Using Peer to Peer Voice Over Wireless Ad Hoc Networks as an Emergency Command and Control System

Master’s Thesis in Computer and System Engineering

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Abstract:

Peer-to-Peer networking technology is evolving rapidly. P2P networks overcome the limitations of client/server networks where each computer shares resources of other computer. There are different types of P2P networks depending upon their functionalities. Peer to peer networks provide long list of features like: selection of nearby peers, redundant storage, efficient search/location of data items, data performance or guarantees etc. It is important to see that how P2P can work with wireless ad hoc networks and why it is important. What are important issues which come across by using P2P and wireless ad hoc networks together. How TCP/IP stack can be affected. How the whole system looks like in which P2P techniques are used with wireless ad hoc routing protocols to perform different tasks and services.
Chapter 1:

1. Introduction

In peer to peer (P2P) networks data and computational resources are provided by number of random hosts interconnected by the Internet, and their combine resources stipulate a consistent service. The idea of integrating P2P and wireless ad hoc networks is very attractive since it can be used to locate a particular service and provide access to that service in wireless ad hoc networks.

The context of using P2P on an ad hoc network requires a whole new way of thinking since the network will be based on resource limited nodes, and the nodes can be highly mobile, the network topology may change rapidly. Important issues to investigate are what type of protocol stack that can fulfill the requirements that are present in this scenario. The nodes are limited in terms of memory and processing power, so implementing whole TCP/IP stack is probably not an available approach. Is the P2P concept able to handle the mobility of nodes in an ad hoc network? Is it possible for the P2P application, application layer, to benefit from information available on the network layer, i.e. is it beneficial to consider a cross layer design between the application layer and network layer for this kind of futuristic systems.

1.1 Project Goal

Mobile phones and IP phones are very popular, but the operators do very seldom provide location specific services. This could be an interesting branch of applications for wireless ad hoc networks. By keeping track of peer’s location, specific services can be provided to a specific location or specific areas. But there exist a number of problems that must be solved in order for such a vision to become true, examples are: how the application layer and network layer will interact, how computational load and memory requirement of the protocol stack can be minimized and what kind of hardware that can be used supporting such a system. The goal of this thesis is to investigate how to use the idea of P2P and wireless ad hoc networks together in a single system. It is important to investigate how to establish voice connection with specific peer in a specific area, where peers are wireless sensor nodes and connected with each other in P2P manner, and then provide different services in specific area.

1.2 Motivation

Peer to peer and wireless ad hoc networks are two different kinds of technologies, but some functionality is common which may enable a merge of these two technologies into a single system. P2P is based on distributed systems which mean that information is distributed over different peers and on the basis of this distributed information, particular service can be provided in the absence of a central server. When wireless ad hoc networks are considered, nodes are spatially, and often randomly, distributed without any central administration and nodes are often free to move from one place to another, i.e. the network topology is highly dynamic. The idea of
merging these technologies is an attractive idea as it provides services on the basis of location over various peers that may move from one place to another.

However, it is problematic to keep track of the location of specific areas and its specific services and what nodes are present in a specific area where a particular service is to be provided. The locations of different services are more important than the specific nodes. It is required to provide a service to particular area with the help of information that different peers contain and these peers are connected in a wireless ad hoc network. This approach could possibly provide an autonomous wireless communication system with location based services. When the mobility factor is included then standard routing protocols may not be always efficient, so the idea of a cross layer design is introduced, a location based peer to peer routing algorithm on a wireless ad hoc network is introduced.

There is much similarity in wireless ad hoc networks and P2P networks as both are decentralized in nature. Some P2P networks are centralized but in this thesis we concentrate on decentralized P2P applications. The basic logic of the idea is, “what the user wants and where he wants it” is introduced in this concept.

If peer to peer and wireless ad hoc technology is observed in the context given in the previous logic then three strong parameters can be found.

1) Relation.
2) Location.
3) Service.

In fact the logic also gives that these parameters are strongly related to each other. Interesting to see is if it is possible to build an autonomous communication system on these three parameters. This would provide a system where

The user can found services on the basis of relations with other users that are participating. Relation means that how strongly peers know each other and how shareable data peers have in common. On the basis of this shareable data, which includes user location also, decisions will be made if a specific service will be provided.

1.3 Method

Different aspects of peer to peer protocols and wireless ad hoc routing protocols and how these interact is discussed in detail. How a protocol stack possibly could work in such scenario and how such a conceptual system could look like is discussed.
Chapter 2: TCP/IP on platforms with limited resources

It is a common opinion that TCP/IP stack is not suitable for devices with minimal resource e.g. in wireless sensor networks. This is due to the fact that nodes in wireless sensor network exhibit limited resources and implementing whole TCP/IP stack in a sensor node is often not a feasible approach. However, some mechanisms can be used to implement TCP/IP in minimized way and achieve similar performance to a standard TCP/IP stack implementation. The TCP/IP stack implementations is different for a wireless sensor network (WSN) and wireless ad hoc networks, as there is slight difference in wireless sensor network and wireless ad hoc networks. Wireless sensor network consists of sensor nodes communicating with each other with a central administration involved. Central administration can be a gateway, base station etc. wireless ad hoc network is fully distributed network, and nodes communicate with each other without any central administration. However, nodes in wireless ad hoc networks are more mobile than in wireless sensor networks. Therefore the TCP/IP stack implementations are often more challenging and complicated for wireless ad hoc networks as the mobility factor is more involved. Spatial IP address assignment [2] and distributed TCP caching [2] are among those techniques that may enable the use of TCP/IP for wireless sensor networks and wireless ad hoc networks.

2.1 Making TCP/IP work for devices with scarce resources

Wireless Sensor Networks are often application specific, they consists of sensor nodes that are statically deployed to perform specific tasks very efficiently by, e.g. sensing and gathering environmental data and perform functions accordingly. Generally sensor nodes are extremely limited in terms of memory and processing capacity, so a full standard TCP/IP stack is not well fitted for a wireless sensor network. Present problems are: overhead, management of connection, congestion control and many more. Because of these drawbacks, the performance, of a WSN based on a standard TCP/IP stack, can be affected badly [1, 5]. However, there are three different approaches to integrate TCP/IP into WSNs. The first is referred to as “Direct TCP” in which TCP/IP is enabled as communication technology. Second one is referred to as “Proxy TCP” in which a WSN gateway is operated as a proxy and performs address translation and flow control adoption. The third and last one is “Native TCP” in which TCP/IP traffic is passed by WSN on the top of its infrastructure and WSN is considered as transparent medium [1]. TCP/IP communication is directly routed on the WSN in direct TCP, whereas the TCP communication is adapted at the gateway in proxy and native TCP. WSN protocols are used for communication by proxy and native TCP as shown in Figure 1. Direct and proxy TCP supports TCP/IP application and sockets.

A TCP route is a path for TCP/IP communication and WSN data are sent along that route. Every WSN node can be a part or a communication end point of TCP route in direct and proxy TCP, but in the case of native TCP, nodes relay TCP/IP data between the gateways. Adaptation of TCP flow control, IP addressing and packet fragmentation is required in proxy TCP and native TCP. Addressing and fragmentation in native TCP is handled by the TCP/IP adaptation layer in the gateway, but flow control is handled over the WSN. The protocol stack of direct TCP, native TCP and proxy TCP are shown in the Figure 1.
In a WSN, the network topology may changes rapidly which may cause errors, a WSN node must adapt to these changes that occur in WSN environment and should therefore be self organizing and self configuring. If the relation between WNS and TCP/IP is considered, then it is quite obvious that TCP/IP is connection oriented and connection is built by two way handshaking. Two or more TCP/IP end points that build communication over WSN are data centric. This end to end connection generates large amount of overhead. In a WSN the flow control and error is typically performed on a single hop basis, to avoid end to end retransmission that is very costly. In WSN, packet losses are often caused due to topology changes and that nodes’ are temporarily unavailable [1].

Furthermore, applying a general TCP/IP stack often requires resources which are not present in a WSN, however there are some portable TCP/IP implementations available, Micro IP and lwIP (low weight IP) for 8-bit architecture [2]. Low weight IP (lwIP) provide simplified TCP/IP implementations of IP, ICMP, UDP and TCP. It has support for multiple local network interfaces and has flexible configuration options. Micro IP (uIP) implementations have only some absolute features that fulfill the requirement of whole TCP/IP stack. It can only handle single network interface and it does not implement UDP, instead focuses on IP, ICMP and TCP protocols.

2.2 Spatial IP Address Assignment:

Spatial IP address assignment is a technique to make TCP/IP viable for location centric sensor networks. Normally IP addresses are based on the topology of the network. In the case of
spatial IP addressing, each sensor node constructs its IP address based on its physical location. It does not really matter, if two nodes get same address. Two or more adjacent nodes can have same physical location, so they may construct same IP address. Nodes having adjacent address may share large parts of routing paths towards the required node. There is no need to transmit the full IP address in the header packet as all nodes are having the same IP subnet. Similarly, for WSN data packets, only a small range of UDP ports are necessary, since packet that contains sensor data do not need a full 16-bit port number. Since it is assumed that every node knows about its spatial location, so address assignment requires no central server, nor communication between the sensor nodes [2]. Nodes having their spatial locations can be overviewed in the diagram below:

![Diagram of spatial IP address assignment](image-url)

**Figure 2: Example spatial IP address assignment Source: [2]**

In the particular network in Figure 2, the IP address is constructed by each sensor node by taking \((x,y)\) coordinates of the node as the two least significant octets in the IP address. Regional subnet can be defined as a set of sensor nodes that share a prefix in which regional broadcast mechanism is implemented, as location information is encoded in the IP addresses. Mapping between logical and physical location is not needed in this mechanism [2].

2.3 Distributed TCP Cashing:

Distributed TCP Caching (DTC) [2] is especially designed for multi-hop sensor networks in which retransmitted packet is forwarded by every sensor node on the path from sender to receiver. DTC reduces all computations which are required by traditional TCP. In a DTC segment caching is used to achieve retransmission. In Figure the functionality of DTC is displayed, the
data segment 1 is sent and cached by an intermediate node, N₅, after that another data segment 2 is sent which is cached by another intermediate node, N₇. After that data segment 3 is sent, this is reached by the receiver. After that an acknowledgement is sent for data segment 1 which is again cached by intermediate node N₅ and retransmitted. Acknowledgment for data segment 2 is cached by node N₇ and acknowledgment for data segment 3 is received by the first sender and the request is fulfilled. This technique is known as local transmission. [2].

The dynamic nature of wireless Ad hoc networks and the absence of any central administration introduced new challenge that how to transmit packets over such network. It is interesting to investigate how to establish a voice connection over a wireless ad hoc network. For that it is important see, how voice packets will travel without the use of IP. Somehow it is required to use some identification number to build communication, but that number should not be IP.

Switching technique should be discussed before discussing transmission of voice packets. There is packet switching and circuit switching. Since packets to be transmitted are voice packets so circuit switching is best approach in this particular case. The answer to question that why cir-
cuit switching and why not packet switching is simple. Circuit switching is good for long packets and packet switching is used when ever short text messages are to be transmitted. More about circuit switching will be discussed below:

2.4 Circuit switching v/s Packet switching:

The dynamic nature of wireless ad hoc networks and the absence of any central administration introduced new challenge how to transmit packets over such network. It is interesting to investigate how to establish a voice connection over a wireless ad hoc network. For that it is important see, how voice packets will travel without the use of IP. Somehow it is required to use some identification number to build communication, but that number should not be IP.

Circuit switching technique could be considered for transmission of voice packets. There is packet switching and circuit switching. Since packets to be transmitted are voice samples circuit switching is the most reliable approach in this particular case. The answer to question that why circuit switching and why not packet switching is simple.

In circuit switching [13] a permanent connection is established between two callers. All resources remain allocated to the same connection irrespective of the fact that data is flowing or not over the media. Circuit switching cannot predict or react according to the network topology changes. A back up circuit is also maintained to avoid errors, breakage and failure of circuit.

In packet switching [13] data is divided into smaller packets and routed through different networks. So it is not necessary to establish any dedicated network. Also when there is not data transfer over the network all the resources remain free.

Packet switching can accommodate according to the network topology changes. Because every packet contains destination and source address in its header so it can be routed through any possible network.

A compromise is virtual circuit (VC) switching [7, 13], benefits of both circuit and packet switching are added together. Packets travel on logical or virtual circuits instead of permanent or physical circuits. In VC switching one or more circuits can be assigned to each communication session and thus different amount of bandwidth can be assigned according to the need of session.

In VC switching, packets flow on logical circuits so no physical resources like frequency or time slots are included. In VC switching routing is performed when the circuit is established so that packets are forwarded fast. The drawback in VC switching is that unlike datagram switching the packets are recomputed by every router to keep the forwarding table up to data, thus VC switching is not reactive to topology change occur in the network. It is possible to use VC switching in ad hoc networks but performance is affected badly.
Chapter 3: Ad hoc Routing Algorithms

Routing is a process of selecting paths in network and along that path data is sent to the required destination through intermediate nodes. The routing process is usually done on the basics of routing tables. Routing tables maintain record of the routes to destinations. Routing protocols define how node forward packet and through which way, among different nodes in mobile ad hoc networks. Nodes do not have prior knowledge about topology of network in ad hoc networks. In wireless ad hoc networks, a node broadcasts the information about its presence to its neighbors. Its neighbors receive this information and they further broadcast their information to other nodes which are in the range. In this way each node knows about all other nodes and ways to reach them. Routing protocols for wireless ad hoc networks need different approaches from existing protocols intended for a wired infrastructure. There are various routing algorithms for mobile ad hoc networks. These algorithms can be divided into two main groups proactive routing algorithms and reactive routing algorithms. These routing algorithms can also further be divided into subgroups like hierarchical routing algorithms and geographical routing algorithms.

In proactive routing [7] every node maintains routing table and keep a update about its neighbor, if any change occurs in the network topology a update messages by broadcast to all nodes, this broadcast can either be triggered periodically or on the occurrence of a topology change event. There exist a trade of between if periodic broadcasts or event triggered broadcasts should be used, i.e. it is dependent on the rate of change of the topology. In reactive routing algorithms [7] the up to data routing information is not maintained as it is being done in proactive routing algorithms. In a reactive routing a source node starts a route discovery process, when it needs a path to specific destination node, which obtains the necessary information about the route to the destination. By the use of reactive routing algorithms, routing overheads are reduced as traffic control are sent only when the nodes need to communicate but in reactive routing, on the other hand access time is long as it has to wait for the reply from route discovery process.

The basic concept of hierarchical routing [7] is breakdown of large networks into smaller subnets. Nodes which are close to each other are grouped in to a cluster and among these nodes; one node is selected as cluster head of the subnet. The node that is present in two or more clusters can function as gateway. These algorithms are generally not applicable when the size of the network is increased as it may cause overhead like assigning clusters and cluster heads, but they work efficiently in small networks.

Geographic routing algorithms adopt the nature of wireless ad hoc networks. As in the wireless ad hoc networks, mobility is the major issue and geographical routing can manage this issue very well, as it is based on the geographical location of the nodes and as the topology changes, every node get updates about the geographical location information of itself and neighboring nodes. Geographic routing conceptually forwards data to the specific area instead of a unique node. Any node that is located within the given geographic area will be acceptable as a destination node and can receive and process message.

3.1 Optimized Link State Routing:

Optimized Link State Routing (OLSR) [7] is a proactive routing algorithm developed for mobile ad hoc networks. It exchanges the topology information periodically to the neighbor
nodes. Nodes which are selected by neighbor nodes as Multipoint Distribution Relays (MPRs) exchange topology information in their control messages. The task of MPR is to form the route from a source node to the destination node. It floods the neighbor’s topology table to all nodes and then computes the optimal path. OSPF and IS-IS floods the topology table according to a designed algorithm, but such an algorithm is very difficult to design for ad hoc networks, so OLSR simply floods the topology table to all nodes. OLSR needs large amount of bandwidth and CPU power to compute optimal paths.

3.2 Location Aided Routing:

Location Aided Routing (LAR) [7] is based on reactive routing algorithm and it uses geographical information to control the flow of packet. It works on geographical location of nodes, and then sends control packets accordingly. By the use of the geographical location of nodes the expected area, where the destination nodes is, can be estimated. LAR uses GPS (Global Positioning System) to get the location information.

3.3 Geographical position assisted routing:

With the help of a Global Positioned System (GPS) receiver [7], wireless nodes can get their geographical positions and when these exchange their geographical locations with each other they can clearly build a network and perform routing. This map is very useful to improve the routing efficiency. Geographical Position Assisted Routing is somehow implementing the same idea to improve its performance and is based on hierarchical routing algorithms.

3.4 Geographic Virtual Circuit Routing Protocol For Ad hoc Networks

The concept of packet switched and circuit switched networks can be directly applied in routing protocols based on geographic positions. Geographic routing gets location information of nodes and on the basis of this information, it makes the forwarding decisions. It adapts to the dynamic nature of wireless ad hoc networks but in Geographic Virtual Circuit Routing Protocol (GCRP) [4] there is an overhead included due to the recovery process of local minimum. The concept of local minimum and recovery process from local minimum will be discussed later. Geographic routing makes forwarding decisions on the basis of topology information and it does not guarantee that the path will be optimal. The good feature of geographic routing is that, it can find correct routes very quickly and at low cast. Due to these facts geographic routing is assumed to be very promising approach.

The process of forwarding the packet on the basis of geographical information is known as geogram routing [4]. Packets are sent independently in geogram routing. In geogram routing the information regarding destination and how to manage mobility scheme is recorded in the packet header. On the basis of the destination location and its view of the network topology, each node including the source selects the next hop. To optimize the decision according to information available, a metric value is also maintained.

In geographical routing, geocircuits [4] are just like virtual circuits. To each geocircuit a GC number is assigned in a table and each node maintains such a table that holds entry for each geocircuit establishment. This table is known as GC number translation table. The geocircuit and GC tables are shown in figure 4. GC table maintains the links of upstream and downstream. The
upstream link of node A is node B and node B has further upstream links. In the same way the downstream links are maintained so that if route breakage occurs, an new route can be provided immediately according to GC table, as GC table contains all the information about available links and links in use. In the GC-Table of node A, ‘i’ specifies the downstream link of node A and ‘j’ specifies the upstream link of node A. Same condition applies in the GC-table of node B.

Table 1: GC Table A

<table>
<thead>
<tr>
<th>GCNO J</th>
<th>GC NO K</th>
<th>Tj</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: GC Table B

<table>
<thead>
<tr>
<th>GCNO J</th>
<th>GC NO K</th>
<th>Tj</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4: Geocircuits solutions and GC table Source: [4]

In geographical forwarding [4] each node maintains the table of the neighbor and its position. Nodes exchange their information by first sending a hello messages. The information is like their location, neighbor’s location etc. A time stamp is included in the neighbor table. If the node does not hear from its neighboring node for a specific time, link is assumed to be broken by the node and the particular entry will be deleted.

3.5 Local Minimum:
Local minimums [4] may be encountered where the current node is closest to the destination among all its one-hop neighbors. To understand the concept of local minimum, let’s assume a diagram as in Figure 5.

Assume that a packet is sent by S to D. D encounters a local minimum N known as concave node as shown in figure 5. N is the transmission range that intersects with the area that has better location and there occurs a void area which is empty of nodes. To recover from a local minimum, a combination of depth-first and geographic forwarding is used. Neighbor nodes are sequenced in ascending distance from the destination and no nodes can be visited more than once. There is an identifier record in each packet which helps to check, whether node see the particular packet before or not. There is a variable, $D_{max}$, that determines the maximum depth of the search. When a node that is closer to the destination node is found, the algorithm switch back to geographical routing and the geographical position of the concave node is recorded on the data packet.
Figure 6 shows how to recover from local minimum by using depth-first search and geographic forwarding. Each node allocates a number that gives that how many times that node is visited. Variable $D_{\text{max}}$ shows the number of hops to be reached from concave node. The ninth node is found closer to the destination then concave node. When ninth node is found better then at that point packet is switched back to geographic routing. The path which packet has followed is always recorded and maintained. Nodes are appended while searching in depth for paths is performed and when come back, nodes are deleted as inverse of the path is also known.

Geographical routing uses greedy forwarding technique to forward the packet from source to destination. Greedy forwarding is that method in which packet is sent to the neighbor that is closest to the destination and it works as long as there is a neighbor which is more closer to the destination then the current node, but fails when no such nodes exists. Some time it happens that there is no active node in some specific area, such area is called a void area. To solve this problem there is another method used which is perimeter routing, that solves the problem of void area.

3.6 GPSR: Greedy Perimeter Stateless Routing for Wireless Networks:

GPSR [16] is a novel routing protocol that uses router’s location and destination’s location, according to this location information, it makes the forwarding decisions. GPSR is based on two protocols, first it is based on greedy forwarding and second it is based on perimeter stateless routing. As long as there is a closer neighbor to the destination, packet will be forwarded to that
neighbor, but when some void area occurs, this protocol is switched to the perimeter routing. So perimeter stateless routing is used whenever greedy forwarding not works.

3.6.1 Greedy Forwarding:

All packets have their destination locations marked in their header. A locally optimal, greedy choice is made by forwarding node to choose a packet’s next hop. Especially if a node knows its neighbor location, the locally optimal choice of next hop is the neighbor that is geographically closest to the packet’s destination. This process is continued until the packet reaches to its destination or until void area comes [16].

3.6.2 Perimeter Routing:

When the void area is encountered then greedy forwarding fails and node is entered in to the perimeter mode [16]. A void area is that area where there is no active node; means inside that area there is no communication possible. So the region is drawn according to nodes in the edges of this void area. Each node knows its location and location of next hop. When the region is drawn then this routing started works on right hand rule and forward the packet to the destination or the node closes to the destination. When it recovers the void area, then again protocol is switched to the greedy forwarding. At each node, where packet visits, its record is maintained and planner graph is drawn accordingly.
A wireless ad hoc network is often mobile in its nature, where nodes are moving from one place to another, without any central administration. It is often better to keep track of their geographic location rather than their physical address or IP address. Geographical routing introduces some implications regarding the accuracy of the physical location of nodes; circuit breakage, neighbor information, etc. The problem arises how to embed peer-to-peer networks on a wireless ad hoc network.

Peer to Peer and wireless ad hoc networks have one basic idea in common both work without the help of any central administration. However, the focus of P2P applications and the wireless ad hoc networks are on totally different levels, P2P on the application layer and the and the focus for ad hoc network protocols are mainly on data link, networking and transport layer. But the combination of these two technologies can plausibly provide a new framework and provide a totally new way of accessing services. Due to the mobility factor breakage of routes is common as nodes are in motion in an ad hoc network. A crosslayer design between the networking layer and the application layer could possibly overcome this problem, by providing frequently new available routes. Frequent communication between the P2P protocol and under laying networking and transport layer protocols can be the solution to the problem of route breakage. The network layer on which the P2P protocols are running must have good knowledge about P2P application to establish appropriate communication paths. In general higher protocols do not know about the underlying network topology and they assume that there is a fixed network infrastructure. When a connection breaks, P2P nodes assume that their partner, who is in distant communication, has left the network and its attention is switched to other node or nodes as service or information source.

A P2P application may offer services to find a particular node in the particular area in a large mesh networks and these selections are based on the interests and preferences of specific nodes. In P2P, peers contain shareable data objects and connection is established on the basis of request generated by a node and also on the basis of the shareable data objects. Preferences and interests are prioritized on the basis of the requests made and data shared by peers. P2P applications like Feenet [14] and Gnutella [14] provide services like file sharing among different nodes, and these services are in completely self organizing networks. CAN [14], CHORD [24] and Tapestry [14] are not utilizable for MANET as they do not have the capability to match the overlay network to underlying physical network topology.

There are lot of P2P applications that tries to fulfill the requirements of both P2P and wireless ad hoc networks, but in all cases some drawbacks occur. All P2P implementations available today are working independently without any knowledge about the underlying protocols. A connection may be established with a node which is faraway even if a node with similar preferences and interest exists nearby. This is because the P2P application is not aware of information available in underlying protocols and the physical location of information or services.

There exists some proposals that are well suited for both P2P and wireless ad hoc networks [9][10], as they provide efficient searches and discovery techniques and provide direct communication of P2P protocols with wireless ad hoc protocols. Problems like route breakage, finding availability of new routes quickly etc can be resolved by these techniques. Some of these techniques are discussed in the following sections.
4.1 Mobile Peer to Peer Information System:

In mobile ad hoc networks, every node has a limited transmission range and nodes that are in range with each other can directly communicate with each other or utilize the concept of multi hop by relaying messages over several hops to further distant nodes. Geographical routing methods like GPSR [16] or GCRP [14] are discussed before, and with the help of these protocols, all nodes are well aware of their location. Now let’s assume that all nodes contain some amount of shareable data objects, which they are sharing with each other. Each data is assigned an attribute key, the search method is defined as finding a node that has stored data object and has specified key and then obtain relevant data or service of interest. This satisfies when there are multiple such data objects or services and it is plausible to merge this data objects or services to provide a specific information or service of interest.

4.1.1 Multi Level Peer Index:

In multi level peer index (MPI) [9] the first step is a search mechanism to find data objects of interest within the network. Data objects are equipped with geographical coordinates and nodes in a local network region are sharing these data objects with each other and their geographical locations. If the search is first made locally, long distance information transportation can be avoided as nodes are equipped with geographical locations and sharing data objects. Nearest source can be found by any requester on the basis of data objects stored in various nodes. Spatial information is embedded, so that nearby nodes can take advantage of their physical proximity.

When the index structure of MPI is formed [9] the network is partitioned into squares of equal size and the squares are further partitioned and spatial information is embedded in the index. Squares are labeled by the name “Level”. A hash index is constructed by every node. Key value is generated and then that key value is associated with data objects. This key and the geographical location of a particular node are taken as input. As an output the geographical coordinates, bounded by specific region, is generated. When any node joins the network, data objects are locally stored by that node, its geographical coordinates are calculated, and then index information of available data objects are published by the use of these calculated geographical coordinates. In Figure 7, $I_{1A}$ and $I_{2A}$ show index node for key A. Area Q is partitioned into $Q_1$, $Q_2$, $Q_3$ and $Q_4$. Node $N_1$ in area $Q_1$ contains data object with key A and it publishes the index information for this data object to the entire region $Q$ and $Q_1$, $Q_2$, $Q_3$ and $Q_4$ [9]. Note that $Q_{i+1}$ is a child level of $Q_i$. $Q_{11}$, $Q_{12}$, $Q_{13}$ and $Q_{14}$ represent further partitioning of wireless regions. $L_{i1}$ is a location node that contains information about the location of the required node. Location node performs searching for the location of the required node. $I_{iA}$ shows the index node for the key A in the level i and $L_{i1}$ is the location node for node $1_{i,n}$ at level i.
4.1.2 MLS:
Multi load lookup service (MLS) [9] is embedded in MPI to handle the node mobility. Nodes at each region or level apply hash function. In this hash function ‘NodeID’ is provided as input instead of key value for data objects. On the basis of this hash function nodes choose their location node. Location node is that node which contains relevant information about the location of the required node. When a node moves from one location to another, it updates its location accordingly. When node changes its level square its old location information is deleted from location node. It updates its new location to the location node, which is in the current level square. This location information is also updated to the location node, which is in the parent level. Means location node in Q4 should send its location updates to location node in Q3.

When a node generates a request, it first checks its own locally stored data. If the result is found then the search is terminated otherwise a data lookup function is generated by sending request to an index node, which is in its lowest level square. If the result is not found at that index node, then the request is forwarded to the index node that is in the next higher-level square. This process is repeated until the index for the requested key is found or it is not present in the index.
hierarchy. In the figure 8, index node \(I_{4,B}\) will first check, whether it contains relevant information or not. The result is not found and the request is forwarded to another index node \(I_{3,B}\), where ‘3’ is the level and ‘B’ is key. It shows that search is being made for key B and data assigned to this key. Index node \(I_{2,B}\) performs data lookup function and relevant information is found at \(I_{2,B}\) as shown in the figure 8. The information it contains is key B and the source id.

If the requested key is found at an index node, then a “location request” is generated and routed to the “location node” and that location node is responsible for “Node ID” of the source node at the same square. The location node from which location lookup function is requested will then find the location of the required node. When the desired node is found then the “data retrieval” process is initiated. When the searched key and the data associated to that key is found, at index node \(I_{2,B}\) in figure 8, then this index node simply forward the request to the closest location node, \(L_{2,2}\) at the same level in figure 8. Location node \(L_{2,2}\) forward the request to the location node in its children square level, which is \(L_{3,2}\), in figure 8. From that location node the location lookup function is initiated to find the location of the source.

The data retrieval is invoked at the desired node and the request data will be provided to the source node. If in the meanwhile, some source node have changed its location and moved to another location within the same level. The data will be provided to that level and then again the lookup function is invoked and the data will be sent to the new location. If the source node or the requesting node changes its location, moves to another level, the node will always leave a forwarding pointer that points to level that the requesting node has moved [9]. Functions “data lookup”, “location lookup” and “data retrieval” are shown in Figure 8. Where \(L_{2,2}\), \(L_{3,2}\) and \(L_{4,2}\) are location nodes and \(I_{4,B}\), \(I_{3,B}\) and \(I_{2,B}\) are index nodes.

![Figure 8: Search Using MPI Source: [9]](image-url)
4.2 Index Maintenance:

When a node joins a network, it performs two functions, publishing its data objects and its location information. To obtain the index and its location information, a joining node broadcasts HELLO message to all nodes. Those nodes that are within the range of the joining node can hear that HELLO message. When a node moves from its previous level square, it becomes index node to those data objects that have hashed coordinates points to that square in which that node moves and thus it deletes its old index information and obtain its new index information from any node that is in its new square [9].

4.3 Zone based hierarchical link state:

Another approach is a peer to peer zone based two level link state routing for mobile ad-hoc networks which is based on global positioning system (GPS) routing protocol. Network is divided into non overlapping zones. Zones are wireless regions. Nodes distributed in these different zones conceal the detail of network topology. By geographical routing protocols, each node knows its position and its zone ID. After the network is established, each node knows about the node level topology means each node knows about the connectivity of nodes with each other. Zone level topology means connectivity of zones with each other. A packet is forwarded my specifying zone ID and node ID in the packet header.

In ZHLS, topological information is distributed in a peer to peer manner. If the destination is found within the zone then it will act as proactive routing scheme but if the destination is not within the zone, then it will act as reactive routing scheme and then location search is needed to find the zone where the destination node is located. The location search is done by unicasting one location request to each zone. In this method, routing is not done by specifying intermediate nodes; it is done by specifying the zone id and the node id.

There are two important main entities in this protocol, node level topology and zone level topology. The node level topology tells how nodes are connected to each other whereas zone level topology tells about the connection of zones [10].

![Figure 9: Zones and Nodes connectivity Source: [10]](image-url)
In the Figure 9 and Figure 10, the node level topology and zone level topology is depicted. It shows the connectivity of nodes and zones, and the path from one node to required node. During these connections each node receives two types of link state packets (LSPs). Node LSPs and zone LSPs. The node LSP contains a list of neighbour nodes that connected to each other and zone LSP contains a list of which zone that is connected to each other [10].

4.3.1 IntraZone Clustering:

In intra zone clustering [10], when particular node broadcasts a link request, then in response the nodes that are within its communication range will send Node ID and Zone ID. When the responses from all links are received, the node generates its LSP accordingly. This LSP is propagated, locally, throughout out the zone with the help of intermediate nodes. This LSP is not propagated to other zones. If a node moves to another zone, its LSP will remain in its old zone. After receiving all node LSPs of the same zone, the node level topology will be known by each node within that zone. Then the shortest path algorithm is used to build an intra zone routing table. This intra zone routing table is generated by each node and it tells how to reach a specific destination and through which intermediate node.

The node LSP contains the Node ID of its neighbours of the same zone and zone ID of its neighbours of different zones. In Figure 11, B, C and D are neighbours of ‘A’. The LSP generated by each node is shown in table 1. In table 1 node A has neighbours B, C and D whereas ‘4’ is the zone ID in which node ‘G’ is located. This node has also connectivity with node A shown in Figure 11. It means that LSP of each node also shows, to which zone connectivity is possible. If node B is considered then its LSP only contains its neighbours ID in Table 1. There is no neigh-
bour node in other zone, hence no connectivity with other zone is possible, and therefore no zone ID is given there. In short, the node LSP created by each node in intra-zone clustering shows the connectivity with neighbours and the way to reach other zones.

<table>
<thead>
<tr>
<th>Source</th>
<th>Node LSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B,C,D,4</td>
</tr>
<tr>
<td>B</td>
<td>A,E</td>
</tr>
<tr>
<td>C</td>
<td>A,3</td>
</tr>
<tr>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>E</td>
<td>B,F,2</td>
</tr>
<tr>
<td>F</td>
<td>E,2</td>
</tr>
</tbody>
</table>

Table 1: Node LSPs in Zone 1 Source: [10]

4.3.2 Inter Zone Clustering:

As LSP, which is generated by each node, also contains Zone ID, each node knows about the connectivity of the zones. After node LSP is generated, zone LSP will be generated. Zone LSP is depicted in Table 2. The node that acts as a gateway node will broadcast this zone LSP throughout the network as shown in the Figure 12. In Figure 12, node ‘A’, ‘C’, ‘E’ and ‘F’ are gateway nodes which mean that they have connectivity with neighbouring zone through their neighbour nodes. In inter zone clustering gateway nodes broadcast zone LSP through out the network as shown in Figure 12. As zone LSP is propagated throughout the whole network, each node knows about the zone level topology of the network. When all nodes receive the zone LSPs, the shortest path algorithm is used to build the inter zone routing table [10]. The inter zone routing table is generated by each node that tells the connectivity of zones and through which intermediate node request can be forwarded to other connected zone. Table 2 shows a Zone LSP and how zones are connected with each other through gateway nodes. For example Field 1 of Table 2 shows that zone 1 has connectivity with zones 2, 3 and 4 through gateway nodes ‘A’, ‘C’, ‘E’ and ‘F’
4.4 Location search and Routing Mechanism:

Zone IDs for nodes are not fixed due to nodes mobility; so a source must search for the zone ID of a destination node. In the Figure 13, the location and search mechanism is depicted. Node A wants to send data to node Z, before sending data node A will check that if node Z is in its intra zone routing table or not. It means if node Z exist in same zone or not, if it is not then it is sure that node Z is in different zone and location request will be generated from node A to every zone. Every gateway node will receive the location request and checks its intra zone routing table, if the requested node is its zone or not. When the request will reach to the gateway of the zone where node Z exists, it will also check the intra zone routing table. As the node exits in that zone, data will be forwarded to that node. In short when a node forwards a request to another zone, the request is forwarded according to it’s inter zone routing table and when a node forward request to nodes within the same zone, it is forwarded according to their intra zone table.
ZHLS is also a P2P based protocol which is adaptable to topology changes. In ZHLS, zone ID and node ID is known and that zone ID is searched in which the destination node is located by sending one location request. The search for the destination is made in P2P manner and the request is forwarded to all connected zones through gateway nodes. It avoids single point of failure, which simplifies the mobility management.

Mobile P2P Information System (MP2PIS) is purely working on a P2P basis. Connection is established with those nodes that are sharing important data information and on the basis of the data shared by various nodes, appropriate destination can be found even in large mesh networks. Nodes are spread across the area and they are connected with each other in P2P manner and each node is sharing information about destination or a way to reach destination. This is more efficient technique as runtime connections are established in this approach and different nodes perform computations on the basis of the data they shared and take important routing decisions based on this knowledge.
Chapter 5: System Design

A P2P application is a strong tool for sharing information among different users and it builds connectivity on the basis of interests and preferences. A typical P2P application is file sharing, a user makes a request for a particular file and on the basis of this request a connection is set up with those clients which have relevant information. Most of these famous P2P applications are based on a centralized implementation. The users’ connectivity is based on a central server or administration. Users’ registers are kept by the server and vital information is stored on the central server. When request is made for a particular file, the server knows to which client a connection should be set up.

In a real decentralized P2P application, each user only contains shareable data objects and no central server is used to coordinate the connection set up. Peers build connections with each other on the basis of these data objects. When P2P applications and wireless ad hoc networks are to be used together in a single system, nodes build connections with each other on the basis of shared data and interests. The P2P algorithm MP2PIS [9], fulfils the requirement of an entirely distributed P2P application and it set up connections with the peers on the basis of interests and preferences. In wireless ad hoc networks, nodes in range are connected with each other and they are often by definition strongly related to each other. In a P2P application a connection is built on the basis of the request made and the data contained at each host, in a P2P overlay network two strongly related nodes may exist far from each other.

5.1 Application scenario:

The scenario depicted in figure 14 describes an emergency command and communication system based on a wireless ad hoc network. The network is formed as areas of interests; Area 1 is a forecast office which analyzes the forecast of different areas. If any emergency occurs in a particular area, forecast area will try to inform that area before emergency occurs to take necessary information. If forecast office has no way to contact emergency area directly, then forecast will search for the area, which is closest to emergency area. That closest area will then inform that area, where emergency will occur. The area closest to emergency area can only communicate with emergency are, if there is any node in emergency area. If there is no node in emergency area, then nodes in the area closest to emergency area will be asked to perform services in the emergency area. Node spread across different areas mobile in nature. They are people with some communication equipments. Area can be any area, where wireless nodes are spread. These areas have certain range. This range and area boundary can be defined by using different geographical routing algorithms. These areas are divided in to x and y coordinates and nodes spread across these areas get their geographical location by using different geographical routing algorithms. This emergency command and communication system can be used in many different emergency situations, snow storm, earthquake etc. If an emergency area is not reachable directly by the forecast office, then any area which is closer to emergency area will be searched. When the area which is closer to emergency area is found then the node which is closest to emergency area and has connectivity with any node in emergency area will be searched for. When that node is found
then it will be asked to inform emergency area about coming snow storm, earthquake etc, or the node which is closest to emergency area will be asked to help people in emergency area. The forecast office (Area 1) has analyzed that in the coming hours there are chances for, bad weather, vulcano, avalanche, earthquake or tsunami in some particular area and people should be shifted to the safe place before the emergency occurs. For that, forecast office will try to reach emergency area, but there is no direct communication possible between Area 1 and emergency area. So the area which is closer to the emergency area will be searched, through that area which is closest to emergency area, emergency area can be informed to take necessary actions against the emergency.

Figure 14: Designed Case Study

A brief description of each area in the scenario depicted in figure 14:

○ **Emergency Area:**
  Emergency area can be that area where some emergency like bad weather, earthquake, and flood or snow storm can occur. This is the area where specific service is to be provided in the case of emergency.

○ **Area 1:**
  “Area 1” is the area having forecast office and it checks the weather forecast, so that if emergency occur, it will inform to that area, which can provide services to emergency area.

○ **Area 2:**
  This area is closer to Area from where the request is generated and also closer to Area 3. This area provides the connectivity to both areas through different sensor nodes.
- **Area 3:**
  This is the area which has helpers to help out the people and get them first aid if needed. Request generated from Area 1 for Area 3 will pass through Area 2, and then will reach to the best node in the Area 3.

5.1.1 Application Overview:

The emergency command and communication system depicted in Figure 14, is assumed to be based on location dependent P2P voice over wireless ad hoc networks. It is assumed that MP2PIS [9] and ZHLS [10] are used, a peer to peer protocol and a geographical routing protocol. By using this approach, each sensor node must send the routing and topology updates to its neighbor, if any change occurs. This is the same approach as used in proactive routing algorithms [7]. Ideas of reactive routing algorithm [7] can also be used, but it is important to keep every node up to date according to network topology changes. So that each node knows up to date location information of itself and its neighbors and thus routing is performed efficiently and effectively. Tables stored by each node are given below:

- **Geographical Table:**
  Geographical table for each area will contain the node IDs within that area and their geographical location. If a sensor node changes its location, the table will be updated.
- **Database Table:**
  Database Table stored at each node will contain its neighbor nodes IDs, their geographical location and their area. If any node changes it location or changes its area, the table will be updated accordingly.
- **Forwarding Table:**
  Forwarding Table stored at each node contains the source area and destination area.

5.2 Description of system operation

Relevant information is shared among various nodes. Nodes having information relevant to the request made will get connected with each other, and after they establish connection they share other relevant information with each other. It can be the area name for example ‘Emergency Area’, ‘Area 3’, or any area which is closer to emergency area. Information can be nodes IDs and their geographical location, e.g. a node resided in Area 3, IDs and geographical location of those nodes that can reach Area 3, node that is closer to emergency area etc. geographical location will be in x,y coordinates.

Figure 14 shows that Area 1, the forecast office, which has information about all areas, nodes within each area and the geographical location of each node. Area 1 gets this information through intermediate nodes. Then each node has a database table and a forwarding table. In these tables up to date geographical location information of node’s neighbors is stored. Each node is also storing information about the source area and destination area. Source area is the area from where the request is coming and destination area is considered that area where the request should be forwarded. This information changes as request reaches from one area to another.
From figure 14, it is clear that direct communication is not possible between Area 1 and emergency area, therefore a request from Area 1 will be generated for the area that is closer to the emergency area (Area 1 in this scenario). Nodes that contain name of that area (Area 3), which is closer to emergency area or nodes that contain node ids and their geographical location, that can reach the required area (Area 3) will get connected and request will be forwarded to the required area. Nodes in the emergency area can communicate with Area 3 as they are in range with each other; therefore nodes in Area 3 contain information about the emergency area and a way to reach the emergency area. This information is again the same information as stored in the database table of each node and forwarding table of each node. This information is also shared among various nodes in P2P manner.

When the request reaches the required area, then request will be forwarded to the node that is closest to the emergency area. When the node closest to emergency area is found, Area 1 which is weather forecast office will be informed about that node id, and a request for a voice connection with that node will be generated by Area 1. This node that is closer to the emergency area will be informed about the emergency that will be occurred in the emergency area. If that node has connectivity with any node in emergency area, then it will be informed about the emergency. The P2P protocols and wireless ad hoc routing protocols will select the best node according to node’s geographical location and data shared by that node. The criteria of selection of best node can be the node which is far from the axis point and that contain information about the desired area. If the idea of MP2PIS [9] is considered then in this scenario node 33 and node 36 are location nodes as they know the location of a node that holds information about the desired area, because the selected node shares this information about desired area with these location nodes.

Figure 15: System working

Figure 15 depicts how the P2P routing algorithm and the wireless ad hoc routing algorithm work together. By using geographical routing algorithms, those nodes that are geographically closer to each other and are in range with each other will get connected with each other. When the connection will be established among nodes on the basis of their geographical location, then P2P routing algorithms allow these nodes to share information with each other. Information shared among nodes can be area in which that particular node resided, geographical location of itself, information about its neighbor and neighbor’s geographical location etc. When the connection is
established among nodes on the basis of their geographical location and data is shared among connected nodes, then routing decisions will be made. Routing decisions are taken against request generated by any node. Routing decisions can be for example; which path should be followed to forward the request, what the next node should be etc. Node will forward the request to that node which is geographically closer to it and sharing information relevant to the request made.

5.2.1 Modified Database Table working:

The database table can be modified in such a way, so that nodes that are connected with each other in a particular area should know its neighbor nodes and neighboring area of its neighboring nodes; e.g. the database table for node 33 can be modified from the database table shown in figure 15 in the following way:

<table>
<thead>
<tr>
<th>Neighbors’ node information</th>
<th>Geographical location</th>
<th>Area</th>
<th>Neighbor nodes and their neighbor areas</th>
<th>Neighbor Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID 36→ID 32</td>
<td>ID 36 (x,y) ID 32 (x,y)</td>
<td>Area 3</td>
<td>ID 31→ Area 2</td>
<td>No Area</td>
</tr>
<tr>
<td>ID 31</td>
<td>ID 31 (x,y)</td>
<td>Area 3</td>
<td>ID 32→ Emergency Area</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Modified database table for node 33

If this database table is considered then it provide information about all nodes that are connected to each other. This table contains the detail information about its neighbors. The type of information is depicted in the field ‘Neighbors’ node information’. This field tells about connectivity of neighbors with further nodes. The field named ‘Neighbor nodes and their neighbor area’ is also containing very important information, as it tells about the neighbors and neighbors’ connectivity with zones. If this information is shared among various nodes, then required area and the appropriate node can be found more efficiently and effectively, because this information tells that which path should be followed to reach desire area. This table contains the information of multi hops and tells how to reach required area. Area 1 has the geographical table of all areas, as all the information of nodes like nodes’ geographical location and areas where these nodes are resided is shared among all nodes and sent to Area 1. In figure 14 geographical tables of Area 2 and Area 3 is shown. The geographical table of emergency area is also maintained in which information about nodes that are resided in emergency area is stored. This information is reached to Area 1 through intermediate nodes. Information stored in modified database is shared among various nodes connected with each other in P2P manner, and by the use of this database table, the required area can reached through intermediate nodes.

In the Table 1, the information like ID 32 has a connectivity to emergency area and ID 32 resides in Area 3 is very important information, because this information is telling about emergency area and its connectivity. When this information is shared among various peers then it will be considered that Area 3 is nearest area to emergency area so request is forwarded to the Area 3 through
intermediate nodes. In this way connection will be established among various nodes and request will be forwarded to the desired location.

In the case study idea of P2P protocols and wireless ad hoc protocols is used to forward the request from source to suitable area and then appropriate node within that area, based on its location not its “ID”. If ZHLS (Zone Based Hierarchical Link State Routing Protocol) is considered, then in ZHLS[10], the topological information of zone level (Areas in this case) is distributed to all nodes. Same idea is used in this case study. Each node knows areas and request is sent to requested area. When request reaches to appropriate area, then suitable node is searched. This searching is based on the data contained by each node. Since geographical routing protocol is used, so geographical location of all nodes is known and geographical location of each other node is also stored. The best node will be selected by the protocol running according to node’s location in x-y coordinates and other related data.

5.3 Protocols:

This scenario visualizes how one can reach a specific area and then can get connected to specific node in that specific area. Ideas from MP2PIIS [9] and ZHLS [10] are used and merged into a proposed system. In this approach, each sensor node must send the routing and topology updates to its neighbor, if any change occurs. This is the same approach as used in proactive routing algorithms [7]. Ideas of reactive routing algorithm [7] can also be used, but it is important to keep every node up to date according to network topology changes. So that each node knows up to date location information of itself and its neighbors and thus routing is performed efficiently and effectively.

Location aided routing (LAR) [7] is a reactive routing algorithm based protocol which handles geographical location of nodes by using GPS. LAR may not be useful when we are considering a P2P overlay network over a wireless ad hoc network as LAR is based on a reactive routing algorithm. Reactive routing algorithms are not table driven routing algorithms and the main disadvantage of reactive routing algorithms is the high latency time for route finding. In a reactive routing a source node starts a route discovery process, when it needs a path to specific destination node, which obtains the necessary information about the route to the destination. Geographical location of nodes can be obtained by using other geographical routing algorithms like GPSR [16] and GCRP [4].

To begin with, HELLO packets will be broadcasted to all nodes and in response geographical location of all nodes will be obtained. Each node is equipped with a database that contains its neighbors’ ID and geographical location. In this way all nodes know about the existence and location of each other. Geographical table for each area is also maintained. This table contains all nodes within that particular area. Node also contain forwarding table, which contains area ID from which the request is generated and also contain required destination area ID. This concept is same as node level topology and zone level topology discussed in ZHSL [10]. The node that acts as a gateway between two areas is important source of information. As in the figure, node 25 is forwarding request from area in which it is located to the destination area. It means that node 25 is holding relevant information and data. As initially request was generated for area 3. Among all nodes in area 2, node 25 is a node that is supposed to have information about area 3, and about the closest neighbor in area 3. This connectivity is in P2P manner. The underlying protocols like P2P protocols and protocols for wireless ad hoc networks frequently communicate with
each other and take decisions. If route breakage occurs then better node and better route will be found quickly on the basis of geographical location of node and the data shared by that node.

According to MP2PIS discussed in [9], nodes are distinguished according to functions performed by these nodes. These nodes are named index nodes and location nodes and they perform specific functions. If same concept is applied in this case study, then efficient output can be obtained. In this case study there are overall four areas. Area 1 is the area from where request is generated, then Area 2 that has various nodes, then Area 3, which can be a required area and then Emergency Area where the specific service is to be performed. Request is generated by ‘node 21’. If any closer neighbor occurs within ‘Area 1’ and if that node contains relevant information about Area 2 and Area 3, then this request will first reach to that node. In the case study no such node exists to request is forwarded to ‘node 21’. It is important to see that ‘node 11’ and ‘node 21’ are index nodes and they are searching for the node that contains information about location of a required area. Node 25 performs the function of ‘location node’, as it is closer to the required area and it contains information about that area. To make it clearer, let’s have another view of forwarding table and database table stored by each node. If location node 25 is considered then its table is like:

![Figure 17: Protocol working](image)

Where key attributes generated are assigned different data objects. The advantage of key attribute is that, it is used to perform search efficiently. These keys are stored in various nodes and search will be performed by checking key and assigned data object, e.g. in the forwarding table of node 25, we assume that node which contains key 50, is supposed to be important source of information and knows about destination. That node will perform searching for the location of required area. Here it is important to notice that, how node 23 knows that node 25 know something about required area. It is discussed before that all node share data objects with each other.
Node 25 may also share information to its neighbors, that he got something important. Another way to understand this idea is that, information is shared among all nodes that attribute key 50, has something important. And nodes containing this index information are getting connected. From the case study, let’s suppose there is another node with id 27 and it is closer to area 3, but that node does not contain information about area 3 or information about nodes in area 3. In this case, topology will remain same and same connectivity will take place. This is because nodes are connected in P2P manner over wireless ad hoc networks and nodes know that which node has relevant information.

When request is forwarded to node 31, then required area is achieved. But issue is that to which node, voice connection should be established to inform about the services to be provided in emergency area. The geographical routing algorithms and P2P algorithms will select the best node, which will be closest to the emergency area, and to that best node voice connection will be established. As in the case study, node 32 is considered to be best node, as it is closer to the emergency area. As it may be sharing information about its location and location of emergency area. If it moves away from emergency area, then this information will be updated immediately and another appropriate node will be found.

If P2P protocol ZHLS [10] is considered then, node level topology and zone level topology is also maintained. As in ZHLS [10], node LSPs and zone LSPs are maintained to perform efficient routing. Same concept is applied in this case study. In the case study the database table of node is same as node LSPs generated in the protocol ZHLS [10]. Forwarding table is just like interzone routing table discussed in ZHLS [10], which tells that what is the source area and destination area of node. Forwarding table shows that from which area the request comes and to which area, request should be forwarded. It reaches to node 25, as node 25 has information about area 3 as shown in its database node. Some of the functionalities of protocol ZHLS [10] can be used in this case study, but main routing functions of MP2PIS [9] are more suitable for this case study. Let’s take another look of overall system working:

**System Benefits:**

The system that is designed purely for the required application that provides variety of benefits, as it works in distributed manner completely where nodes are spread across different areas and user has just to make single request to build connection with a specific node (can be a person). Nowadays P2P is considered very effective invention, where users get connected with each other on the basis of request made and the amount of data they contain. But they share data as long as user is connected to the specific application or Internet. If the connection is lost, data sharing will be stopped. If wireless ad hoc network is considered, then connection is established, as long as nodes are in range with each other. If node moves away from the range of other node, connection will be lost and other node in range will be searched. This system is designed by combining both technologies where user has just to make request for particular area and user will get what he wants.

This application can also be designed for wireless phones or wireless devices and any user can use this device in daily life e.g. if wireless phone or device is considered, then this device show the list of connected zones/areas. Person will generate a request for particular area to find his friend whose mobile service is not working. When the request will be reached to the particular area, then the best node/person will be selected according to his/her geographical position. The information that best node/user contains, will be spread across the area and request will be for-
warded to required node/user. Then connection will be established between these two users. In this way combining both technologies eliminates drawbacks of both technologies, as there is no issue of Internet. There is no issue of wireless range. If one node gets out of range, other node gets connected on the basis of data shared.

5.4 Minimized Protocol Stack:

Different wireless ad hoc routing protocols and peer to peer protocols and algorithms can be used to construct an efficient system that uses both ad hoc routing protocols, peer to peer routing protocols and perform different services to facilitate the user accordingly. In the coming section it will be discussed, how a conceptual system could look like and why peer-to-peer protocols and ad hoc routing protocols can be merged. Important issues like how a protocol stack can be minimized and how new protocol stack should look like will be discussed.

Figure 18 is a plausible version of a protocol stack in which the application layer is placed directly on the top of the network layer. It doesn’t mean that the other three layers have been completely eliminated. Necessary functionalities can be embedded in the application layer and thus minimizing the footprints of the protocol stack. In Figure 18 the application layer is at the top and within application layer e.g. look up and UDP.

Since voice connection among peers is being discussed, UDP is used instead of TCP as transport layer. So no pre defined session is required in this case. A request is generated and this request contains a request for a particular area. Request will go to Lookup function, which will check the existence of area. A request will be forwarded to UDP then and to Network layer afterwards. In Network layer wireless ad hoc routing protocols and peer-to-peer protocols are running. By the help geographical routing algorithms, geographical location of the peers, area ID and node ID are determined and listed in “Location Table”. These protocols will determine the best nodes to which the connection will be established and then provide services to the particular area which was requested before. The discovery function work like address resolution protocol, which provide MAC address of selected node to build connection.

This is how the system will work. This protocol stack is designed according to required scenario. Now a question arises that why the protocol stack is minimized, why the simple protocol stack including all layers is not being used. Answer to that is very simple. First the load of protocol stack should be minimized as much as possible because every node will communicate on the basis of this protocol stack, and in sensor nodes there is limited amount of memory and resources.

Secondly, peer to peer application is running at the top of application layer and wireless ad hoc routing protocols and P2P protocols are running at network layer. Both layers must communicate with each other very quickly and efficiently as the topology and network changes occur. So the other three layers, in between are not of much use, though some of their functions are important but those functions are embedded in application layer and network layer. So including whole three layers in between is not a good approach in this particular case, as direct communication between application layer and network layer is needed.
Figure 18: Minimized Protocol Stack
Conclusion:

Combination of P2P and wireless ad hoc networks is an attractive approach which can be used to provide different services needed in particular area. GPS is used before to identify the location of nodes individually, but this location information can be used for strong decision making by the use of P2P protocols and wireless ad hoc routing protocols. For runtime decisions, communication between Application layer and Network layer should be quick and efficient. Nodes are generally limited in memory and in other resources, so minimized protocol stack with maximum efficiency can be one solution to that. Hardware of sensor nodes is also important to design, so that nodes can perform efficiently with minimal resources.

In this project we have tried to discuss different ad hoc routing protocols and Peer to Peer protocols and tried to identify their problems regarding mobility issues, overhead problems and managing nodes in large networks. We have also tried to discuss that how we can integrate Peer to Peer with wireless ad hoc networks and what the benefits of doing so are. We have tried to discuss that how protocol can communicate with each other to find the best node in the particular area and to show that we have proposed one case study. One problem for sensor nodes is their limitations regarding memory and processing. So we tried to discuss various architectures that may fulfill these requirements. Another solution to this problem is in the shape of minimized protocol stack. We have tried to minimize the protocol stack according to our usage and to make it work in our scenario.
References:


