# A Novel Approach for Multi-Path Routing in Wireless Sensor Networks

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**Abstract:** Routing in Wireless Sensor Networks has been considered an important field of research over the past decade. Wireless sensor network essentially consists of Data Sensor Nodes and Video Sensor Nodes, which senses both sound and motion of events. Single path routing protocol has been used for route discovery. Though this protocol reduces computation complexity and resource utilization, there are some disadvantages like reduced network throughput, network performance, increased traffic load and delay in data delivery. To overcome these drawbacks a new protocol called Interference Aware Multi-path Routing (IAMR) is proposed to improve the reliability of data transmission, fault-tolerance, Quality of Service. It also provides congestion control for both wired and wireless networks. Here, the traffic intersection spread out among the multiple paths. This technique is applied between the sources and sink to reduce routing overhead and energy consumption. The proposed protocol is simulated using NS2.

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## INTRODUCTION

Routing in wireless sensor networks has been considered an important field of research over the past decade. Wireless Sensor Networks consists of light-weight, low power, small size sensor nodes. The areas of sensor network are distributed in various fields such as civil, healthcare, environmental and commercial issues. Some of the well-known applications are inventory control, surveillance, energy management etc. Nodes can be deployed in two ways namely random fashion or pre-engineered way. Since the costs of the nodes are low, nearly thousand to million nodes can be deployed.

The main responsibility of the sensor nodes in each application is to sense the target area and transmit their collected information to the sink node for further operations. Resource limitations of the sensor node and unreliability of low-power wireless links[1], in combination with various performance demands of different applications impose many challenges in designing efficient communication protocols for Wireless sensor networks[2]. Meanwhile, designing suitable routing protocols to fulfill different performance demands of various applications is considered as an important issue in wireless sensor networking.

Sensor nodes transmit the measured data after processing, to a base station named sink node through a wireless channel. The sink node collects data from all other nodes and analyzes them to derive the results from the activity performed. Sinks are efficient data processor that act as gateways to other networks. Key issues to be handled are energy constraints that are stringent in nature and the sensors that are vulnerable to dynamic environment. This leads to the need for an energy-efficient and a robust protocol designed with the unique features of sensor networks considered. Some of the protocols designed recently for WSNs use a single path to transmit data. The unique features to be considered are power limitation, addressing convention etc. Optimal path is selected based on some metrics like gradient of information, distance of destination. Network reliability is the feature prioritized in the design of routing protocols for multiple paths.

The need for routing process is that, most of the existing routing protocols in wireless sensor networks are designed based on the single path routing strategy without considering the effects of various traffic load intensities. The performance requirements needed for an application to transmit traffic towards the sink node are fulfilled by each and every source node in single path routing strategy. Although route discovery through single-path routing can be performed with minimum computational complexity and resource utilization, the limited capacity of a single path highly reduces the achievable network throughput. Furthermore, the low flexibility of this approach against node or link failures may significantly reduce the network performance in critical situations.

In order to cope up with the limitations of single-path routing techniques, another type of routing strategy, which is called the multipath routing approach has become a promising technique in wireless sensor and ad hoc networks. Dense deployment of the sensor nodes enables a multipath routing approach to construct several paths from individual sensor nodes towards the destination[3]. Discovered paths can be utilized concurrently to provide adequate network resources in intensive traffic conditions.

The new protocol named Interference Aware Routing Protocol (IAMR) has been proposed to reduce the energy consumption and routing overhead during the transmission of data between the sources and sinks that is common in multi-path concepts. The rest of this paper is organized as follows. The related work with a brief description about the single path routing, multipath routing, their steps and their performance is presented in Section II. Section III includes problem statement, which gives the need for the whole process and how it is done. Section IV specifies routing protocol, which explains the design, the modules with its input and the framework of the project. Performance evaluation, its analysis and the results in graph format are described in Section V. Section VI concludes and provides directions for future works.

**Related Work**

Energy-Efficient and Collision-Aware Multipath Routing Protocol (EECA) is an on-demand multipath routing protocol and uses the location information of all the sensor nodes to establish two collision-free paths between a pair of source-sink nodes. EECA aims to reduce the negative effects of wireless interference through constructing two paths in both sides of the direct line between the source-destination pair. Furthermore, the distance between these two paths is more than the interference range of the sensor nodes. In the first stage of the route discovery process, the source node checks its neighboring nodes to find two distinct groups of the nodes on both sides of the direct line between the source-destination pair. After finding the neighboring sets, the source node broadcasts a Route-request packet towards these nodes to establish two node-disjoint paths.

During the route discovery process, intermediate nodes utilize the same technique (used at the source node) to select their next-hop neighboring nodes and broadcast the received Route-request packet towards the sink node. Upon reception of a Route-request packet by an intermediate node, the receiver node uses a back-off timer to restrict the overhead introduced by the route discovery flooding. Before broadcasting the received Route-request packet by the intermediate nodes, they set a back-off timer according to their distance from the sink node and their residual battery level. Neighboring nodes with higher residual battery and shorter distance to the sink node select shorter back-off timer. Therefore, at each stage of the Route-request flooding only one node wins to broadcast its received Route-request packet towards the sink node. Upon reception of the Route-request packet at the sink node, it sends a Route-reply packet in the reverse path towards the source node. When the source node receives a Route-reply packet, it can transmit its traffic through the established path.

Although EECA tries to discover the two shortest paths such that their distance from each other is more than interference range of the sensor nodes, it needs the nodes to be GPS-assisted and relies on the information provided by the underlying localization update method. These requirements increase the cost of network deployment and intensify the communication overhead, specifically in large and dense wireless sensor networks. In addition, as low-power wireless links exhibit significant signal variations over time, calculating the interference range of the sensor nodes based on the distance may not result in an accurate interference estimation. Moreover, while transmitting data over minimum-hop paths can theoretically reduce end-to-end delay and resource utilization, however, using such paths in low-power wireless networks increases the probability of packet loss and intensifies the overhead of packet retransmission over each hop.

Ad hoc On Demand Multipath Distance Vector Routing extends AODV to provide the multipath. Here each Route Request and Route Reply defines an alternative path to the source or destination. Node-disjointness is achieved by suppressing duplicated Route Request at intermediate nodes. Routing entries contains the list of next hops in which the multiple paths are maintained. AOMDV introduces the maximum hop count value which is the advertised hop count for a node i in destination d. Alternative paths at node i for destination d is introduced with a lower hop count value than the advertised hop count.

Since sensor nodes have limited energy capacity, the quality of some applications is influenced by the network lifetime and the energy consumption. The multipath routing protocol utilizes a multipath routing approach to provide energy-efficient communications through balancing of the network traffic over multiple paths. The residual battery lives in the node are considered as most important metric in the route discovery phase. Nevertheless, as this protocol neglects the effects of wireless interference and assumes error-free links, it cannot achieve significant performance improvement in throughput and data delivery ratio.

An Interference Aware multipath routing protocol (IAMR) to support high rate streaming in wireless sensor networks is proposed. This protocol constructs link-disjoint paths by assuming a specific network model and localization support. It is assumed that there are several gateway nodes connected directly to the command center using non-interfering and high capacity links. The source node constructs three link-disjoint paths towards the three distinct gateway nodes. After that, the source node utilizes the primary and secondary paths for data transmission and preserves the third path for prompt packet recovery from path failures. IAMR shows higher performance compared to the standard AOMDV. Moreover, to reduce the negative effects of intra path interference, IAMR constructs shortest paths towards the gateway nodes. Since the longest hops should be used to create the shortest paths, the time varying properties of wireless links highly affect the performance achieved by this protocol.

**Problem Statement**

In Wireless Sensor Network, designing routing protocols is a big challenge because of the stringent QoS requirement of throughput and delay. Designing an energy efficient low-overhead communication protocol to satisfy the performance requirement of different application in wireless sensor node is a limited process. In the effort to support QoS demands, many researchers have proposed various algorithms and protocols for different layers of the wireless sensor network protocol stack. Most of the existing routing protocols are based on single path routing strategy; they cannot support high data rate. End-to-End throughput is limited here and due to constant flow data it consumes more amount of energy. In contrast, multipath routing protocols enable the source nodes to discover several paths towards the destination. Since in multipath routing technique data packets are propagated over several paths, it provides higher throughput, more balanced energy consumption and improved latency [5, 6].The broadcast nature of the wireless medium is to estimate inter-path interference and establish minimum interference in a localized manner. Since the existing protocols mainly utilize the node residual battery life to determine the optimal traffic rate of the paths, they do not account for the effects of wireless interference on the capacity of individual paths. Through including the experienced interference level in the load balancing algorithm, we consider the effect of interference on the tolerable traffic rate of the paths.

The neighborhood information is acquired by each node in the initialization phase. This information will be used in the route discovery and establishment phase to find the next best hop node towards the sink. The route discovery and establishment phase is triggered whenever an event is detected. The outcome of this phase is multiple-interference-minimized paths between the source and the sinks. Finally, the route maintenance phase handles path failures during data transmission. The load balancing algorithm is taken here by distributing the traffic over the multiple established paths. When a route is established the node starts transmitting data. The ETX is the Estimated Transmission cost of each node where the cost is used for the calculating the path cost. Thus the ETX value is calculated, which gives the cost of the neighbor towards the sink[7]. This value indicates the required number of transmission for successful packet reception at the receiver. The ETX value of the link is defined as follows:

$$ETX = \frac{1}{p*q} \qquad (3.1)$$

where $p$ and $q$ are the probabilities of forward and backward packet reception over that link. Each of the node calculates its own accumulated ETX value to the sink node

$$accETX_i = accETX_i + \frac{1}{p_{ij}q_{ij}} \qquad (3.2)$$

Node $i$ receives a broadcast packet from node $j$ and saves the cost included in this packet as the accumulatedETX cost of node $j$ to the sink. The path cost is calculated here for each path and the transmission of data packet is based on that cost.

**IAMR Algorithm**

In the effort to support QoS demands, there are many algorithms and protocols for different layers of the wireless sensor network protocol stack. In contrast, IAMR protocol enables the source nodes to discover several paths towards the destination. Since in multipath routing technique data packets are propagated over several paths, it provides higher throughput, more balanced energy consumption and improved latency.

*A. Design*

The design of the process is given in Figure 1 which explains how the working process is taken over. The neighborhood information is acquired by each node in the initialization phase. This information will be used for route maintenance and establishment phase, to find the next-hop node towards the sink. The route discovery and establishment phase is triggered whenever an event is detected. The source node starts the route discovery by transmitting a route request packet towards the sink node. Whenever a node receives Route Request (recvRREQ), it checks whether it is an active node or disabled because of low transmission cost or a new node.For a new node,it computes the transmission cost and compares it with the previous cost. If the new node cost is minimum than the existing node, it will precede the route discovery with the new path which is random channel. The next step is to check whether it know a route to destination. If yes it will send a Route Reply(sendRREP). If not it will send a Route Request(sendRREQ) and it will repeat the process.

Whenever a node receives RouteReply (recvRREP), it checks for the channel conflict. If there is a channel conflict, then checks whether it is a source , if it is a source then updates the channel and establish a route between source and destination. Otherwise it will not update the channel and send Route Reply and this process is repeated until it reaches source node.

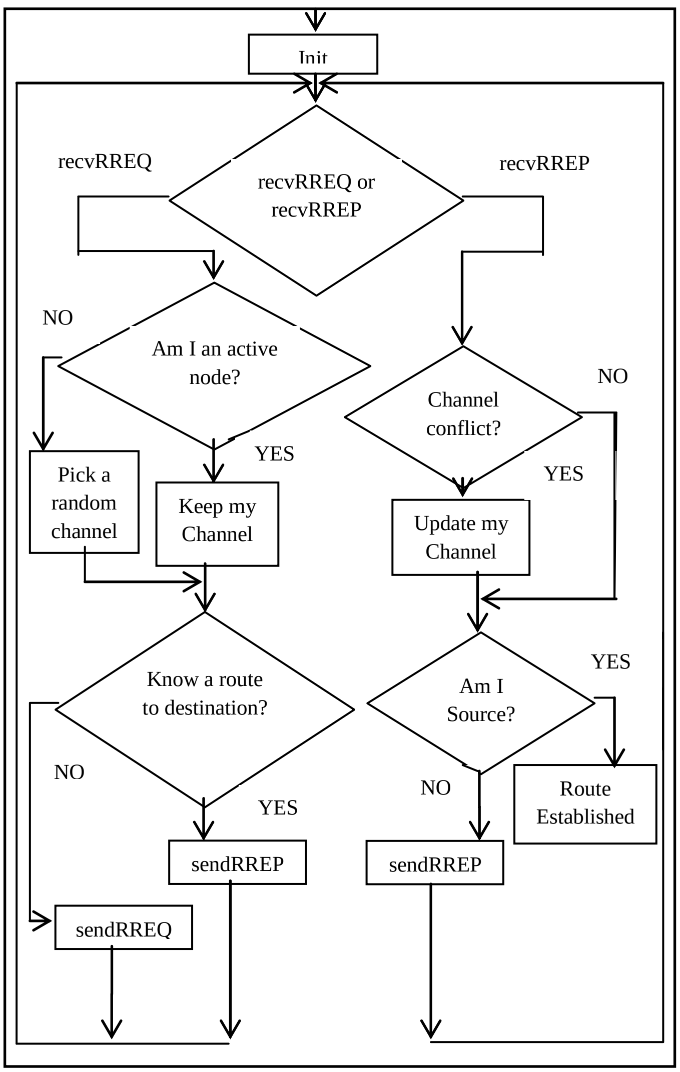


Figure 1: Design of IAMR

*B.Initialization phase*

In IAMR protocol, each node obtains its neighbourhood information, which also includes the ETX cost of its neighbour towards the sink. The ETX value of a link indicates the required number of transmissions for successful packet reception at the receiver. Thus, ETX is affected by the link loss ratio, the difference between forward and backward reception rates, and the interference level of successive links (i.e., intra- path interference) [8].

Initially a set of data packets are forwarded to other nodes and the number of successful packets received is recorded, so that it will record p and q value in the neighbourhood table. Then, the sink node sets its cost as zero and broadcasts to the neighbours. Whenever a node receives packet with cost, it records the retrieved cost as the accETX cost of the neighbour node. For example, when node i receives a broadcast packet from node j, it saves the cost included in this packet as the accETX cost of node j to the sink.

TABLE I Neighbourhood Table

| Neighbor's Information | P | Q | accETX | resBatt | Hopcounts |
|---|---|---|---|---|---|
| 1st neighbor | | | | | |
| 2nd neighbor | | | | | |
| | | | | | |
| Nth neighbor | | | | | |

Node *i* should broadcast the newly calculated accumulated ETX cost if it is lower than the current cost of node *i* towards the sink. In fact, whenever a node receives a broadcast packet from one of its neighbour’s, it should calculate its accumulated ETX by (3.1) and broadcast that value if it is lower than its current ETX cost towards the sink. In addition to the initialization phase, the cost update process should also be performed during normal network operation whenever a node finds a new transmission cost to the sink.

*B. Route Discovery and Establishment phase*

Whenever the event is detected the route discovery phase is triggered. After the discovery, it uses the neighborhood table and updates it. The source node starts data transmission by sending Route Request to the neighbor node. After receiving the route request packet, the node will calculate its transmission cost for the neighboring nodes, which are not included in any path from the current source to the sink. This avoid the same node included in the different path. The node with minimum cost is included in the path selection. Transmission of packets is through the node which has the least cost.

$$cost_{i,j} = \left(accETX_j + \frac{1}{p_{i,j}q_{i,j}}\right) . \ K \quad (4.1)$$

Where $K = \left(\frac{1}{resBatt_j}\right).\left(1 + ilevel_j\right)$

In (4.1), accETX*j* is the ETX cost of node *j* to the sink, which is contained in the neighborhood table of node *i*. *pi,j*and *qi,j*are the forward and backward packet reception rates between node *i* and node *j*, respectively. resBatt*j* is the remaining battery level of node *j* expressed in percentage. Interference Level *j* is the maximum interference level that node *j* has experienced. Path membership variable is used to set 1 for Route Request, and shows that the particular node is already used by another path. Automatic Repeat Request is used for ensuring packet delivery. Receiving a Route_request packet at the source node indicates that the algorithm cannot establish another node-disjoint path. When the sink receives a Route_request packet, it replies by transmitting a Route_reply packet along the reverse path. Here the Path membership variable for Route_reply is set as 2 to indicate an active path passing through this node.

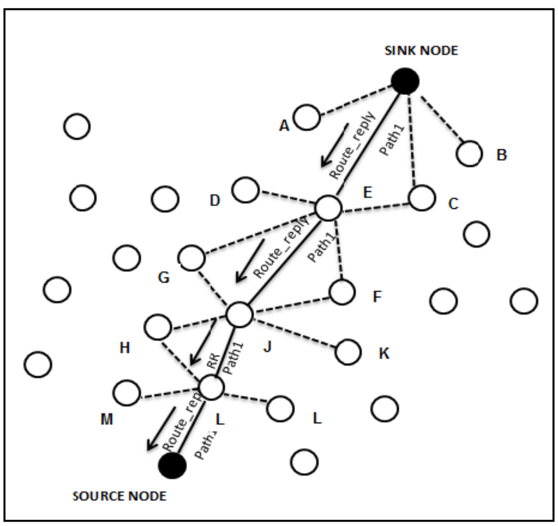


Figure 2: Construction of First Path

In order to reduce the end-to-end latency, it starts packet transmission immediately after the first path is established. To initiate the second path, route discovery will send Route_request to another path. The source node distributes data packets over the first and second path using the load balancing algorithm.

Received Packet Throughput(RPT) is used at the sink node to measure the performance improvement. It is calculated for each data packet from source node separately. Positive feedback is sent to the path which has higher RPT and negative feedback for lower RPT. Suppose that n numbers of paths are established and data packets are being transmitted through n paths, then it compares RPT of n paths with the RPT of n-1 paths and decides if transmitting over the n paths results in higher performance.

Figure 2 shows the updation of interference level during the construction of the first path. From Figure 2 node F overhears the packets from node E and node J. Whenever a node overhears a Route_reply packet, it should update its interference level variable. To this aim, it adds the reverse packet reception rate (q) of the node from which the Route_reply packet has been overheard to its interference level variable.

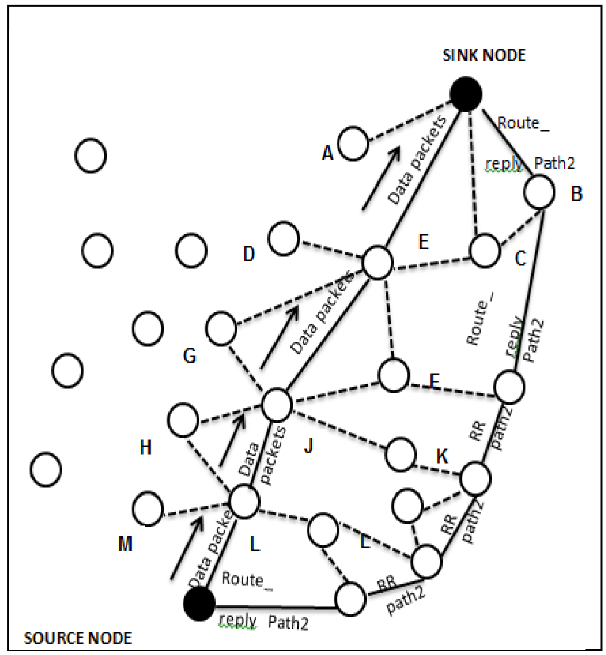


Figure 3: Construction of Second path

In Figure 3 node F retrieves the values of $q_{F,E}$ and $q_{F,J}$ from its neighborhood table and adds them to the current value of its interference level variable. In addition, the new interference level should be broadcasted to notify neighboring nodes.

**Performance Evaluation**

In this section, we present a comprehensive evaluation of the proposed multipath routing protocol. First, we introduce the performance evaluation metrics. Then, we describe the applied simulation framework and its parameters. Finally, we analyze and discuss the simulation results.

*A. Performance Parameters*

We have designed and evaluated IAMR in terms of the following performance metrics:

1) *End to End latency*: measured as the average time between packet transmission from the

source and its reception at the sink.

2) *End to End Throughput:* total number of data bits received at the sink divided by the transmission duration.

*3) Packet Generation:*ratio of data packets received successfully at the sink to the total number of data packets generated from the source. Accordingly, this metric reveals the data transmission reliability.

*B. Simulation Parameters*

TABLE II ASSUMED PARAMETERS

| Parameters | Value |
|---|---|
| Transmission range | 250 m |
| Simulation Time | >800s |
| Topology Size | 1000m x 1000m |
| Number of Sensors | 100 |
| Number of sinks | 1 |
| Traffic type | Constant bit rate |
| Packet size | 512 bytes |
| Bandwidth | 2Mb/s |
| Transmission range | 250m |
| Interference range | 550m |
| Initial energy in batteries | 10 Joules |
| Energy Threshold | 0.001mJ |

*C. Simulation Results*

1) *End to End Delay:* The capability of IAMR to meet the delay requirements is shown in Figure 4 (a) and Figure 4(b). As the offered load grows, the average queue length at each node increases and data packets suffer longer queueing delays. Both Figures show the comparison of end to end delay of IAMR and EECA protocols.

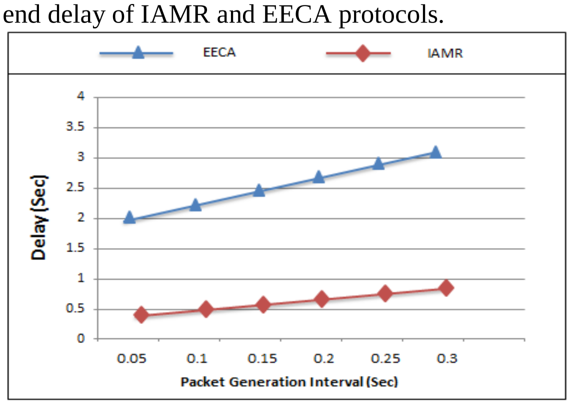


Figure 4(a): Delay for 25 nodes

The X co-ordinate is considered as Packet Generation Interval and the Y co-ordinate is considered as End to End delay. The scaling for X axis is 50ms per unit and Y is 5ms per unit. Initially, as interval increases the end to end delay of EECA increases gradually to a higher level, whereas IAMR has low end to end delay.

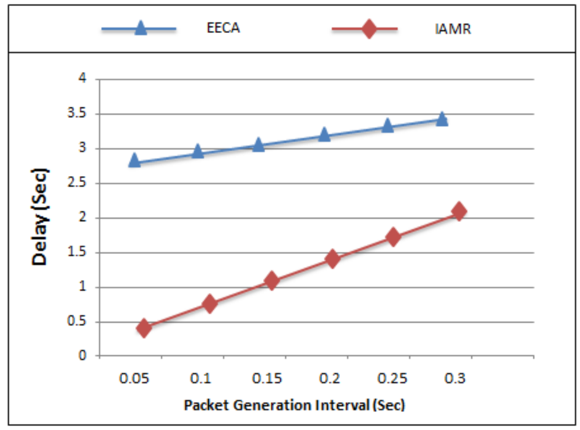


Figure 4(b): Delay for 50 nodes

*2) Packet Generation:* It is the number of packet generated with respect to the interval taken for generating the packets. Comparison of packet generation of IAMR and EECA protocols is shown in Figure 5(a) and Figure 5(b). The X co-ordinate is considered as Packet Generation Interval and the Y co-ordinate is considered as Generated packet.

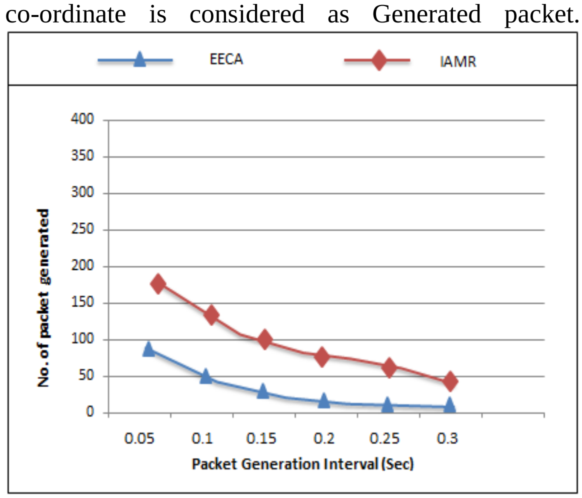


Figure 5(a): Packet Generation for 25 nodes

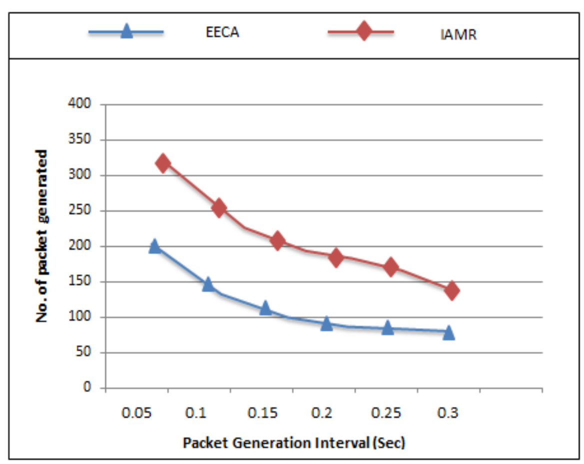


Figure 5(b): Packet Generation for 50 nodes

The scaling for X axis 50ms per unit and Y axis is 50 packets per unit. Initially, as interval increases, the packet generation of IAMR increases gradually to a higher level whereas EECA has low Packet Generation.

*3) Throughput*: Figure 6(a) and Figure 6(b) shows the comparison of throughput of IAMR and EECA protocols. The X co-ordinate denotes the packet generation interval where the Y co-ordinate denotes throughput at each interval. From the plotted graph the throughput for IAMR is higher than EECA.

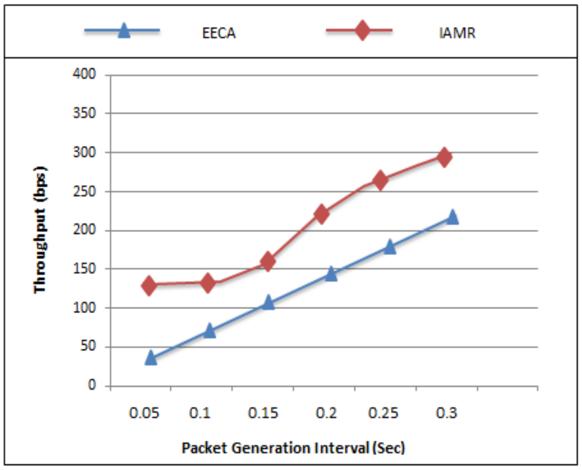


Figure 6(a): Throughput for 25 nodes

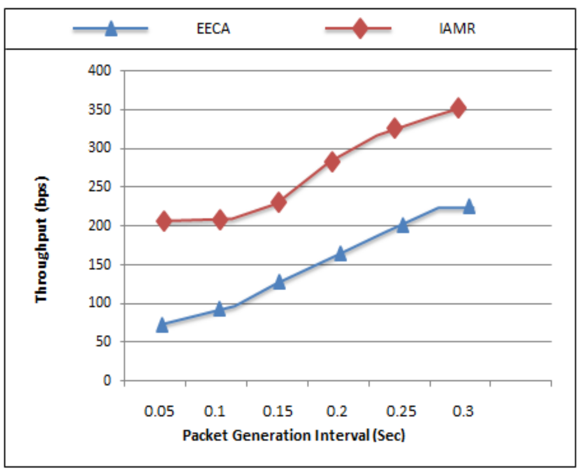


Figure 6(b): Throughput for 50 nodes

**Conclusion**

A Multipath routing protocol is implemented to improve QoS demands for event-driven applications in Wireless Sensor Network. The nodes are generated and the ETX cost is calculated for each node by using the forward and backward probabilities of successfully received packets. Cost is calculated for each node based on which the packet transmission takes place. The graph plotted for the resultant values is compared with EECA and IAMR based on various metrics like End to End Delay, Throughput, and Packet generation. IAMR achieved low energy consumption since it employs the available energy resourcefully. The Interference Aware Multipath Routing protocol can also be applied for multimedia data and for mobile nodes in the future.

**References**

[1] Shuang Li, Raghu KisoreNeelisetti, Cong Liu and Alvin Lim, "Efficient Multipath protocol for Wireless Sensor Networks", In Proc International Journal of Wireless and Mobile Networks (IJWMN), Vol.2, No.1, February 2010.
[2] Jonathan L. Bredin, Erik D. Demaine, Mohammad Taghi Hajiaghayi, and Daniela Rus, "Deploying Sensor Networks With Guaranteed Fault Tolerance", In Proc IEEE/ACM Transactions on Networking, Vol.18, NO.1, February 2010.
[3] Lou,W, Liu, W and Zhang,Y. "Optimizations in Mobile AdHoc", In Proc. Combinator Optimization,2006.
[4] Zijian Wang, Eyuphan Bulut, and Boleslaw K.Szymanski, "Energy Efficient Collision Aware Multipath Routing for Wireless Sensor Networks", In Proc. International Conference on Communication, pp.1-5, June 2009.
[5] Tsai J and Moors T, "A Review of Multipath Routing Protocols: From Wireless adhoc to mesh networks", In Proc. of the First ACoRN Early Career Researcher Workshop on Wireless Multihop Networking, Sydney, Australia,17-18, September 2006.
[6] Lou Wenjing, Liu Wei and Zhang Yanchao, "Performance Optimization using Mulitpath Routing in mobile ad hoc and Wireless Sensor Networks", In Proc. Combinatorial Optimization in Communication Networks, 2006, Vol 18,117-146.
[7] MarjanRadi, BehnamDezfouli, Kamalurlnizam Abu Bakar, ShukorAbdRazak and Mohammad Ali Nematbakhsh, "Interference-aware multipath routing protocol for Qos improvement in event-driven wireless sensor networks", In Proc Tsinghua Science and Technology, Vol.16, No.5,October 2011.
[8] Couto D, Aguayo D and Bicket J, "A High Throughput path metric for multi-hop Wireless Routing", In Proc. Wireless Networks, 2005,pp.11(4).419-434.
[9] S.J. Lee and M.Gerla, "Split Multipath routing with maximally disjoint paths in ad hoc networks", In Proc. IEEE International Conference on Communications", Vol. 10, pp.3201-3205, May 2001.
[10] Akkava K and Younis, M, "A Survey on Routing Protocols for Wireless Sensor Networks", In Proc. Ad Hoc netw.J. Vol.3, pp.325-349, December 2005.
[11] Y. Wang and S.Lin, "Error resilient Video Coding using Multiple Description motion compensation", In Proc. IEEE Fourth Workshop on Multimedia Signal Processing, pp.441-446, 2001.
[12] W.Xiuchao, Simulate 802.11b channel within ns2, SOC, NUC, Tec.Rep.

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