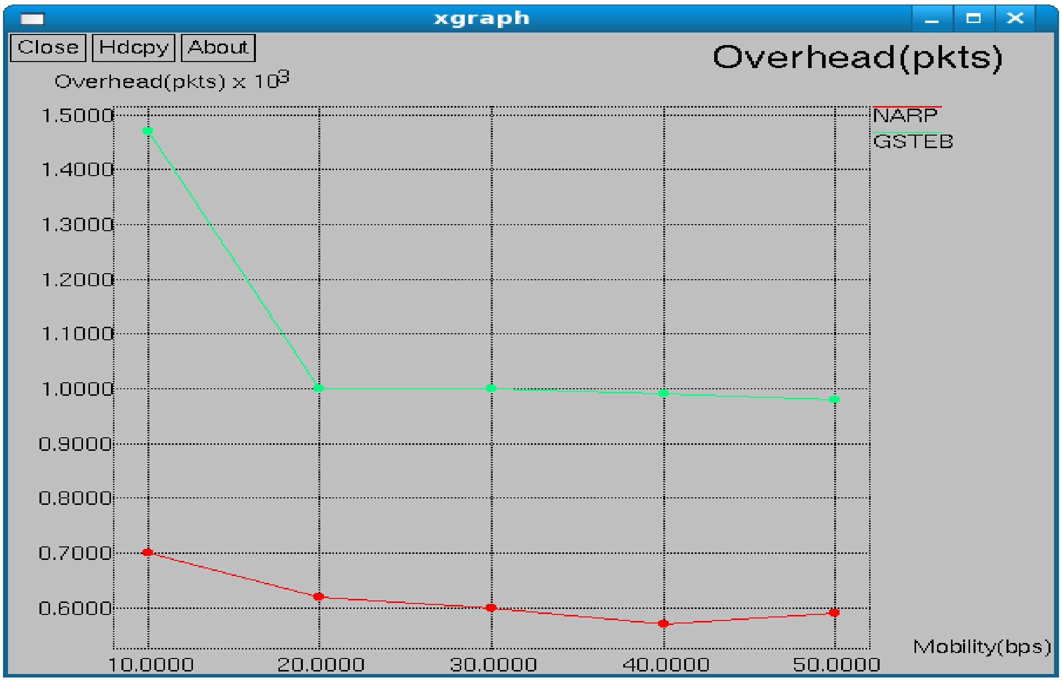

Figure 6. Mobility Vs Overhead

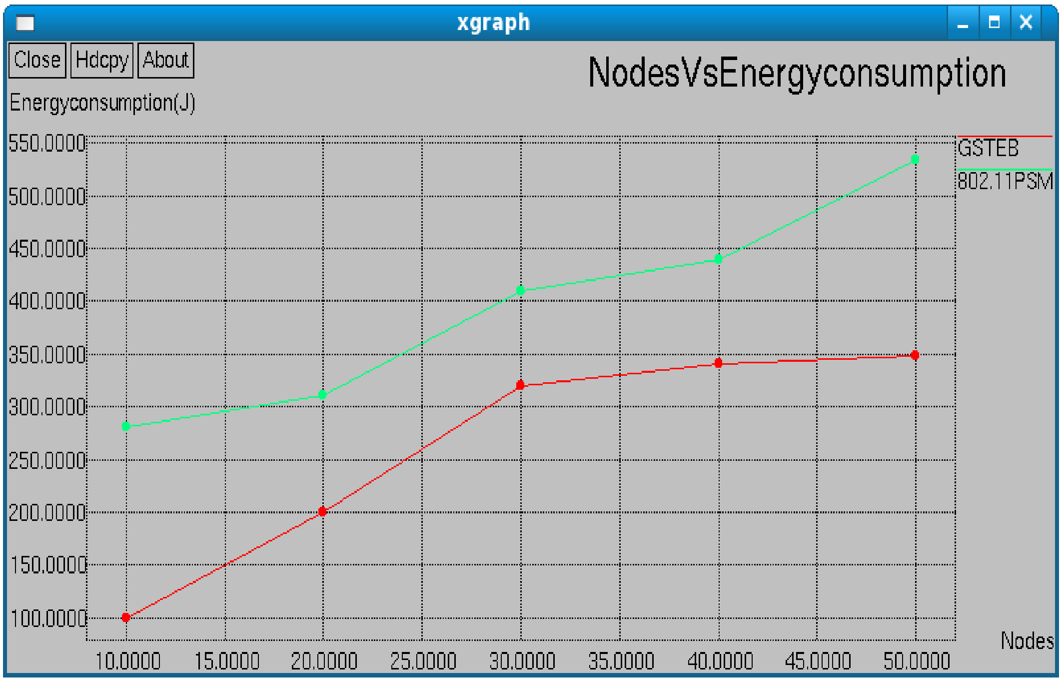

Figure 7. No.of Nodes Vs Energy Consumption

From figure 3 to figure 7 it shows that the Network Connectivity, Packet Delivery Ratio, Network lifetime, End to end delay, overhead and energy consumption of NARP are better compared to the previous scheme GSTEB. The proposed scheme NARP achieves high network connectivity ratio, delivery ratio, network lifetime, low end to end delay, low overhead and low energy consumption while varying the number of nodes, simulation time, mobility.

V. CONCLUSION

In WSNs, the nodes are totally distributed in a random manner. The control may be issued by base station or without any base station. Here we focus on to improve the path stability model to avoid the packet drop and to improve energy efficiency. So we propose NARP protocol to provide the multipath routing based scheduling to maximize the network connectivity ratio and throughput. In first phase multipath routing is proposed. Here the load balancing is well improved. In second phase, path stability model is proposed to avoid packet drops. Each packet attains the time slots which are sent through the highest link scheduling priority. The scheduling status, connectivity status and energy conservation ratio is verified using our proposed scheme. By using NS2, a discrete event simulator, our scheme achieves high connectivity ratio and delivery ratio, low overhead, low end to end delay and minimum energy consumption while varying the time, throughput, number of nodes and mobility than the existing scheme NARP.

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