Literature Survey: Role of Computational Geometry Methods in Wireless Ad Hoc Network (WAN)

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Abstract— **The fast growing use of wireless technology among the common man has increased the speed of development and research in this area so that an efficient and robust network can be developed. Ad hoc network is one kind of wireless network where the researchers have shown a great interest. Computational Geometry has grown into an independent field in the last two decades and the methods of computational geometry are widely used for providing efficient solutions in wired as well as wireless network. This paper gives a review of one of the basic structures of computational geometry and also summarizes their role in solving issues related to wireless Ad Hoc network.**

Keywords: ***computational geometry, wireless ad hoc network, routing, coverage control***

I. Introduction

Advancement in technology has increased the use of wireless Ad Hoc network among people. Earlier for long time the research for Ad Hoc network was only for military, but later it was used outside military domain. The nodes of Ad Hoc network have special characteristics unlike the wireless network. Due to these specific characteristics of nodes in Ad Hoc network there are many challenges attached to it. To solve these issues computational geometry plays an important role.

This paper gives introduction to Ad Hoc network computational geometry, computational geometry methods and summary of issues solved using computational geometry problems. The paper is further divided into three sections. The second section defines wireless Ad Hoc network. The third section defines computational geometry and its methods. The fourth section briefly gives the summary of research done in wireless Ad Hoc network using computational geometry.

II. Ad Hoc Network

The wireless network unlike the wired has no end to end physical connection. This technology has come a long way since the development of wireless signaling techniques in the late 1800s.

Today there are many types of wireless technologies used in variety of applications. One type of wireless network is the wireless ad-hoc network, also known as IBSS - Independent Basic Service Set. In Ad Hoc network each node is willing to forward data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity i.e. there is no pre existing network infrastructure. the wireless network can be further divided as : mobile ad hoc networks (MANET), Vehicular Ad hoc Networks (VANETs), Smart Phone Ad hoc Networks (SPANs), Internet based mobile ad hoc networks (iMANETs), Military MANETs. The figure below shows the changing topology of Ad Hoc Network.

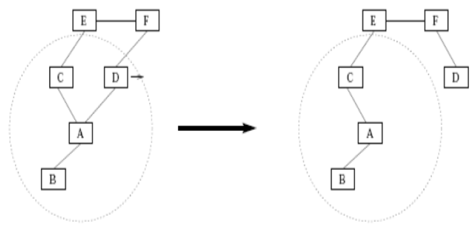

Fig 1: Topology change in Ad Hoc Network

The wireless Ad Hoc network is widely used technology and is of high research value but there are several issues to be addressed like: Route changes due to mobility, Limited bandwidth, Routing Overhead, Dynamic topology, Security threats, Power Management, Fault Tolerance etc.

III. Computational Geometry

Computational Geometry emerged from the field of algorithm design and analysis in the late 1970s. It is a subfield of algorithm theory that involves the design and analysis of efficient algorithms for problems involving geometric input and output. It deals with design and analysis of algorithms for problems which involve geometric objects and a lot of focus is on mathematical analysis for proving the efficiency of the solutions. Computational Geometry problems find a lot of applications in the field of VLSI, Geographic Information Systems (GIS), graphics and databases. Research is ongoing since years on computational geometry structures to provide solutions for problems of wireless network. The problems solved in the field of Computational Geometry can be classified into two categories: (a) single-shot problems, and (b) multi-shot problems. The Delaunay triangulation voronoi diagrams and convex hull are some of the basic structures in computational geometry and it is used in many applications in wireless network.

A. Delaunay Triangulation

Delaunay triangulation is part of computational geometry and is a special triangulation defined as: A Delaunay triangulation for a set of points on a plane is a triangulation such that no point is inside the circum circle of any triangle. Delaunay triangulation (shortly *DT*) was proposed by a Russian scientist Boris N. Delone. [2]

There is also an alternative definition of the Delaunay triangulation: the *DT* is a dual of the Voronoi diagram *Vor*(*S*), which is a set of points having the same distance from at least two points from *S* and, moreover, there is no other point from *S* with a smaller distance.

There are different types of algorithm for creating Delaunay Triangulation. In general these can be classified as follows:

- Local improvement
- Incremental construction
- Incremental insertion
- Higher dimension embedding
- Divide and conquer

The figure below shows Delaunay triangulation constructed using divide and conquer method.

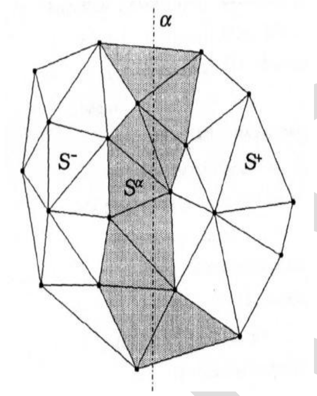

Fig 2: DT constructed using Divide & Conquer

B. Voronoi Diagram

A Voronoi diagram records information about what is close to what. Let $P = \{p_1, p_2, . . . , p_n\}$ be a set of points in the plane (or in any dimensional space), which we call *sites*. Define $V(p_i)$, the *Voronoi cell* for p_i, to be the set of points q in the plane that are closer to p_i than to any other site.[3] That is, the Voronoi cell for p_i is defined to be:

$$V(p_i) = \{q \mid |p_i\, q| < |p_j\, q|,\ \forall j \neq I\}.$$

Another way to define $V(p_i)$ is in terms of the intersection of half planes. Given two sites p_i and p_j, the set of points that are strictly closer to p_i than to p_j is just the *open* half plane whose bounding line is the perpendicular bisector between p_i and p_j . Denote this half plane $h(p_i, p_j)$. It is easy to see that a point q lies in $V(p_i)$ if and only if q lies within the intersection of $h(p_i, p_j)$ for all $j \neq i$. In other words,

$$V(p_i) = \cap_{j \neq I}\, h(p_i, p_j).$$

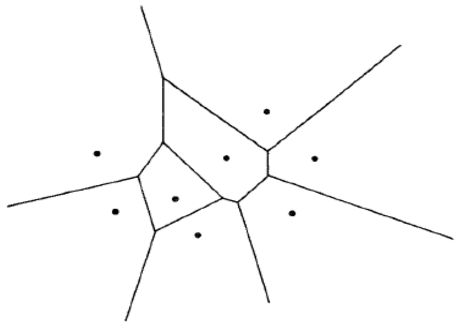

Fig 1: voronoi diagram of eight sites in a plane

C. Convex Hull

A geometric set is *convex* if for every two points in the set, the line segment joining them is also in the set. One of the first problems identified in the field of computational geometry is that of computing the smallest convex shape, called the *convex hull* that encloses a set of points.

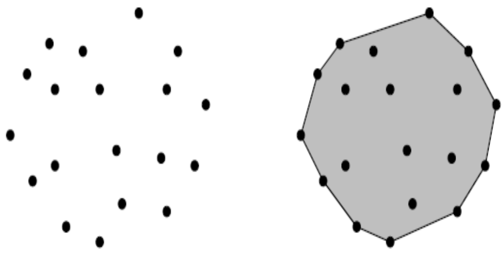

Fig 4: Point Set and Convex Hull

The figure above shows the example of convex hull for given set of points. There is a simple $O(n^3)$ convex hull algorithm, which operates by considering each ordered pair of points ($p; q$), and the determining whether all the remaining points of the set lie within the half-plane lying to the right of the directed line from p to q. There are lots other of algorithms like *Graham's Scan, Divide and Conquer, Quick Hull* to compute convex hull better than this basic algorithm.

IV. RESEARCH WORK

There are many issues and challenges in wireless Ad Hoc networks so many scholars are attracted to research on these issues in this domain. This section summarizes some of the research work done that uses computational geometry and give solution for these problems.

The coverage problems for Ad Hoc networks is an important issue to be addressed and it is classified broadly as [6] - area coverage, target coverage and breach coverage. In [8] the author used triangular grid based deployment scheme to deploy the nodes. They used Delaunay triangulation for this as it has the property that for each circumscribing circle of a triangle formed by three vertices in, no vertex of is in the interior of the circle. So the nodes are deployed by dividing the field into triangles using Delaunay triangulation.

An *area coverage* problem is to find a minimum number of sensors to work such that each physical point in the area is monitored by at least a working sensor. By combining computational geometry and graph theoretic techniques, specifically the Voronoi Diagram (VD), Delaunay Triangulation (DT) and Graph Search algorithms, can solve the problem. The VD allows sensors to distribute the sensing task by partitioning the space in a meaningful way. The voronoi cell of a sensor *s* is the subset of the plane in which all points are closer to *s* than to any other sensors. By using Voronoi Diagram and graph search algorithms, S. Megerian, F. Koushanfar and M. Potkonjak gave an optimal polynomial time worst and average case algorithm for coverage calculation for homogeneous isotropic sensors. Here they used Delaunay triangulation to find the two closest sites several experimental results were provided to show that the coverage problem can be improved. [7]

The VD and DT can also be used for connecting a disconnected network along with Spanning tree and Steiner heuristic which was proposed in [1]. The problem was to find a set of locations to place additional sensor nodes, i.e., relay nodes N with minimum cardinality such that the resulting graph becomes connected. They used Optimum relay sensor placement algorithm (ORSP) for enhancing the connectivity of wireless sensor network and this algorithm also supports the fault tolerance of the network. In [5], authors propose an optimized relay node placement algorithm using a minimum Steiner tree on the convex hull. The algorithm identifies Steiner points in which relays are populated such that the segments can be connected with minimum number of relay nodes. The relay nodes deployment strategy of the algorithm is inwards from the periphery of the area identified by the convex hull.

Wireless sensor network (WSN) is formed by a large number sensors that communicate through Ad Hoc wireless network to collect information of sensed objects of a certain area. If the locations of sensors and objects are known then only the acquired information is useful. Therefore, localization is one of the most important technologies of Sensor Network. The Voronoi diagram-based localization scheme (VBLS) and its extension weighted Voronoi diagram-based localization scheme (W-VBLS) is used to solve this problem. In [4] the algorithm proposed by the author used mid perpendiculars between each beacon node and its neighbor beacon node to compose the Voronoi region boundaries and then weighted all the nodes within this region. In first step the algorithm obtains all the beacon nodes' Voronoi regions in order and in second step different weight values are added to the obtained regions and in the final step the centroid of the largest weight value region is obtained as the estimated coordinate of the node to be located. The improved version of this algorithm in [9] by selected two beacon nodes weighted bisector as the region boundaries, then calculated the two weighted bisector intersection coordinates as estimate coordinates, and in last step they used the weighted average values of all the estimate coordinates as the final estimate coordinates of the node to be located. The authors conducted experiments and also gave a graph showing the relation between localization accuracy of the three algorithms (w- centroid, VBLS and W-VBLS) and the number of nodes. The graph is shown in the figure 5 below.

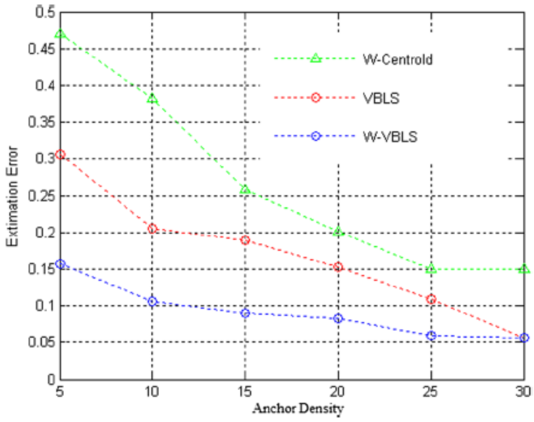

Figure 5: Relationship Between Positioning Accuracy and Number of beacon nodes.

The task of finding and maintaining routes in Ad Hoc network is another important issue as host mobility causes frequent unpredictable topological changes. There are a number of network protocols are proposed for achieving efficient routing. [4] The corresponding selection of neighbors for most forward progress within radius (MFR) routing is done using convex hull. The convex hull CH(S) of all neighbors of a given node S is constructed, and tangents from S to the circle of possible location of destination which touch the circle at points U and V. The nodes on CH(S) can be projected onto tangents t' and t" to determine nodes U' and V' and other nodes between them that belong to the request zone. The convex hull of n nodes is constructed in O (n log n) time using Graham's scan algorithm.

V. CONCLUSION

The computational geometry and graph theory concepts are used in many areas. The wireless Ad Hoc network is one such area that uses these concepts for solving the fundamental problems. The paper is to show the use of computational geometry structures like Delaunay triangulation, voronoi diagram and convex hull in the wireless Ad Hoc network.

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