Efficient Routing Strategy for Prioritized Messages in Mobile WSN using Geographic Forwarding Protocol

Manjula T
MTech: CSE Dept.
CMRIT, Bangalore, India
manjut_thekkencheri@yahoo.com

Dr. Jitendranath Mungara
Professor & Dean, CSE Dept.
CMRIT, Bangalore, India
jmungara@yahoo.com

Sagarika Behera
Assistant Professor, CSE Dept.
CMRIT, Bangalore, India
sagarika_b1@yahoo.co.in

Abstract

The current work represents a new routing protocol considering the environment of wireless sensor network with dynamic mobility. The approach addresses the issues for both real time and non-real time data dissemination from the mobile sensors to the sink. The prime target of this approach is to resolve the issues of QoS, mobility, and heavily congested area that are identified by considering the framework of running competition. The technique used is aimed to provide a superior route quality along with mitigation of network traffic congestion. The approach uses node-to-node routing phenomenon for selecting an optimal mobile node for forwarding the data packet. The performance evaluation is done considering packet delivery ratio and deadline miss ratio to show that proposed system outperforms the existing routing policy.

Keywords-component; Mobile wireless sensor network, Geographical routing, network condition.

I. INTRODUCTION

Over the last few decade, the application of wireless sensor networks (WSN) has been spread to different scenarios, such us environment monitoring, smart spaces, medical systems or robotic explorations, to name a few. WSN typically consist of hundreds to thousands of self-organized low-cost nodes whose batteries cannot be easily refilled [1]. Sensor nodes are constrained by resources such as storage capacity and data processing capability [2], but the main drawback of these networks is often due to energy consumption. Although different architectures have been considered for WSN, the potential of distributed cooperation among nodes to perform advanced signal processing tasks with unprecedented robustness and versatility makes decentralized multi-hop WSN one of the most appealing architectures. One of the multiple roles sensors can play in such WSN consists of forwarding information originated by other nodes. As a consequence, sensor failures (thus battery consumption) originate changes in re-routing and network re-organization. Energy conservation and power management are then crucial issues to prolong network lifetime as much as possible while preserving network connectivity and data delivery at the same time. In order to save energy, considerable research has been focused on the design of power-aware techniques for WSN [1]. This research includes: (i) sleep modes, where nodes turn off their radio, that are often used to reduce the energy consumption (this needs to be done without compromising connectivity so that a path between a source and a destination can be ensured [3]); (ii) power scheduling, used to reduce the energy consumption in the physical layer [4], [5]; (iii) or different energy-efficient algorithms, for network coverage, medium access control protocols, and routing (see e.g., [6], [7], and [8]). Many routing protocols and algorithms have been proposed in the literature to transmit data efficiently on multi-routes in multi-hop WSN ([2],[11]). However, route discovery still remains a challenging issue given the difficulty of designing a routing algorithm which shows good performance under all scenarios and for all applications [2]. As topological changes require updating the node distributions periodically, location techniques are reasonable useful, especially when forwarding data. Several techniques have been proposed on the topic of geographical forwarding and greedy forwarding. Different alternatives for routing protocols are GFG [9], GPSR [10], GEAR [11] [12] and GeRaF [13].

The proposed study has considered a specific track of running competition where the runners are considered as mobile sensors with specific lifetime. The entire running track is equipped with sink to disseminate the data gathered from runners (mobile sensors). If an abrupt change on physiological behavior is detected, an alert message must be delivered within a given deadline so that a medical team can be immediately triggered. This running competition scenario introduces many challenges to the WSN design. In fact, topology changes due to mobility must be treated carefully, because it is necessary to keep the knowledge about the neighborhood. Another challenge is high workload, since all mobile nodes must send athlete’s data and, additionally, nodes can also route data from others sensors. Therefore, the protocol must pay attention to channel congestions in order not to overload the network. To face all these challenges, a novel routing protocol is introduced that copes with mobility and provides priority to real-time messages. The option for geographical forwarding was due to its already known best performance in message delivery with timing requirements, beyond to provide scalability. The strategy to be aware of network congestions is a way to reduce packet dropping. Managing buffer capacity should be treated like a QoS metric, so that it may be possible to find areas with good remaining
buffer, enhancing chances to forward the data. In section 2 an overview of related work is given which identifies all the major research work being done in this area. Section 3 highlights about the proposed system. Implementation and Analysis is discussed in Section 4 followed by conclusion in Section 5.

2. Related Work

Most previous geographic routing protocols use greedy algorithms to forward the packet to the destination. They differ in how they handle communication holes.

Gao and Pottie [14] proposes a table driven, multi-path network structure for the communication between a large number of sensors and a central information gathering entity called the USER. However, their pre-built routing table and multi-path structure may not scale to large size sensor networks. Moreover, table driven approach may not be able to adapt well to network dynamics or traffic dynamics at a low cost. Li et al [15] propose a scalable and distributed location database service, which tracks mobile nodes’ locations. It selects multiple location servers to store each node’s location. Queries for a mobile node’s location are resolved using the predefined identifier ordering and spatial hierarchy to find a location server for that node. As mentioned before, such a location database service is not necessary in our target application. Scalable Location Update-based Routing Protocol (SLURP) [16] constantly maintains approximate location information of nodes in the network, and finds accurate routes to specific nodes on demand. It uses approximate geographic routing to route a packet to the region that contains the destination, and once the packet is inside that region, it uses source routing to reach the destination. It relies on route request to circumvent holes. The route request/ reply overhead and constant snooping mode in SLURP make it unsuitable for sensor net applications. Finn [17] is the earliest work known in geographical routing. He used restricted flooding search to navigate around holes. One drawback of this mechanism is the difficulty in determining an appropriate scope for the search. There has been substantial research interest [18] in localization systems. Such systems are a prerequisite for geographical routing and other sensor net applications. Of those, Ward et al. [19] propose a ultrasonic location system based on trilateration principle; Bulusu et al. [20] propose a coarse-grained connectivity metric method for localization in outdoor environments in the absence of GPS; Girod and Estrin [21] propose a robust range estimation technique using acoustic and multimodal sensing; Savvides et al. [22] propose Ad-Hoc Localization system (AHLos), a find-grained localization technique for ad-hoc sensor networks. Chang et al. [23] proposed a class of flow augmentation algorithms and a flow redirection algorithm which balance the energy consumption rates among the nodes in proportion to the energy reserves. Ko et al. propose Location Aided Routing (LAR) [24], which limits the search for a new route to an estimated “request zone”. The geographic location information is not used to make routing decision, but to limit the route request flooding to a smaller region. The request zone is estimated based on the destination’s previous known location and its known mobility pattern. However, when mobility information is not accurate, the request zone may have to be enlarged to the whole network.

GPSR, by Karp et al [10], elegantly avoids this problem by deriving a planar graph out of the original network graph. In GPSR, the packet follows the perimeter of the planar graph to circumvent holes. The derived planar graph is much sparser than the original one, and the traffic concentrates on the perimeter of the planar graph in perimeter mode. Thus, the nodes on the planar graph tend to be depleted quickly. In addition, nodes are assumed to operate in promiscuous listening mode and consequently consume energy [25].

PAMAS [26] proposes a new power aware multi-access protocol for ad-hoc radio networks. It conserves battery power at nodes by intelligently powering off nodes that are not actively transmitting or receiving packets. Less directly relevant is the work of Inäelinski and Goel [16], who propose querying and monitoring DataSpace. One primitive in this application is to send a query to a datacube, which is analogous to forwarding a query to a certain region in this paper. They first use geographic routing to forward the query to the geonode responsible for the datacube specified in the query. Then the corresponding geonode multicasts the query to relevant nodes based on its prebuilt indexing structure. However, it is difficult to build and maintain an efficient index structure under the high level of dynamics that sensor networks are exposed to.

3. Proposed System

The proposed protocol is targeted for applications consisting of mobile sensor nodes communicating with fixed sinks and incurring into very high workloads. Additionally, the protocol supports applications that require timely delivery of messages. Essentially, the protocol consists in a geographical forwarding approach that is aware of nodes location that takes into account several network aspects to perform routing decisions. The forwarding mechanism adopted by proposed technique has three main goals: (i) deliver real-time messages within a deadline; (ii) deliver non-real-time messages in a best-effort way; (iii) avoid local congestion in order to provide a load balance in the network. The proposed application scenario of the project work is as shown in figure 1.

![Figure 1. Considered Application Scenario](image-url)
To deploy such metrics, however, there must be a proper equilibrium. For this reason the proposed system carries weights for each metric so that they are used to compute a score to the node, as shown below.

\[
\text{Count}_n = \sum_{i=1}^{3} \theta (R_Q + B_{res} + V_{init})
\]

Count specify the gain/score of the node, \( \theta \) is allocated weight, \( R_Q \) is route quality, \( B_{res} \) is residual buffer, and \( V_{init} \) is initialized velocity. Additionally, it should also be energy efficient. Additionally, the proposed system is decided to be aware of the remaining buffer as strategy to avoid packet dropping due to network congestions. The proposed architecture is as shown below in Figure 2.

**Figure 2. Proposed System Architecture**

Our proposed protocol architecture is constituted by seven components, where four are located in the network layer, two in the MAC layer, and one in the physical layer. The congestion constituent is possibly the prime component of the proposed technique. It is responsible for providing the measurements about the buffer situation. This is a significant factor because the awareness of congestion situations can avoid packet dropping and retransmissions, which lead to a high channel contention. The neighborhood manager constituent is responsible for keeping the neighborhood table updated. The update process is performed by each node, which broadcasts a beacon message to neighbors one hop distant. The route quality evaluator is implemented in the MAC layer and can be used whenever the routing layer needs to compute the link quality metric. The velocity counter constituent uses the delay of a transmission packet and the relative distance of neighbor nodes to the closest sink. The round trip time is calculated considering the moment that the packet is transmitted and that the acknowledgement message is received. If \( R_i \) is time that the acknowledgement of packet \( i \) is received and \( S_i \) is the moment that packet i is sent with \( N \) number of successful transmission than round trip is expressed as,

\[
T_i = \sum_{i=0}^{N} \frac{R_i - S_i}{N}
\]

The energy control Component was implemented in the physical layer to allow setting the transmission power to a desirable velocity. Thereby the velocity counter constituent could interact with it at runtime to change the velocity according to the application needs. The Service Differentiation Mechanism was designed to prioritize real-time data packets (those packets with deadline) over normal ones. It provides a differentiation on the queuing processes so that packets in the priority queue are dispatched first, than it come those in the normal queue. If the forwarding node has its priority buffer full, it borrows space from the normal buffer. Additionally, if the normal buffer is also full, \( n \) normal packets are dropped to store the \( n \) new deadline packets. Therefore the total size available to store normal and deadline packets is the sum of the two initial designed buffers size. The process flow chart of the proposed system is as shown in Figure 3.

**Figure 3. Process Flow Chart of Proposed System**
To do so, each node in proposed technique must keep knowledge of the buffer situation from neighbors up to two hops distant. Combined with that, the proposed system implements a service differentiation mechanism that prioritizes packets with deadlines (real-time data) in comparison with packets without timing requirements. Another important feature that must be highlight is the fact that the proposed system does not keep route to destination given the constant topology changes in mobile environments. The forward choices are performed node-by-node and just a neighborhood table is proactively maintained. The following is a list of assumptions and dependencies upon which the successful implementation of the project depends:

- To be aware of the remaining buffer as strategy to avoid packet dropping due to network congestions, each node in the proposed system must keep knowledge of the buffer situation from neighbors up to two hops distant
- The proposed system addresses QoS which needs to be considered as three metrics: velocity of packet, quality of link estimation, and - to comply with high workloads - it also include buffer remaining as metric. It is considered that together these three metrics can lead to a highly optimized node-by-node forwarding decision. These metrics are available to each node in the components that constitute the protocol architecture.

An energy aware metric is used in the estimated cost function to balance energy consumption, and achieve energy efficiency for the whole network. However, under some circumstances, taking the geographically direct path is more energy efficient, and consequently prolongs network lifetime. After the number of hops traversed crosses some threshold, pure geographical routing is used instead of energy aware routing. The motivation behind this is to get to the target directly if the packet has already traveled a long way. The threshold is tunable, however, the algorithm is not very sensitive to this parameter which is confirmed by the simulation results. After a packet reaches a node whose neighbors are heavily depleted (which indicates a neighborhood where nodes are heavily depleted), the packet will switch to pure geographic mode to avoid taking an alternative longer path, and consequently consuming more energy than the direct path. When nodes are near the target region, pure geographic mode is used. Since the packet is supposed to be disseminated to all the nodes in the target region, the nodes bordering the target region are the bottleneck. Pure geographic mode is used near the target region to avoid taking a longer path and thereby avoid burning out more bottleneck nodes more quickly.

4. Implementation & Analysis

For the complete functionality of the project work, the project is run with the help of well equipped computer containing at least P4 processor, 20 GB HDD and 2 GB RAM. Normally, the OS is Windows, Linux or Unix. The main theme of this project work is to introduce a novel routing protocol using geographical forwarding protocol in mobile wireless sensor network that copes with mobility and provides priority to real time messages. This is achieved by viewing the different node activities inside the network and the specified way has to be mentioned to monitor those activities. The option for geographical forwarding was due to its already known best performance in message delivery with timing requirements, beyond to provide scalability.

Figure 4 represents simulation for network conditions aware geographical forwarding protocol for real-time applications while Figure 5 represents real time power aware routing protocol. The application scenario is characterized by a very high workload, as all nodes must periodically send a data packet with the vital signals of the athlete. Additionally, nodes must deal with the possibility of having to route other data packets. To simulate such situations, different data sets in number of packages is experimented where in each data set the nodes have different numbers of packages to send, chosen
randomly within the set bounds. Thereby the creation of areas is forced with buffer spaces available. While real-time data represents 10% of the packets sent by the node, the other 90% represent normal (non real-time) packages. In the application scenario, these real-time data represent alert messages sent to the organization staff.

Figure 6. Data Delivery Ratio for Real time Traffic

Figure 7. Deadline miss ratio for Real Time Traffic

Figure 6 represents data delivery ratio for real time traffic where x-axis is payload and y-axis is delivery percentage. Figure 7 represents deadline miss ratio for real time traffic considering payload on x-axis and loss rate in y-axis. Figure 8 and 9 shows data delivery ratio and deadline miss ratio for non-real time traffic respectively. It can be observe that at slow speeds it increases the probability of link break between neighbors, what justifies having a proactive neighborhood table maintenance. However, this maintenance should not overload the network. For such reason, the proposed protocol presents such very good performance, as it was designed with a lightweight proactive mechanism that keeps neighborhood table updated and does not generate very much overhead to the network. While designing the proposed system, the request-response strategy is first evaluated, where only nodes at distances shorter or equal to the source nodes in relation to next sink responded to the request. It can be also visible that in both experiments, speed and workload variation, RACE could sustain a small rate of deadline misses.

Figure 8. Data Delivery Ratio for Non-Real Time Traffic

Figure 9. Deadline miss ratio for Non-Real Time Traffic

5. Conclusion

The present work faced a very challenging problem, as it proposed a new routing protocol in a research scenario that already has several contributions. Our main motivation for that was the mobility issues introduced by our application scenario: a running competition where every athlete carries a sensor node that broadcasts data. It introduces problems that were not addressed so far, such as high mobility and high workload, and this is due to the large number of information sources and sinks, as every node produce and route data messages. To solve such challenges, a protocol in mobile wireless sensor network is introduced. The proposed system aims to provide...
QoS requirements to the application layer by giving priority to real-time messages and also by handling network congestions. Routing is performed node-by-node, where each node calculates a score to choose the best node to forward the message. Our main innovation is the mechanism to keep knowledge of the buffer situation from the transmitting node until the sink node. Such mechanism provided a considerable improvement in the packet delivery ratio.

References


[22] Andreas Savvides, Chih-Chieh Han, and Mani B. Strivastava. Dynamic fine-grained localization in adhoc networks of sensors. In Proc. ACM Mobicom


