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AN A MULTIPLE ACCESS SCHEDULING FOR ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORKS

S.Bharathidasan[1] and P.Ramamoorthy[2]
[1]Department of Electronics and Communication Engineering, KTVR Knowledge Park for Engineering and Technology (KTVR KPET), Coimbatore, Tamil Nadu, India
[2]Department of Electronics and Communication Engineering, SNS College of Technology, Coimbatore, India
E-Mail: ktvrbharathi@gmail.com

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 Multiple Access Scheduling (MAS). It attains both throughput and network connectivity while keeping the nodes moving in dynamic manner. The scheme consists of 4 phases. In first phase, we proposed multipath routing to provide load balancing to improve the throughput. In second phase, the CDMA based scheduling algorithm is proposed. Here the sensor nodes are assigned with the constant codewords and different time slots.In third phase, energy consumption model of sensor nodes is proposed. In fourth phase, new packet format of proposed scheme is introduced. It consists of scheduling status and connectivity status. By using the extensive simulation results using the discrete event simulator, the proposed MAS achieves higher packet delivery ratio, connectivity ratio, less overhead and delay than the existing scheme like NMRA, SBYaoGG and AFTMR.

Keywords: WSN, MAS, energy consumption, scheduling priority, multipath routing, scheduling status, congestion status, end to end delay, connectivity ratio and code words.

1. 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.

B. Requirement for scheduling in WSNs

A Wireless Sensor Network consists of group of nodes called sensor nodes. Each one of these has an embedded processor, a radio and one or more sensors. These nodes operate together in the area being monitored and collect physical attributes of the surroundings, say temperature or humidity. Data gathered by these sensor nodes can be utilised by various top level applications such as habitat monitoring, surveillance systems and systems monitoring various natural phenomenon. Sensor nodes have limited battery life. In some applications the sensors are placed in difficult to reach locations, expecting manual intervention for renewal of battery is impractical. In fact, with advances in technology it is expected that in near future these sensor nodes will be disposable and will only last until their energy drains away. The node has to sustain itself on its battery's limited energy resources and without power management it can last only for a short period of time.

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

2. 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*etal.* [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 AkankshaBalyan [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*etal*. [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'sperspective 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.

RakhiKhedikar*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 *etal.* [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-

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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.

GauravBathla*etal*. [12] developed proposed algorithm with data aggregation and 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 *etal.* [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.

Tapiwa*et al.* [15] proposed the new distributed topology to enhance the energy efficiency and radio interference to preserve the global connectivity. The drawback of the approach is lack of balancing the energy consumption and security. It does not provide better authentications to the information carried by the packets. To overcome this issue, our scheme enhances the cross layer based multipath routing to achieve the correct balance between the energy consumption and network connectivity.

In my previous work [16], a New Multipath Routing Approach is developed which attains energy model, maintenance of optimal energy path, multipath construction phase to make a correct balance between network life time, energy consumption and throughput to the sensor nodes. In the first phase of the scheme, construction of multipath is implemented. In second phase, the optimal energy path is maintained. In third phase, residual energy consumption is increased using energy model. It uses following factors called distance , residual energy, mobility factor, mobility factor and data correlation to favor packet forwarding by maintaining high residual energy consumption for each node.

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.

3. IMPLEMENTATION OF MAS ALGORITHM

In our proposed scheme Multiple Access Scheduling, CDMA based scheduling is used to provide energy optimization. The schemes are explained below.

A. Multipath routing

Node supports with number of mobile 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 mobile 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.

B. CDMA based scheduling algorithm

Let us consider the CDMA based scheduling procedure to divide the transmitter receiver pairs into subset and this is done through energy optimisation problem as follows:

$$\min F(K,M) = M\sum_{i=1}^{N} K_i \quad (1)$$

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$$\frac{P_{kl}G_{kl}}{\frac{1}{L}\sum_{n=1,n\neq l}^{L} P_{kn}G_{kl} + \frac{1}{L}\sum_{q=1,q\neq k}^{L}\sum_{n=1}^{L} P_{qn}G_{nl} + \sigma^2} \geq \chi \quad (2)$$

The solution of the above optimisation problem results in 2M + 1 equations with 2E + 1 unknown, which we can solve for P and L.

$$\frac{-1}{\varphi^2}\sum_{e=1}^{E} P_e + \alpha\sum_{e=1}^{E}\lambda_e \sum_{d=1,d\neq e}^{E} P_d G_{de} = 0 \quad (3)$$

The solution provides the optimum spreading gain and the transmitter powers for all transmitters. Here, it is worth to be mansion that transmission power control is automatically taken care of by the optimisation problem as we optimise total network energy.

The algorithm starts finding minimum spreading gain for the network and individual transmission powers for all transmitters in the network following the above optimisation problem. If spreading gain of the optimisation problem results lesser than some positive value then all nodes can transmit at the same time, otherwise the first node to be eliminated from transmission is the transmitter closest to any receiver other than its intended receiver. Elimination of this transmitter receiver pair will decrease the required spreading gain. This loop with the algorithm will be executed unless a set of transmitter receiver pair is found where the spreading gain upper limit is satisfied. All eliminated nodes will be considered for the next consecutive time slots. As a result all transmitter receiver pairs in the network will be divided into different subset and nodes in each subset will transmit in one time slot with spreading gain less than some positive value.

This algorithm could be invoked at the beginning of every time slot in order to cope with the interference level or at the end of all transmitters from all subset finishes transmission. Theoretically the later gives the optimal solution. The invocation time of this algorithm is very important. Let us first consider that a set of n nodes is dividing into m subsets according to the Scheduling-Spreading gain. These m subsets will transmit in m consecutive time slots. Hence, theresults of the algorithm are true and optimum if within m consecutive time slots no other new transmitters are considered. In other words this result is true for m consecutive time slots and within this period no mobility, addition or deletion of nodes are considered within the network. It is much realistic to assume that this algorithm is invoked at the beginning of every time slot with the assumption that interference level at each receiver remains constant during one time slot. In this case this algorithm will find a subset from all transmitters to transmit in the next time slot, where spreading gain is less than some positive value. Mobility, addition and deletion of nodes could be taken into account at the beginning of every time slot. This ensures realistic approach, but lacks of fair scheduling. This means that a node may not get a chance to transmit at all because of new set with k nodes are formed within the network.

C. Energy consumption model

In order to consider the energy const for the path of minimum energy consumption, we developed minimum energy consumption model. Here each mobile host dynamically changes the weight which is based on the path lengths to its nearby hosts. The following is the behavior of the method when*Mi*accesses *Dnew*, which is not held by it.

a) Here, the data information reply packet includes the information on the path length from *Mi*to *Mk*.

b) If*Mi*receives reply packets, it calculates the following criterion, Δ*i,j→new*, for each data item held by *Mi*:

$$\Delta_{p,q\rightarrow new} = \beta(a_{p,new} - a_{p,q}) + \alpha\frac{\sum r \in T_{fresh}}{E_i} + .\lambda\left(\frac{A'_{k,fresh}}{U_{k,fresh}+1} - \frac{A'_{k,l}}{U_{k,l}}\right)$$

The Received and Transmitted energy of the proposed model is

$$Ptop\_Tx(vj\text{-}1) = Transenergy\left(\frac{Sizeof\ \mathrm{Re}qToSend + Sizeoforiginaldata + PDR}{Bandwidth}\right) + \mathrm{Re}ceenergy * \left(\frac{SizeofCleartosend + Acksize + RERR}{Bandwidth}\right)$$

$$Ptop\_Rec(vj\text{-}1) = Transenergy\left(\frac{SizeofClearToSend + ACKsize + RERR}{Bandwidth}\right) + \mathrm{Re}ceenergy * \left(\frac{Sizeof\ \mathrm{Re}qtosend + Datasize + PDR}{Bandwidth}\right)$$

Here, *Gj*denotes the set of sensor nodes within *h* hops that do not hold $D_j$and $h_k$denotes the path length from $M_i$to M_k.

c) *Mi*selects *Dj*among its own data items so that Δ*i,j→new*has the positive maximum value and replaces $D_j$with D_{new}.

The minimum energy consumption model prevents mobile hosts from being accessed by far away hosts. This method can adjust data availability and power consumption by changing parameters *α*, and *β*.

D. Proposed packet format

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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 Figure-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.

4. 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 mobile 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 AFTMR [14], SBYaoGG [15] and our previously proposed scheme NSEES, NMRA [16] in the presence of energy consumption.

Table-1. 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

Table-2. Analysis of proposed method and existing methods in terms of different parameters.

Metrics	MAS	NSEES	NMRA	SBYaoGG	AFTMR
Energy consumption	95-82	114- 90 Joules	1009-721 Joules	1907-1209 Joules	907-646 Joules
PDR (pkts)	923-1321	890-1197	695-704	518-633	156-417
NetworkL_time (Secs)	589-976	564-912	252-421	111-342	218-415
End to end delay (msec)	0.12-0.21	0.20-0.36	0.59-1.63	0.61-1.87	0.9-1.59
Overhead(pkts)	0.04-0.05	0.08- 0.12	0.48-0.92	0.97-1.83	0.67-0.81
NCR (%)	145-793	121-764	71-164	45-91	10-31

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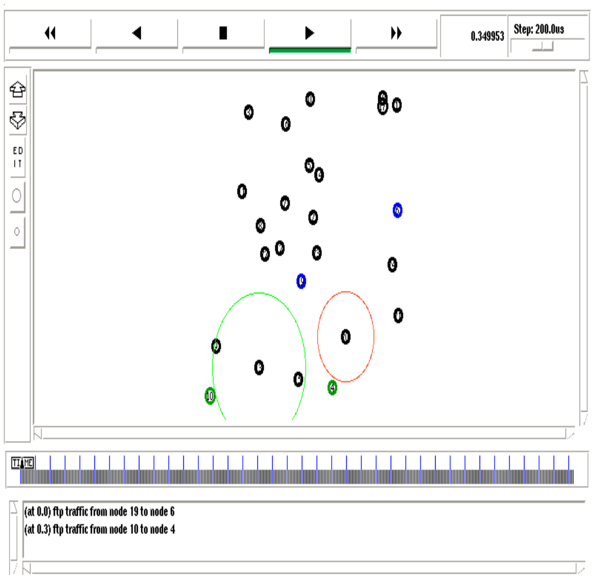

Figure-2. Topology of the proposed scheme.

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.

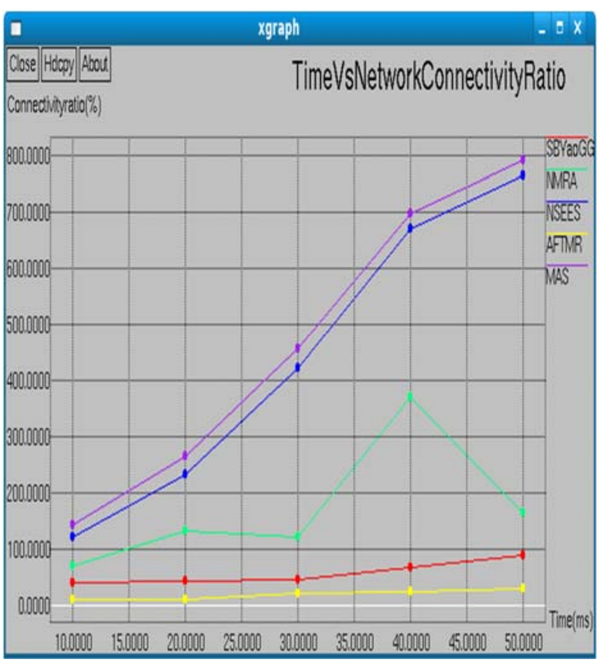

Figure-3. Time vs. network connectivity ratio.

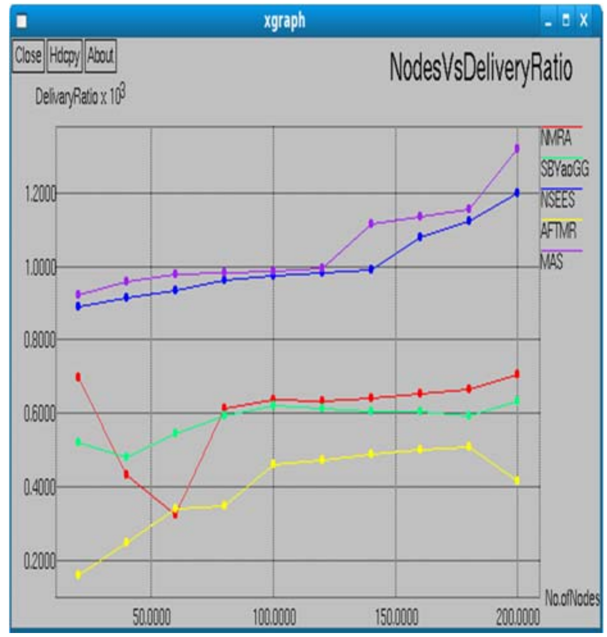

Figure-4. No. of nodes vs. packet delivery ratio.

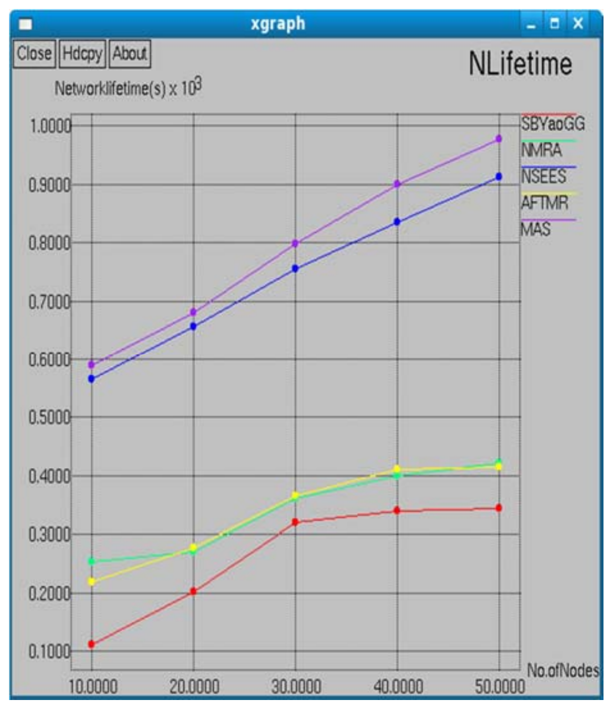

Figure-5. No. of nodes vs. network lifetime.

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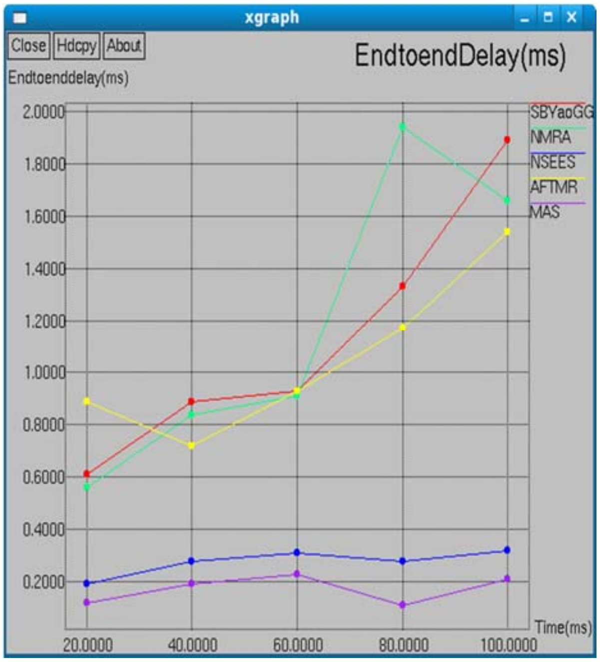

Figure-6. Time vs. end to end delay.

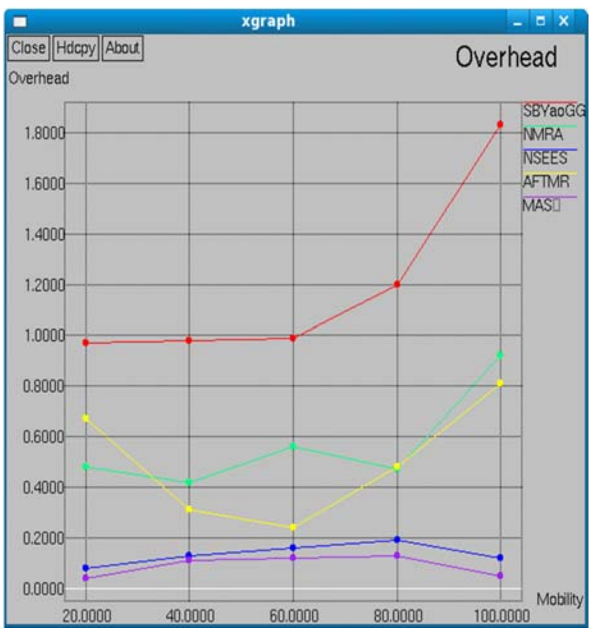

Figure-7. Mobility vs overhead.

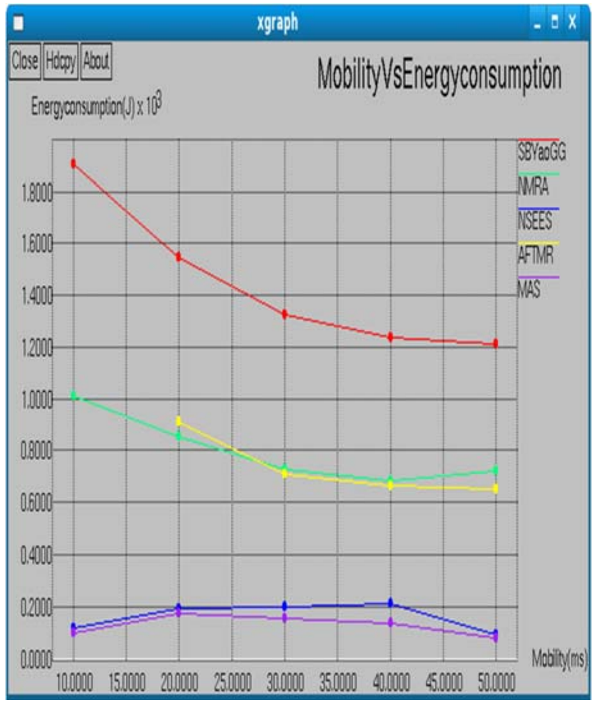

Figure-8. Mobility vs. energy consumption.

From Figure-2 to Figure-8 it shows that the Network Connectivity, Packet Delivery Ratio, Network lifetime, End to end delay, overhead and energy consumption are better compared to the previous scheme NMRA, NSEES and existing schemes such as SBYaoGG, AFTMR. The proposed scheme MAS 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, time, mobility.

5. CONCLUSIONS

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 scheduling link priority to avoid the packet drop and to improve energy efficiency. So we propose MAS scheme to provide the multipath routing based scheduling to maximize the network connectivity ratio and throughput. In first two phases multipath routing and CDMA based scheduling are proposed. Here the load balancing is well improved. In third phase, energy consumption model is proposed to attain maximum energy efficiency. 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 NSEES, NMRA, SBYaoGG and AFTMR.

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