Location Aware Peer-to-Peer System

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Abstract

Orthogonal Recursive Bisection and Delaunay based spatial data structures are commonly used in various applications. In this paper, we study these two data structures in implementation location aware peer-to-peer system. We evaluate these data structure with criteria which characterize peer-to-peer system, that is decentralization, unpredictable, fault-tolerance etc.

1 Introduction

Peer-to-Peer (P2P) started by Napster, changed in the way we have been using Internet in the past 10 years. The success of Napster also motivated researcher to apply the concept used by Napster which useful for general population in large. Location aware P2P (henceforth LP2P) is one of the practical and interesting applications of the P2P system. These systems realize that many times an user is interested in gathering local information which are physically close to their physical location. example include search for nearby cinema theater, local climate forecast information etc. There are many instances, when physical closeness is more important and meanigful than logical closeness that may be possible using Internet.

Most of the existing P2P systems are classified under either structured or unstructured P2P systems. In an unstructured P2P system, nodes do not have fixed topology therefore flooding mechanism is used to gather information from other nodes. This flooding become expensive and also we can not guarantee that we will get information close to our need. Structured P2P system on the other hand, such as Pastry, Tapestry, Chord etc. are content based P2P system and use distributed hash tables to search for the content. Structured P2P systems are not suitable when the search values are not mapped accurately to the keys. Both kind of P2P systems have overlooked the importance of physical closeness which is an important parameter for location aware information. A new classification of the P2P is needed which focus on providing local information.

In order to develop new L2P system, we study computational geometry algorithms. Computational geometry is a branch of algorithm design and analysis which study the geometric problems such as convex hull calculation in arbitrary N-dimension, 2-3d triangulation,fast proximity information retrieval etc. Many of the computational geometry algorithms and data structures have been studies for ad hoc wireless networks. For survey paper, please refer to [6]. Among the various data structures, kd-trees, and 2-3D delaunay triangulation are most popular because of their simplicity and practical importance.

Lieberherr used Delaunay triangulation to construct overlay network which support application layer multicasting. GeoPeer P2P system [1] has addressed the issue of location aware system. In this system, nodes are arranged themselves to form Delaunay triangulation augmented with long range contact to achieve small network diameter. The major difficulty in constructing LP2P system is to arrange nodes in some fashion which take into account the unpredictability of node removal and insertion.

Physical location is the most important parameter in location aware P2P system. There are many technologies available which can provide fairly accurate physical location of the system. Perhaps the most popular among them is GPS(Geographical Position System) which is a satellite based navigation system. GPS is fairly accurate within approximately 10 meters. To use GPS, every object must be able to receive message from at least three satellites, therefore this technology is useful only for outdoor object identificaions. There are indoor location technologies such as Active Badge [4], Active Bat [3], Cricket [8], and Radar are available, which can be used for LP2P to provide services within large building complex. In this paper, we assume that physical location is available for each system participating in the LP2P system. For more detail about location system, please refer to [7]

2 Nature of LP2P system

- *Decentralized:* Decentralization of services is the core of P2P system. Gnutella, although uses centralized server to locate the peer which might have information, is the single point of failure, which P2P systems want to avoid. Decentralized service also reduces the cost of maintenance.

- *Unpredictable join and leave:* Any P2P system should take into account that peers may join or leave the system at their own will. A network overlay should be robust enough to repair the network efficiently.

- *Time for join:* Group membership is the mechanism by which an user join the network. In order to place the node into network at appropriate location, some messaging or forward messaging is required among the set of other peers which incurs lots of time. In a good system, there should be some upper bound, which an user may be willing to wait to join the system.

- *Fault tolerance:* Client-Server model of computing is the single point of failure. P2P system on the other hand, break away from the model and should ensure that some nodes' failure or departure from the network do not bring down the entire network.

- *High Clustering:* In LP2P, there could be large number of peers in certain location compared to other. Imagine the location near university, big office complexes, hospitals etc. Any P2P system should address this issue.

- *Security:* Security is one of the most important issue in P2P system.

- *Geometric robustness:* This issue is specific to the problems which need geometric calculations. In many case, the use of IEEE floating point produces arbitrary large errors which are unacceptable for any meaningful application.

- *Message Routing:*

With these characteristic in mind, we want to design our P2P system. In the following sections, we give two approaches i.e. Delaunay triangulation and ORB spatial data structures. Both seems to attractive and have been widely used in other application areas, we need to know which method work better in practice. ORBtree is very simple to implement, but parallel Delaunay is difficult to implement. Compressions between these data structures is valid only when the most efficient implementations are employed.

3 Parallel Delaunay Triangulation

Definition: A Delaunay triangulation of set of points is the triangulation in which every triangle has an *empty* circumcircle: meaning that the circle enclosed no vertex of the triangulation[9].(Figure 1)

There are many algorithms to construct a Delaunay triangulation [9], but we use Bawyer-Watson incremental algorithm because of it is easy to implement (both sequential and parallel). Whenever a node in inserted or removed from the mesh, only local operations are needed to repair the mesh, therefore it is ideally suited for P2P systems.

In order to maintain the overlay network, nodes regularly exchange informations. The following five types of messages are necessary for P2P system.

- *Becon Mesage:* A beacon message is used to notify its neighbors that the sender is still actively participating in the overlay network. By default any new member is given some predefined value of *Time to live* value, which can be changed by the user.

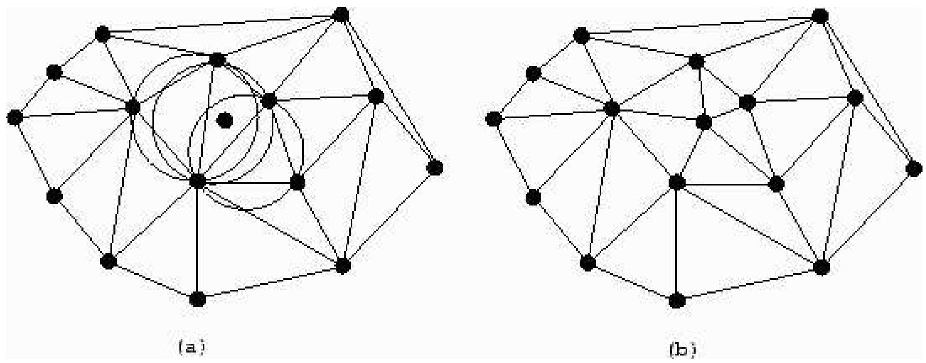

Figure 1: Delaunay Triangulation

- *Join Message:* Whenever a node want to join the network, it must first connect to any node already in the network. If the node not in the correct position, the messages are forwarded to the neighbors till the correct node is identified in the network.
- *Leave Message:* When the user want to notify all the neighbors about his/her to leave the system.
- *Failure Message:* Many time, an user may not able to notify, (power outrage, network failure etc.) The network then try to recover from unavailability of neighbors.

3.1 Node Joining: Bowyer-Watson Kernel

To construct a Delaunay triangulation, each node is associated with a vertex in the the plane with a given (x, y) coordinates. These coordinates are obtained or calculated by external means as described earlier. Bowyer-Watson algorithm is an incremental algorithm for constructing Delaunay triangulation in which a new point is inserted one at a time. After each insertion, Delaunay property is maintained but removing a set of triangles which violates. A set of all triangle which violate *empty* circumcircle property make a cavity. This cavity is removed and re-triangulated. Nikos [2] has exploited parallelism inherent in this algorithm and have shown near linear speed up.

There are four basic steps involved in iterative Bowyer-Watson algorithm:

1. *Point Location:* Whenever a new point(a node) p_i wants to join the network, the point location algorithm provide the triangle within which the given point lies: Let it be T_i. In the next section, we present some of the techniques which are efficient for point location problem.
2. *Cavity Identification:* Given the source triangle T_s and point p_i, the cavity is the union of all triangles which violates the circum-circle criteria. i.e.

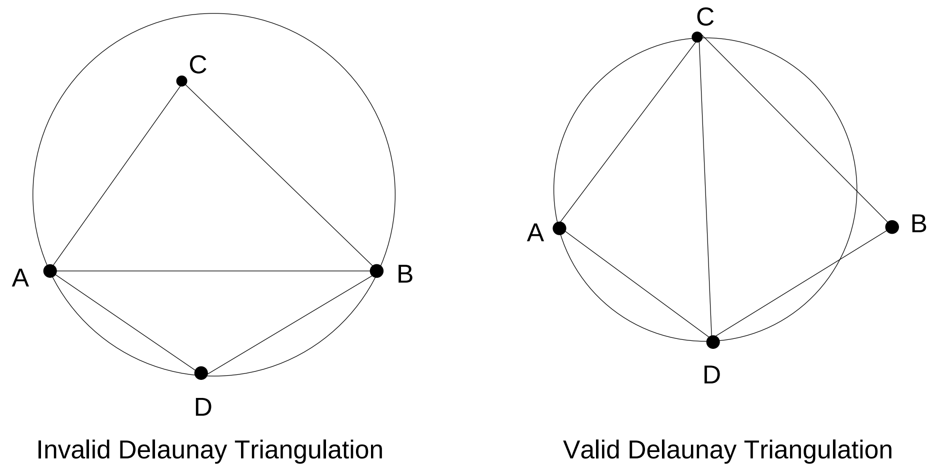

Figure 2: Edge flipping operation to create valid delaunay triangulation

$B_i = \cup T_j$ where T_j is the triangle which violates the circumcricle condition for the point p_i. Either depth first or breadth search can be used in this step.

3. *Cavity Removal:* A cavity is formed by removing edges which share at least two triangles in the set B_i.

4. *Cavity Re-triangulation:* Step III, create a hole in the space which is re-triangulated with the boundary segments of the cavity and the new point. The properties of Delaunay triangulation ensures that the resulting triangulation is Delaunay.

3.2 Node leaving: Polygon retriangulation

Compared to node joining, node removal is difficult from the triangulation. We use the following two properties of Delaunay triangulation which are useful for node removal [9]

Lemma 1 Let T be a triangulation. If all the triangles of T are Delunay, then all the edges of T are Delaunay, and vice versa.

Lemma 2 Any triangulation can be converted into Delaunay triangulation but using edge flipping operations.

Once a node is removed, the resulting region consists of a closed polygon which can be triangulated by any method followed by edge flipping operations till we get Delaunay triangulation.

3.3 Advantages of DT Overlay Network

There are many advantages with Delaunay triangulation :

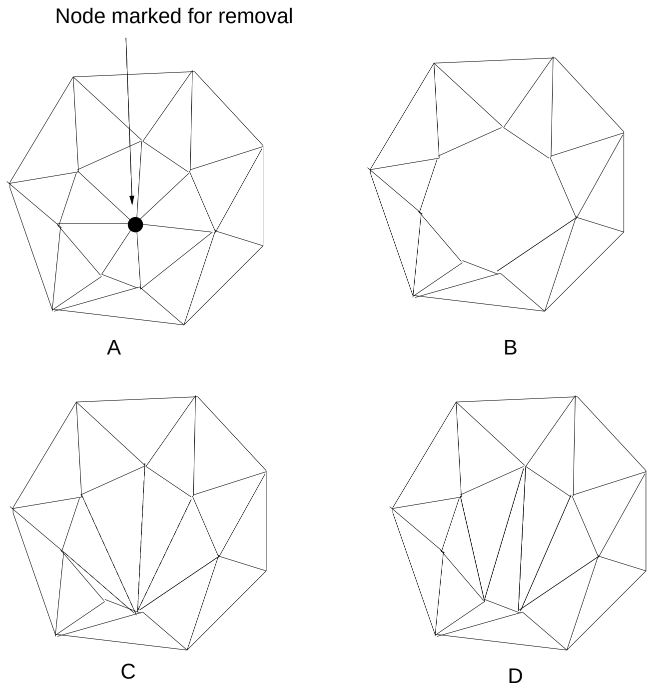

Figure 3: Node removal operations: (B) hole created (C) probably non-delunay triangulation (C). Deluany triangulation using edge flipping

- Mathmatically robust algorithm exist. It is always possible to create Delaunay triangulation.
- It create an overlay topology in which application-later multicasting is efficient.
- Degree of each node is usually very small. The average number is six.
- Decentralized implementation is easy.

4 Orthogonal Recursive Bisectional Data Structure

Compared to Delaunay triangulation, construction of orthogonal recursive tree(ORB) is very simple. In ORB , a space is divided into into rectangular regions in a way that distribute number of nodes equally between the two . Quadtree (in 2D) and Octree (in 3D) are simpler implementation of ORB where the space is divided exactly into half. In general, Quadtree or Octree trees are not suitable for P2P systems as they create unbalanced tree and have large number of empty leaves as shown in the (Figure 6).

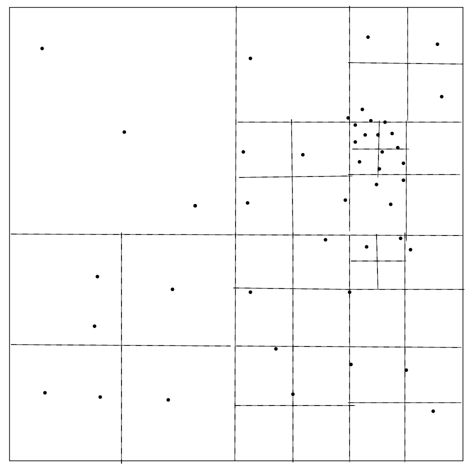

Figure 4: Quadtree based Overlay Network

5 Localized Geometric Routing Protocols

In point location problem, we need to find the correct triangle within which the newly added node lies. Whenever a new node is added, it picks up one existing node in the network, which forward message to its neighbors which in turn forward the *Join Request* message to their neighbors, till be correctly identify the position. In geometric graphs the problem is formalized as follows: Given a source node S_n and destination D_n, find the optimal path from S_N to D_N.

There are many geometric routing algorithm possible For more information, Xiang [6], Bose [?]. In Compass routing, a current node u find the next forwarding node v which minimizes the angle between vut. Compass routing does not always find a path from starting point to target for some triangulation but Kranakis [5] *et.al.* has proved that Delaunay triangulation always support compass routing.

References

[1] Filipe Araujo and Luis Rodrigues. Geopeer: A location-based peer-to-peer system.

[2] Nikos Chrisochoides and Demian Nave. Parallel delunay mesh generation kernel. *Int. J. Num. Methods in Engineering*, 58(No 2):161–176, 2003.

[3] A. Harter et al. The anatomy of a context-aware application. *Proc. 5th Ann. Int'l Conf. Mobile Computing and Networking*, 10(1):59–68, 1999.

[4] R. Want et al. The active badge location system. *ACM Trans. Information Sys.*, 10(1):91–102, 1992.

[5] Evangelos Kranakis. Compass routing on geometric networks.

[6] Xiamg-Yang Li. Applications of computational geometry in wireless networks. Technical report, Department of Computer Science, Illinois Institute of Technology.

[7]

[8] A. Chakraborty N. Priyantha and H. Balakrishnan. The cricket mobile support system. *Proc. 6th Ann. Int'l Conf. Mobile Computing and Networking*, pages 32–43, 2000.

[9] Jonathan Richard Shewchuk. Delaunay refinement algorihtms for triangular mesh generation. Technical report, University of California, Berkeley, 2001.

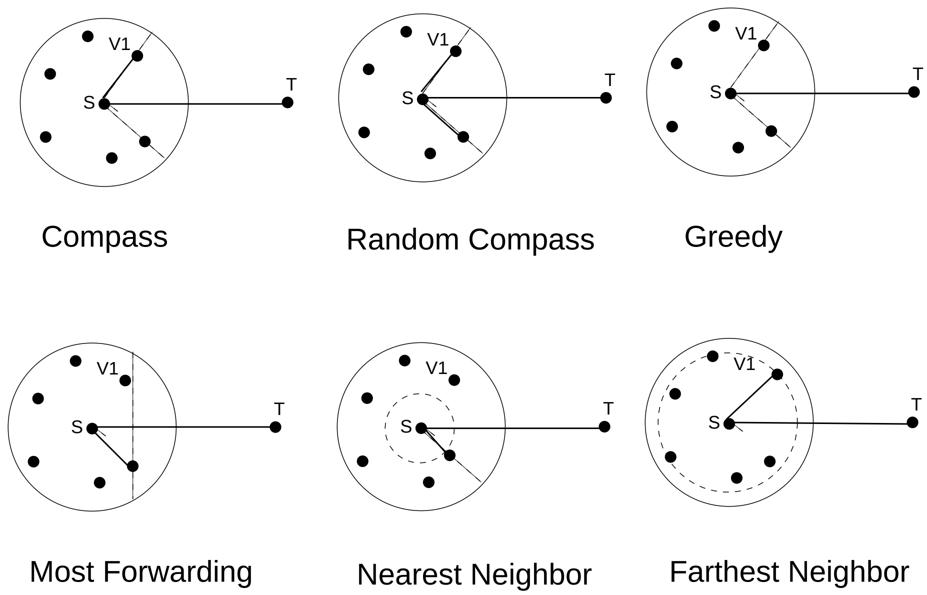

Figure 5: Geometric Routing

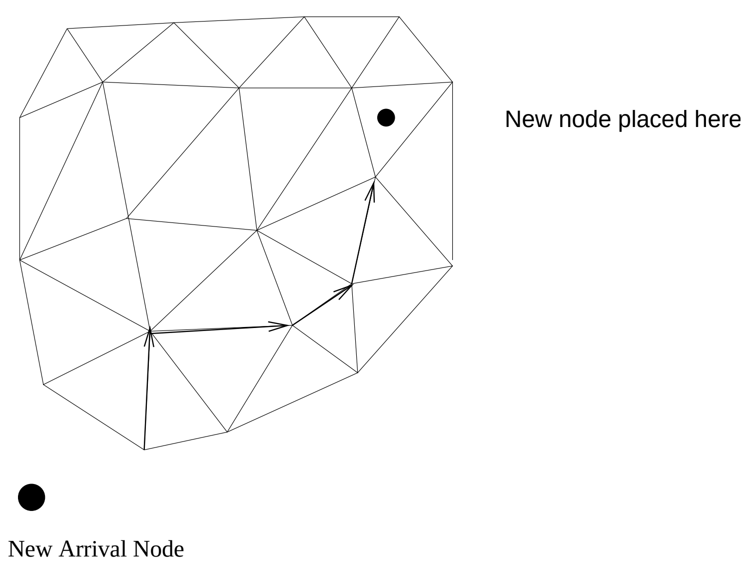

Figure 6: Compass routing in Delaunay triangulation