Routing Decisions in Cross-Layer Mobile Peer-to-Peer Network using popular Mobility Models of Ad hoc Networks

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In the name of Almighty ALLAH,

The most Beneficent, the most Merciful.

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Final Approval

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Dedication

This project is dedicated to Our Creator ALLAH, without His will nothing is possible. It is also dedicated to the Prophet Muhammad (SAW) and to my family.

A dissertation submitted to the

Department of Computer Science,

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As a partial fulfillment of the requirements

For the award of the degree of

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Declaration

I hereby declare that this Research Project, neither as a whole nor as a part thereof has been copied out from any source. It is further declared that I have developed this research project entirely on the basis of our personal efforts made under the sincere guidance of our teachers. No portion of the work presented in this project has been submitted in the support of any application for any other degree or qualification of this or any other university or institute of learning.

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Project In Brief

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Undertaken By:	Rashid Amin
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Abstract

Peer-to-peer networks are stationary networks and devices do not move. But with the growing demands and enhancement in technologies it has becomes necessary to add mobility in peer-to-peer networks. Many research organizations and individuals around the world are working to add mobility in Peer to Peer network. They have deployed peer-to-peer network over an Ad hoc network. All the researchers used mainly AODV, DSR, OLSR as routing protocols. They compare the results of three protocols with each other. All the authors consider only one mobility model namely Random Waypoint. According to our findings Random Waypoint mobility model covers only 5% to 10% of real life scenarios. Since devices have definite starting and ending points so Random Waypoint does not fit into many real life scenarios. The other mobility models are totally ignored by the researchers. Moreover cross-layer design of Peer-to-Peer over MANET which reduces the complexity and removes the duplication is not evaluated with different mobility models. Testing of ad hoc routing protocols under cross-layer peer-to-peer network by using different mobility models has given the correct idea and results about the performance. We have considered three mobility models Freeway, Boundless Simulation Area and Probabilistic Random Walk and the results gained from these mobility models have also been compared with Random Waypoint mobility model.

We in this project have evaluated the efficiency of the AODV ad hoc routing protocols under peer-to-peer networks by using different mobility models. A cross layer optimization has been made of peer-to-peer protocol Gnutella and ad hoc routing protocol AODV. The mobility models are again used to evaluate the performance of this cross layer network. The results have been validated by using NS2 and we compared the results from these two networks for suggested mobility models and we compared these results. Results gathered from this research showed that cross layer optimization give improved result compared to the layered model.

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Introduction

1.1 Introduction

In the world of future, wireless communication will be everywhere. There will be wide variety of networks from PANs (Personal Area Networks) to VANs (Vehicle Area Networks). The hotspots and mobile networks will still exist but with greater bandwidth. In these networks, Peer-to-Peer network will get lot of importance as it has got in wired network, because of its efficiency and reliability. Although, Peer-to-Peer network was actually designed for wired network, due to growing demands and enhancement in technology it became necessary to add mobility in Peer-to-Peer network. Peer-to-Peer network is going to be deployed on Ad hoc network. This deployment of Peer-to-Peer network over Ad hoc network is more complicated and complex in nature. Although there are similarities in both these networks, differences are also there.

1.2 Peer-to-Peer Network

Peer-to-Peer is network architecture [1], in which independent devices share information, content or hardware capacity directly with each other and make their own control decisions without the definite need of using an intermediate central controlling point. P2P network perform better than the conventional client-server design also as well as a good enhancement for trade and promotion channels. While the benefits of P2P have made it very famous and popular among the internet community, there are a large number of issues like security, privacy, and authentication that need to be discussed and resolved.

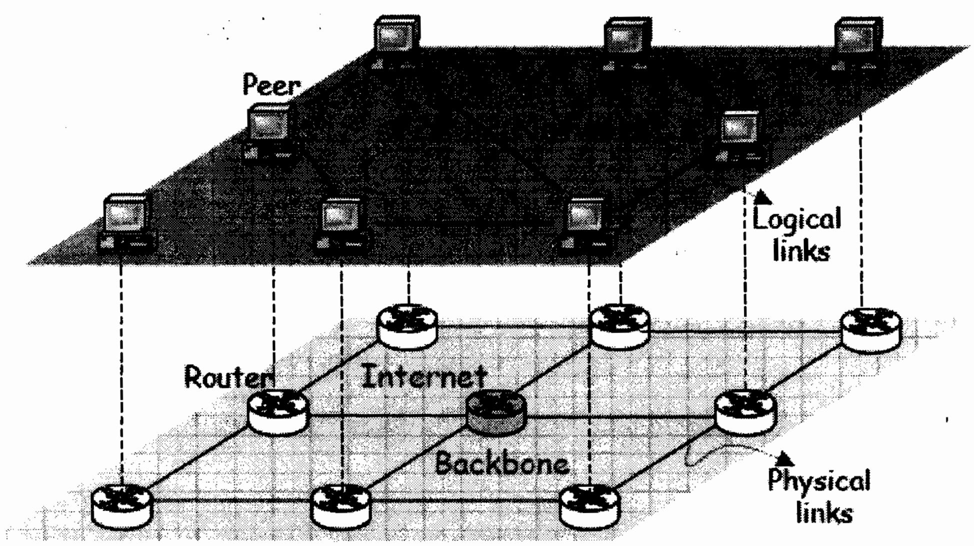

Figure1.1: Peer-to-Peer Network [30]

The distributed and decentralized nature of P2P makes it beneficial in multiple ways as compared with client-server model: No need for administration: distributed control, content and processing decrease the need for centralized management tasks, and thus save costs as well as leaves more resources for other tasks.

- **Cost saving:** since peers are using their own infrastructure for providing the services and resources, there is no need for purchasing, maintaining, and administrating servers and network infrastructures to keep up the services.
- **Performance:** distributed and replicated resources bring content closer to its consumer and enable redirecting the requests to peers with lower utilization. This means there are fewer bottlenecks in the system, and thus the performance is better from the viewpoint of the peer.
- **Efficiency:** distributed processing optimizes the need for hardware resources. The network resources are utilized more efficiently, because the aggregated resources increase the processing power, optimize the network usage, and reduce costs, as well as increase storage space for storing the information.
- **Availability and Reliability:** distributed and replicated resources bring content closer to its consumer; this improves the availability of the content. Since Peer-to-Peer network has distributed database and resources are spread across the number of nodes, the fault tolerance of the network is increased.
- **Scalability and independency:** the size of network is not limited by server resources. Each new peer contributes to the system, which makes the system automatically scalable and requests can be made regardless of location because the resources are distributed.

1.2.1 Peer-to-Peer Communication Architecture

P2P networking is becoming more and more imperative as a technology for today's communication system. P2P is functional in different application areas, varying from, e.g. computational resource sharing in applications like Seti@Home [8], to the session management in messenger applications, such as Skype [10].

The basic dissimilarity between the Peer-to-Peer and Client Server network design is that in Client Server models, there is a central management authority that controls all the operations of whole network. By contrast Peer-to-Peer systems are peer slanting, and the nodes in such a network play the role of client and server at the same time. There exist a number of different definitions for P2P [2], depending on the viewpoint. We can define the Peer-to-Peer are a network architecture in which independent devices share information, content or hardware capacity directly with each other and make their own control decisions without the definite need of using an intermediate central controlling point, i.e. server. In fundamental parts, this is also the most popular definition for P2P.
The P2P [3] networks architecture can be roughly categorized by using the terms of their centralization and structure. Since this categorization describes the overlay architecture, it is directly related to the Peer-to-Peer generations.

1.2.2 Centralized Peer-to-Peer network

The centralization of P2P can vary from purely decentralized, where all peers have same role in the entire network, to hybrid decentralized, where centralized server facilitates the interaction between the peers by performing some operations on behalf of them. In the middle of these categories, there is partially decentralized, where some of the peers, called super-peers, have more responsibilities than the others. The before mentioned 3rd generation P2P architectures fall into this category, whereas the 2nd generation P2P architectures are obviously purely decentralized architectures and the 1st generation architectures represent the hybrid decentralized architectures. Consequently, the P2P generations, for one, describe the centralization of the architectures. Example of hybrid decentralized architecture: Napster is typical hybrid decentralized architecture. The architecture consists of peers and a dedicated server or a server pool for maintaining an index of the connected peers and their resources. Data [4], [5] transfers and communication between the peers are made directly between the peers.

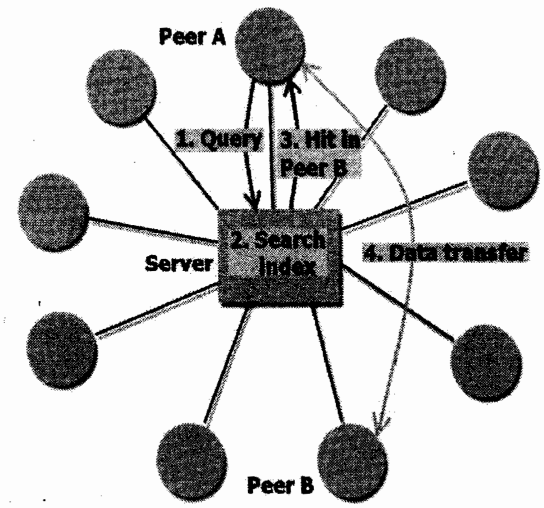

Figure 1.2: the operating principle of Napster.

The above figure explains the function of a Peer-to-Peer network Napster. When peer connects to the local server, peer A keeps alive to the server of its cluster. When the user of node A needs some file from the central server then peer launches the query message to the server group. Different servers in a group can cooperate with each other to find requested file. If they find then they return a complete list of peer containing requested file. Now peer can download this file from node B, assuming that file is available on B alone.

The overlay network structure describes how tightly the overlay network structure and content placement in it is controlled. In unstructured overlay networks, the network is created nondeterministically when nodes and content are added. The overlay does not have any rules for joining peers, and the behavior of the network is ad-hoc type. The advantage of this type of network is that it is simple and thus more appropriate for highly transient node populations. Gnutella [6] is a good example of unstructured P2P architecture.

In structured overlay networks, the overlay has specific rules for nodes joining it and for the routing between them. The overlay also controls the content placement, meaning that the location of the content is always known by the overlay. This means that in structured overlay networks the search mechanisms can be made simple and efficient, which makes it better in performance. Unlike the unstructured networks, the structured networks are better in more static node populations, since it is harder to maintain the network in highly transient node populations. (Distributed Hash Table) DHT-based [7] P2P networks are always structured, whereas many traditional protocols, like Gnutella, KaZaa, DC++ and Napster are unstructured.

1.2.3 Structured and Unstructured Peer-To-Peer

The P2P overlay network consists of all the participating peers as network nodes. There are links between any two nodes that know each other: i.e. if a participating peer knows the location of another peer in the P2P network, then there is a directed edge from the former node to the latter in the overlay network. Based on how the nodes in the overlay network are linked to each other, we can classify the P2P networks as unstructured or structured.

Structured P2P network employ a globally consistent protocol to ensure that any node can efficiently route a search to some peer that has the desired file, even if the file is extremely rare. Such a guarantee necessitates a more structured pattern of overlay links. By far the most common type of structured P2P network is the distributed hash table (DHT), in which a variant of consistent hashing is used to assign ownership of each file to a particular peer, in a way analogous to a traditional hash table's assignment of each key to a particular array slot. Some well known DHTs are Chord, Pastry [9], Tapestry, CAN, and Tulip.

1.2.4 Peer-to-Peer routing protocols

1.2.4.1 The Gnutella Protocol

The Gnutella protocol is a simple reliable distribution system which provides the facility to share and deliver literature, art and music to other users. The main idea is that it has no central servers to control traffic and administration. Actually, this type of network is based in peers that act as both client and server and hence called servants. These peers operate independently and make a library of digital content.

The Gnutella protocol is used in area of Peer-to-Peer for flat routing [10]. The network based on Gnutella protocol is distributed all around the world, and this network is consists of Servents that act both as client and server. These Servents are managed by TCP/IP protocol; files are downloaded by TCP/IP connections.

1.2.4.2 Query Routing

When we are connected to a network it is difficult to find the resources. To find these resources we use different flooding techniques, which create a huge amount of traffic. The Query Routing concept is used to minimize the flooding in the entire network. We can decrease these queries for different files in network by using search words to find contents. The query routing for some contents is the same, as different nodes exchange information with each other and with their neighbors from time to time. There routing information are arranged in some table so that this can be used for the future querying. These routing tables mostly consist of metadata of hosted content like keywords used for search and the IP-address of corresponding peers from which the metadata was received. The query is first examined for its search keywords, and then matched up to the query routing table of the peer.

1.2.4.3 Dynamic Hierarchical Routing

This routing tries to combine the advantages of centralized and decentralized routing. Within this approach, which is the basis for the Fast Track architecture, Servents are elected at logon to become so called Super Nodes, if they offer sufficient bandwidth and processing power. Further on the additionally receive a list of already active Super Nodes, to which they connect. These Super Nodes thus establish a network, with high bandwidth connections to each other and high computing power at each Super Node.

1.3 Mobile Ad hoc Network (MANET)

Mobile ad hoc network is a network of mobile nodes for a limited time with limited resources. This type of network is usually built in area where there is no infrastructure available for traditional communication. These networks are mostly self managing and self configuring networks because there is no central management authority to handle searching and content distributing tasks. This network is formed for military operations, disaster recovery and accidental handling. In this network every node works as source of information, a router and drain for information. Every node has specific contents that can shared in the network, each node maintain its own contents.

In wireless ad hoc network [11] node can move anywhere within the transmission range of enlisted nodes, this node must be within the transmission range of at least one node of the entire network. Wireless node can connect to a faraway node by using its neighbor nodes. As the mobile nodes have faced the problem of limited battery, so transmission of nodes is also affected by the power of node. For this reason, transmission range of mobile node is smaller than that of whole network.

In wireless ad hoc networks, for the transmission and reception of data all the mobile nodes use the similar frequency band as a common medium. As this frequency band is unreliable for data transmission so there is a chance of irregular errors in the transmission. So it is necessary that reliable protocols should be used that can minimize the variation in channel.

1.3.1 Mobile Ad hoc Networks Routing Protocols

Now we shall give brief description of routing protocols used for Mobile Ad hoc network that we will use in our simulation for analysis. There are a large number of routing protocols that are being used in for research in ad hoc networks and this is very important research field in these days and in near future. These routing protocols have been classified in to different categories and groups the classification helps understand the functionality of protocols.

We can classify these protocols on the basis of different methods and procedures. They can be classified on the basis of communication like unicast, multicast and broadcast. In mobile ad hoc network the mobile modes search for the destination node and the routs for that node are stored in the routing table. Protocols are divided in to three different routing categories for their node search and maintain rout information procedure. These three types are proactive routing, reactive routing and hybrid routing.

1.3.1.1 Proactive Routing

These protocols are also called "table driven" protocols as in these protocols tables are used to keep track of node location. In these protocols nodes have complete information of the destination nodes and they maintain these routs continuously. Nodes keep an eye on the entire network and when there is a change in the network topology; nodes update their routing table so to accommodate the entire change in the network. So in these types of routing protocols, routs are updated periodically whether the data is exchanged between different nodes are not. Proactive routing includes the protocols like Wireless Routing Protocol (WRP) [46], the Destination Sequenced Distance Vector (DSDV), Optimized Link State Routing (OLSR) [47] and Fisheye State Routing (FSR) [45].

1.3.1.2 Reactive Routing Protocols

In this category of routing protocols, routing paths are searched to the destination node only when it required sending data to that node. These protocols are also called On Demand Routing Protocols as routs are searched on the demand of source node. If a node wants to send data to some other node then a discovery procedure is used to locate the destination node and it continues until the desired node is found or it does not find any route for that destination. Due to longer discovery time the node has to wait for long time to send data if it suffers to find rout to the destination node. These routing mechanisms include the following routing protocols: Dynamic Source Routing (DSR) [5,15] and Ad hoc On- Demand Distance Vector Routing (AODV) [16], Ad-hoc On-demand Multipath Distance Vector [17] and MultiMate Ad-hoc On-demand Distance Vector Routing Protocol [18]

1.3.1.3 Hybrid Routing Protocols

In these type of routing protocols, it take some qualities form reactive routing and some form proactive routing so it can benefit from both these networks. In this routing scheme the routs are initially established using some proactive manners and after that it serve as reactive when node send queries for the other nodes. This type routing protocol includes Hybrid Routing Protocol for Large Scale Mobile Ad Hoc Networks with Mobile

Backbones (HRPLS)[19], Hazy Sighted Link State routing protocol (HSLS) [20] ,Zone Routing Protocol (ZRP) [21,22], Zone-based Hierarchical Link State routing (ZHLS) [23] and Hybrid Ad hoc Routing Protocol (HARP) [24].

The following Protocols have been chosen for the analysis.

1.3.2.1 Ad Hoc On-demand Distance Vector Routing (AODV)

The Ad hoc On Demand Distance Vector routing protocol is a unicast routing protocols that acts as reactively. Due its reactive nature the path to the destination node is searched when it is required to communicate with a node or send data to that node. The path to the destination is stored in routing table which is currently used by the node. These tables only have most recently used routes in it and after certain time when routing table is refreshed its information about these paths are updated.

The procedure of route discovery in AODV is that when a node wishes to send a data packet to another node, it firstly initiates the route discovery operation and sends a broadcast message route request packet (RREQ). This route request packet (RREQ) contains the address of sending node and the address of the receiving node, the broadcast identification number, the last filed contain the sequence number of the destination node and the sequence number of the source node. These sequence numbers are very important and are used for a loop-free and up-to-date route.

In the beginning, the RREQ packet starts with a minimum value of TTL (Time to Live) and search for destination but if it does not find the requested node then the value of TTL is increased. When a node in AODV receives a RREQ packet then it checks its cache that destination number it contains and compare both these numbers. If the sequence number of the destination node is greater or equal to the specified sequence number then this node will generate a route reply packet RREP. This RREP packet will return back to the source node, this packet will follow the same path for returning to the source node. When a node in way to source node receive this RREP packets it will also update its routing table. Node can check the links which are active by these hello packets. When there is disconnection then a route error RERR packet are flooded in the network.

The RREQ starts with a small TTL (Time To Live) value but if destination is not found then the TTL value is increased. In AODV when a node receives a RREQ then it checks in its cache the destination number currently it has and the one that is specified in the RREQ. If the destination sequence number is greater or equal then a RRRP packet is created and forwarded back to source and follows the same path as that of RREQ. Upon receiving the RREP each node in the way updates its table entries with respect to the destination node. Each node drops the RREP with lower destination sequence number. Active links and the status of the neighbors can be checked by hello packets. On discovering a disconnection it broadcast a route error packet to neighbors which in turn broadcast the packet and in this way all the nodes updates its information. Figure1.3 shows the route forwarding and route reply (reverse arrows) in AODV.

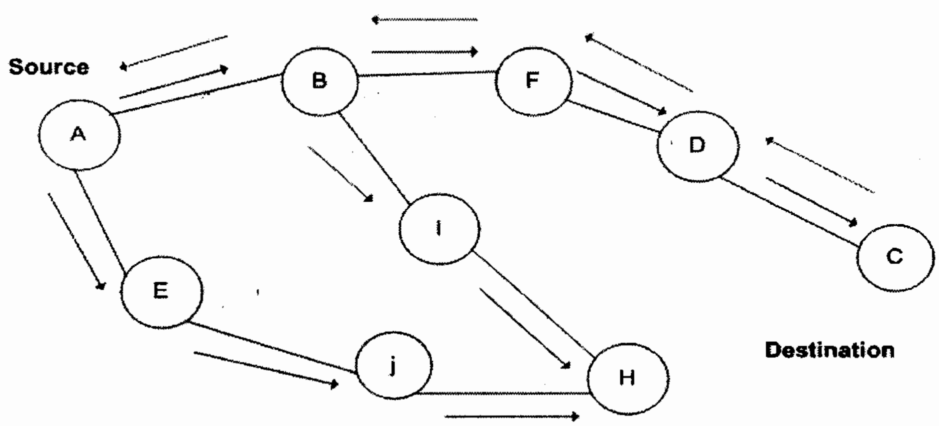

Figure 1.3 Route Request and Route Reply in AODV

1.3.2.2 Dynamic Source Routing (DSR)

Dynamic Source Routing protocol is unicast routing protocol that uses reactive mechanism to find the path to the destination node in which each packet contains the complete route to the destination node. DSR protocol routing can be divided into two different phases; first one is the route discovery and second one is the route maintenance. Every node uses its own cache to keep the routing information. When a mobile node wishes to send some to another node then it checks its own cache to get the routing information, if it is available in its then it uses that information to send data to the destination node. If its local cache did not contain the destination node address then it generates the route request packets launching route discovery procedure.

The route request packet contains the address of the source node as well as the address of the destination node and it also contains the sequence number to identify the route request packet. Same procedure is repeated as in the case before, when a node receives the route request then it checks its local cache whether it has destination node, if it is not then it appends its own information with it and sends this packet to the neighbor node. Each node which receives this packet will append its own information with it until this packet reaches the destination. These intermediate nodes process the packets only if this packet has not passed through this way.

When the route request packet reaches the destination, a route reply packet is created that will be sent to the source node. This route reply packet contains the complete information about the route to the destination. This route reply packet follows the same path to the source or it can calculate another path form the route record field.

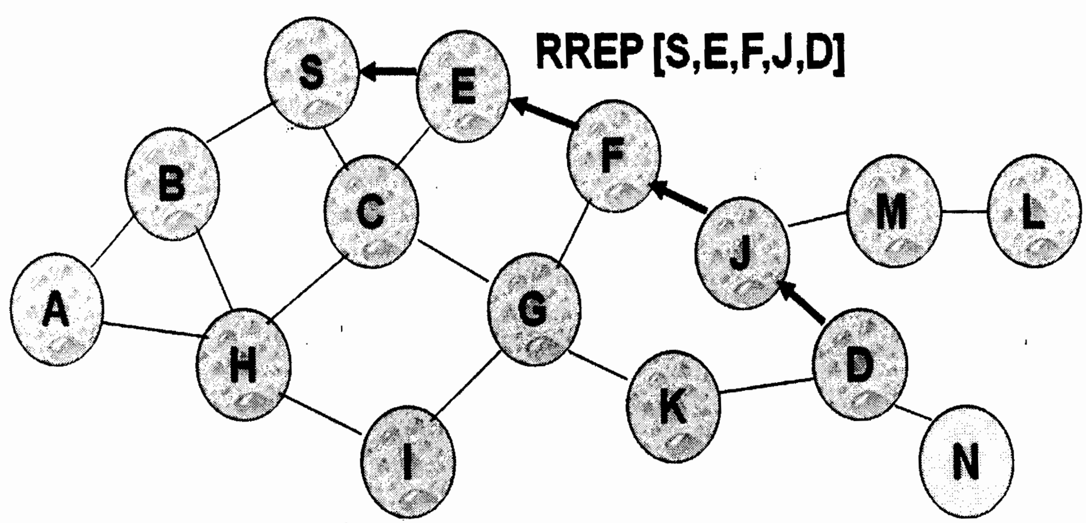

Figure 1.4 Route Reply in DSR

1.4 Peer-to-Peer Network and Ad hoc Network

P2P applications and mobile ad-hoc networks are emerging technologies and there are lot of similarities between them. The actual model of both of these (P2P and MANET) based on same paradigms. Since, in both the networks Ad-hoc and P2P application networks, there is no any central server in these networks. Communication between the participants occurs when they want to interact with each other. These networks also have same dynamic topology due to constant change in the connection used by the user. In MANET these changes are due to the change in position of node. When a node moves out the transmission range of another node then the link between these will be broken and need to be re-established. In Peer-to-Peer networks, the topology of network is changed due to low availability of peers. As Peer-to-Peer application are mostly deployed over a fixed network and there is no mobility of actual nodes but due to small duration of communication session. As we know P2P applications are generally built over a Client/Server model based network and these model have some different characteristics than that of Peer-to-Peer paradigms. MANETs, in contrast, have their own communication mechanism and, therefore, are more realistic to the distributed model.

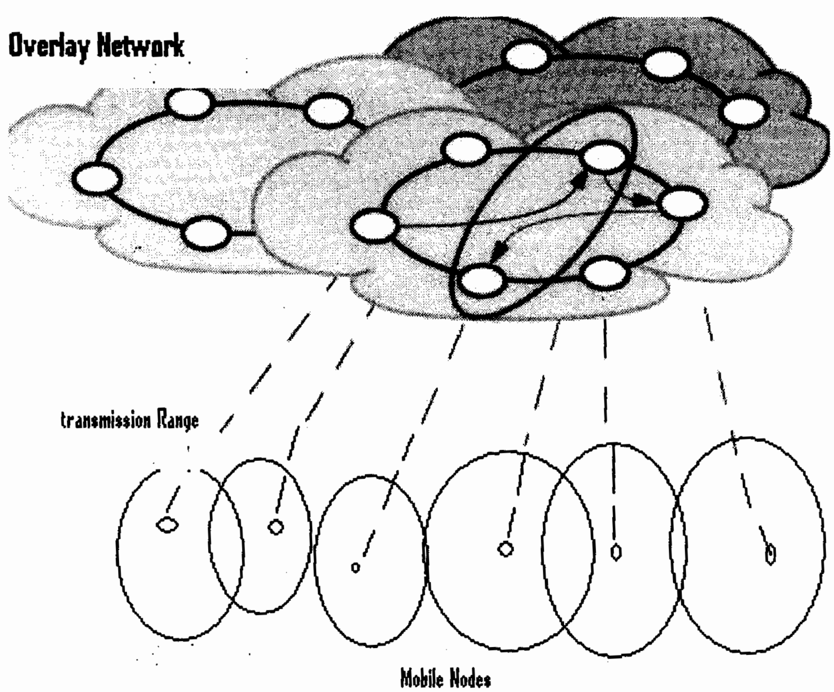

Figure 1.5: P2P Network on Mobile Nodes

1.5 Cross-Layer Interaction of Peer-to-Peer over Ad hoc Network

When we deploy Peer-to-Peer overlay network on the top of ad hoc routing protocols, this form of network results in low performance and throughput. This happens due to the lake of communication and collaboration between the application layer and network layer. Due to different behaviors of these layers, message overhead increases and delay latency also affects the communicating nodes.

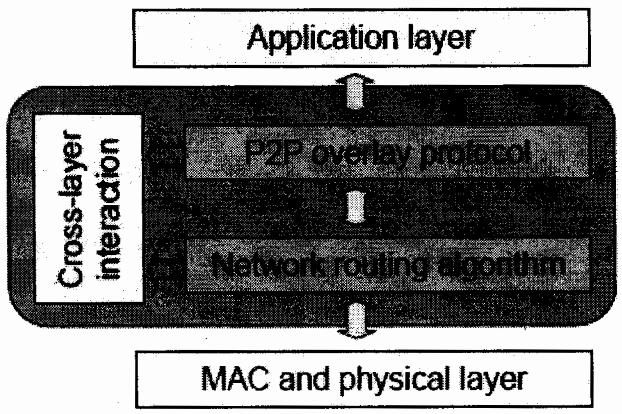

Figure 1.6: Inter-Layer communication in Cross-Layer Design

Peer-to-Peer node discovers the peer nodes that contain the requested file and they form a route to the destination node to retrieve that file using underlying ad hoc routing protocols. But this layer design approach is not efficient for communication due to lack of Inter-Layer communication. To overcome the limitation of layered design approach, a Cross-Layer design is introduced for Inter-layer communication. In this cross-layer design, both the layers : application and network layer take advantage of the functionality of each other, the overall procedure of peer discovery and downloading a file from a destination becomes simple.

1.6 Ad hoc Network Mobility Models

The mobility models provide the movement patterns for mobile nodes and are considered a key component in the simulation of mobile ad hoc networks. The mobility models also represent different characteristics that affect the wireless communication in real world. The mobility model should provide the characteristics of real world scenarios because in real world there exist different factors that do affect the wireless channel. Now the trend is towards the generation of realistic mobility models because for accurate and complete results there is no advantage in using a non realistic mobility model for simulation as they do not cover most of the needed parameters. Vehicular mobility models are usually considered microscopic or macroscopic [25]. In macroscopic point of view roads, streets, crossroads, and traffic lights, node density, initial position and speed is considered [4]. On the other hand in microscopic point of view, the movement of each individual vehicle and its behavior with respect to other vehicles is determined [4]. The microscopic characteristics include the driver behavior, overtaking, braking, acceleration, road side obstacles, atmospheric factors and motion constraints etc.

The following mobility models have been chosen for the analysis.

1.5.1 Freeway Mobility Model

In [21] et. al. has introduced Freeway Mobility Model and its some important characteristics. A certain path is followed by the nodes in Freeway Mobility Model which also has a particular direction. A Freeway Mobility Model consists of number of Maps. Each map has large number freeways and each freeway consists of set of traffic lanes in both directions. The velocities of vehicles are partially dependent on their previous velocities. During the movement of vehicles, there will be a safety distance between vehicles in the same lanes. The velocity of preceding node should be greater than the velocity of following node. As the nodes are restricted to their lanes, so Freeway mobility Model has higher temporal and spatial dependency. These nodes also have geographic restriction on them. Freeway Mobility model can perform well for exchanging traffic position or finding a vehicle on a freeway.

There is safety distance between the two nodes that must be maintained while moving in the same lane and the velocity of following node can not exceed the preceding node. The freeway mobility model has high spatial and temporal dependency and also follows strict geographic restrictions on nodes because the nodes are restricted to their lanes only. The application of freeway mobility model are exchanging traffic status and tracking a vehicle on a freeway.

1.5.2 Boundless Simulation Area Mobility Model

A Boundless Simulation Area Mobility Model [15] presents a relationship between previous direction and velocity of mobile with recent parameters of these two [20]. It is different from other Random Mobility Models like Random Waypoint, Random Direction and Random Walk as these all models are memory less models and Boundless Simulation Area Mobility Model is a memory model. Actually, in this model current values of speed and direction are dependent on the last values of these parameters. Mobile node speed v and direction θ is described as $v = (v,\theta)$. After each t the new values of speed and direction are calculated using following formulas:

$$v(t + \Delta t) = min[max(v(t) + \Delta v, 0), Vmax]$$

$$v(t + \Delta t) = \theta(t) + \Delta\theta$$

$$x(t + \Delta t) = x(t) + v(t) * cos\ \theta(t)$$

$$y(t + \Delta t) = y(t) + v(t) * sin\ \theta(t)$$

In the above equation Vmax is maximum defined velocity of the simulation, Δv is change in velocity of node in Δt time. This is selected form $[-A_{max} * \Delta t, A_{max} * \Delta t]$ equally. Amax is a Maximum acceleration of mobile node. Hence $\Delta\theta$ is change in direction in Δ time which is uniformly obtained from $[-\alpha * \Delta t, \alpha * \Delta t]$, where α is maximum angular change in the direction in Δt.

A Boundless Simulation Mobility Model has different border behavior than other mobility models. In this mobility model when node reaches to the boundary of the simulation area, instead of returning back it continues travel in the simulation area and appears in some other place in the simulation area. This mobility model creates a more realistic behavior than the other mobility model like Random Waypoint, Random Walk, and Random Direction.

1.5.3 Probabilistic Random Walk

In [21] et. al. have introduced a new mobility model that uses the probability matrix for the movement of a node to the next point. There are three different states that describe the next position of the node. The state two represent the next position if a node moves in the same direction. While state 0 gives the current position of node and state 2 tells us the next position and state three tell us the previous position of the node.

1.6 Motivation

The research on Mobile Ad hoc Network research is proceeding actively for the last ten years. During last five years incredible development has been made in this field. Peer-to-Peer network has ability to create and manage a network with any central arrangement, so it is known as the art of networking without network. Peer-to-Peer networks are also a new focus in the network research that can form a virtual overlay network to share contents between different nodes.

In the beginning Peer-to-Peer Networks were stationary networks and devices were not moving at all, but with the growing demands and enhancement in technologies it becomes necessary to add mobility in Peer-to-Peer networks. So there are number of researcher that uses the mobility models in ad hoc routing protocols performance evaluation. The result showed that routing protocols are affected from the mobility model which is used in different scenario. The deployment of Peer-to-Peer network over an ad hoc network makes the network more complex and ad hoc routing algorithms are used, it is need of time that mobility model should also be used in this network. Researcher used only one mobility model for the evaluation of P2P network using ad hoc routing protocols.

1.5 Problem Domain

Peer-to-Peer networks are developed for fixed networks and these networks are perform very well in wireline networks. Due to enhancements in technology and increasing demands of users it is necessary to deploy Peer-to-Peer network in the ad hoc environment. Mobile ad hoc network do not behave like wired networks they face the problem of Link breakage, change in network topology, network partition and mobility of nodes. Nodes can be removed from network at any time as well as new node can join the network frequently. These non probabilistic conditions make it difficult to design Peer-to-Peer network over Mobile ad hoc network. As mobility is a challenging issue for Mobile ad hoc network, there is a need for a mechanism that truly represents the actual world scenarios and to provide all the necessary components for simulations. Mobility models provide the necessary components for the simulations that are why a number of mobility models have been presented by the researchers. These mobility models try to present an environment that truly represents some of the components of real world.

1.6 Proposed Approach

In our proposed approach, we have first identified the necessary realistic and non realistic components for the development of a Peer-to-Peer network application over an Ad hoc routing protocol. This network is then analyzed for performance evaluation of different mobility models. As the performance of network is because of the lack of interlayer communication so a cross layer design in proposed for this network which increase the network performance by decreasing the redundant message generation. Now the same mobility models are evaluated and results will be gained. A comparison between these two approaches will be made on the basis of these mobility models. The comparison will show the overall performance of a cross layer design using different mobility model. It will show the importance of mobility model in mobile ad hoc network. The performance of routing protocols is affected by the choice of mobility model.

1.7 Thesis Structure

The rest of this thesis is organized as follows. In chapter 2 we have presented the related work. In chapter 3 problem domain and in chapter 4 Peer-to-Peer network, Mobile Ad hoc network and mobility model entities and its characteristics has been presented. In chapter 5 a simple framework for the Peer-to-Peer network over mobile Ad hoc network is presented and a cross layer optimization has also been shown there. Chapter 6 deals with implementation and simulation results and performance evaluation has been shown in chapter 7. Chapter 8 concludes and gives future work.

Chapter 2

Related Work

2.1 Introduction

A large number of thesis and research articles are available on Peer-to-Peer Network and Mobile Ad hoc Network. There is a large variety of routing protocols that are under research for Mobile Ad hoc network and Peer to Peer network. These protocols are being analyzed and verified for future communication models by different research communities. Peer to Peer network was mainly deployed on wired network, where it is actively working for different tasks like file sharing, video and voice content sharing etc. There are number of protocols that are used for Peer to Peer network like Gnutella, CAN and Chord. These Peer to Peer networks are of two types Centralized and Decentralized. Centralized network has central management that is responsible for allocation of contents and it help is searching these contents. Whereas in Decentralized network Peers manage their own files by themselves and requests are forwarded to other peers if corresponding node did not have requested file.

The Peer to Peer network over an Ad hoc network is a new paradigm in network research, as Peer to Peer network are more promising for file sharing. Both these networks are decentralized and self configuring with dynamic topology and liable for routing queries in distributed locations. In many situations MANET are envisioned to be widely used like rescue teams in disaster recovery and in military battle field which require that the information should be exchanged between communicating nodes using peer to peer system. It is observed that simple deployment of Peer to Peer network application with mobile ad hoc network is not a good solution at all specially in term of performance and reliability. This simple coupling of Peer to Peer network with ad hoc network may lead to network resource wasting in term of routing overhead and redundant message passing between different nodes. To solve this problem some researcher proposed cross layer optimization of two layers Peer to Peer overlay protocol on application layer and MANET routing protocol on network layer. When we deploy Peer to Peer network over Mobile Ad hoc network, the most important factor which affects the network connectivity is mobility.

In current research of Peer to Peer over MANET, only a Random Waypoint Mobility Models was used. But, with the passage of time the research trends have changed and new dimensions are included in the mobility models generations, so it is necessary that other mobility models should also be analyzed.

2.2 Related Research

The Peer-to-Peer over the Ad hoc networks are current research trends, as different P2P application have been used to analyze the performance of MANET protocols. A number of approaches have been used to analyze both networks with different protocol combinations. Using mobility models as key element for simulation, different researchers have analyzed different mobile ad hoc networks protocols with a number of parameters. For this purpose different projects have been conducted. The following papers, surveys and technical reports have been considered for related work for the Peer to Peer network over Mobile Ad hoc Network.

On the Performance of ad hoc routing protocols under a peer-to-peer application [26]

In this paper authors have presented evaluation of different ad hoc routing protocols under a peer to peer application. They have used three ad hoc routing protocols for analysis like Ad hoc On demand Distance Vector (AODV), Destination Sequenced Distance Vector (DSDV) and Dynamic Source Routing (DSR) protocols. They use these protocols because of two reasons. One consideration is that these protocols have been extensively used in research for testing and validating. Second, these protocols have different characteristics as DSR is of proactive nature, DSDV is of reactive and AODV is a combination of both above. The author used Gnutella as a peer to peer protocol, because it is mostly used for peer to peer communication. This protocol belongs to the category of unstructured peer to peer network which are totally decentralized in nature.
The performance of ad hoc routing protocols under a peer to peer application has been evaluated using these metrics; Workload, Mobility, Network density and Peer

connectivity. The results from this papers show that these protocols perform good in some scenarios and have low performance in rest of the situation. In the case of workload DSDV has performed better for extremely high load, while DSR and AODV did not give good results. In mobility, the DSR was the protocol that presented highest number of hop and latency in high mobility. The AODV performed well for peer connectivity and it consumed less energy while joining the peers. This paper also presented the comparison of this peer to peer application with a client/server application. The result shows that client-server also performs well in some scenarios like increasing mobility did not badly affect the client server model as in peer to peer network. Finally it is suggested that the performance of peer to peer application over ad hoc routing protocols can be increased by modifying existing protocols or by taking advantage of services of other layers.

Routing in Mobile Ad hoc and Peer-to-Peer Networks, A Comparison [27]

This paper describes the similarities and differences between Peer-to-Peer network and Mobile Ad hoc network. As both of these networks are decentralized and self organizing networks so there are hidden synergies that should be should also be shown. If concentrates on different routing algorithms that are used in Mobile Ad hoc network and Peer to Peer network. All this effort emphasis on that how these synergies and similarities can bring these two different networks into a single network. This paper discusses different routing protocols for mobile ad hoc network like DSR, AODV, DSDV and Zone routing protocol (ZRP). They point out different limitation and enhancements for these protocols. For Peer to Peer network three types of different routing strategies have been discussed. These include the Gnutella Protocol, Query routing and dynamic Hierarchal routing. In first Servents are used to rout network information to the connected node, while in query routing Servents exchange their query routing tables with other servents. In hierarchical routing Servents which are elected at logon become super nodes so different layer of operation are formed. Next section discusses the difference between the mobile ad hoc network and peer to peer network.

Difference	P2P Network	MANET
Reason for creating network	Create an abstract/virtual infrastructure which is more or less independent of physical one	Create an initial/physical infrastructure for connectivity
Connection between two noes	Wired and direct connection (at P2P layer)	Wireless and indirect connection over several nodes
Reliability of connections	High, due the wired links	Low, due the wireless link
Structure	Virtual overlay, physical structure is separated	Logical and physical structure correspond
Physical diameter of network	Can span the world	Members are densely distributed in area, therefore the position of the network is roughly known
Routing	Stops when TTL is 0	Stops when destination is found
Proactive routing algorithm	Not possible	With limitation to network size possible
Broadcast	Virtual broadcast, realized with multiple unicast	Physical broadcast performed
Mobility of nodes	Fixed	Mobile
Usage of PKI	Possible	Not feasible

Table 2.1: Differences between Peer-to-Peer and Mobile Ad hoc Network

They also describe the similarities between these two networks as the basis for both the network is the same that is the concept of self organization. In both networks no hierarchies are given by default but can be introduced using different protocols [33]. The detail of these similarities has been arranged in the following table.

Similarity	Peer-to-Peer	MANET
Basic routing principle	Virtual broadcast, flooding	Physical broadcast, flooding
Network topology	Flat and frequently changing topology, caused by frequent log-on and log-offs	Flat and frequently changing network topology, caused by log-on and log offs and additional terminal mobility of the nodes
Reliability of nodes	low	low
Connection establishment	Hop by hop, via TCP links, whereas the single hop path length is not physically limited	Hop by hop via radio links, which are thus limited by the radio transmission range
Network log on	Via a portal, which is in this case a fixed server ("beacon server"). The IP address of the portal must be known for new servents	Via a portal, which is in this case a specified broadcast radio channel. The frequency range of the portal must be known for new nodes
Scalability	Limited by bandwidth consuming signaling traffic (flooding) and additional high user data rates(→ approx. 50.000-60.000 currently)	Limited by bandwidth consuming signaling traffic (flooding) and additional physical constraints(→ approx. 100 users)
Network management	QoS and AAA are difficult to realize, as a central management unit is not implemented	QoS and AAA are difficult to realize and additional physical constraints have to be taken into account
Security	Due to the separation from lower layers, no lower layer security (e.g. IPSEC) useable. Possible solution: end-to-end encryption to establish security in an untrustworthy environment	No lower layer security concepts for MANET implemented until now. Possible solution: end-to-end encryption to establish security in an untrustworthy environment

Table 2.2: Similarities between Peer-to-Peer and Mobile Ad hoc Network

Due to above similarities between these two networks one could think about the combination of these networks as Peer to Peer network over mobile ad hoc network as the current research has proved this supposition into reality. Growing demands of users and enhancement in technology have proved this in a new beginning.

"Cross-Layering in Mobile Ad hoc Network Design" [28]
MobileMan – A Cross-Layer Design

MobileMan is Cross-Layer proposal for Mobile Ad hoc network which increase the network performance by allowing different protocols to cooperate in sharing network status information while still keeping these layers separate at the design time. This paper presents different technique for increasing the performance of mobile ad hoc network. Layer triggers are used in wired and wireless network, these are signal to notify some events like data delivery failure between different protocols. Explicit Congestion

Notification mechanism is used in router to notify TCP layer about the congestion in the network and L2 triggers are also used to detect changes in wireless link status. Instead of these layer triggers a complete layered approach is used in this new architecture. This cross layering is done in the view of basic principle of layered design. It also maintains the benefits of the layered design architecture. MobileMan architecture is shown below.

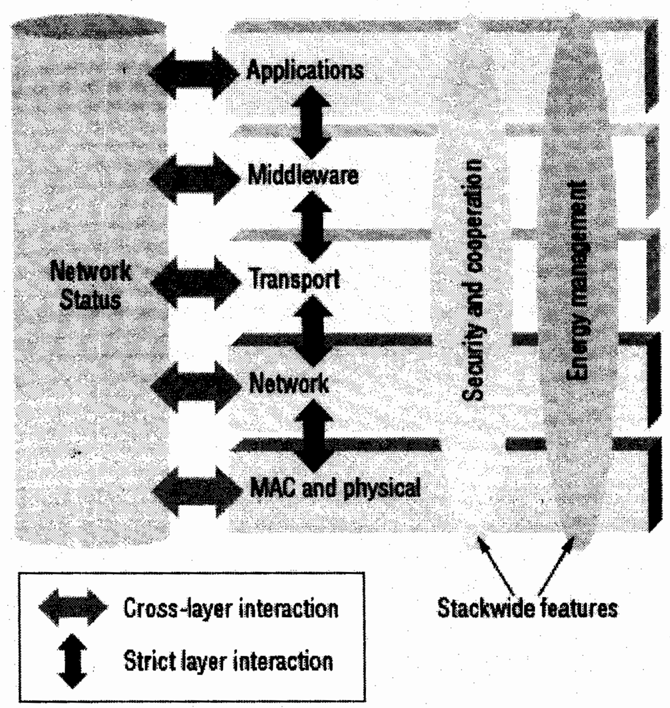

Figure 2.1: MobileMan Architecture [28]

By using cross layer design in wireless network the performance gain is increased, as different network functions provide benefits to whole application. These performance advantages are improved global and local adaptation, full context awareness and reduced overhead. This approach is used to optimize all network performance by integrating functionalities between different protocols.

"A Survey of Mobility Models for Ad Hoc Network Research" [29]

In this paper, the authors have presented the detailed study about the different mobility models. It also includes the group mobility models. Different mobility models are used for analysis and performance is shown in different scenario and movement patterns. The mobility models where the movement of mobile node is dependent on the other mobility model is called entity mobility model. The mobility model where the movement of a mobile node is dependent on the movement of another mobile node is called group mobility model, i.e nodes move in groups.

The seven entity mobility models presented are Random Walk Mobility Model, Random Waypoint Mobility Model, Random Direction Mobility Model, A Boundless Simulation Area Mobility Model, Gauss-Markov Mobility Model, A Probabilistic Version of the Random Walk Mobility Model and City Section Mobility Model and the five group mobility models are Exponential Correlated Random Mobility Model, Column Mobility Model, Nomadic Community Mobility Model, Pursue Mobility Model and Reference Point Group Mobility Model. In this paper authors have tried to explain the importance of mobility models in simulation of mobile ad hoc networks. They have simulated the Random Direction, Random Walk, RPGM and Random waypoint mobility models. They have used DSR as routing protocol and packet delivery ratio, end-to-end delay as performance metrics. In the end they have given their major conclusions about entity and group mobility models.

"Impact of Node Mobility on MANET Routing Protocols Models" [31]

This paper describes the performance of mobile ad hoc routing protocols like Dynamic Source Routing (DSR-Reactive Protocol) and Destination-Sequenced Distance-Vector (DSDV-Proactive Protocol) while using different mobility models. The mobility models used for analysis are Random Waypoint, Group Mobility, Freeway Mobility model and Manhattan models.

The results show that the performance of routing protocols is greatly affected with the change of mobility model. Even if different parameters for simulation of mobility models the performance of routing protocols is affected. So it is necessary that one should use proper mobility model while using the different scenario. They have shown that DSR gives better performance for highly mobile networks than DSDV. Also DSR is faster in discovering new route to the destination when the old route is broken as it invokes route repair mechanism locally whereas in DSDV there is no route repair mechanism. In DSDV, if no route is found to the destination, the packets are dropped.

2.3 Limitations of Existing work

From the literature survey it is clear that some researcher have used mobility models to analyze different routing protocols in an ad hoc network. The Peer-to-Peer networks are mainly used in wireline network so no need of mobility models to use there, because node are fixed. When we deploy Peer to Peer network in mobile ad hoc network [32] it faces problem due to node mobility. It is difficult for peers to keep connectivity with other peers. It needs that a proper mobility pattern should be used which are commonly used in pure ad hoc network. Researcher has used only one mobility model in mobile Peer to Peer network, which did not cover the movement patterns of mobile nodes.

Deployment of a Peer to Peer network over an ad hoc network also faces the problem redundant message generation. This happens due to the lack of inter-layer communication. Both of these networks have different perspectives and they are designed for different environments so cooperation between these two networks is needed. Peer to Peer network is an overlay network and mobile ad hoc network depends on mobile nodes.

There must be a communication mechanism that can make cooperation between the protocols that are running in this network.

2.7 Summary

In this chapter we have given a description of related work. Peer to Peer network has been deployed on mobile ad hoc network in layered form which faces the problem of redundant message generation. Mobility of nodes is another issue in mobile ad hoc networks; there must be a proper mobility model for the movement of mobile nodes.

Different researchers have presented different mobility models with different characteristics and tried to include more realism in their mobility models to find out more accurate results. The choice of mobility models and performance parameters also affects the overall results of simulations. At the end we have given the limitations of some of the existing Peer to Peer architecture which use only one mobility model.

Chapter 3

Requirement Analysis

3.1 Problem Domain

A Peer to Peer network over Mobile Ad hoc network [2] is a latest research trend in research communities and is a hot research area from last five years. There are number issues relating to this research field like security, malicious peer detection, peer authentication, routing protocols development, mobility management, self organization, which are very common fields of current research. As peer to peer network over ad hoc network is a combination of two different networks, this combination creates a complex and complicated network [35] which introduces new challenges and problem for research communities. Peer to Peer network over ad hoc network faces problem of routing overhead due to lack of interlayer communication. Peer to Peer network is designed for pure wired network and it performs very well when it is deployed on a wired network, and when it is deployed on Mobile ad hoc network it faces problem for connectivity due to mobility. In the area of high mobility it is quite difficult for peers to keep connectivity with other peers.

Mobility is challenging because it has many impacts on network performance [36]. Due to high mobility network topology constantly changes at every moment. This topological change and its management is a key research area in Mobile Ad hoc network. The topological changes and movement patterns are represented by mobility models which are considered a key component in the simulation of Peer to Peer network over mobile ad hoc networks.

3.2 Problem Statement

Peer to Peer networks are developed for fixed networks and these networks perform very well in wireline networks. Due to enhancements in technology and increasing demands of users it is necessary to deploy Peer to Peer network in the ad hoc environment. Mobile ad hoc network do not behave like wired networks as they face the problem of link breakage, change in network topology, network partition and mobility of nodes [37]. Nodes can be removed from network at any time as well as new node can join the network frequently. These non probabilistic conditions make it difficult to design Peer to Peer network over

Mobile ad hoc network. As mobility is a challenging issue for Mobile ad hoc network, there is a need for a mechanism that truly represents the actual world scenarios and to provide all the necessary components for simulations. Mobility models provide the necessary components for the simulations that are why a number of mobility models have been presented by the researchers. These mobility models try to present an environment that truly represents some of the components of real world.

Further-more, only one mobility model that is Random way point has been considered for evaluation of Peer to Peer network over Mobile Ad hoc Network until now. It is therefore necessary that other mobility models should also be evaluated for this complex and complicated network.

3.3 Proposed Solution

Our proposed solution consists of two phases:

Phase 1: To identify all the necessary entities and their characteristics for the development of Peer to Peer network application over Mobile ad hoc network.

Phase 2: Using cross layer model, optimization of Peer to Peer network over Mobile ad hoc network.

Phase 3: Analyze the performance of different Mobility models in Peer to Peer over mobile ad hoc network

Phase 1

In this phase we have first identified the necessary entities and their characteristics for the development of a Peer to Peer network application over mobile ad hoc network. On the basis of these entities and their characteristics we have developed a simple Peer to Peer network application over an Ad hoc routing protocol so that Peer to Peer application can work as an overlay application running on application. This framework will be used to analyze the performance of different mobility models and we can compare these results with existing mobility model. This will provide the base for the researchers to develop a new mobility model.

Phase 2

In this phase we identify the problems and constraints that are faced in the deployment of Peer to Peer network over Mobile Ad hoc network. The performance of this layered architecture is also influenced due to redundant message passing by both the network. So a cross layer approach is adopted to optimize the performance of the whole network. In this model the destination node is searched, and route is established to that node at same time with the collaboration of application and network layer. This cross layer model will increase the performance of whole network as routing overhead is decreased.

Phase 3

In phase 3 of project we have analyzed the performance of Peer to Peer network over ad hoc network using different mobility models of ad hoc network and presented our conclusions and findings. In this phase we have used the existing random waypoint mobility model, and some other mobility models like Freeway mobility model, Boundless Simulation Area mobility model and Probabilistic Random Walk mobility model. A number of experiments, each with several tests, have been conducted for this purpose. The main purpose of this phase is to find out the effect of different mobility patterns and other mobility model parameters e.g. node density, acceleration deceleration etc. on the performance of routing protocols.

3.4 Contribution

The main contributions of this proposal can be summarized as follows.

- A detail of important components for the development of Peer to Peer network over Mobile Ad hoc Network.
- The performance of ad hoc routing protocol under a peer to peer network application, problems faced during this complex network functioning. This model shows the micro and macro characteristics of these entities.

- A cross layer model is proposed for the betterment of inter layer communication. Routing overhead that is produced during the legacy deployment of Peer to Peer overlay network over ad hoc network is reduced.
- Different metrics are used to analyze the influence of different mobility models on performance of Peer to Peer over Mobile ad hoc network.
- Results of simulations with different mobility models with some realistic parameters for P2P over an Ad hoc network.

3.5 Summary

A detailed study about the problem domain is described above. The problem statement and proposed solution is also presented in this chapter. Peer to Peer network over Mobile Ad hoc network research is a common and very hot research area these days. As deployment of Peer to Peer network is not designed for Mobile Ad hoc network so it faces different problems, and some of these problems have been addressed in this research thesis. Mobility is a key issue in Mobile Ad hoc network research and there are a large no of mobility models in literature that are being evaluated for different mobility patterns. Our proposed solution will be to identify the necessary components for development of Peer to Peer network application over mobile ad hoc network, and analysis of different mobility models. Only Random Waypoint mobility model is considered for evaluation for this type of network.

Chapter 4

System Design

4.1 Introduction

Peer to Peer networks are designed for wireline networks while the wireline system are different from the wireless system, because a wireless system has limited frequencies and reduced number of channels are available for data transmission. Designing wireless network architecture involve the identification of different process and modules of the system and allotting them roles and responsibilities respectively. Deployment of Peer to Peer networks over Mobile ad hoc network in layered manner is quite simple and peer to peer application work as an overlay network on ad hoc. Gnutella protocols [10] is used in this overlay network which is most flexible and decentralized protocol. This protocol is totally self configuring and dynamic in nature. There are number of factors that affect the performance of this complex type of network, which is formed by the combination of these two networks. Mobility of nodes is key factor which affects the node connectivity in high mobility areas.

Mobility models are used for simulation of routing protocols because the real world tests are too expensive, difficult to deploy and also time consuming. If we want to use the mobility model in simulation then it should represent the real movement of nodes in the respected environment. The main focus of the mobility models are on the movement patterns of the nodes which is accomplished by the introduction of road maps in the mobility models. For realistic design of mobility model, a number of meaningful parameters that do exist in the real world must be included in the architecture of the mobility models. So it is very important to use a mobility model that has most of the required components of the real world scenarios. But mostly used mobility model for Peer to Peer over ad hoc network is random way mobility model. There is a need that other mobility model should also be used and tested for this type of complex network.

4.2 Design Requirements

From an architectural perspective Peer to Peer network over mobile ad hoc network, the identification of most of the important components for the development of a framework is very important. We have identified most of the important components for the development of Peer to Peer network over mobile ad hoc network and mobility model.

4.2.1 Peer-to-Peer Networks, Ad hoc network and mobility models entities and their characteristics

Following are the main entities along with their micro and macro characteristics.

4.2.1.1 Peer to Peer Gnutella Protocol

A Peer to Peer application is implemented in NS2 using Gnutella protocol to fulfill the described requirements. Peer to Peer architecture is a decentralized architecture which uses the servents that perform the tasks in the network. Gnutella is a decentralized and self configuring protocol that is used for file sharing. This protocol can adopt any change in the network dynamically which is the most important characteristics. There are different types of messages that are transmitted in the network as defined as below.

Message Type	Operation	Size of message (bits)
Broadcast Send	Look of Neighbor nodes	23
Broadcast Reply	Answer for Broadcast send	38
Ping	Check the peer activity	23
Pong	Answer a Ping	38
Query send	Search for a File	26
Query Forward	Retransmit a query originated from other peer	26
Query Reply	Answer a query	26
Push Request	Require the transfer of a file	51
Pull Request	Transmit data	210

Table 4.1: Messages Transmitted in Peer to Peer Network

4.2.1.2 Roads

Road is the main entity for the development of mobility traces or maps for any mobility model used for MANET. Roads provide a specific path for the movement of the vehicles and remove the randomness in MANETs which exists in mobile ad hoc networks. Some of the characteristics of Roads and how they affect the mobility are as follows.

4.2.1.3 Number of Lanes

The roads may have single lane or multiple lanes as in figure.8. In single lane roads there is usually one lane for one direction of traffic. It means that only one lane is available for the vehicles to move in a direction. The single lane roads also affect the driver's behavior because if the driver wants to vary his speed or wants to overtake a vehicle he will consider the vehicles that are coming in the opposite direction. On the other hand in multiple lanes roads there are multiple paths for vehicles to move on as in fig. These vehicles have more freedom to change their lanes and vary their speed accordingly compared to the single lane roads. Also there an ease for the drivers to overtake the vehicles because there is no vehicles coming from the opposite direction only the driver has to consider the vehicle in front and the vehicles in lane he wants to join. These lanes have usually assigned certain speed limits so if a driver want to change a lane then he must change his speed according to the lane he want to move.

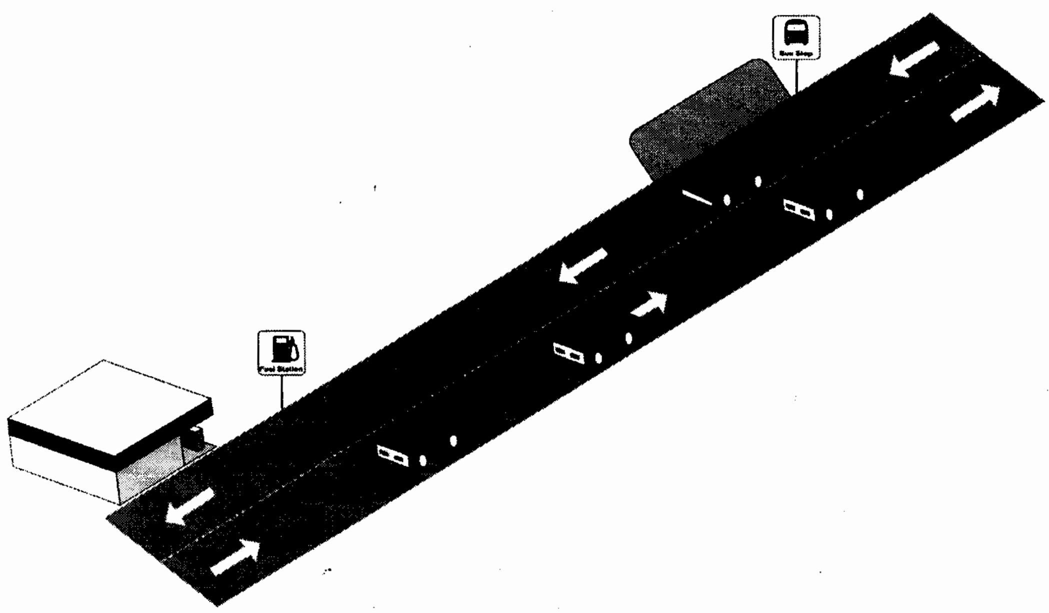

Figure 4.1: Single LANE Road

4.2.1.4Number of Streets and Intersections

Multiple streets and intersections roads are represented in Manhattan mobility model [4].The number of streets and intersections in a road also affects the speed of vehicles and also the behavior of the drivers because in case of multiple streets. The drivers can choose the alternate route or shortest route or he can avoid the congested streets. The intersections are the junctions of two roads where they cross each other. In real world situations, at intersections the drivers slow their speed because they can neither cross the road nor they can take a turn with the speed they are moving to the cross points e.g. if they are moving with a speed of 80 km/hr then they will reduce their speed to 20 to 30 km/hr. At intersection the vehicle density also increases so the vehicle speed reduces and the performance also greatly affects. This speed reduction causes deceleration which is not considered in most of the existing mobility models rather in these models vehicles moves with the pre given speed even at the cross points. Also, on reaching at cross points certain vehicles will move to their desired directions so certain probability must be assigned to these vehicles as given in Manhattan mobility model.

4.2.1.5 Traffic Sign and Traffic Lights

The Traffic signs and lights on road sides, referred to as Traffic Control Mechanism by some researchers; provide help and instructions to drivers for safe driving. These traffic signs include signs for speed limits, fuel stations, bus stops, bridges ahead signs, sharp turn signs etc. These signs restrict the drivers and the driver acts according to the instruction on the signs i.e. the driver may reduce his speed or stop at a fuel station or on a eating spot on the road side. The traffic signs, at the cross points or somewhere else on the road, has an impact on vehicle mobility because on these traffic lights the drivers will reduce their speed or stop for certain time interval. Also these signs cause traffic jams, increasing the number of vehicles and ultimately increasing the contention for channel so performance will affect. On the basis of these characteristics Stop Sign Model (SSM) and Traffic Sign Models (TSM) have been developed [6].

4.3 A simple architecture of Peer-to-Peer Network over Mobile Ad hoc network

A Peer to Peer application is built on the top of mobile ad hoc network. In this application Gnutella protocol is used as a peer to peer overlay protocol. Gnutella client can be used to locate the certain file that has been shared by some other node and can be downloaded by Gnutella client. The structure of this protocol is very simple and uses simple broadcast to locate file. The applications mostly using Gnutella are Limewire, Bearshare. The network layer protocol is AODV (Ad hoc Ondemand Distance Vector) which is reactive routing protocols. It uses RREQ messages to find destination node. The RERR message is used to indicate that a loss of link has been occurred. RREP message is used to reply the source node from the destination node. The following is simple view of Peer to Peer network application over Ad hoc network.

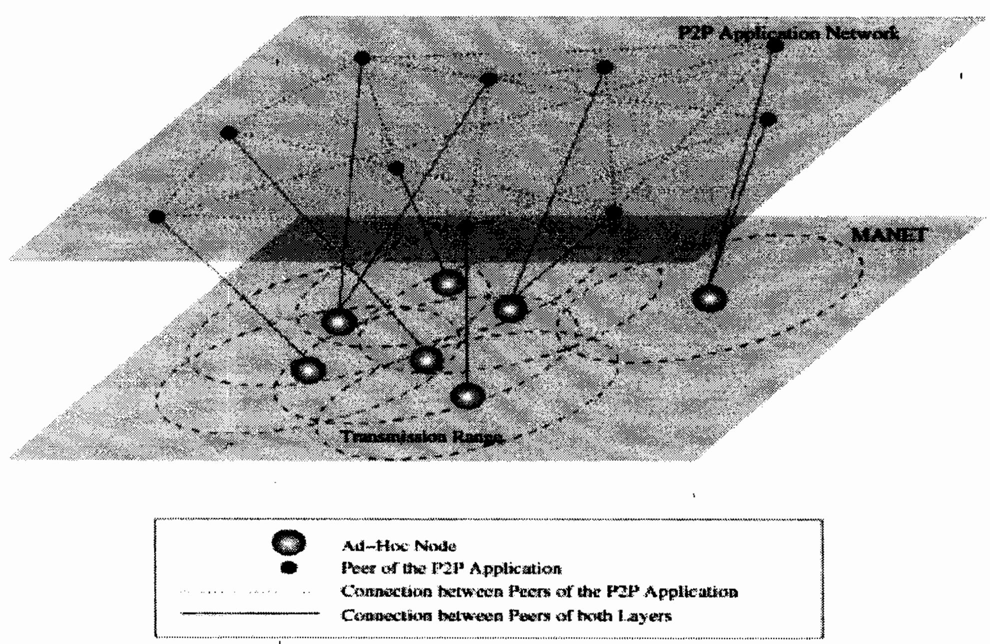

Figure 4.2: Peer-to-Peer network over Mobile Ad hoc network

In the above framework the mobile ad hoc nodes have different directions and velocities and they connect with each other using a multi hop ad hoc connection. The topology of network is dynamic so these nodes have terminal mobility. The overlay network is created above the IP layer and nodes in this network mostly called servents.

4.4 Overview of cross-layer Peer-to-Peer over Ad hoc Network

When we deploy Peer to Peer network application on a mobile ad hoc net work routing protocol it faces the problem of routing over head due to redundant message passing by both of these network. So, to overcome these problems created by this complex and complicated network a cross layer approach is adopted. The basic model of this is shown in the following figure.

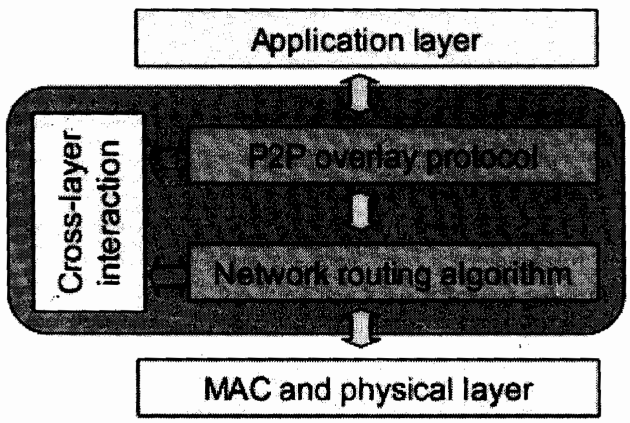

Figure 4.3: Overview of a Cross Layer Model

In the above figure an overview of a cross layer model is shown. Peer to Peer routing protocol has been deployed on ad hoc routing protocol. In this cross layer model the information exchange is done by creating new interfaces between layers, so these layers can take benefit from each other. The information flow between these layers is in both directions. In strict layer approach, the components of system are totally independent from each other, and perform their functionalities independently and interact with each other using specific interfaces.

4.5 Architecture of Cross-Layer Mobile Peer to Peer Network

The Peer to Peer over Ad hoc network architecture created by using cross layer approach consists of an overlay peer to peer protocol and an ad hoc network routing protocol. Peer to Peer protocol is an overly protocol that operates at application layer, while Ad hoc protocol is used for routing on network layer. As both these protocols are from different networks and operate on different layers and there is no cooperation between these two protocols, some mechanism is needed that is used to share data directly between these protocols. For this purpose, a cross layer mechanism is used that informs the routing agent of ad hoc protocol about the overlay information. Ad hoc network mostly have ability to form a communication infrastructure on the network layer, it uses the pro-active method to find nodes in the network in case of DSR, and uses re-active algorithm to find nodes and links in case of AODV.

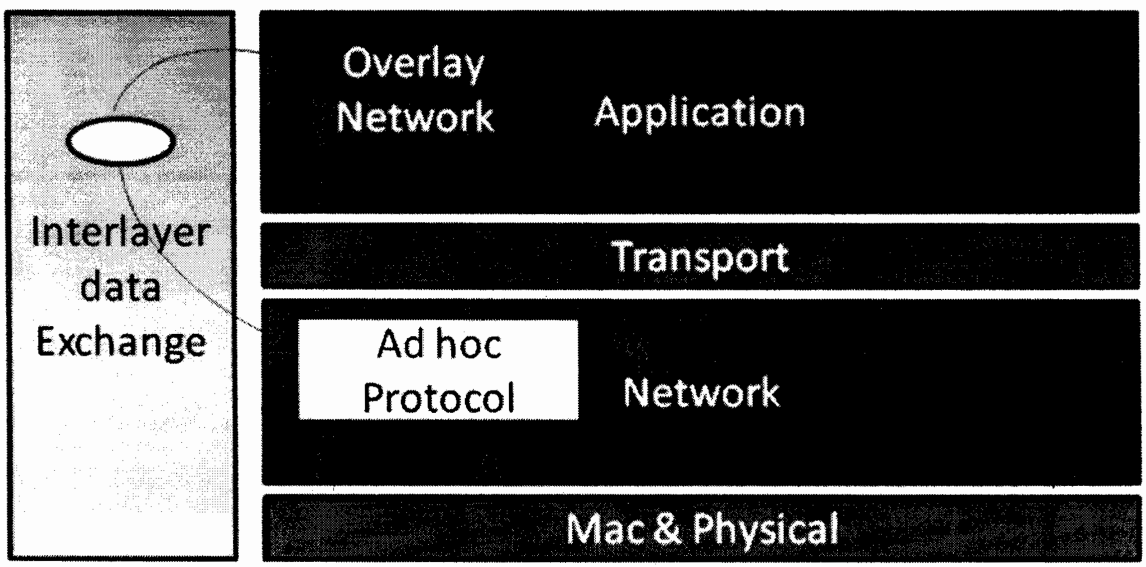

Figure 4.4: Cross-Layer Architecture for Peer-to-Peer over Ad hoc Network

As shown in above figure, an overlay protocol operates on application layer and an ad hoc routing protocol on the network layer. A new cross layer interface is created that is used to share data between these two protocols. This cross layer interface is used in a way such that all the layers perform independently, such that new data is generated but existing information is shared between protocols. A cross layer interface is indirection to represent the actual functioning of the protocols; it works with data and events that are generated during different network condition.

4.6 Description of the Framework

Peer to Peer network over mobile ad hoc network using cross layer design has different strategy from the layered approach. In this we improve the performance of Gnutella protocol, which is an unstructured overlay framework for peer to peer systems. When we use gnutella in ad hoc environment it faces the problem of peer discovery as a main issue. As this discovery mechanism based on application layer flooding which increases the overhead and in high mobility area Gnutella does not react properly. It is desired to re-design the peer discovery and link selection procedure so that this can interact with routing agent at network layer. The following figure shows the complete design of cross layer framework.

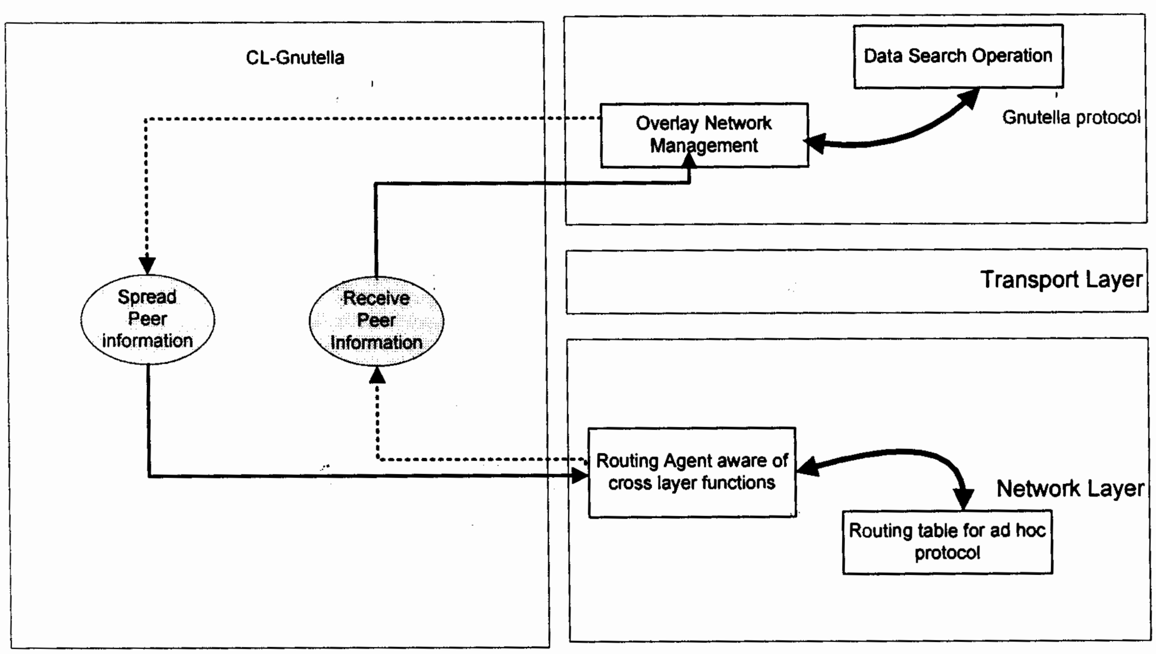

Figure 4.5: Cross layer Operation

In the above figure it is shown that we introduce two new classes that will be used for cross layer data exchange. In this model we use publish and subscribe scheme to exchange peer information between two different protocols. Routing messages like Hello and peer discovery are sent to neighbor nodes. We use a call back function to get the cross layer data from the protocol. A call-back is a function that is stored in the library and can be fired at a later time. This cross layer interface does not generate its own information it just works as intermediary between two protocols.

This cross layer interface is responsible for collecting the subscribe events from the Gnutella protocol and work with network layer protocol to get the information requested by the gnutella layer. These events are responsible for notifying Gnutella peer about the recent peer information from the other peers. Peers at the application layer connect with other peers for finding files and it also keeps connectivity with other peers. If the corresponding peer is not available then it sends peer request messages. Application layer protocol is also responsible for sending application layer subscribe messages to ensure its peers connectivity alive. There are different type of messages that are exchanged between two layers route request messages, route reply messages and hello messages.

As in the layered design approach of Peer to Peer network over Mobile Ad hoc network, there is a problem of routing overhead due to lack of inter layer communication. Both of these networks have different perspective so they operate on the different layers. So this redundant messages generation has been overcome by the use of cross layer design of mobile Peer to Peer network. This framework has been used for the evaluation of different mobility models of ad hoc networks.

4.7 Research Methodology

In this section we will describe the complete setup for the simulations. We conducted several experiments and several tests in each experiment. Two experiments were conducted for each mobility model, one for the effect of node density and the other for the effect of high or low mobility. In each experiment we will analyze the effect of packet delivery ratio, end to end delay, and routing overhead. So on the basis of these simulations we will present our conclusions about each mobility model and its effect. We have performed the simulation experiments in open source network simulator NS 2.29[12], Fedora Core 6 Operating System, Pentium 4 processor 2 GHz and 512 MB RAM. We have used Omni Directional antenna with 250m transmission range. UDP is used as transmission protocol with a packet size of 512 bytes. Table 2 shows the general parameters for the whole simulation.

Table 4.2: Simulation Parameters

Variables	**Values**
Simulation tool	NS2.29
Propagation model	Two Ray Ground
Antenna Type	Omni directional
Topology size	1200m x 1200m
Simulation time	300 sec
Mobility models	Freeway, Random way, Probabilistic Random, boundless Simulation Area
Transport protocol	UDP, TCP
Packet size	512 bytes
Traffic Type	CBR
Transmission Range	250 m

Table 4.3: Peer to Peer Network Setup

Variable	Values
No of Nodes	50
Grid Area	300m x 300m
Pause Time	0.1 m/s
No of Node Online	50% of Total Nodes
No of File Each Node	5
Total no of Files	250 for 50 nodes
TTL	4

4.7.1 Experimental Setup

The details of complete experimental setup are given as follows.

4.7.1.1 Experimental Setup for Freeway mobility model

Besides the above general parameters in table 4 and in table 5 each mobility model is tested with their specific parameters. We have conducted two experiments for Freeway mobility model one for the effect of high mobility on performance and the other is for the effect of high node density. Maps with multiple lanes are used for freeway model. The details of both of these experiments are given in the following tables 6 and table 7. In experiment 1 we have kept constant the node density to 50 and performed tests for each velocity input. In experiment 2 we have changed the node density on freeways and eight tests were conducted for different node inputs. The velocity is kept constant to 20m/s for all nodes and in all tests.

Table 4.4: Parameters for Experiment No. 1

Variables	**Values**
Experiment	Effect of Hit rate
Model	Freeway
Node variations	20, 30, 40, 50, 60, 70, 80, 90, 100, 110
Node Density	50 constant for all tests
Number of tests	10 tests. One test for each velocity with constant nodes.

Table 4.5: Parameters for Experiment No. 2

Variables	**Values**
Experiment	Effect of Speed
Model	Freeway
No of Nodes	50 for all tests
Speed variations	0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m/s.
Node Density	0.5 for all test
Number of tests	8 tests. One test for each node density with constant velocity.

4.7.1.2 Experimental Setup for Random Waypoint model

For Random Waypoint Mobility model we have conducted two experiments and several tests in each experiment. We have used different parameters for these experiments. Both for number of nodes variation and speed variation experiments were performed. Besides the general parameters for the whole simulations the following tables summarizes the parameters for the Random Waypoint Mobility model. In experiment 1 we have performed 5 tests in which we kept the velocity and node speed constant and varied the number of nodes for 10 to 110. Experiment 2 is conducted for the effect on node speed in we keep the no of nodes constant and we changes the node speed.

Table 4.6: Parameters for Experiment No. 3

Variables	**Values**
Experiment	Effect of changing nodes
Model	Random Waypoint mobility model
Average Velocity	20 m/s
No. of Nodes	20, 30, 40, 50, 60, 70, 80, 90, 100, 110
Acceleration	Constant
Number of tests	10 tests.

Table 4.7: Parameters for Experiment No. 4

Variables	**Values**
Experiment	Effect of node Speed
Model	Random Waypoint mobility model
Average Velocity	20 m/s
Node Speed	0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m/s.
Number of Nodes	50
Number of tests	10 tests.

4.7.1.3 Experimental Setup for Boundless Simulation Area model

For our Boundless Simulation are Mobility Model we have performed two experiments. One experiment is performed for node variation and the other for high node speed. The nodes moving on roads normally vary their speed and due to these variations in speed the variation in velocity is produced. In each experiment we have further performed 10 tests for each parameter of node variation and node speed. In node variation we have taken node speed constant at 2 m/s. The details are given in the following tables.

Table 4.8: Parameters for Experiment No. 5

Variables	**Values**
Experiment	Effect of node Variation
Model	Boundless Simulation Area Mobility Model
Average speed	2 m/s
Node variation	20, 30, 40, 50, 60, 70, 80, 90, 100, 110
No of Peer nodes	Half of total nodes
Number of tests	10 tests

Table 4.9: Parameters for Experiment No. 6

Variables	**Values**
Experiment	Effect of Speed Variation
Model	Boundless Simulation Area Mobility Model
Nodes	Fixed 50 nodes
Node Speed	0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m/s.
No of Peer	Half of total
Number of tests	10 tests.

4.7.1.4 Experimental Setup for Probabilistic Random Walk model

As clear form its name, in Probabilistic Random walk mobility model node uses some probability matrix to move in the next direction. In this model there are three positions of the nodes first one is the current position of the nodes, previous position of node and the next position of the node. The experimental details are given in the tables. The first experiment is performed for node variation. In certain area when the nodes are moving using this mobility model we shall see variation when numbers of nodes are varied. In the second experiment we shall vary the node speed to test the peer connectivity in the network.

Table 4.10: Parameters for Experiment No. 7

Variables	Values
Experiment	Effect of nodes Variation
Model	Probabilistic Random Walk mobility model
Average speed	2 m/s
Node variation	20, 30, 40, 50, 60, 70, 80, 90, 100, 110
Number of tests	10 tests.

Table 4.11: Parameters for Experiment No. 8

Variables	Values
Experiment	Effect of node speed
Model	Probabilistic Random Walk Mobility model
No of nodes	50
Node Speed	0.5, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 m/s.
Number of tests	10 tests.

4.8 Summary

In this chapter a detailed studies are presented about the required entities and their characteristics for the development of Peer to Peer network over an ad hoc network. We here also described the mobility model that we shall use to determine the performance of the network. Furthermore, we have presented a detailed study about the simulation and experimental setup for each mobility model.

Chapter 5

Implementation

5.1 Introduction

Wireless and mobile ad hoc networks are mostly used for disaster and military operations in the far away areas where no previous infrastructure. To realize a Peer-to-Peer application in such an environment needs a careful study for deployment. Peer-to-Peer application deployment on ad hoc network does not operate efficiently. Peer-to-Peer protocols need to collect information from under layer network which creates a routing overhead for the application layer protocol. To eliminate these problems a cross layer design approach has been adopted which increases the network performance by decreasing the routing overhead which is created by this complex and complicated network. As Peer-to-Peer network was designed for pure wireline network where the nodes are fixed and a predefined infrastructure is used to for routing queries through the network. But in the case of ad hoc network there is no fixed topology and nodes are moving most of the time, so it is difficult to keep connectivity between nodes. As mobility increases the connectivity of nodes becomes weak and weak so as mobility models are used in ad hoc network it also necessary that there must be a proper mobility model for specific movement. As wireless ad hoc networks experience high inconsistency in channel so real life test would be costly, time consuming compared to simulations but still they are crucial to be performed because they provides the actual factors that do affect the wireless channel. Real world tests, no doubt, represent the actual scenarios. Is it possible for a particular area to represent all the factors? e.g. high node density, speed restrictions. There are areas that may have all the factors but the researcher may wait for a proper time in which there will be maximum factors available for testing. The performance of Peer-to-Peer network over ad hoc network can be tested by using simulation tool. In simulation researchers can easily choose and find the effect of different parameters. Also the researcher can repeat simulations with different scenarios in a variety of ways and can present the results under repeatable tests. Due to these benefits the simulation has become a popular tool for Peer-to-Peer and ad hoc networks research. The Ns2 is popular network simulator which is event-based and is used for research in universities, research agencies and commercials companies. Other simulation tools for Peer-to-Peer network are P2PSIM [61], PEERSIM [60], and OMNET++ [59] etc. A number of models are available in Qualnet and also offers graphical tools to generate a number of scenarios. Another popular commercial simulation tool is OPNET [65] and Qualnet [64] which offer a variety of simulation analysis tools.

5.2 Implementation in Network simulator (Ns 2)

We have implemented and simulated the VANETs mobility models in NS 2.31 [12] simulator. As NS is open source, so it is widely used in network simulations. NS development began in 1989 as REAL network simulator. Ns development was supported by DARPA through VINT project at LBL, Xerox PARC, UCB and USC/ISI. NS is open source and a number of researchers have contributed in e.g. wireless code from UCB Deedless and CMU Monarch projects.

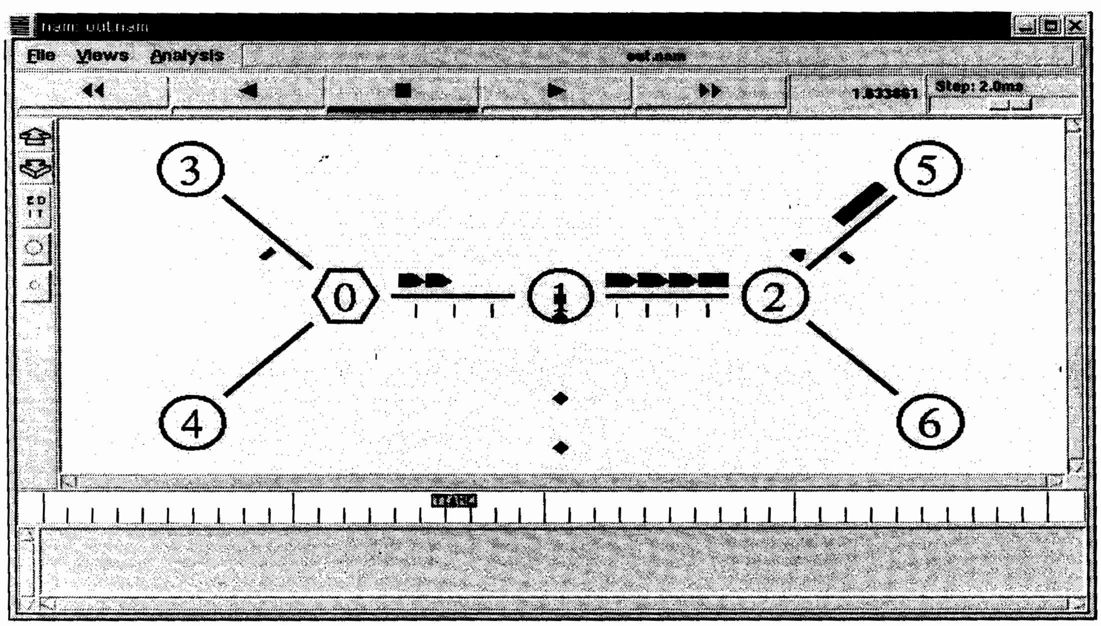

Figure 5.1: Network Simulator 2 An overview

NS is an object-oriented simulator, written in C++ and OTCL interpreter as front-end. NS uses C++ for detailed simulations of protocols requiring efficient manipulating bytes, packet headers, and implanting algorithms that run over large data sets. Because of performing these tasks the run time speed is important and turn-around time is less important that is provided by C++. OTCL is used for varying parameters or configurations, or quickly exploring the number of scenarios [62].

Currently in NS-2 following ad hoc routing protocols are built in for wireless mobile nodes.

Destination Sequence Distance Vector (DSDV)

Dynamic Source Routing (DSR)

Temporally Ordered Routing Algorithm (TORA)

Ad hoc On demand Distance Vector (AODV)

NS can be used on UNIX, Linux, and Windows platforms. However, using Windows as platform, Cygwin emulator is required for NS.

5.3 ProtoLib

ProtoLib [76] stands for Protean Protocol Prototyping Library; it is a simulation extension toolkit for NS2 form Naval Research Laboratory (NRL). It is very flexible and provides a number of methods to develop a cross layer platform. It provides a C++ class that allows simply developing network protocols and applications. The Protolib supports different real time environment. NS2 simulation is also supported by this platform. ProtoLib helps in developing protocol implementation, network applications and simulation models.

5.4 Implementation of Project

Peer-to-Peer over Ad hoc network implementation includes the a Peer-to-Peer application that will be deployed over Ad hoc network and mobility models will be used to evaluate the performance of these mobility models. Due to problems of Ad hoc network like link breakages, changes in topology and network partition it is quite difficult to design the P2P system over ad hoc network. Peer-to-Peer over ad hoc network picture that represent the actual design of this network is shown below.

The following figure shows the implementations details of our project in NS 2.

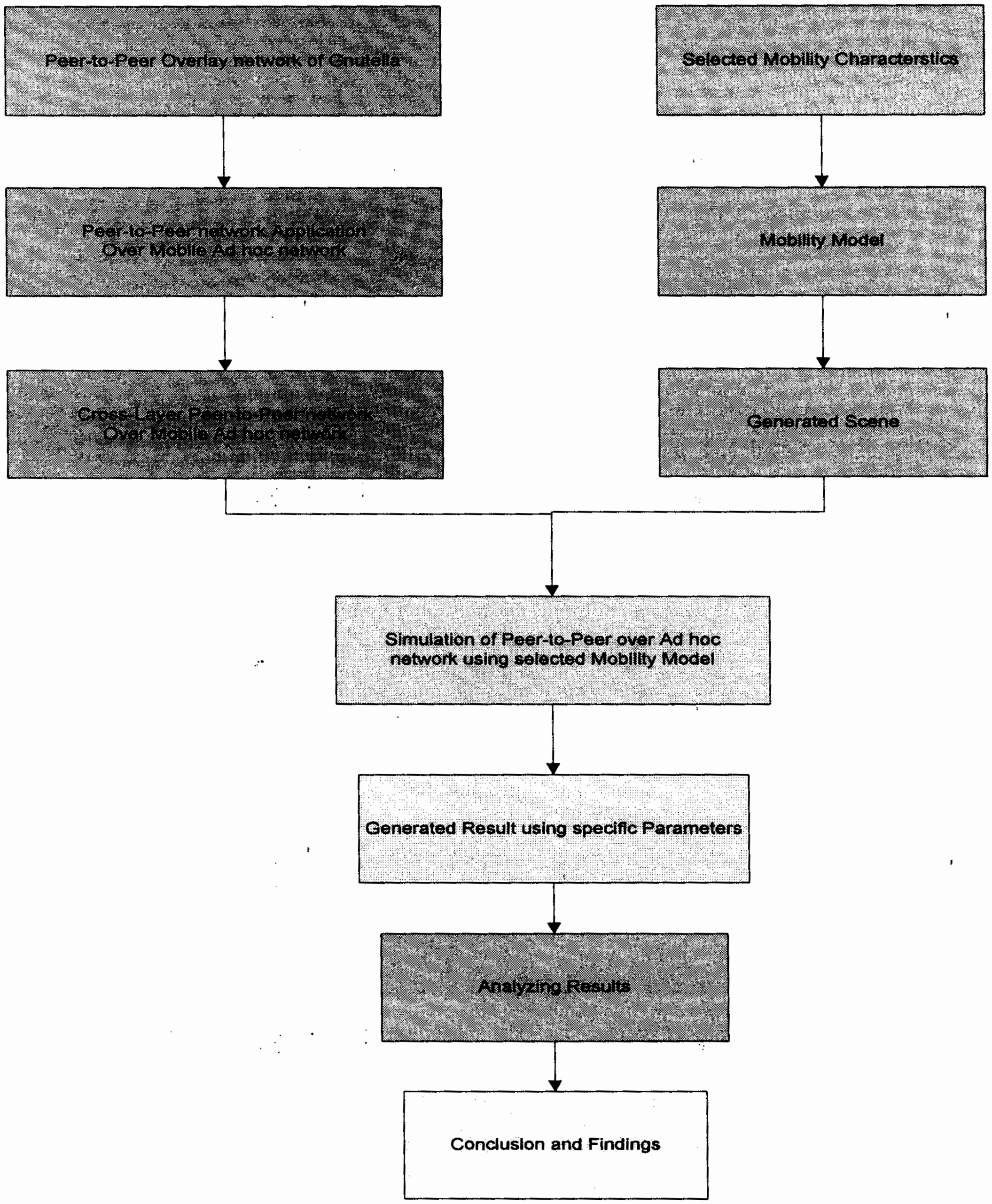

Figure 5.2: Implementation of mobility model in Peer-to-Peer over Ad hoc network

Figure 5.2 shows the implementation details. After generating the mobility model from the chosen mobility characteristics, we then generate the scene from the mobility model. Peer-to-Peer network Gnutella network application is built and after that it is deployed on an ad hoc network where the AODV routing protocol is used. Next step is to apply cross layer optimization on this network. Now we have cross layer Peer-to-Peer network over and ad hoc network. Now the generated scene and the chosen mobility model are passed to the tcl file for analysis. The tcl file is run and it generates the results which can be noted to some file. After getting these results we plot these result in an excel file. On the basis of these results we generated the graphs. These resulting graphs are analyzed and the conclusions and findings are presented.

5.5 Structure of tcl file

After generating the scene file and CBR (Constant Bit Rate) they are passed to the Tcl file which is then run and the trace and nam files are generated. The parameter of our tcl file is as follows.

```
set opt(start)            0.1                        ;# Start the peers
set opt(seed)             123                        ;# Seed for random numbers
set opt(ifqlen)           30                         ;# Max packet in ifq
set opt(energymodel)      EnergyModel                ;# Enabled
set opt(initialenergy)    1000                       ;# Initial energy in Joules
set opt(rx)               0.204                      ;# Reception energy
set opt(tx)               0.280                      ;# Transmission energy
set opt(x)                850                        ;# SOH FACHADA, O SETDEST EH
set opt(y)                850                        ;# QUEM DETERMINA
set opt(threshold)        7.69113e-08                ;# Threshold - range: 50m
set opt(stop)             500.0                      ;# Stop the peers
set opt(chan)             Channel/WirelessChannel
set opt(prop)             Propagation/TwoRayGround
set opt(netif)            Phy/WirelessPhy
set opt(mac)              Mac/802_11
set opt(ll)               LL
set opt(ant)              Antenna/OmniAntenna
set opt(rp)               AODV
```

Line 1 shows the number peer in the network; energy model and initial energy are shown in line 3 and 4. Transmission rate is shown in line 7 and 6 for reception and Line 12 and 13 shows that the channel used is wireless channel and propagation method is two ray ground. Line 15 and 16 show Mac layer protocol and the queue used. We have used the Omni Antenna. For the simulation we set a simulation boundary in which the vehicles will move so we have to specify the x and y parameters. Line 18 shows the type of protocol used in simulation. The node movement models, showing the nodes which will transmit packets and nodes which will be as intermediate nodes, the packet size and transition rate, is passed in line 3.

Gnutella Protocol Operation

Gnutella is a protocol from the category of unstructured overlay networks. Peers in the Gnutella protocols are named as servents as they work as server and clients. These servents open and mange application layer connection among other servents and peer discovery messages, link control and data lookup are sent using overlay network. There is a TTL field to control the congestion in the network. There is a handshaking procedure when the peers are going to send data or new peer is going to enter in the network. A peer mostly has two or three open connections and waits for other peers to connect.

```
# Dynamic Agent/Gnutella options
set opt(sim)            [lindex $argv 0]        ;# Simulation number
set opt(nn)             [lindex $argv 1]        ;# Number of nodes
set opt(sc)             [lindex $argv 2]        ;# Scenario (speed and
direction)
set opt(workload)       [lindex $argv 3]        ;# Workload (multiplied
by np = maxfiles)
set opt(error)                  [lindex $argv 4] ;# Channel error rate
(packets)
set opt(static)                  [lindex $argv 5];# Channel error rate
(packets)

set opt(np)                     $opt(nn) ;#[expr round($opt(nn) * 0.7)]
```

```
#set opt(initnn)                    [expr $opt(np)/2]
;# Number of nodes at start (50% of the total)
set opt(initnn)                    [expr round($opt(nn) * $opt(static))]
```

The topography object is created and then loaded by the following commands. The values passed to x and y is set here and new topology is created.

```
set topo        [new Topography]
$topo      load_flatgrid $val(x) $val(y)
```

Setting when events can start to be fired.

```
set opt(startevents)   5.0
set opt(stopevents)    [expr $opt(stop) - 5]

Agent/Gnutella set agent_port_          $opt(port)
Agent/Gnutella set pkt_size_            $opt(pktSize)
Agent/Gnutella set ping_timeout_         $opt(pingTimeout)
Agent/Gnutella set neighbors_timeout_    $opt(neighborsTimeout)

LL set mindelay_              50us
LL set delay_                 25us
LL set bandwidth_             0        ;# not used
LL set off_prune_             0        ;# not used
LL set off_CtrMcast_          0        ;# not used
```

The specified number of p2p nodes is created by the following command

```
for {set i 0} {$i < $opt(nn) } {incr i} {
    set node_($i) [$ns_ node]
    $god_ new_node $node_($i)
    $node_($i) random-motion 0 ; # disable random motion
    Agent/Gnutella set agent_addr_ [$node_($i) node-addr]
    set peer_($i) [new Agent/Gnutella]
    $ns_ attach-agent $node_($i) $peer_($i)
```

}

As we have passed 50 to nn so it will create 50 nodes and will off the random movement of nodes.

The following code shows that when the simulation end and it will generate the trace file.

```
# Trace e nam files
set traceFile    [open "ali.tr" w]
$ns_ trace-all $traceFile
$ns_ use-newtrace

$topo load_flatgrid $opt(x) $opt(y)}

$ns_ at  $val(stop).0002 "puts \"NS EXITING...\" ; $ns_ halt"

puts $tracefd "M 0.0 nn $val(nn) x $val(x) y $val(y) rp $val(adhocRouting)"
puts $tracefd "M 0.0 sc $val(scne) cp $val(cp) seed $val(seed)"
puts $tracefd "M 0.0 prop $val(prop) ant $val(ant)"
```

Follwing code shows the number of scheduling actions the will be take palce during simulation run.

```
source $opt(sc)
puts "MAX $opt(maxfiles)"
for {set i 0} {$i < $opt(maxfiles)} {incr i} {
   for {set j 0} {$j < $opt(nn)} {incr j} {
      set r3 [$rng uniform 0 1.0]
         if {$r3 < [$r1 value]} {
            puts "NODE $j OWNS FILE $i"
            $ns_ at 0.01 "$peer_($j) file $i"
         }

         set r4 [$rng uniform 0 1.0]
         if {$r4 < [$r1 value]} {
                  set query_schedule_ [$rng uniform $opt(startevents) $opt(stopevents)]
```

```
            puts "NODE $j WILL SEND A QUERY FOR FILE $i AT TIME $query_schedule_"
            $ns_ at $query_schedule_ "$peer_($j) search $i"
        }
    }
}

for {set i 0} {$i < $opt(initnn) } {incr i} {
    $ns_ at $opt(start)  "$peer_($i) set-online"
}
for {set i 0} {$i < $opt(initnn) } {incr i} {
    set stime [expr $opt(start) + [$startV value]]
    $ns_ at $stime        "$peer_($i) join"
    $ns_ at $stime        "$node_($i) start"
}
for {set i $opt(initnn)} {$i < $opt(nn) } {incr i} {
    set stime2 [$startV2 value]
    $ns_ at $stime2       "$peer_($i) set-online"
    $ns_ at $stime2       "$peer_($i) join"
    $ns_ at $stime2       "$node_($i) start"
}
for {set i 0} {$i < $opt(nn) } {incr i} {
    #$ns_ at $opt(stop)  "$peer_($i) leave"
    $ns_ at $opt(stop)  "$node_($i) reset"
}
```

Finish simulation

```
# Finishes the simulation
$ns_ at $opt(stop) "finish"
```

```
$ns_ at $opt(stop).01 "puts \"NS EXITING...\" ; $ns_ halt"

# finisher procedure
  proc finish {} {
     global ns_ traceFile
     $ns_ flush-trace
     close $traceFile
     exit 0
}

# Run ns
puts "Starting Simulation..."
$ns_ run
```

5.6 Summary

In this chapter the details of the implementation of our project are given. For implementation purpose a number of implementation tools are used. But we choose an open source discrete event Network Simulator NS2 and ProtoLib. A Peer-to-Peer application is built in NS-2 as an overlay network, and routing protocol is chosen from ad hoc network is Ad hoc Ondemand Discrete Vector routing (AODV). After developing Peer-to-Peer applications for mobile ad hoc network then the mobility models are used for analysis. Cross layer optimization is applied on this network to increase performance and resulting framework is also analyzed for given mobility models. These results have been compared and it is shown that performance of whole network is increased. As in the previous research only one mobility model is used for movement pattern, a proper mobility should be used for the specific environment.

Chapter 6

Performance Evaluation

6.1 Introduction

In this chapter we analyzed the effect of different Ad hoc network mobility models on a Peer-to-Peer network application on mobile ad hoc network routing protocol. After creating a proper research and experimental design we have implemented different popular mobility models. In addition, we have simulated this work in ns2 and result obtained from this framework has also been analyzed. The performance of routing a protocol varies with different mobility models because each mobility model provides its own characteristics behavior and movement pattern. Peer-to-Peer over ad hoc networks is an emerging technology which has got much intention from research communities. So the routing decisions can be taken in this new type of network with evaluation of mobility models. The performance of routing protocols has a measure of movement pattern in which nodes move. But the performance also depends upon some other factors as well e.g. the simulation time, performance metrics, etc.

6.2 Performance metrics

We can evaluate both protocol used in Mobile Peer-to-Peer network like Gnutella and AODV. We use the following performance metrics to evaluate the Peer-to-Peer over Ad hoc network.

1. Hit Rate
2. Response Time
3. Peer Node Mobility

The results of the simulations not only depend upon the chosen mobility model but also upon the performance metrics chosen for simulations. In order to analyze the effect of mobility models we have chosen three performance metrics, namely Packet Delivery Ratio (PDR), Average End to End delay and Routing Overhead for both node density and velocity variations.

Network Load

It shows the workload of Peer-to-Peer application in the network. If network load is increased then it may cause increase in latency, packet dropping control overhead. The latency of a network is amount of time needed for a particular event to happen like query-hit. Overhead of a network can be measured in the from of number of packets exchanged in the network.

Peer Node Mobility

It can be described as the speed and pause time that is applied to the network. In this experiment we have changed the speed by using values like 1, 2, 3 and up to 9 meter per second. The time taken by a packet to reach its destination including route acquisition time is calculated.

Network Size

We can change the network size by changing the number of nodes in the network and the area used for simulation. The number of queries in the network is fixed and node density is also kept fixed.

Routing Overhead

It is defined as the number of routing packets transmitted per data packet delivered to the destination. In this network routing overhead has been tried to decrease by using an optimization method.

6.3 Simulation Results

The simulation results of the mobility models in a Peer-to-Peer over ad hco netwrok have been shown below.

6.3.1 Peer-to-Peer Network over Mobile Ad hoc Network

Hit Rate

Figure 6.1 shows the hit rate of MANET routing protocol under a Peer-to-Peer network application. As we see from the figure, each mobility model performs differently in same scenario and mobility characteristics. Freeway mobility model has more variation as it is has been designed for vehicular network and node speed is almost higher than the other mobility model. Hit rate of probabilistic mobility model is higher than other mobility models. It has almost smooth curve compared to other mobility models.

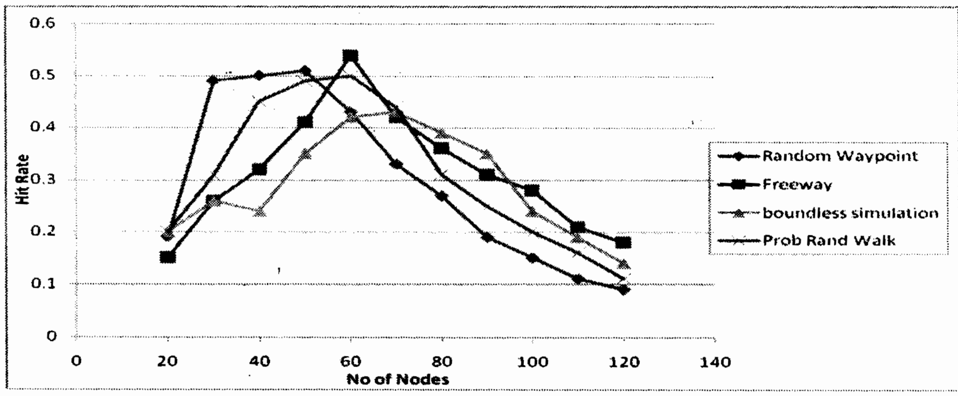

Figure 6.1: Hit Rate with increasing number of Nodes

In figure 6.2 the number of nodes is kept fixed in the network and the node speed is varied from 0 to a maximum value of 10. Hence boundless simulation area performed some better than the other mobility models. Random waypoint mobility model has not shown good performance at all.

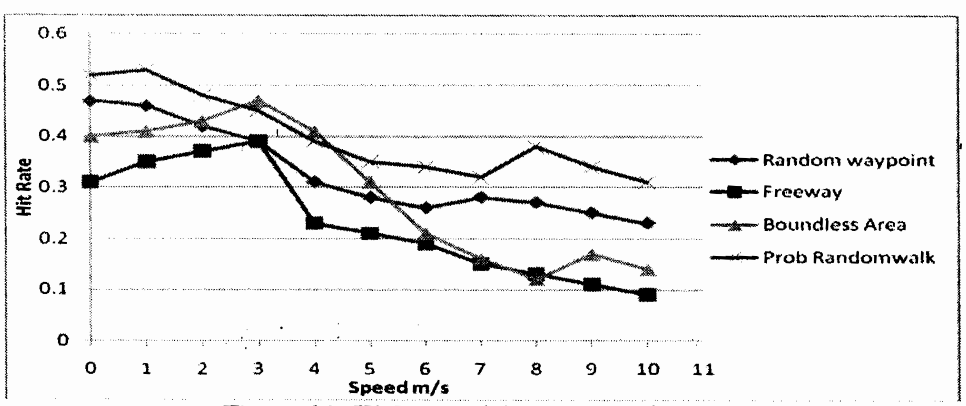

Figure 6.2: Hit Rate with increasing node Speed

No of Messages sent

In the Figure 6.3 it shows the total number of messages sent in a Peer-to-Peer network over mobile ad hoc network. As the number of nodes increased the no of messages sent were also increased but at a certain time nodes are more than the half of the network than number of messages going to decrease, and this happen almost same for the entire mobility model. In Random Waypoint Mobility model curve shows that no of messages sent decreased at a certain time.

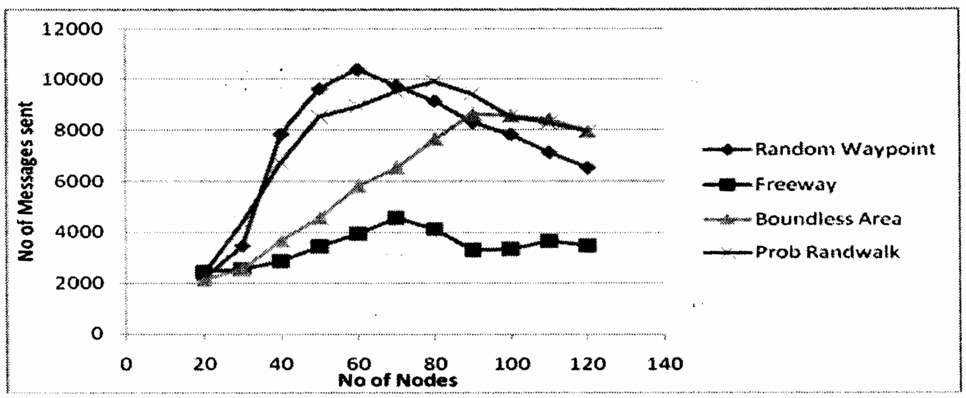

Figure 6.3: No of Messages sent in network verses No of nodes

In figure 6.4 it is represented that when we vary the node speed then the number messages sent in the network while number of nodes are same. Freeway Mobility model shows better values than its previous results. Probabilistic Random walk has highest no of messages sent in the network.

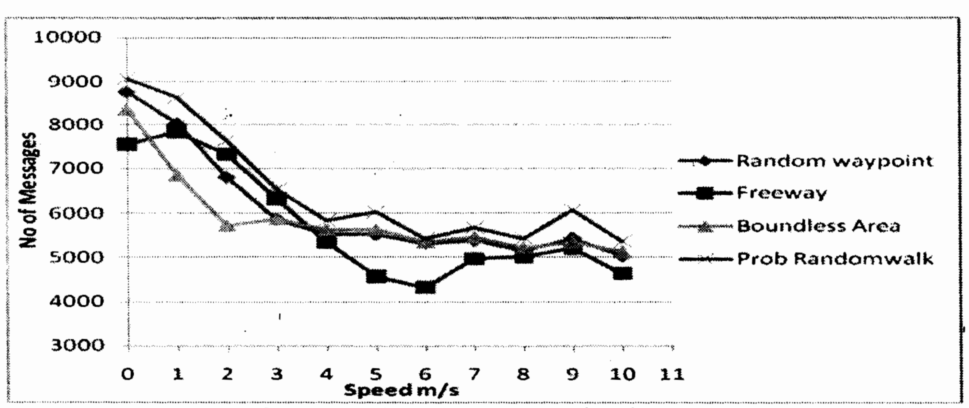

Figure 6.4: No of Message and node speed

Response Time

Figure 6.5 shows that the average end to end delay, or response time, of AODV under a Peer-to-Peer network is initially high but with increase in speed the average delay decreases. The Freeway and Boundless are mobility models face the problem of high node density so the response time for these two is varying as rapidly as others.

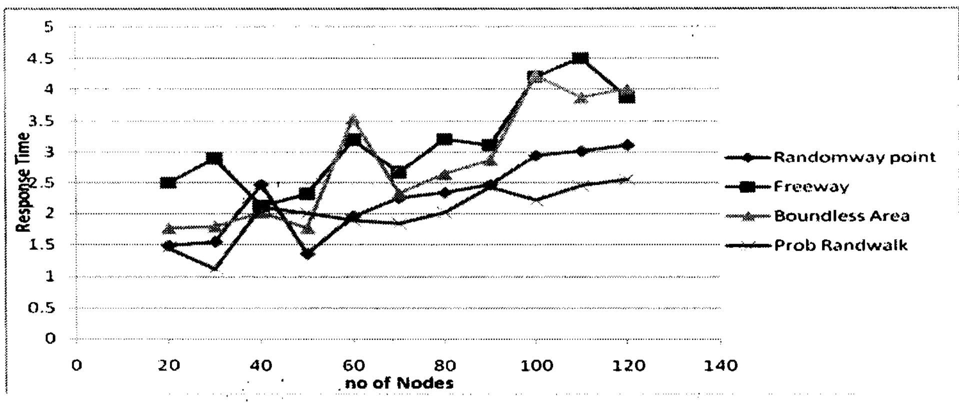

Figure 6.5: Response Time with changing no of nodes

In the figure 6.6 below the response time of network is shown when the speed is increasing while the number of nodes in the network are remain constant. Figure shows that Freeway mobility model has largest response time when speed of node is increasing. Probabilistic mobility model has lowest response time than other three models.

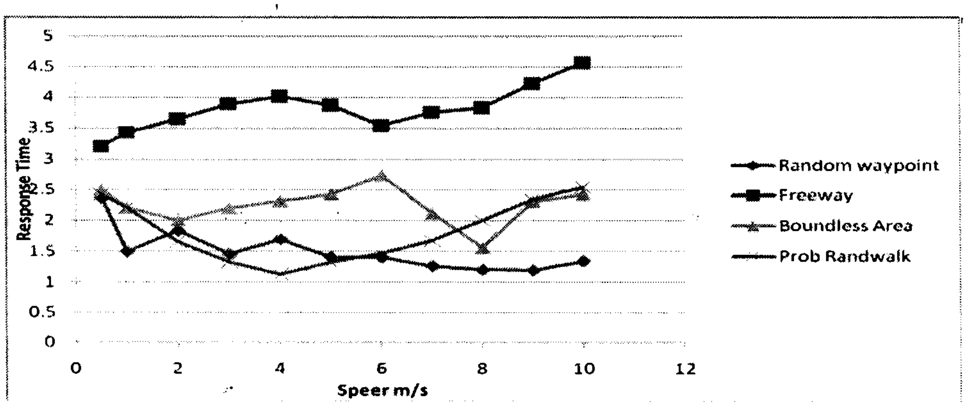

Figure 6.6: Response Time with changing Node Speed

6.3.2 Cross-Layer Peer-to-Peer Network over Ad hoc Network

Hit Rate

Figure 6-7 shows the hit rate of Cross-Layer Mobile Peer-to-Peer network using different mobility models. There are four mobility models we used to evaluate the performance. We see from figure each mobility model performs differently in same scenario and mobility characteristics. Freeway mobility model has more variation as it is has been designed for vehicular network and node speed is almost higher than the other mobility model. Hit rate of probabilistic mobility model is high than other mobility models.

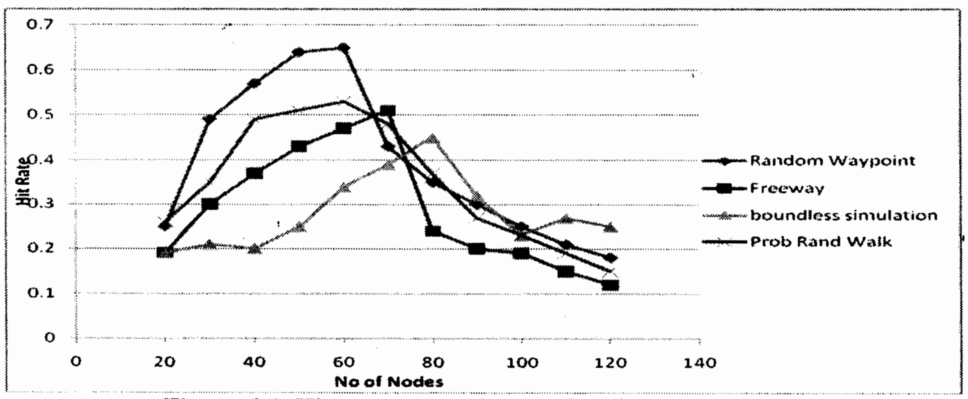

Figure 6.7: Hit Rate against the No of Nodes (Cross-Layer)

In figure 6.8, Hit rate of peer nodes has shown when the speed of node is changing while the other factors of network remain constant i.e number of nodes are fixed. In this figure it is shown that Probabilistic Random walk has high hit rate than other two mobility models. Freeway mobility model shows the minimum hit rate as the change in the speed is increased.

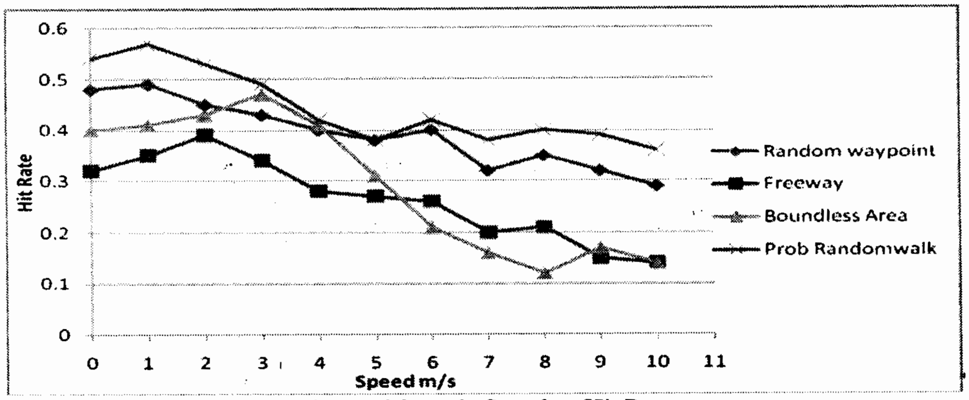

Figure 6.8: node Speed vs Hit Rate

Average End to End Delay or Response Time

Figure 6.9 shows the response time of different mobility models while we apply on a cross-layer P2P network over an ad hoc network. The results of other mobility models are compared with random way point mobility model which was most commonly used for network research. The result shows that Probabilistic random walk has lowest response time than other mobility models. Boundless simulation area mobility model perform better than the freeway mobility model.

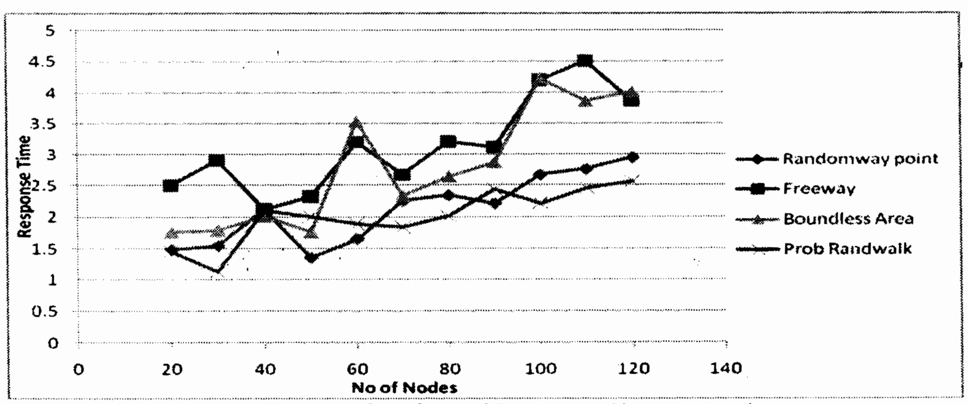

Figure 6.9: No of Nodes and Response Time comparison

The figure 6.10 shows the average end to end delay or response time for different mobility models. Response time of free way mobility model is more than other three mobility models. While other mobility models have less response time. Probabilistic random walk has less response time than other mobility models.

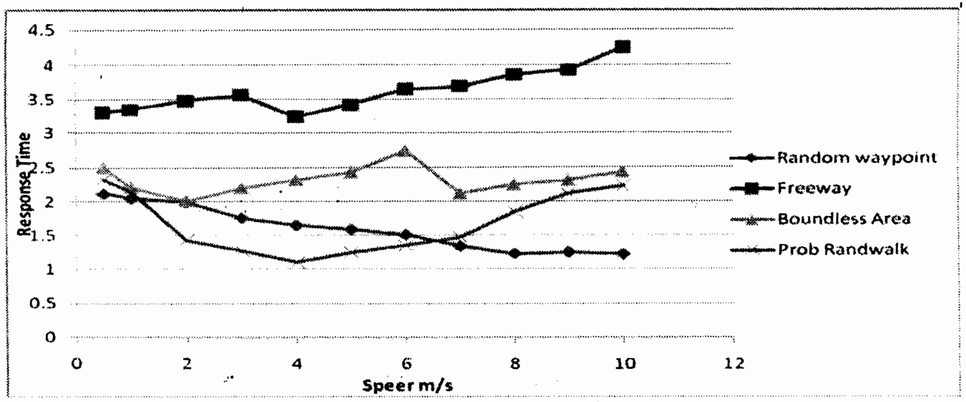

Figure 6.10: No of Message sent and Response time

No of messages sent

In the figure 6.11, number messages sent in the network are shown when the numbers of nodes are changed. Random waypoint mobility model have highest no of messages sent in the network. Next the Probabilistic Random Walk has higher value than other two mobility models.

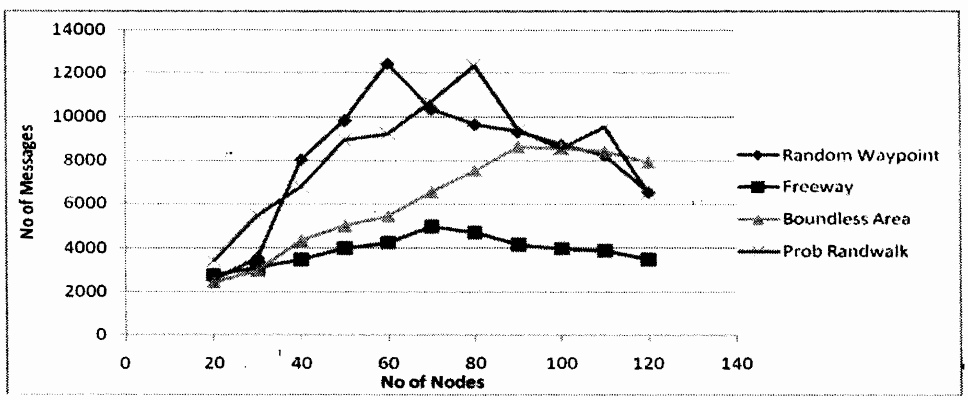

Figure 6.11: No of Message sent while changing node speed

In the figure 6.12, the no of messages sent the network are shown while speed of node is increasing. Boundless simulation area mobility model has minimum value than other mobility models. Probabilistic random walk has relatively highest number of messages. It shows 20% to 50% increase in sending messages than the random way point mobility model.

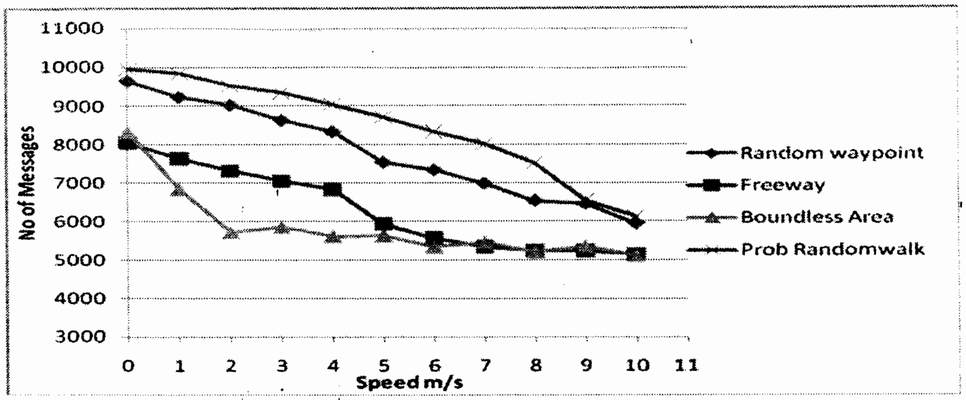

Figure 6.12: No of messages sent against node speed.

6.3.3 Comparison of Layered and Cross-Layer Peer-to-Peer Network over Mobile Ad hoc Network.

In the layered design approach of Peer-to-Peer network over Mobile Ad hoc network, there were the problem of routing overhead due to lack of inter layer communication. Both of these networks have different perspective so they are operating on the different layers. Due to these reasons redundant messages are generated which make the network performance low. To solve these problems a cross layer design approach has been adopted and used in this thesis. Coordination between these two layers application and network layer has been made by creating a cross layer interface. In this cross layer interface necessary information is exchanged between these protocols so that the redundant message generation can be decreased.

Different mobility models have been used to evaluate the performance of this cross layer mobile Peer-to-Peer network. This performance of mobility models is compared with the existing mobility model that is random way mobility model. At the end we also compared the both networks performance layered approach and cross layer approach for Peer-to-Peer over mobile ad hoc network.

Hit Rate

In the figure 6.13, we choose two mobility models for comparison of cross layer and layered design approach. Random waypoint mobility model and free way mobility model have been chosen for evaluation. In Cross layer environment random waypoint model gives high bit rate than in layered model. A 30% to 60% increase can be observed. While in case of free way mobility model its hit rate is increased but slightly higher than in layered model.

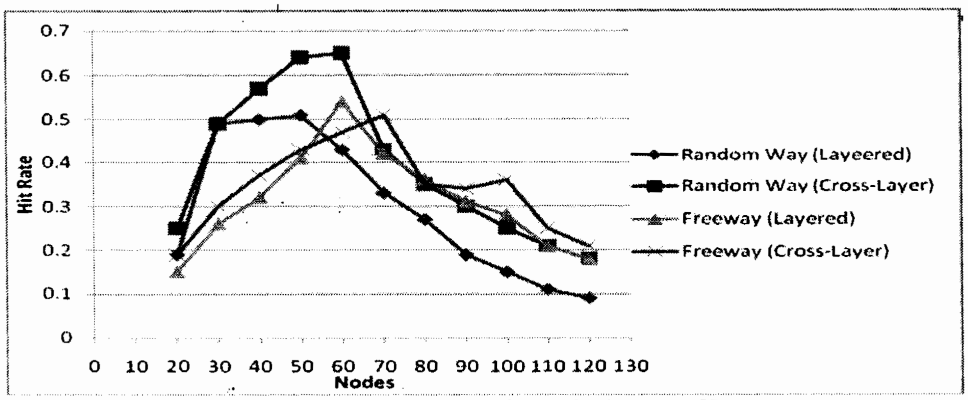

Figure 6.13: Number of Nodes and Hit Rate of Peers

Figure 6.14 shows the hit rate of peers in layered and cross layer design. The increase in hit rate in observed in case of cross layer approach, there is 10 to 30 percent increase in the case random way point mobility model. In freeway model it is also increased but at a certain time layered approach has higher hit rate than cross layer.

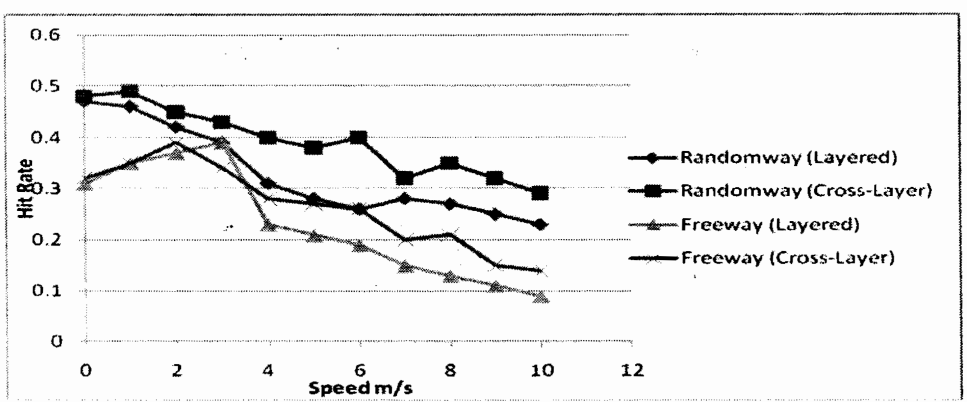

Figure 6.14: Speed verses Hit Rate

No of Messages sent

Now we shall compare the performance of different mobility models using layered and cross layer design approach. The number of messages sent in the network is compared with the no of nodes and node speed. The following figure shows that cross layer design approach gives the best performance when no of nodes are increasing.

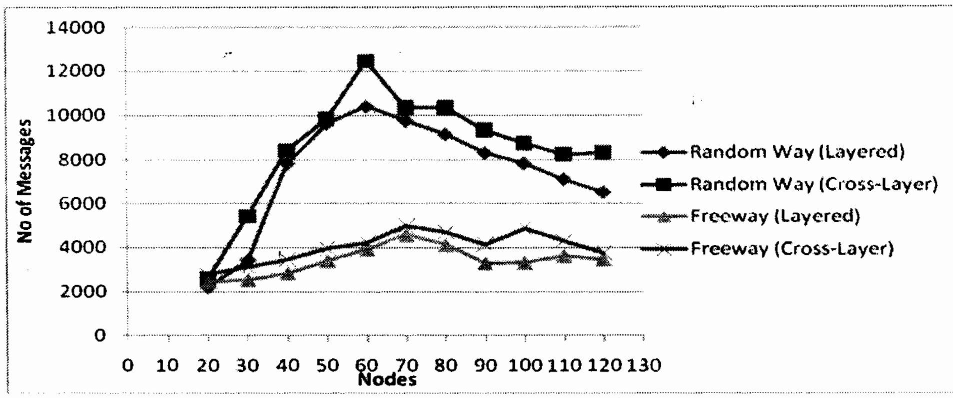

Figure 6.15: No of messages sent and no of nodes

In the figure 28 it is shown that while changing node speed the no of messages sent in the network. Random waypoint mobility model shows the highest no of message sent in cross layer design. While freeway mobility model also have an increase of 30% to 50% increase in sending messages in the network.

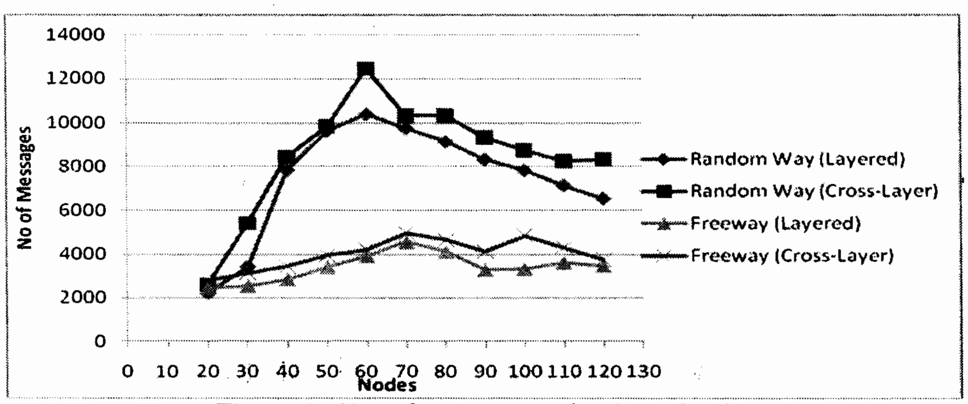

Figure 6.16 No of Messages send and no of nodes

Response Time

Response time of node or average end to end delay has been presented in both cases layered design and cross layer design. In figure it is shown that cross layer design has a significant decrease in the response time. Layered design has highest response time.

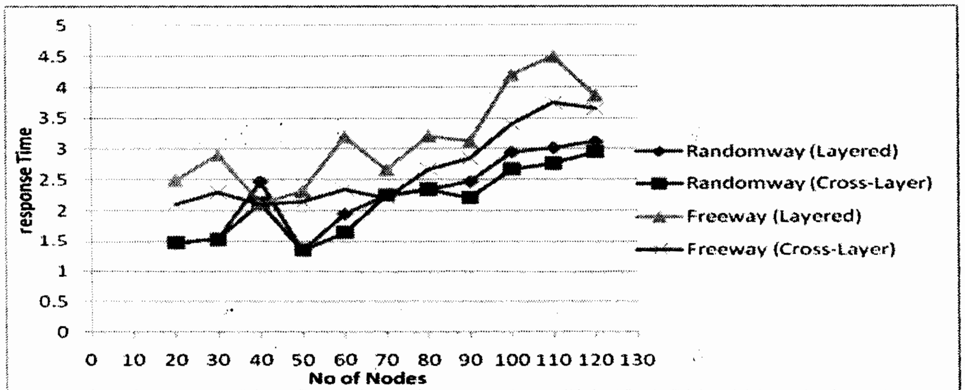

Figure 6.17: No of nodes with response time

In the figure 30, it presented that cross layer design for random waypoint has a minimum response time. As in high mobility scene the mobile nodes has more response time. Freeway mobility model has also decrease in response time. But it has variation on different points due to high mobility or no peer connected in the network.

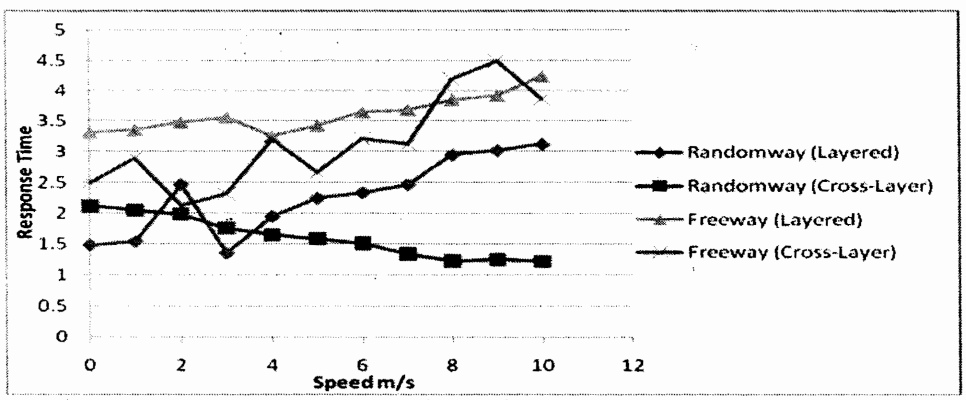

Figure 6.18: Node speed and Response Time

6.4 Major Conclusions about the impact of mobility models

Peer-to-Peer networks are most commonly used in wireline network and perform better for different type of file sharing like audio and video contents sharing, clips and data files. The Mobile Ad hoc network are infrastructure less and are self configuring, these networks can be formed anytime and anywhere. The deployment of Peer-to-Peer network over an Ad hoc network in a layered manner has been used for performance evaluation of different mobility models. There were two different analyses that are to be made; first one is about the performance of routing protocols while using different mobility models. Second one is the comparisons between the use of different mobility models values and currently and most commonly used mobility model which is random waypoint mobility model. Hence the result shows that the performance of routing protocols also depends on the use of mobility model. It is necessary that a proper mobility model should be used for specific scenarios.

The performance of the routing protocol is affected by the mobility model and the route finding mechanism of ad hoc routing protocols. Different mobility models provide different characteristics that affect the overall performance of Peer-to-Peer network application in an ad hoc network. The layout of lanes, streets, intersections, and other characteristics like including obstacles affect the overall performance of the moile ad hoc networks. Also the route finding mechanism of each protocol is different from the other so it is also a factor that must be considered for performance evaluations.

In the layered design approach of Peer-to-Peer network over Mobile Ad hoc network, there were the problem of routing overhead due to lack of inter layer communication. Both of these networks has different perspective so they operate on the different layers, for such reasons redundant messages are generated which make the network performance low. To solve these problems a cross layer design approach has been adopted and used in this thesis. Coordination between these two layers application and network layer has been made by creating a cross layer interface. In this cross layer interface necessary information is exchanged between these protocols so that the redundant message generation can be decreased.

In freeway mobility model the mobile nodes moves on a predefined freeway, with a predefined velocity. All the vehicles are assigned same velocity which is constant during the simulation time. There are two things about the freeway model one is that the vehicle follows a straight path and they don't moves to left or right directions; it means it provides less topological changes to the vehicles and as a result the performance is not much affected. The second thing about the freeway model is that the vehicles move with a predefined speed with no acceleration or deceleration as a result the links that have been created at start remains in tact for longer duration. It means that the numbers of broken links are less with constant speed of vehicles resulting high packet delivery ratio.

6.5 Summary

In this chapter detail of performances metrics and the simulations results have been presented. We have chosen Hit rate, Number of messages sent in the network and the average end to end delay or response time. Each mobility model is tested in layered design approach of Peer-to-Peer network over ad hoc networks, cross layer Peer-to-Peer network over ad hoc network and a comparison of these two approaches. It is shown that Cross-Layer design approach for this complex network give better result as compared to layered design approach.

Chapter 7

Conclusion and Future Work

Introduction

In this chapter we will sum up our conclusions about the routing decision in Mobile Peer-to-Peer network using popular mobility models of ad hoc network. Detailed results and evaluation has been presented in previous chapter. We shall also describe the possible future research dimension related to this topic.

7.1 Achievements

The main achievements of this research project can be summarized as follows.

- We have presented a detailed study of important components for the development of Peer to Peer network over Mobile Ad hoc Network.
- The performance of ad hoc routing protocol under a peer to peer network application is presented in layered design architecture. On the basis of important entities and their characteristics for mobility models, we evaluate these mobility models for a number of scenarios and condition.
- We studied the problems faced during the complex network operation of Peer-to-Peer over Ad hoc network and an enhanced model is proposed for better performance.
- A cross layer model is used for the betterment of inter layer communication. Routing overhead that is produced during the legacy deployment of Peer to Peer overlay network over ad hoc network is reduced.
- We used different metrics to analyze the influence of different mobility models on performance of Peer to Peer over Mobile ad hoc network.
- Evaluated results of simulations with different mobility models with some realistic parameters for P2P over Ad hoc network.

7.2 Conclusion

Peer to Peer networks are most frequently used in wireline network. These Networks has been designed for wired network for example Gnutella, Bear share. Mobile Ad hoc network are infrastructure less and are self configuring. These networks are mostly formed in area, where there is no infrastructure for wired and wireless network. The Peer to Peer network has been deployed over Mobile Ad hoc Network in layered form as well as in Cross layer form. Performance of different mobility models has been evaluated using layered and cross layer architecture of Peer to Peer network over MANET. The Peer to Peer protocol Gnutella is used on application layer and MANET protocol AODV is use on network layer. Hence the result shows that the performance of routing protocols also depends on the use of mobility model. It is necessary that a proper mobility model should be used for specific scenarios.

In the layered design approach of Peer to Peer network over Mobile Ad hoc network, there were the problems of routing overhead due to lack of inter layer communication. Both of these networks have different perspective so they operate on the different layers, for such reasons redundant messages are generated which make the network performance low. To solve these problem a cross layer design approach has been adopted and use in this thesis. Coordination between these two layers application and network layer has been made by creating a cross layer interface. In this cross layer interface necessary information is exchanged between these protocols so that the redundant message generation can be decreased.

7.3 Future work

The future dimensions of this work are that the researchers should use the other realistic mobility models. As the mobility is a big issue in mobile ad hoc network so it is necessary that peers that are joining the network should have proper connectivity mechanism. This can increase the performance of whole network. Another approach can be used to reduce the network traffic which is the use of Ultra peers. Ultra Peers are the nodes that are responsible for a group of peers and peers in that group can only connect through these ultra peer nodes. Peers have direct connections with their group members. A group mobility model can be used to evaluate the performance.

7.4 Summary

In this chapter we have concluded our work and the future dimensions of our work. The performance of mobile ad hoc routing protocol under a Peer to Peer network is affected by the mobility models used because each mobility models has its own characteristics. There is a need of more enhanced architecture that can be used for Peer to Peer over Mobile Ad hoc network.

Chapter 8

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