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Incremental Development of Geographical Routing Protocols for WSNs: A Review

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Abstract: Geographical routing has been widely deployed by many researchers to overcome the pitfalls of traditional routing strategies. Initially, geographical routing is merely based on location service and forwarding strategies. But this paper presents the review of conceptual and application specific idea behind their development. We investigate the ways that defines which type, how and swhy new geographical routing algorithms are developed. This paper have reviewed new paths towards development of other location based routing protocols with advanced feature. This paper represents an overview on the benefits as well as limitations of location based routing protocols on the basis of their evolution like routing with or without location information, network topological challenges, transmission ranges problem and Link Asymmetry solution.

Keywords: Sensor Networks; Geographical Routing Protocol; Link asymmetry; Location errors.

I. INTRODUCTION

Network is made up of two or more computers with no master and slave relationship between them for remote information sharing. Network can be wired and wireless on the basis of Wireless network includes special type of infrastructure less ad hoc networks called sensor networks. Sensor networks are specialized ad hoc network with large number of sensing units to make interaction with the environment in order to transport information during routing. Due to large number of sensing units, routing in these networks is a challenging task. So many routing strategies are suggested to meet the requirement of recent technological advances. When we study the routing protocols of sensor network on the basis of their network structure [1], location based routing is better than other routing strategies that's why it is used by many researchers to enhance the characteristics of WSNs. Location based routing is our mean concern in this paper and it outperforms other topology based routing protocols[13] [14][16] as they reduces the route discovery and table formation overhead for each and every node in the routing field as geographical routing is based on the location information of the neighboring and destination nodes. This paper represents the pros and cons of the existing routing protocols. Geographical routing is based on the aggressive use of the geography to enhance the scalability and efficiency of existing routing strategies and it is quite better than hierarchy and caching based routing algorithms. All previously proposed geographic routing protocols are based on the location information but geographic routing without location information [20][24][25] or the limited information [17] is possible to some extent. Incremental growth of geographic routing means the enhancement of the properties of the initial geographical routing protocols to evolve new and improved routing protocols. The Problems with these routing protocols leads to the development of the new protocols. This paper highlights the properties of existing routing algorithms so that future researchers can decide their future work. Our paper represents the basic geographical routing, face routing, problems with face routing, a new novel stateless routing protocols combining greedy with face routing and many more advanced routing protocols with their problems. Geographical routing protocols are customized to remove problems like data consistency, unidirectional links leading to the degradation of the routing performance, location errors and effect of non uniform transmission ranges. This paper will give an instant review on the improvement of routing protocols. In section two, we will give a brief picture of the state of art or the related work. Section three represents the basic idea behind geographical routing and stepwise development of the location based routing protocols. Section four outlines the limitations of existing routing protocols that provide path towards future work or the conditions under which existing routing protocols can be failed. Last section will give the conclusion and open issues for future work.

II. RELATED WORK

Geographical routing protocols or position based routing are generally based on the forwarding strategies like greedy forwarding and location based services like grid based location service for moving information in the form of packets across a network from source to destination. Basic geographical routing is based only on greedy forwarding [9] [15] where the packets are forwarded to the neighboring nodes of the source node closest to the destination. Greedy forwarding failure leads to the face routing algorithm with guaranteed delivery by following the facial boundary [10] [17]. Many new protocols are developed for extraction of the planar graphs, that is, graph with no crossing edges so that unit disk graph assumption can be fulfilled. The routing protocol that

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combines the features of the greedy forwarding and face routing [9]. It gives better performance than routing protocols which are purely based on the greedy forwarding. The advancement to these routing protocols is provided by the routing protocol that limits the boundary of routing area by the ellipse to find the optimal path towards the destination [10]. Many of data centric applications are build atop greedy perimeter stateless routing protocol such as GHT[17].Since, planarization failure leads to many problems like unidirectional, disconnected and the crossing links that lower their performance [17][18]. That's why geographic routing without planarization is developed to introduce a new geographic routing protocol called GDSTR (Greedy Distributed Spanning Tree Routing) [20] for finding the shorter paths and maintenance cost is also reduced. The limitations of face routing along the effect of location errors in the face routing is reviewed in [18] [19]. Geographic routing is generally based on the location information obtained by either with GPS[27] based and GPS free services[28].Geographical routing is still an open research issue for many researchers due to many challenging problems like energy inefficiency due to unnecessary path traversal, data consistency problems, location inaccuracy and problem faced due to communication voids.

These problems are also discussed in coming sections. These papers give the incremental view of the geographical routing protocols. Many position based routing protocols suffers from the local minimum problem due to voids or the regions with dead nodes. Many paper presents the solution to these problems like BOUNDHOLE algorithm [21] and Greedy Landmark Routing (GLR) [25].At last, this paper gives the directions to decide future function and provides a brief knowledge layout for many researchers. We have reviewed many topics related to geographical or the location based routing but still there are many open issues which need our attention.

III. INCREMENTAL DEVELOPMENT OVERVIEW

In the previous section, we represent the research work related to geographical routing. But this section will give complete overview of the evolution of the geographic routing protocols and the problems solved by these routing protocols. Geographical routing is better than topology based routing Protocols which is based on the caching based on topological changes like Dynamic Source Routing (DSR) [5], Ad-Hoc On-Demand Distance Vector Routing (AODV)[7] and DSDV[2].

The step by step development of geographical routing algorithms is reviewed along their pitfalls. Position based routing protocols are better than reactive and proactive routing protocols as they have neither to store routing tables nor to transmit messages to keep routing tables up to date. Now come to the incremental growth of geographical routing protocols which is shown in following subsections.

1. Basic Idea behind Geographical Routing.

Basic idea here reveals the initial phenomenon on which geographic routing was based. Here, we represent a brief discussion on this topic by reviewing few geographical routing protocols that are purely based on the location service to deliver the packets towards the destination. Geographical routing ,as the name suggest is based on the geography of a particular location as well as geographical information related to the node participating in the information traversal. The basic idea behind geographical routing is represented in following figure1.

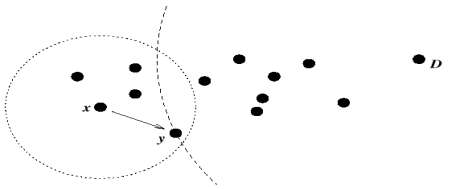

Figure 1: Greedy Forwarding Example: x forwards to y, its neighbor closest to D.

This figure gives the clear picture of the geographical routing in which large number of nodes are distributed in the geographical region .Here, x act as the source node and D as destination node. The nodes within the dotted circular region are considered to be present within the transmission range of that node; y is one of these nodes. x will transmit the packet towards next node on the basis of the location information. y is closest to D, so x transmit packet to y. But here, one thing important is the location information of the nodes. This information is obtained from GPS (Global Positioning System) [26].Sometimes, this method does not work due to distance problem or the obstacles or opaque objects between their path. So, GPS free services [27] are also available to provide the location information of the nodes. After understanding this diagram, we obtain a picture of geographic routing and the information related to it. The basic geographic routing which is based on the location information undergoes many problems like transmission ranges may vary, location information may be incorrect, and nodes may be mobile and at last but not the least node boundary may also vary due to topological changes according to application requirements. The face routing or routing by following the facial boundary is represented by [10] which comes as the alternative to initial geographical routing that only depends on the location services.

1.1 Sequential growth of Geographical Protocols.

This paper gives a brief review of the routing protocols related to the geographical routing protocols. These protocols plays important role in the evolution of new routing protocols on the basis of removal of their problems. These geographical routing protocols are reviewed here according to their sequential development.

A .Geographical Routing based on Greedy Forwarding.

1) GPSR (Greedy Perimeter Stateless Routing)

GPSR [9] is one of the novel routing protocol that combines the greedy forwarding strategy as described in

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the figure1 with the face routing strategy. When greedy forwarding gets failed due to local minimum problem, we have to adapt the face routing.The local minimum problem is shown here.

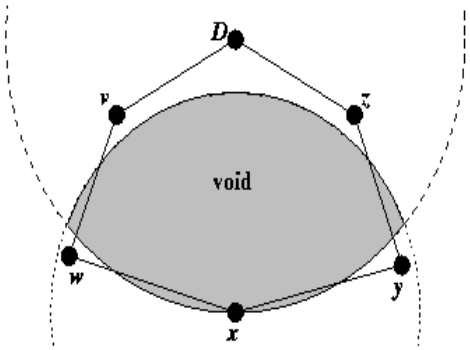

Figure 2: Local Minimum Problem

This figure indicate the problem where x is at the same distance away from its one hop neighbors and x as a source node is nearest to the destination than any one of its neighbors. This failure leads to the development of the Right Hand Rule where we have to follow the faces to handle such type of problems. This is represented in the following figure to handle the greedy forwarding failure by assuming no crossing heuristics. Here, no crossing heuristics means removing every second edge which crosses the first edge.

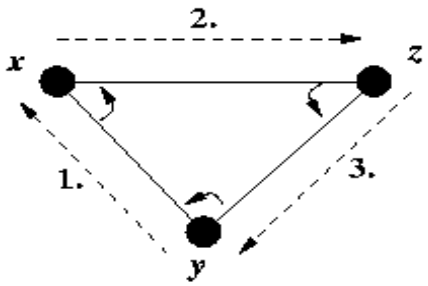

Figure 3: Right Hand Rule after Local minimum Problem

This figure represents the motion of the packets along the boundary of the nodes in counterclockwise direction. But Right Hand Rule still suffer from another problem called crossing edges problem. This problem is further solved by following the planarization. Planarized graphs are graphs with no crossing edges. Types of these graphs are discussed in [28] and [29].The three problems related to the perfect geographical routing are link asymmetry, data consistency problem and boundary problem whose solutions are provided in [16].

2) Face Routing

In the previous sections, we represent the overview of geographical routing protocol at its initial stage. This subsection represents the review of face routing algorithms with or without greedy forwarding strategy. Hence, the face routing is the next step of the development of the geographical routing protocols. Face routing is adapted when the greedy forwarding get failed. Face routing begins with simple face routing strategy which starts with the exploration of the boundaries of the planarized graphs by local right hand rule but here we have to follow whole boundary [10][17].Face routing can be easily understood from [10].These paper presents the overview of common geographical routing protocols which depends on the face routing. Simple face routing suffers from one of the problem of the exploration of the boundary of the whole facial boundary that leads to the wastage of large amount of valuable energy. Then, new face routing algorithm is developed called BLR (Bounded Face Routing) in which face exploration is limited to certain area or within the ellipse. Extension to this is Adaptive Face Routing (AFR) [14] that restricts the exploration of the boundary to some predetermined value and doubles the value in successive attempts of routing. Another routing algorithm GOAFR (Greedy Other Adaptive Face Routing) [14] is adapted to enhance the features of the existing routing algorithm in which greedy routing with other adaptive face routing is followed by following the greedy routing and when it fails, we switch to the face routing within the elliptical region to find the point on the boundary which is closest to the destination. Main benefit of this algorithm is that it is both Worst case optimal and average case efficient geographical routing algorithm .This is also beneficial in detecting the disconnected links in the sub graphs. The difference between simple face routing and the Greedy other face routing is shown in the following figure. This figure involves the two nodes s as the source and t as its destination's is the face which is to be followed when greedy forwarding get failed.

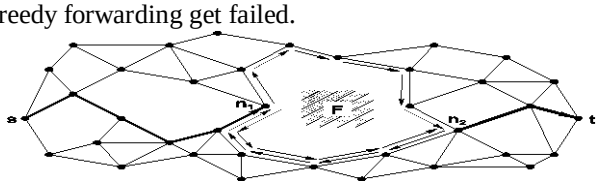

Figure 4: Face Routing Example

The facial traversal is reviewed in this subsection that represents the sequential development of the face routing algorithms. Geographical routing is based on the forwarding method whether it is greedy based or facial forwarding. So this algorithm adapted both according to the change in sensor net environment.

3) Robust Face Changes and Revised Right Hand Rule.

This section involves the incremental development of the geographical routing protocols and issues related to them. Face routing is based on the two primitives – one is planarization and other is face traversal. When these primitives get failed due to non uniform transmission ranges and the violation of the Unit Disk Graph assumption, this leads to the unidirectional, disconnected and cross links that leads to the routing failure due to location errors and physical obstacles. These concepts are shown in [18].Routing failure may be due to inconsistent information about the witnesses during the planarization as reviewed in the previous sections, for this Mutual Witness Procedure is adapted but this may create crossing links. Face routing failure occurs when there are incorrect face

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changes or right hand rule get failed. This leads to the discovery of the robust face changes and the revised right hand rule.

4) Modified Planarized Graph

Planarized graphs bear no crossing edges with unit disk graph assumption. Location errors affect the performance of the planarized graphs by violating their conditions. The removal of the inaccurate nodes and non removal of the actual node creates permanent loops and cross links that prevent the successful delivery of packets towards the destination. Destination inaccuracy is another cause of routing failure. All these causes are shown in [18]. This paper gives a complete view of the bounds and the conditions under which the face routing get failed. This problem is resolved by providing the solution to the graph disconnection due to violation of the properties of the planarized graphs in terms of the modified unit disk graph in which no node can be removed until witness node is seen by both the nodes at the same time.

B. Geographical Routing independent of Greedy Forwarding

1) Non planarized Geographical Routing

As we have previously reviewed, planarization is one of the main factor on which the geographical routing is based. Major limitations of the planarized graphs are failure due to location errors and non ideal ranges, higher maintenance costs and its complexity. A new geographical routing protocols is developed without any planarization [17] to reduce the errors induced due to planariztion failure. In this section, we will focus on the properties of this routing algorithm. This protocol is based on the greedy forwarding but here we does not follow the face routing instead we follow the boundary of the spanning tree. Spanning tree bears no loop and the tree nodes also contains the location information about its child nodes. The main benefit of this algorithm is that it performs better in case of the network topological changes with both denser and sparser networks. Planarization failure degrades the performance of the position based routing protocols, so it remove those failures. Hence, in this section we represent the new approach to lead the future work towards the development of new geographical routing protocols.

2) Routing with or without Location Information.

The protocols that depend on the location information are already discussed. Location based routing is based on the location information of the nodes and their neighboring nodes. Many of the routing algorithms exploit geographic information for successful packet delivery on the basis of location information. Geographical routing that does not depend on the location information is shown in [22].This paper considers three scenarios to construct the virtual edges for the both perimeter and non perimeter nodes. These geographical routing protocols with the virtual coordinates give better performance than the geographical routing protocols with true coordinates in terms of the success rate and path length under losses, mobility and obstacles.

3) Routing with Non Uniform Coverage Area.

We have already reviewed the effect of location errors on the geographical routing. Imagine the nodes are moving out of the transmission range of the sender node or the network topology gets changed continuously. The effect of all these changes leads to the degradation of the performance of the Geographical routing protocols. The impact of non uniform transmission ranges on MAC protocols and location based routing protocols is shown in [19]. Location based protocols have worst impact on its performance than other protocols. Radio irregularity creates the asymmetric links that has more impact on the message exchange and delivery delay of the packets. In MAC protocols, radio irregularity has more impact on the carrier sensing and handshaking while location based routing protocols are affected by the production of the unidirectional links that induces the delay with more energy consumption. This paper give symmetric geographic forwarding is to overcome the problems of the unidirectional links and improve their performance. Radio irregularity model is also introduced to enhance the properties of the geographical routing protocols under non uniform coverage area.

4) Routing with voids.

Voids are the empty regions created due to some failure in the geographical routing or by unwanted regions. We have reviewed in section two that geographical routing gets failed due to the creation of the void. .Here we have studied a different approach [21] in which method to detect the nodes that falls in local minimum condition and ways to bypass these nodes are shown in order to transmit data successfully towards the destination. Packet gets struck at a node when one hop neighbors of source node is closer to the destination than its one hop neighbors. Holes are referred as collection of dead nodes or the communication voids. Holes are beneficial as they are useful in disaster detection, can replace the planarized graphs to reduce the cost, complexity and help in increasing the connectivity of whole network. The holes can create many problems during routing as we have to find out paths for the geographical routing in order to forward the packet information from one location to another location. The benefit of these algorithms (BOUNDHOLE and TENT rule) is that they improves the path quality and performs the efficient routing during non uniform transmission ranges.

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