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Power Aware and Energy Efficient Multipath Routing Scheme for WSNs

***Dr.S.Saira Banu*[1], *J.Shafiq Mansoor*[2]**

[1]Associate Professor, Department of Electronics and Communication Systems,
Karpagam Academy of Higher Education, Coimbatore
sairabanu.ecs@email.com
[2]Assistant Professor, Department of Electronics and Communication Enginering,
Karpagam Academy of Higher Education, Coimbatore
shafiqid@email.com

Abstract:* Wireless Sensor Networks consists of sensor nodes which move randomly. Energy based routing in wireless sensor network is a demanding assignment. Power Aware Routing which attains application-specified communication delays at low energy cost by adapting transmission power and routing decisions. Some of the major issues in wireless sensor networks are energy consumption, lack of authentication, data integrity and instability of path link between sensor nodes which reduces the popularity of the sensor network. In recent years, the existing methods have focused on attaining either energy consumption or security. Here it consists of optimized multipath routing, power aware energy based routing approach to make the wireless sensor networks more secure with minimum energy consumption. The multipath routing is constructed to achieve high throughput and load balancing. The optimal energy path is established to maintain the data packet flow in the wireless sensor network unobstructed and the energy consumption model is developed to produce the minimum energy consumption.

Keywords: Multipath Routing, Routing Protocol, Link quality, Link cost, Path stability.

1. Introduction to Wireless Sensor Networks

A sensor network consists of a large number of densely deployed sensor nodes. The position of the sensor nodes is not usually predetermined, as the network may be deployed in inaccessible terrains or disaster relief operations. On the other hand, this also means that sensor network protocols and algorithms must possess self-organizing capabilities. Another unique feature of sensor networks is the cooperative effort of sensor nodes. Sensor nodes are fitted with an on-board processor. Instead of sending the raw data to the nodes responsible for the fusion, sensor nodes use their processing abilities to locally carry out simple computations and transmit only the required and partially processed data.

1.1 Security Threats:

Eavesdropping

Eavesdropping occurs when an attacker compromises an aggregator node and listens to the traffic that goes through it without altering its behavior. Since aggregator nodes process various pieces of data from several nodes in the network, it does not only leak information about a specific compromised node, but from a group of nodes.

Data tampering and packet injection

A compromised node may alter packets that go through it. It may also inject false messages. Since an aggregate message embeds information from several sensor nodes, it is more interesting for an attacker to tamper with such messages than simple sensor readings. An attacker that controls the meaning of the malicious messages it sends may heavily impact the final result computed by the sink.

Denial of service (DoS)

A compromised node may stop aggregating and forwarding data. Doing so, it prevents the data sink from getting information from several nodes in the network. If the node still exchanges routing messages despite its unfair behavior, that problem may be difficult to solve. Smarter attacks also involve dropping messages randomly. It is also difficult to detect when an attacker sends garbage messages.

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. In the scheduling scheme, the operation was divided into rounds. Each round begins with a self-scheduling phase, followed by a sensing phase. In the self-scheduling phase, nodes investigate the off-duty eligibility rule. 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. A sufficient number of sensor nodes were deployed over a sensing field such that some sensor nodes can go into the sleeping mode without degrading the sensing coverage of the network. Static circular cluster associations were assumed in the sensor network. Each sensor node belongs to the same cluster throughout its lifetime.

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. When every node receives the node information about the other nodes for same cluster they communicate based on the shortest depths and schedules the idle node in to sleep mode for a specific time threshold so energy at the idle nodes can be saved.

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. The solution proposed can test whether a point within the monitored area is k-covered or not. To check k-coverage of this point, it the algorithm CSA_VS is applied and verified if each virtual sensor has at least k active sensors in its neighbourhood.

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. Using these heuristics, the proposed scheme reduces end-to-end delay and maximizes the throughput by minimizing the congestion at nodes having heavy traffic load. The variable active durations are assigned to the nodes based on node distance from the sink node, node topological importance, and occurrence of event in its vicinity. It will enable the nodes to gracefully handle the traffic, as nodes are dynamically assigned active durations according to their expected traffic load. It minimizes delay at the nodes near to the sink node, node having critical topological position, and nodes in vicinity of event occurrence. This ensures rapid dissemination of data to the sink node and hence reduces the end-to-end delay.

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. The aim of the proposed work is to dynamically balancing energy consumption and to enhance the functional lifetime of the network by dynamically scheduling a percentage of nodes to go for a sleep in each round.

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 neighbours. 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 neighbour 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 neighbours. 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 neighbours' 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.

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.

Hamid reza Hassaniasl et.al [16] proposed Score-Aware Routing Algorithm (SARA) which is used to enhance routing quality. For that, they have analyzed the five factors like distance between each node and sink, number of observed sources by each node, remaining energy in each node and reliability of communication link and value of traffic in each node. It was more efficient in terms of decreasing delay, decreasing the number of lost packets, improving the load distribution and purposeful network lifetime.

3. IMPLEMENTATION OF PROPOSED ALGORITHM

Our proposed Multipath routing scheme consists of concept of proposed multipath routing, determination of path stability, load balancing, remaining energy and secure routing in multipath to provide the security and improve energy efficiency in sensor networks.

3.1 Concept of Proposed Multipath Routing

The concept of proposed multipath feature is towards broadcasting the traffic load among two or more routes. Load delivery is to avoid the congestion problems in the network and to increase data throughput rate. The proposed multipath system in figure1 uses multi-path routing in order to select the route with the best maximum data throughput rate.

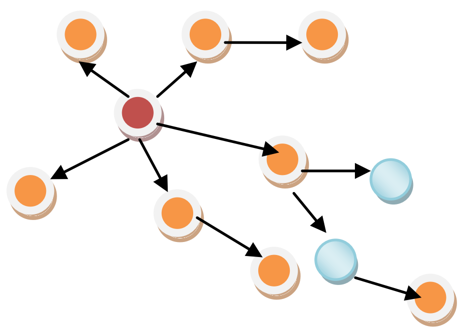

Fig.1. Mulitpath Routing Approach

3.2 Power Aware Routing

In Ad-hoc networks the communication is based on electronic signals and it is possible that a communication path will break. This will happen because of the nodes present in the network are moving around the region. The Figure 2, depicts when the link is active. In the Figure 2, three nodes are present namely a, b and c. The node-b is within the range of the node-a and node-c. But, the node-a is not within the range of node-c and node-c is not within the range of node-a. Hence for transmission of data from node-a to node-c, the node-b acts as an intermediate node. After certain duration, due to the mobility of sensor nodes, the link gets break and the data communication between the nodes becomes unreliable. Due to the mobility of nodes present in wireless sensor network it becomes mandatory to consider the quality of the link. Pre-emptive zone is the region where the signal strength is weaker which leads to the link failure. Pre-emptive zone uses the pre-emptive threshold value to fix the pre-emptive zone’s location. Thus, using the received signal strength from physical layer, the quality of the link is predicted and then the links which are having low signal strength will be discarded from the route selection. When a sending node broadcasts RTS packet, it piggybacks its transmission power. While receiving the RTS packet, the projected node quantifies the strength of the signal received.

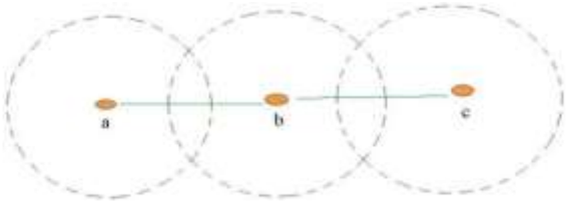

Figure.2. Before the Link breaks

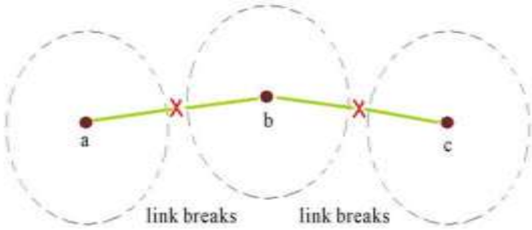

Figure 3. After the link breaks

3.2 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.

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

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

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

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.

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

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 mobile nodes as well as their neighbor nodes. During that period the mobile nodes can successfully transmit data packets.

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

Where L_q is the link quality.

After periodical time t, the energy consumed by the node $E_{j,\ remaining}$ is calculated as follows.

$$E_j = \chi \times T_{nx} + \lambda \times R_{nx} \quad (5)$$

Where T_{nx} = Number of data packets transmitted by the node after periodical time t. R_{nx} =Number of data packets received by the node after time t χ and λ are constants. Its value ranges between 0 and 1. If E_{INIT} is the initial energy of a node, the remaining energy $E_{remaining}$ of a node at periodical time t, can be calculated as:

$E_{j,\,remaining} = E_{j,INIT} - E_j$ (6)

4.. PERFORMANCE ANALYSIS

Network Simulator (NS 2.34) is used 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 1200 meter x 1200 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 1.

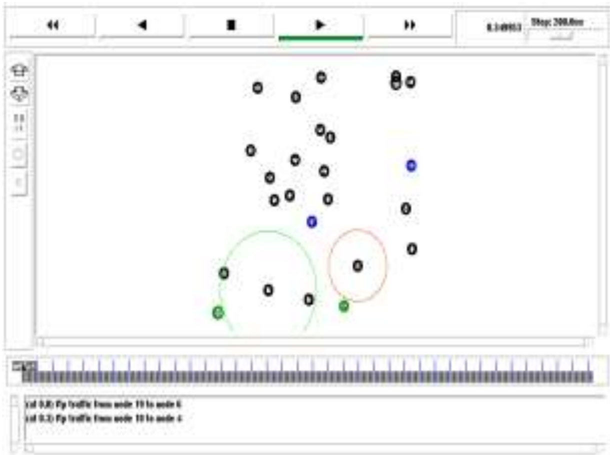

Figure 4 Topology of the proposed scheme

4.1 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.

Table1. Simulation settings and parameters of NSEES

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

5. 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.. multipath routing is proposed. Here the load balancing is well improved. To reduce the effects of eavesdropping, data tampering, false packet injection and denial of service attack, the stability of path is undertaken here.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

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