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Priority Controlled Data Transmission in Sensor Networks

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Abstract

In any real time communication the selected protocol has a majorrole in determining QoS provision. This paper illustrates the working of a protocol which provides real time provision by discovery of multiple paths. The algorithm manages the dynamic changes by computation of alternate routes. Priority of data determines its share of bandwidth. The performance is assessed with different node distributions and scenarios. The protocol resolves congestion, contention, and static route switching limitation. The other advantages include, but not limited to better delivery times, less requirement of bandwidth, and better throughput.

Keywords: Wireless sensor network, real time protocol, packet priority, end to end delay

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1. Introduction

Among the fast emerging research fields such as Internet of things (IOT) and Internet of Robotics of things (IORT), the wireless networks still find their place due to their myriad applications. For realizing any application, multiple sensor nodes interact with each other forming a sensor network [1].Real-time guarantees cannot be ascertained in these networks as a consequence of unreliability and capability limitations. In real time applications, events should be detected well in time to manage the criticality. These networks should have the capability of delay aware routing of information.

The target is to enhance reliability with more reliable services with reduced consumption of energy and latency in data delivery. The end-to-end reliability of data delivery is the probability that all packets reach the destination prior to deadlines [30].In many industrial applications the lost or delayed packets will lead to grave consequences.

The resource limitations and close interaction with the terrain where the network is deployed makes the wireless sensor networks very unique [2], [3]. These features gravely affect the performance of sensor networks labeling them unreliable [4]. Multitude challenges are encountered in critical real time communication in sensor networks , viz. resource, traffic characteristics, dynamic network topology to name a few. Packets achieving the dead line requirements while attaining scalability with minimal communication cost are of concern. The paper addresses this challenge in a lucrative manner. The algorithm illustrated here employs multi-alternate routes to enhance data delivery reliability.

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As the critical packets get higher share of bandwidth the packet loss for such packets is minimized tremendously enhancing the success rate of data delivery. Path discovery ensures loop freedom by enforcing the ordering of nodes. Overheads and latency incurred in route maintenance is least owing to the existing alternate routes.

2. Related Work Identifying the Research Gap

Lu C et al. in [5] considers only local information for routing while determining the priority of packets. RAP [5] is a soft real time protocol and priority based data delivery is not considered. [6] Illustrates a hard real time protocol which supports routing for two dimensional networks. Six messages are to be exchanged between source and destination for initial path set-up which contributes to large delay. He et al. in [7] contributes the SPEED which is a soft real time protocol. Kim et al. in [8], proposes a protocol which tries to attain reliability through forwarding packets in multiple routes after determining the link quality. But priority based data delivery is not considered.

CODA [9] does not address the constraints in real time data transmission. Saniir R.Das et al. in [10] put forward a comparison of AODV [11] and DSR [12]. AODVdoes not make use of multiple paths, whereas DSR extensively uses the service of route caches. The resource constraints in sensor networks restrict the exhaustive useof caches. In RRDTE [13], we present a cross layer protocol. MAC layer gives a feedback about the data transmission rate possible; accordingly, other layers adjustthe data rate. But this protocol does not exploit the advantage of multipath routing. In

[14] we put forward an algorithm which supports multipath. But the priority management of data is not considered here. In [34] a routing method based on geographic forwarding is outlined which is insufficient under the dynamic conditions of the net- work. The protocol illustrated in [35] has multiphase viz. discovery of paths, exploring the suitability of links, assortment of paths. Even though the energy preserving mechanism is effective, the overhead is high. In [36] PRTR, based on potential field approach is presented which supports transmissions with low delays; but this does not exploit the benefit of multipath routing. Authors in [38] make a comparison of multitude routing techniques and conclude that hybrid routing methods have better performance. Sachin et al. in [39] present a routing algorithm to enhance the QoS, but the overheads incurred are high and packet delivery ratio is low. Romana Rahman Ema etal. in [40] highlight the performance of various routing protocols in sensor networks based on simulation. But the paper does not address the data transmission reliability in sensor networks.

The proposed Real Time Protocol for wireless Sensor Networks (RPS) is a multi- path algorithm which finds multiple alternate routes and achieves bandwidth partitioning for different priority transmissions.

Even though many real time protocols are available in sensor network domain many of them are categorized as soft real time solutions. They do not assure the delivery of critical packets. Multipath techniques are also applied in many scenarios. The noveltyof RPS lies in its property of allocating bandwidth depending on the data priority. Implementation of enhanced 802.11e EDCA [37] for medium access differentiates different priority levels. This enables the successful delivery of critical packets. Four categories of data are envisaged here.

The subsequent sections give the outline of the protocol, the simulation environ- ment details, the performance metrics and the simulation results. Section 5 highlights the outcomes of the research work and the future directions.

Table 1. Data Category

Category	Data
0	Real-time Critical
1	Other Real time
2	Control
3	Non Real time

3. The Proposed Protocol

The dynamic nature and the associated unreliability, and the delay uncertainty makethe reliable delivery of data a challenging task [32].

The proposed protocol **RPS** generates dynamic multiple routes. Results indicate better performance in reducing end-to-end delay, improvements in bandwidth allocation, and higher throughput.

3.1. Elaboration of Implementation details

The salient features of the protocol are discovery of loop free multiple routes. Change over to a new route if the current route fails Minimization in the number of route discoveries. Finding alternate disjoint paths to forward its data packets without interruption [15] in the event of failures of links and nodes, is an amicable solution. This will elevate thedata transmission reliability [17]. QoS is achieved once data is transmitted on a priority basis[18], [17].Considering the QoS demands of the applications, higher prioritypaths or lower priority paths can be chosen. Network performance [16], [19] will begravely affected by large spike in critical data transference which may cause contention as well as congestion. As per the bandwidth requirements of each flow the net-work traffic can be split over multiple paths which will minimize the congestion which in turn will result in better energy utilization [20], [21], [23].

In the first phase of the protocol, during the initialization the sink node sends an INIT message which discloses the details of sink node's position. Node's location identification is done through localization techniques [22]. The sink will expect a ROUTE-ACCEPT message within the time out period. These messages are appliedfor path refreshing also.

A topology as in figure 1 in which nodes are deployed in a random manner is considered for the studies. In the second phase of the protocol a ROUTE- SELECT packet initiates the new route discovery. ROUTE-SELECT messages are identified by the unique sequence number. For each destination, the node saves the highest sequence number from the received ROUTE-SELECT. The node receiving the R 3OUT E-SELECT, sends an ACCEPT packet if it has in its routing table viable path information. Whenever there is a path failure the intermediate node that senses the unavailability of the route sends a ROUTE-ERROR message.

3.2.Route Selection

Disjoint paths are preferred in multipath routing due to overhead envisaged in routing and the complexity of scheduling at the MAC layer [24], [23].In this case one path failing will not affect the other paths which will contribute to better channel utilization. Links disjoint as well as nodes disjoint scenarios are explored.
In highly dense sensor networks the probability of having node disjoint paths islow and hence in this work link disjoint paths are considered. Nodes maintain routing tables which contain the information such as sequence number, Next hop, Last hop and hop count. Next hop and Last hop indicate the successor and predecessor nodes in the route respectively. ACCEPT and ROUTE-SELECT packets contain the First hop data. Whenever the routing table is refreshed, due to link failure, the new hop values to each destination are sent; those are named advertised hop counts.

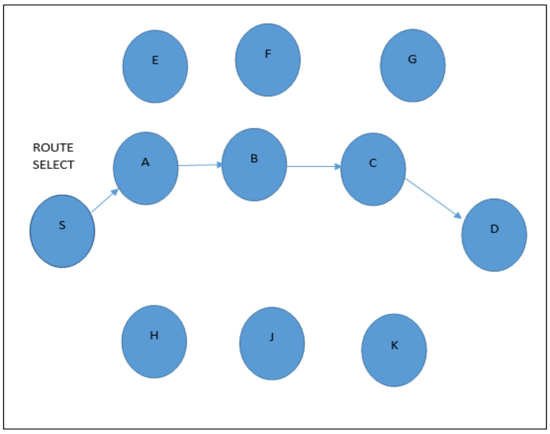
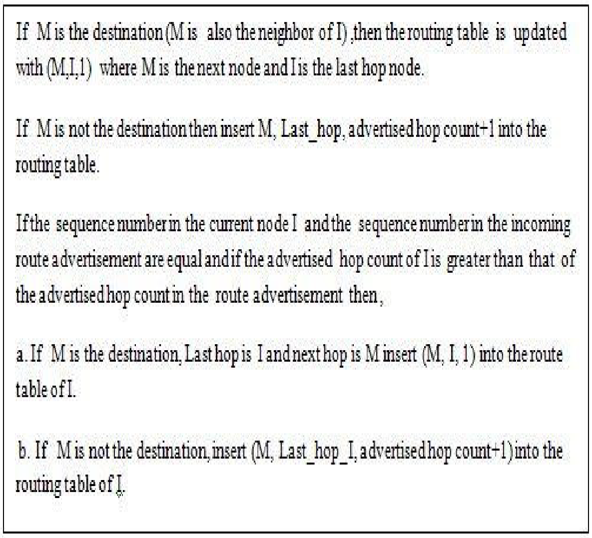


Figure 1. Route Discovery

3.3.Routing table update

Upon receiving a route advertisement, the sequence number in the packet is comparedwith the stored sequence number in the routing table for a particular destination. Updating the routing table will take place at the node I through the steps indicated in figure 2.



If M is the destination (M is also the neighbor of I) ,then the routing table is updated with (M,I,1) where M is the next node and I is the last hop node.

If M is not the destination then insert M, Last_hop, advertised hop count+1 into the routing table.

If the sequence number in the current node I and the sequence number in the incoming route advertisement are equal and if the advertised hop count of I is greater than that of the advertised hop count in the route advertisement then ,

a. If M is the destination, Last hop is I and next hop is M insert (M, I, 1) into the route table of I.

b. If M is not the destination, insert (M, Last_hop_I, advertised hop count+1) into the routing table of I.

Figure 2. Routing table update

3.4. Route Maintenance

ROUTE-ERROR packets are sent for the maintenance of routes. Each newly dis- covered route has a validity period and once the route expires the affected node sends a ROUTE ERROR message. Alternately when an active path fails a ROUTE-ERRORmessage is generated. Routes will be maintained only for the highest sequence number. Packets will be rerouted in the available existing paths in the eventuality of a link failure.

4. Simulation Results and Discussions

This section illustrates the results obtained by the simulation with NS-2 simulator. Sensor networks with different node densities such as 512, 256, 128, 64, and 32 are modeled. A random topology is envisaged with stationary sensor nodes. Two ray ground radio propagation model with Omni directional antenna is applied. The resultsof simulation are compared with those of AODV [11] protocol. Figure 3 illustrates a simulation scenario.

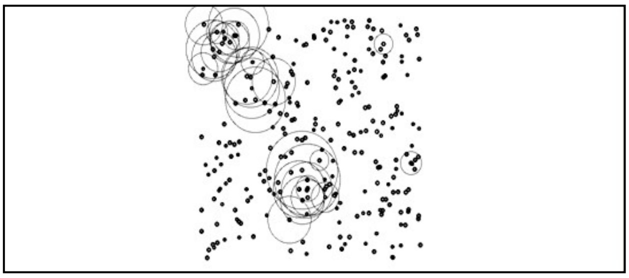


Figure 3. Simulation Scenario with sensor nodes

The bandwidth allocation of RPS is depicted in figure 4 for different data priorities. It is inferred that higher the priority of the data, higher is the bandwidth allocation in RPS. Four priority levels are considered for the study of bandwidth allocation in RPS. Priority 0 is the having the highest priority. RPS does priority based data delivery, andhigh priority packets can achieve low delay in traversing the network. High priority critical data is delivered with least delay which will meet the real time transmission requirements.

End-to-end packet delay [26], [28] includes delays caused by, propagation and trans- mission, retransmission at the MAC layer, and queuing. Figure 5 depicts End-to-End Delays of RPS and AODV. The graph illustrates the results with 32,64, and 256 nodes. Successful packet delivery depends on the latency incurred by the packet.In this study, the performance of same priority data in differerent network sizes is evaluated.With the increase in the number of nodes RPS achieves better results.

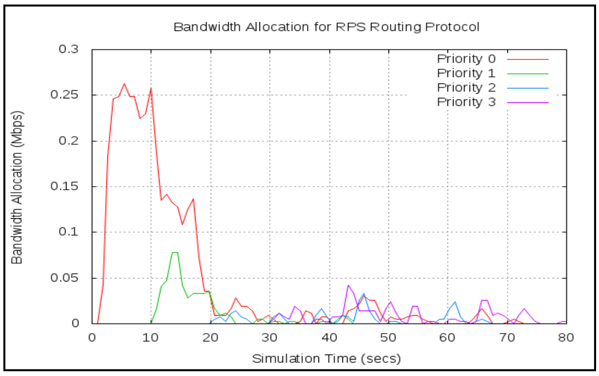


Figure 4. Bandwidth allocation based on the data priority

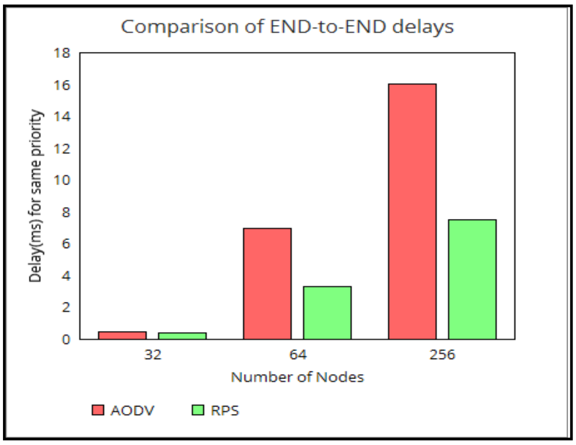


Figure 5. Comparison of End-to-End Delays

Packets collisions, routing loops and drops at the queues at the intermediate nodes due to the lack of buffer space will result in packet loss [29]. The graph in figure 6. indicates that the packet loss of AODV is more compared to RPS protocol with studies on same priority data with variations in the size of network. The share of bandwidth available for crucial data is higher which entails the minimum loss for such data. Minimizing the packet drops elevates the reliability in data transmission. Implementation of enhanced 802.11e EDCA [37] differentiates different priority levels. In the context of scalability RPS illustrates better performance as depicted in figure 7. When subjected to increasing network load RPS does not compromise on performance. The latency graph flattens as the node numbers increase in RPS illustrating this.

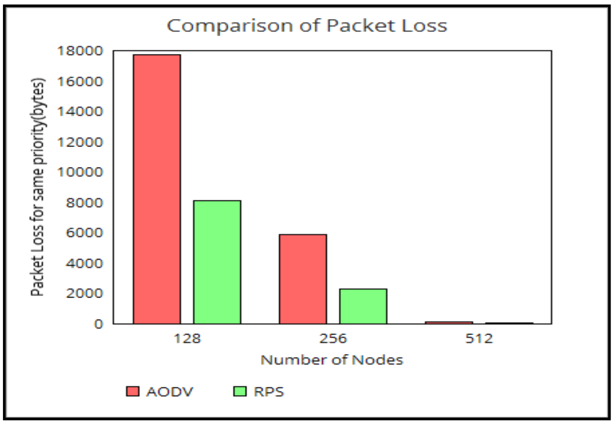


Figure 6. Comparison of Packet loss

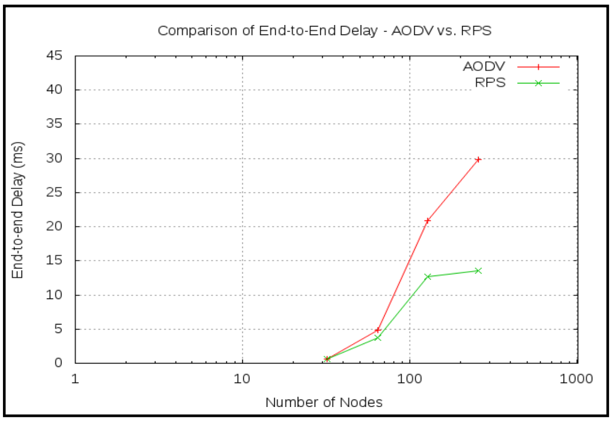


Figure 7. Scalability

5. Conclusion and Future research directions

The unmanned nature of sensor networks makes them vulnerable to malicious at- tacks. Multiple paths provide a better way for data collection providing more security for the collected data. The broadcast nature of the messages causes less overhead for communication [31]. By maintaining an ordering of nodes in each path the protocol achieves loop freedom. Disjointedness is maintained in alternate paths. Overhead is less as new routing paths are explored in the event of collapse in the existing routing paths. Share of bandwidth is decided by the priority of data. The simulation studies illustrate that RPS has better packet delivery and less latency while providing better throughput. Uniqueness of the protocol lies in its ability to ascertain resource sharing based on priority.

5.1.Future research directions

Even though the critical data delivery is appropriately addressed by the protocol, some enhancements are suggested to meet the future needs. For instance, the protocol can be optimized to effectively deal with the complete route cut-off problem by computing more disjoint paths when source and destination nodes are far apart. Incorporating the aspect of load balancing to be further explored. Persistentlyavailable sink may be replaced with a mobile sink. Synergy between other technologies such as cloud computing resulting in Sensor cloud [33] can be further explored. In future, RPS protocol can be extended to other types of wireless networks and the QoS deliverables can be analyzed.

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