A

Project Report On

B.A.T.M.A.N.-ADV AND BABEL HYBRID WIRELESS MESH ROUTING PROTOCOL

Submitted By

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Under the guidance of

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AT

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CERTIFICATE

This is to certify that the Dissertation entitled

"B.A.T.M.A.N.-ADV AND BABEL HYBRID WIRELESS MESH ROUTING PROTOCOL"

submitted by

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is a record of bonafide work carried out by them, in the partial fulfillment of the requirement for the award of Degree of Bachelor of Engineering (Information Technology) at Pune Institute of Computer Technology, Pune under the University of Pune. This work is done during year 2012-2013, under our guidance.

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Examination:

Examiner ——————————

Date:

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Rishabh Pandita

Swapnil Satpute

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ABSTRACT

Better approach to mobile Ad-hoc networking- advanced(B.A.T.M.A.N-ADV) and BABEL are widely used wireless mesh routing protocols. Through a set of benchmarking and comparison tests that were conducted by various researchers it can be observed that both protocols have certain features which make up for deficiencies in their counterpart. In this project we present a experimental hybrid routing protocol which is a combination of B.A.T.M.A.N-ADV and BABEL with certain metric modifications that combine advantages of both the protocols. Through a series of performance tests conducted considering factors like throughput, packet loss, jitter, intermediate node failure, node recovery and link stability visible improvements were observed as compared to original B.A.T.M.A.N-ADV and BABEL standalones running together.

Keywords : MANET, B.A.T.M.A.N.-ADV, BABEL, Routing, Wireless mesh

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Chapter 1

Introduction

1.1 Need

Routing is the most important concern in mobile ad-hoc networks as unlike static networks the topology may change anytime during operation. Due to such dynamic topology it is necessary to detect changes in topology and update the routes as soon as possible to avoid node or network failures. Many different routing approaches are suggested of which B.A.T.M.A.N-ADV and babel are popular and known to have better performance than others.

The aim of the project is to introduce a new a experimental hybrid routing protocol combining B.A.T.M.A.N-ADV and babel into a single routing protocol. In this paper we compare the performance results of running unmodified babel instance with performance results of modified instance of babel both running over B.A.T.M.AN-ADV as a hybrid showing visible improvements in performance.

Considering wireless meshes no protocol is suitable for all types of meshes in general.The hybrid implementation is an attempt to formulate a general solution for all types of meshes.

1.2 MANET

A mobile ad hoc network (MANET) is a self-configuring infrastructure less network of mobile devices connected by wireless links.

Each device in a MANET is free to move independently in any direction, and will therefore change its links to other devices frequently. Each must forward traffic unrelated to its own use, and therefore be a router. The primary challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or may be connected to the larger Internet.

MANETs are a kind of wireless ad hoc networks that usually has a routable networking environment on top of a Link Layer ad hoc network.

The growth of laptops and 802.11/Wi-Fi wireless networking have made MANETs a popular research topic since the mid-1990s. Many academic papers evaluate protocols and their abilities, assuming varying degrees of mobility within a bounded space, usually with all nodes within a few hops of each other. Different protocols are then evaluated based on measure such as the packet drop rate, the overhead introduced by the routing protocol, end-to-end packet delays, network throughput etc.

MANETS can be used for facilitating the collection of sensor data for data mining for a variety of applications such as air pollution monitoring and different types of architectures can be used for such applications. It should be noted that a key char characteristic of such applications is that nearby sensor nodes monitoring an environmental feature typically register similar values. This kind of data redundancy due to the spatial correlation between sensor observations inspires the techniques for in-network data aggregation and mining. By measuring the spatial correlation between data sampled by different sensors, a wide class of specialized algorithms can be developed to develop more efficient spatial data mining algorithms as well as more efficient routing strategies. Also researchers have developed performance models for MANET by applying Queueing Theory.

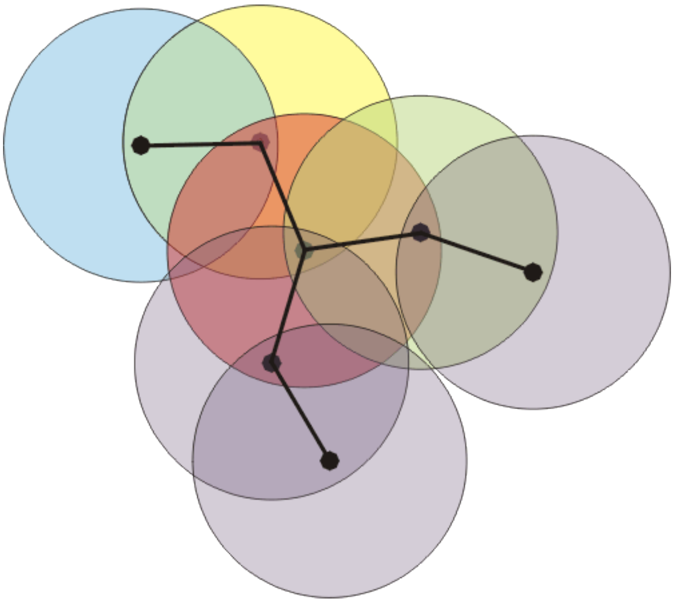

Figure 1.1: Typical MANET scenario

Mobile adhoc networks (MANETs) are infrastructureless multi-hop wireless networks as exemplied in Figure 1.1. By relaying information over the participating devices, the network coverage expands far beyond the transmission range of a single device. Due to the presumed mobility of the nodes forming the network, and the decentralization, self- organization mechanisms have to be employed.

In these characteristics MANETs are closely related to Wireless Sensor Networks, which are used for environment monitoring. Moreover MESH networks deal with similar difficulties. These are basically multi-hop wireless networks as well, but are equipped with stationary backbone devices, often providing several network interfaces. Adhoc networking comes in handy, whenever it is not practical to provide the otherwise necessary infrastructure, e.g. due to the temporary nature of a network, or restrictions caused by the environment. As with many technological developments such circumstances emerge especially in the military context. Apart from these, the already mentioned wireless sensor networks are probably the most commercially important employment of the technique. The third recognizable current use case are community networks, which have oftentimes been built due to a lack of internet coverage in certain areas. Adhoc networks were found very much useful to provide internet acces over the ”last mile”.

1.3 B.A.T.M.A.N.-ADV

B.A.T.M.A.N.-ADV is a proactive data-link layer routing protocol. It uses decentralized knowledge approach for routing. Node participating in the mesh doesn't maintain entire route to each destination but keeps a table of node metric values called TQ(Transmission quality) used to determine the best next hop neighbor in direction of a particular destination. The packets are forwarded in this manner until the destination is reached.

In B.A.T.M.A.N.-ADV nodes periodically broadcast originator messages (OGMs) to their neighbors who in turn relay them to their neighbors thus all nodes in the network become aware of each other's existence. The number of OGMs arriving from a particular link determine it's TQ. Thus, if a link is weaker it will deliver less OGMs resulting in low TQ value.

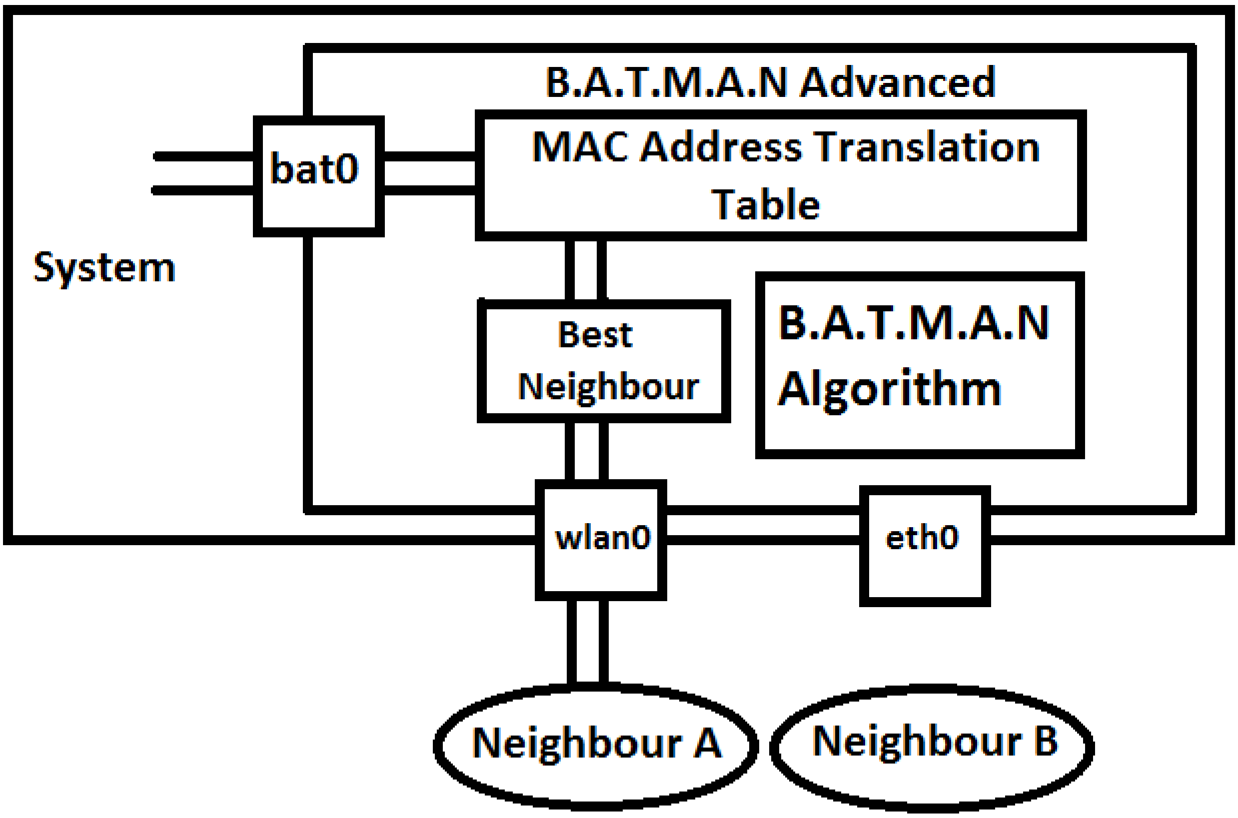

Figure 1.2: B.A.T.M.A.N-ADV System Architechture

Most other wireless routing protocol implementations (e.g. the batman daemon) operate on layer 3 which means they exchange routing information by sending UDP packets and bring their routing decision into effect by manipulating the kernel routing table. Batman-adv operates entirely on ISO/OSI Layer 2 - not only the routing information is transported using raw ethernet frames but also the data traffic is handled by batman-adv. It encapsulates and forwards all traffic until it reaches the destination, hence emulating a virtual network switch of all nodes participating. Therefore all nodes appear to be link local and are unaware of the network's topology as well as unaffected by any network changes.

This design bears some interesting characteristics, network-layer agnosticism - you can run whatever you wish on top of batman-adv: IPv4, IPv6, DHCP, IPX ,nodes can participate in a mesh without having an IP easy integration of non-mesh (mobile) clients (no manual HNA fiddling required) ,roaming of non-mesh clients,optimizing the data flow through the mesh (e.g. interface alternating, multicast, forward error correction, etc),running protocols relying on broadcast/multicast over the mesh and non-mesh clients (Windows neighborhood, mDNS, streaming, etc)

A layer 2 routing protocol also has to handle the data traffic because usually one can't route/forward ethernet packets. Processing packets in userland is very expensive in terms of CPU cycles, as each packet has to be read() and write() to the kernel and back, which limits the sustainable bandwidth especially on low-end devices. To have good support for these devices as well, we implemented batman-adv as a kernel driver. It introduces a negligible packet processing overhead even under a high load.

1.3.1 batctl

To still have a handy tool to configure debug the batman-adv kernel module, the batctl tool was developed. It offers a convenient interface to all the module's settings as well as status information. It also contains a layer 2 version of ping, traceroute and tcpdump, since the virtual network switch is completely transparent for all protocols above layer 2.

1.4 BABEL

Babel is a proactive network layer routing protocol based on distance-vector algorithm. The implementation used here is babeld which is a user space daemon. In babel neighbor cost based on Expected Transmission count (ETX) is calculated by considering transmission and reception link quality. This is done by nodes broadcasting periodical Hello messages and sending back I Heard You (IHU) acknowledgement messages. It also considers some feasibility conditions that every route must meet to ensure loop free routing.

Two main features of babel are that it uses history sensitive routing to minimize rapid changes in selected route, which is particularly useful in highly mobile networks. Also, when it discovers a link failure it forces a reactive update to prevent starvation.

1.5 Behavioral comparison of B.A.T.M.A.N.-ADV and BABEL

Table 1.1 shows different characteristics exhibited by the above mentioned protocols.By observing these properties one can see why hybrid implementation using B.A.T.M.A.N.-ADV and BABEL is feasible.

Factor	B.A.T.M.A.N.-ADV	BABEL
Implementation	Data link layer i.e. kernel space routing module	Network layer i.e. user space routing daemon
Throughput	Tends to route through more number of hops hence low multi-hop bandwidth	Higher multi-hop bandwidth
Packet Delivery	Higher packet delivery rate	Lower packet delivery rate
Mobility	Slower route convergence and frequent route flapping is observed after repair.	Fast route convergence and repair
Scalability	Performance remains consistent as the no. of participating nodes rises.	Low round trip delay for few nodes but increases with the number of nodes
Stability	Higher stability	Route flapping may occur even for tiny changes

Table 1.1: Comparison of behaviors of B.A.T.M.A.N.-ADV and BABEL

Chapter 2

Literature Survey

2.1 Simulation of the B.A.T.M.A.N.-ADV Protocol [1]

In this paper we learned about BATMAN III and BATMAN IV. There features and packet formats were discussed. In this paper a comparative study of the both the protocols were done. It discussed about routing in MANET in general and protocols for MANET like OLSR2 and BABEL were discussed. Comparison of protocols in different scenario like Circle,handover,Grid,Mobility were done.

2.2 A simple pragmatic approach to mesh routing using B.A.T.M.A.N. [2]

In this paper a simple pragmatic routing protocol called BATMAN (Better Approach To Mobile ad hoc Networking) is presented as a response to the shortcomings of OLSR together with a comparison of its performance to OLSR. The experiments are run on a custom developed 7 by 7 grid of closely spaced WiFi nodes. The results show that BATMAN outperforms OLSR in terms of better throughput, less delay, lower CPU load and lower routing overhead.

2.3 Performance evaluation of B.A.T.M.A.N., DSR, OLSR routing protocols [3]

This paper describes the performance of the three routing protocols in case of change in traffic, no. of nodes and node mobility. To analyze the performance, reactive and proactive routing protocols are considered. The routing protocols include Better Approach to Mobile Ad hoc Networks (BATMAN), Dynamic Source Routing (DSR) and Optimized Link State Routing Algorithm (OLSR). This paper systematically analyzes the performance of reactive and proactive routing protocol.

2.4 Improving B.A.T.M.A.N. routing stability and performance [4]

It has been demonstrated that traditional hop count routing is sub-optimal in wireless networks, so a great number of specific routing protocols and metrics have been proposed. In this thesis, study of B.A.T.M.A.N. as routing protocol is done, because it is one of the most diffused, and from many real experiments it results to have good performance. Furthermore it is sustained by an active community and has been also included in the Linux kernel. The know-how gained working on these topics was fundamental to achieve the necessary deep understanding of the protocol implementation. List the most important families of routing protocols, depicting advantages and drawbacks of each solution and reporting the current open research issues. Results of a number of tests executed using both virtual machines and real devices. Collected data con

rm that current B.A.T.M.A.N.implementation converges slowly in case of node failures due to routing misbehaviors, and shows that the modification actually solves these problems.

2.5 BABEL RFC [8]

From this RFC we came to know about the indept working of babel mesh routing algorithim. Feasibility condition which is checked everytime an update is received by the mesh. It is necessary to pass the feasibility check. Feasibility check ensures loopfreeness. In this rfc a well detailed description of the same was given. Various topics were covered in the rfc for example conceptual description of the protocol, protocol operation, protocol encoding IANA considerations and security considerations.

Conceptual description of the protocol included the bellman-ford algorithim, transisent loops in Bellman-Ford algorithm, feasibility conditions, how to solve starvations in network ,sequencing of the routes, how to handle overlapping of prefixes and multiple routers and request by one router. Protocol operation included Message transmission and reception , data structures used, format of acknowledgement packets.How routing tables are maintained and how selection of a route is performed by the algorithm. How a packet update is to be send to the mesh network running the protocol. Protocol Encoding included Data types and packet formats , TLV formats and detailed specific TLVs.The rfc was very resourcefull in describing the cost and metric computations which included maintaining HELLO history, Cost computations, Metric computations.

Chapter 3

Proposed Work

3.1 Problem Statement

To integrate B.A.T.M.A.N.-ADV and BABEL algorithms into a single routing algorithm and to carry out performance analysis for the same

3.2 Scope

The project involves studying routing mechanism of BABEL and B.A.T.M.A.N.-ADV wireless mesh routing algorithms along with their performance behavior for different types of wireless meshes.

The implementation of hybrid is made possible by introducing metric sharing facility.This is achieved by parsing the formatted kernel debug dumps of B.A.T.M.A.N.-ADV and supplying thus acquired metric values to BABEL.

Further the project proceeds to obtain comparative performance measures for the newly developed hybrid with existing protocol implementations.

3.3 Objective

Our objective here is to make BABEL aware of B.A.T.M.A.N.-ADV running under it.Thus metrics of B.A.T.M.A.N.-ADV need to be supplied to BABEL so that it can decisions accordingly.After the protocol is implemented we need to test it to obtain it's performance measures.

Chapter 4

Research Methodology

4.1 Input and output for project

The project being an implementation of a routing protocol the input to the project is network traffic. For a particular node the input will be messages received from other nodes on which the decisions will be based.

The output of the implementation is network route decided by the protocol.

4.2 Metrics under consideration

The routing decisions taken by the routing algorithms are based on their metric values.The values for metrics are determined by the algorithms based on packet flow as described in introduction.

Now,we will discuss the metrics used by B.A.T.M.A.N.-ADV and BABEL,

4.2.1 BABEL

Transmission Cost (Tx)

It is determined by frequency of arriving *I heard you* (IHU) messages arriving at a particular interface.

Reception Cost (Rx)

It is determined by frequency of arriving *Hello* messages arriving at a particular interface.

Estimated Transmission Count (ETX)

It is theoretical metric which BABEL uses.It is not actually calculated in the implementation.It's value is determined by values of Tx and Rx.Higher value indicates better reachability.

$$ETX = 1/(Tx * Rx) \tag{4.1}$$

4.2.2 B.A.T.M.A.N.-ADV

Transmission Quality (TQ)

It is the only metric used by B.A.T.M.A.N.-ADV.TQ represents the bidirectional link quality.The value of TQ is determined by the frequency on originator messages (OGMs) arriving at a particular interface.

Chapter 5

Project Design

5.1 Design of the hybrid

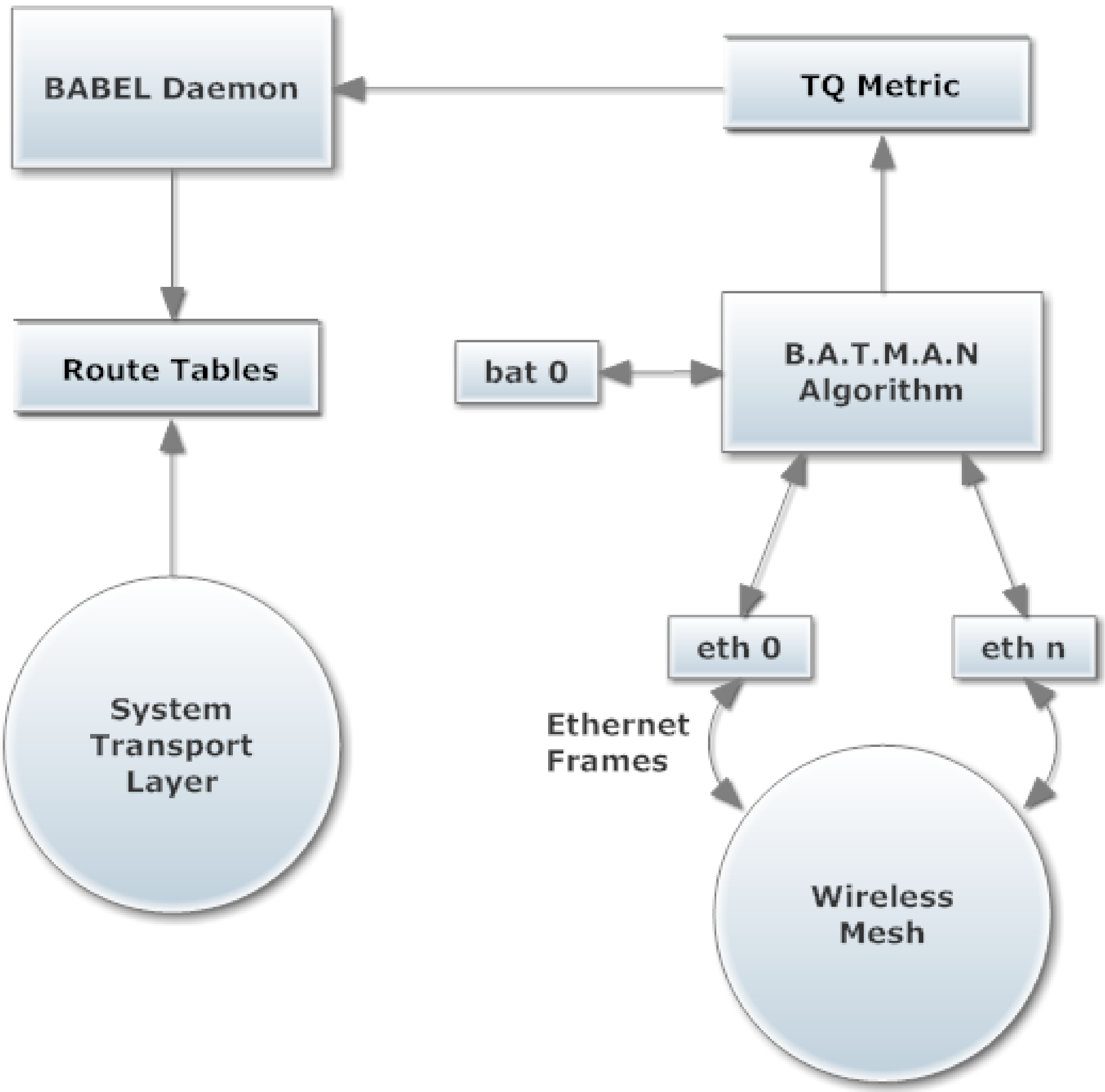

Figure 5.1: Data flow architecture of the hybrid protocol

Figure 5.1 shows the abstract architecture of the hybrid protocol.Here, the B.A.T.M.A.N.-ADV routing metrics are dumped into kernel debug directory which are read from babel and parsed to obtain the TQ value.The TQ value is then used in neighbor cost function to select best neighbor and further set the kernel routing table.

5.2 Component diagram

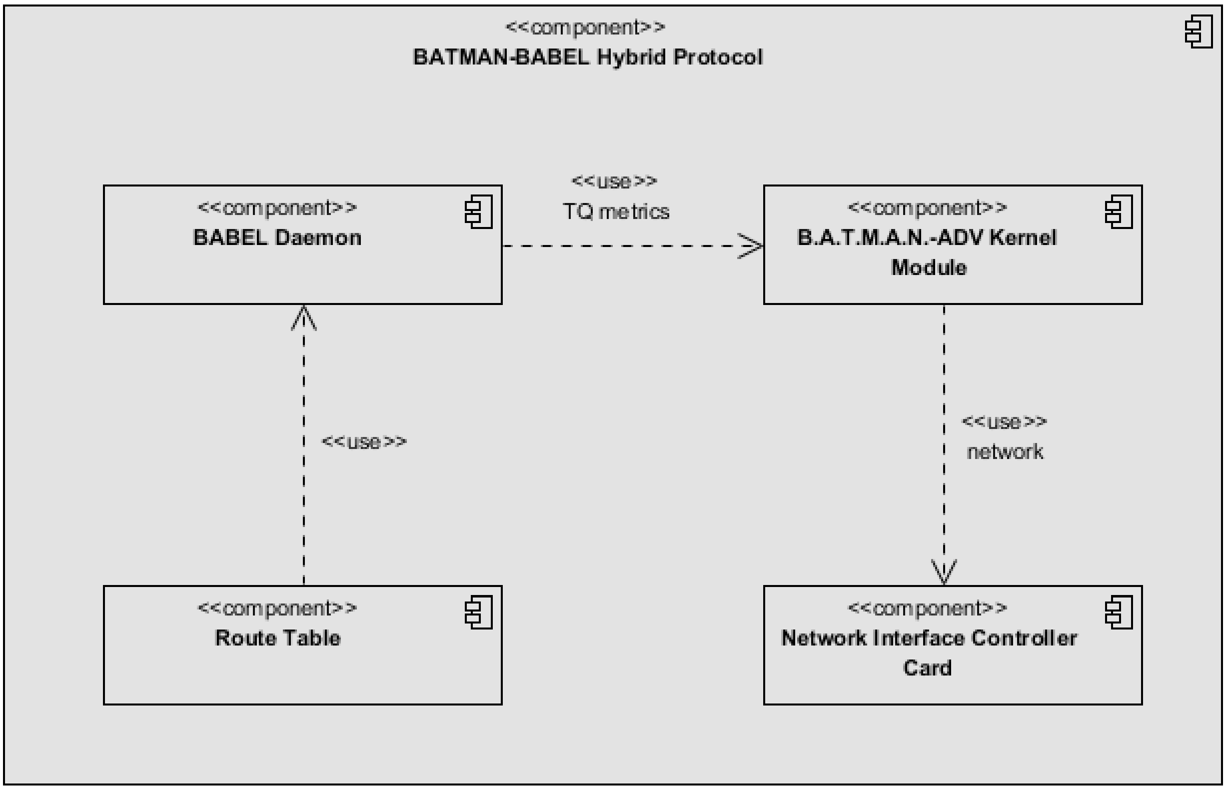

Figure 5.2: Component diagram of the hybrid protocol

As shown in Figure 5.2 B.A.T.M.A.N.-ADV is in direct control of the network interface after the device driver.It handles raw Ethernet frames.

Further the TQ value of B.A.T.M.A.N.-ADV obtained by BABEL is used by BABEL in it's neighbor cost function to set the kernel routing table.

5.3 Deployment diagram

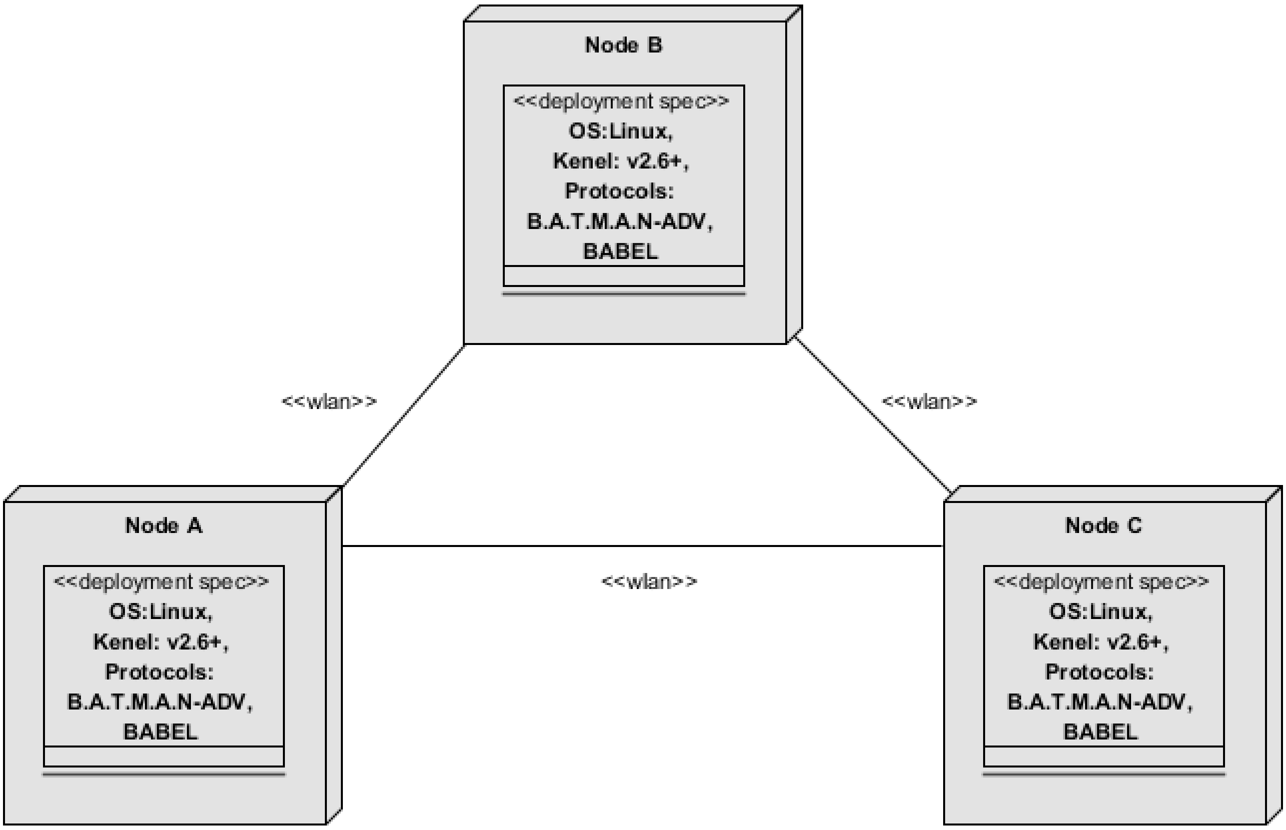

Figure 5.3: Deployment diagram of the hybrid protocol

The deployment stack is as shown in figure 5.3.The BABEL protocol running in userspace at network layer stack over B.A.T.M.A.N.-ADV running in kernel at data link layer.

It is worth noticing that at intermediate nodes(routers) the data is routed just through B.A.T.M.A.N.-ADV as it runs in data link layer and forwards the packets directly to next hop, while BABEL remains ignorant to this fact.

5.4 Software tools used

5.4.1 Build tools

1. Linux (kernel version 2.6 and above):
   The B.A.T.M.A.N.-ADV protocol is available for kernel version 2.6 and above.
2. gcc (GNU Compiler Collection):
   gcc was used to compile the C sources of B.A.T.M.A.N.-ADV and BABEL.
3. bash (Borne Again Shell):
   To automate routine tasks, bash scripts were created and implemented.

5.4.2 Testing tools

1. bwm-ng (Bandwidth Monitor - New Generation):
   bwm-ng was used to monitor the live bandwidth on interfaces and log the details.
2. iperf:
   This network testing tool was used to create UDP data traffic and measure the throughput of a network.
3. jperf(Graphical Front-end for iperf written in Java):
   jperf was used to generate graphs of bandwidth and jitter.
4. Wireshark(Packet Analyzer):
   Wireshark was used to analyze packets in the network.
5. GNUplot.py:
   Resulting test data was used as input to generate 2D plots using gnuplot.py.

5.5 Hardware Requirements

1. Nodes capable of running Linux kernel v2.6
2. NIC supporting Ad-hoc mode configuration

Chapter 6

Implementation

6.1 Metric modifications for hybrid implementation

A normal approach can be to run BABEL instance over B.A.T.M.A.N.-ADV without any modifications. But, such approach doesn't show any good results as both protocols are unaware of each other. Another approach is to provide B.A.T.M.A.N.-ADV TQ metric value to BABEL and to change it's neighbor cost estimation function as shown below,

Existing neighbor cost function:

$$Cost = ((Tx * Rx) + 128) >> 8 \tag{6.1}$$

Modified neighbor cost function:

$$Cost = (((Tx * Rx) + 128) >> 8) - TQ \tag{6.2}$$

Here,
Tx Transmission Cost
Rx Reception Cost
TQ Transmission Quality

Also note, that here presence ETX is implied and not explicit. TQ is subtracted from the original cost function as ETX and TQ grow in the same direction also the numeric domain of cost and TQ is nearly same for significant values.Thus, the increase in TQ indicating a better neighbor results in reduction of neighbor cost increasing the chances of a neighbor getting selected as the best neighbor.

6.2 Performance Measurement

After the hybrid implementation it is essential to carry out performance measurements for the protocol by testing to see how it behaves and compares against other implementations.We now describe the experiment conducted to obtain performance measure,

6.2.1 Testbed Setup

A network of four mesh nodes was setup to assess the behavior of the protocols.The network was kept small so as to control various environmental parameters which allow for a much detailed investigation of the protocols that would have not been possible in a mesh network of large number of nodes where complex propagation conditions, node anomalies and external factors are often out of control and thus making it difficult to obtain exact figures from nodes.

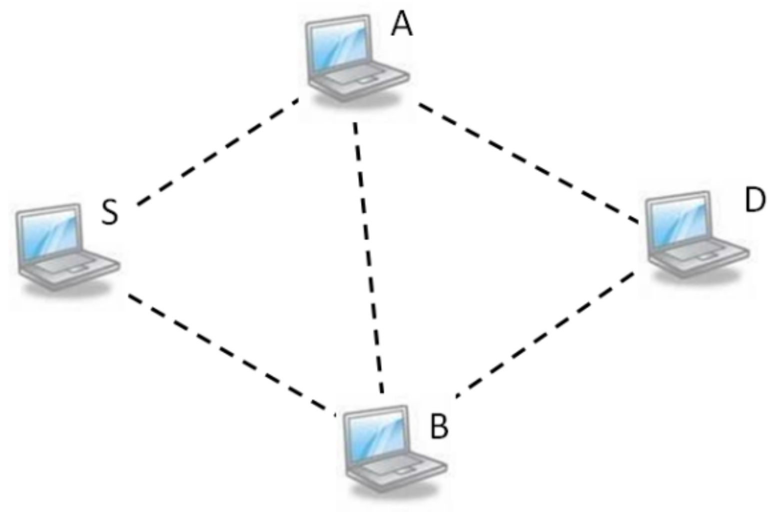

Figure 6.1: Performance evaluation testbed setup

The nodes were laptops running the Linux operating system (specifically Linux version greater than 2.6). The laptops were equipped with Cisco, Realtek, Intel PRO/Wireless cards.Throughout the experiment the source and destination nodes were represented by S and D respectively, while the intermediate nodes were represented by A and B. Nodes S and D were placed sufficiently apart so that the link quality between S and D is poor enough that no packet transfer occurs between them(Figure 6.1).

6.2.2 Network traffic

The iperf client was configured as shown in table 6.1 to generate UDP traffic for testing.

UDP Parameter	Value (size)
Datagram size	1470 B
Buffer size	224 KB

Table 6.1: iperf client configuration

6.2.3 Testing Scenario

As the test progresses various events occur at different nodes. Table 6.2 shows the events occurring at various nodes in the testbed at a given time into the test.

<table>
<tr><th rowspan="2">Time (Second)</th><th colspan="4">Nodes</th></tr>
<tr><th>S</th><th>A</th><th>B</th><th>D</th></tr>
<tr><td>0</td><td></td><td colspan="2">Start bandwidth monitoring</td><td>Run jperf data receiving server</td></tr>
<tr><td>20</td><td colspan="4">Start routing algorithm</td></tr>
<tr><td>60</td><td>Start data transmission with jperf client</td><td></td><td></td><td></td></tr>
<tr><td>100</td><td></td><td>Node shutdown</td><td></td><td></td></tr>
<tr><td>140</td><td></td><td>Node startup</td><td></td><td></td></tr>
<tr><td>300</td><td>Stop data transmission</td><td></td><td></td><td></td></tr>
<tr><td>340</td><td></td><td colspan="2">Stop bandwidth monitoring</td><td></td></tr>
</table>

Table 6.2: Progress of test with respect to time

Chapter 7

Results

From the data obtained from the tests described before, we plot data graphs to obtain performance differences between the protocols tested.

7.1 Protocols tested

In all we test four protocols(mentioned below) on our testbed.

7.1.1 Protocol I

The unmodified hybrid implementation which involves running unmodified BABEL implementation stacked over B.A.T.M.A.N.-ADV.

7.1.2 Protocol II

The modified hybrid with our modifications to the BABEL metrics running stacked over B.A.T.M.A.N.-ADV.

7.1.3 B.A.T.M.A.N.-ADV

The original unmodified B.A.T.M.A.N.-ADV implementation.

7.1.4 BABEL

The original unmodified BABEL implementation.

7.2 Analysis of modified hybrid

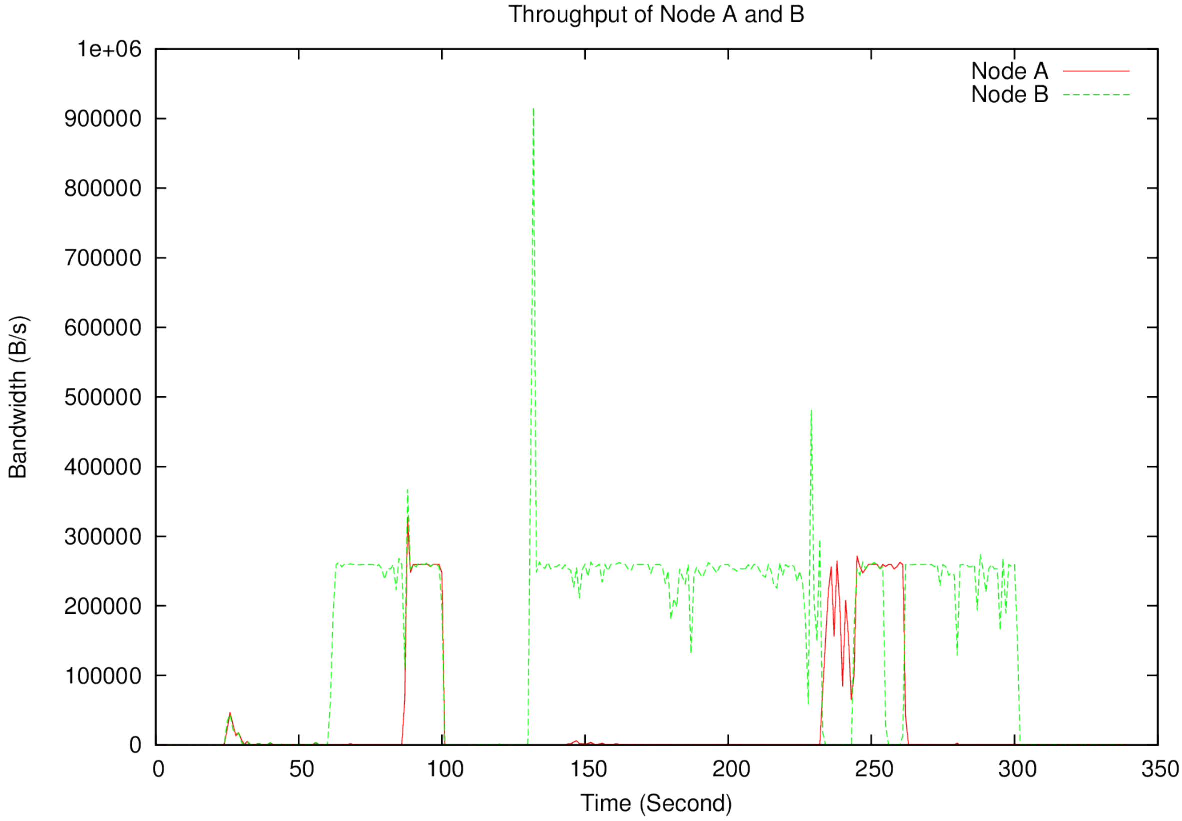

Figure 7.1: Modified hybrid throughput graph

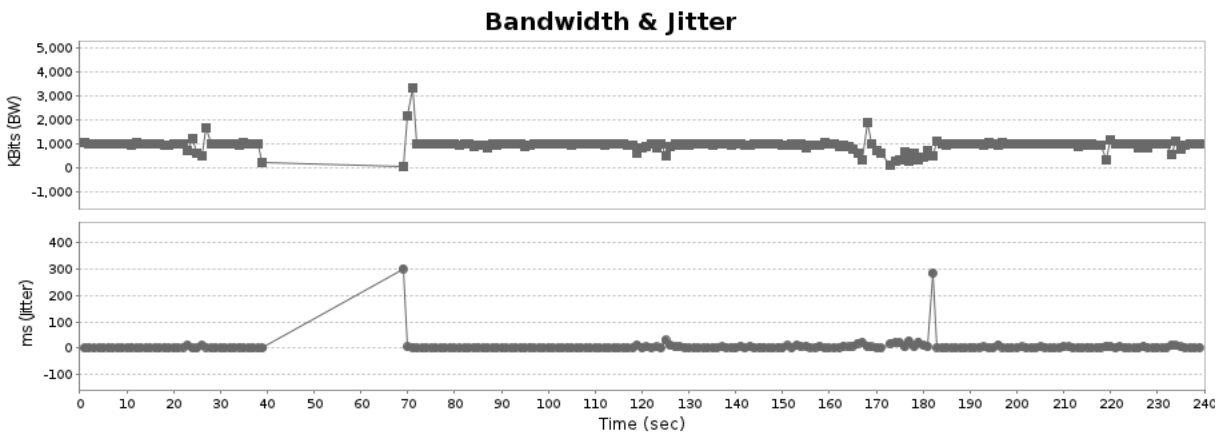

Figure 7.2: Modified hybrid i-perf server graph

Fig 7.1 gives us a visual of bandwidth varying against time of the intermediate nodes A and B. The change in bandwidth was less frequent, almost constant bandwidth was used throughout the transmission. After failure of mesh node A at time 100sec bandwidth shows a little fluctuation and after detection of node A at 140sec traffic is transferred to node A after a gap of less than 100sec.This all shows stability in the mesh routing protocol II. In Fig 7.2 we can see bandwidth and jitter plotted against time for the destination node D. Throughout the time of the transmission bandwidth is constant and jitter is almost zero. Jitter and bandwidth show rise in their magnitude only during node failure and node recovery. On analyzing these graphs obtained from performing various performance tests conclude that protocol II is much stable and reliable as compared to protocol II.

7.3 Graphical comparison

In this section we will focus on comparative analysis between protocol II and other all protocols that were tested.

7.3.1 Protocol I

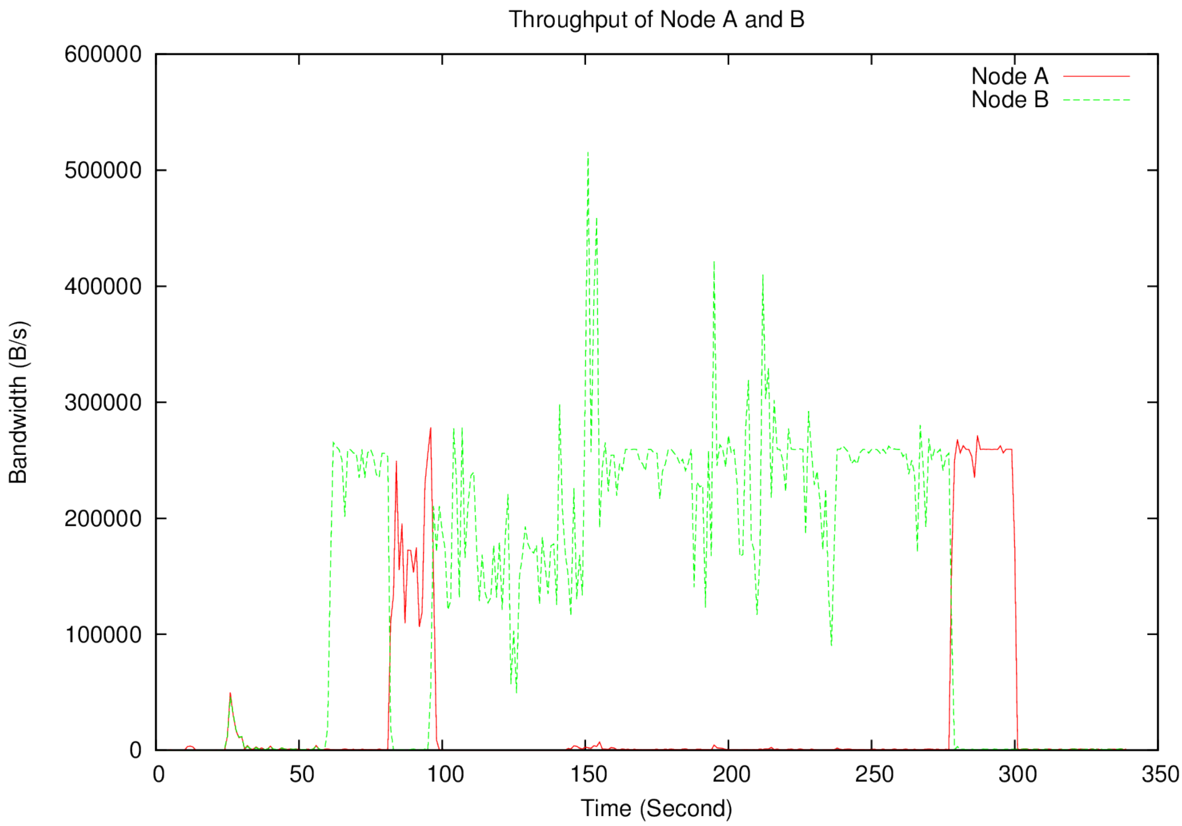

Figure 7.3: Protocol I throughput graph

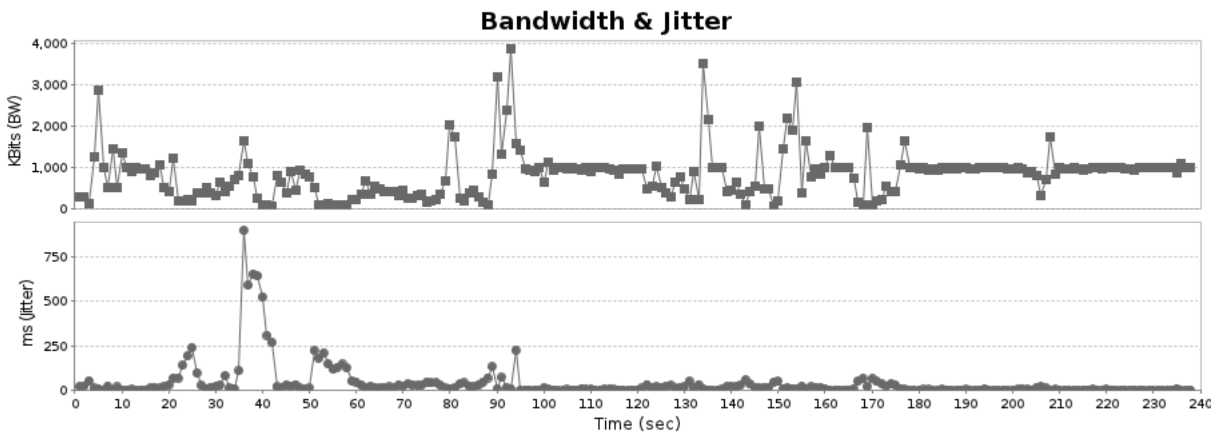

Figure 7.4: Protocol I i-perf server graph

Fig 7.3 gives us a visual of bandwidth varying against time of the intermediate nodes A and B. The change in bandwidth was more frequent and the difference with which bandwidth was changing is greater. After failure of mesh node A at time 100sec bandwidth shows a lot of fluctuation and after detection of node A at 140sec traffic is transferred to node A after a gap of more than 150sec.This all shows instability in the mesh routing protocol I.

In Fig 7.2 we can see bandwidth and jitter plotted against time for the destination node D. Throughout the time of the transmission bandwidth was fluctuating and jitter was in considerable amount.

7.3.2 B.A.T.M.A.N.-ADV

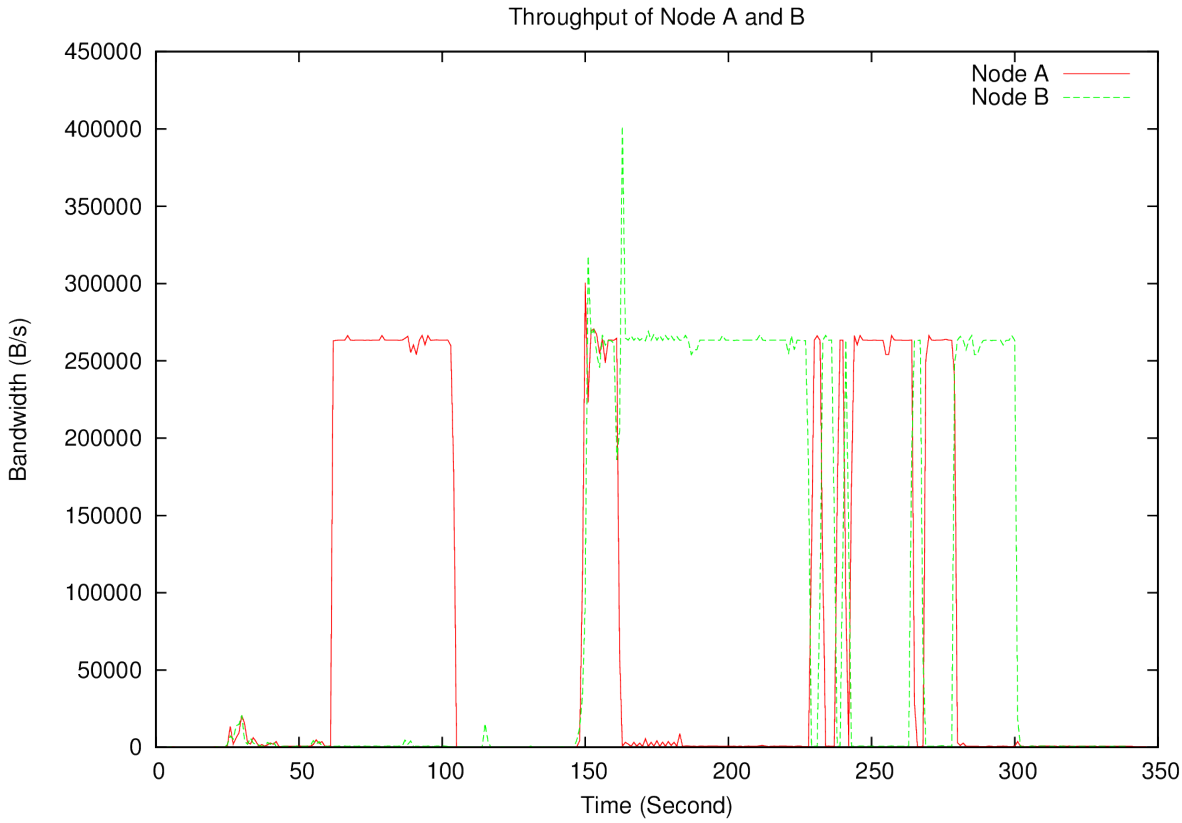

Figure 7.5: B.A.T.M.A.N.-ADV throughput graph

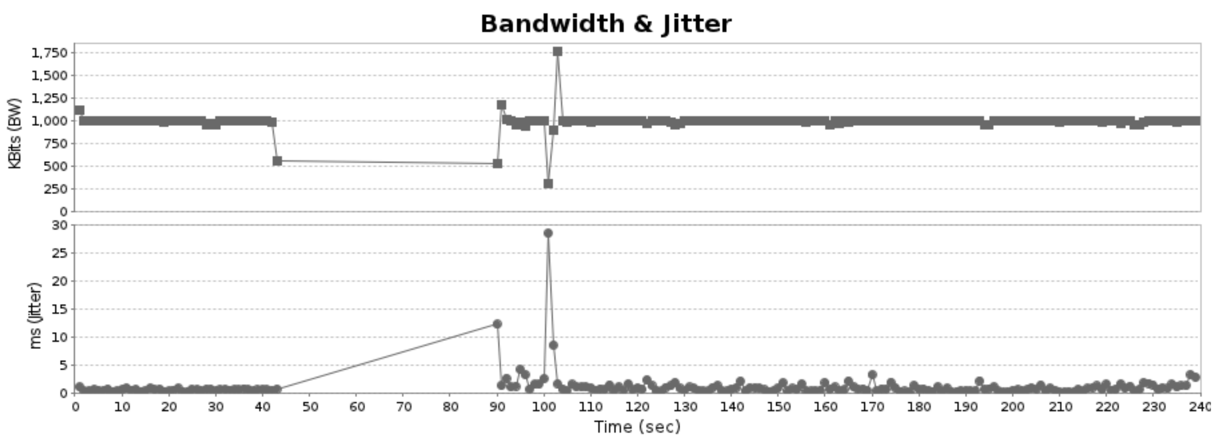

Figure 7.6: B.A.T.M.A.N.-ADV i-perf server graph

Comparing the modified algorithm with the B.A.T.M.A.N.-ADV we observed there was reduction in link switching. More link switching after node recovery in B.A.T.M.A.N.-ADV and less link switching in protocol II shows that protocol II is more reliable as compared to B.A.T.M.A.N.-ADV after node recovery. However it was noticed that the jitter had increased in protocol II as compared to B.A.T.M.A.N.-ADV.

7.3.3 BABEL

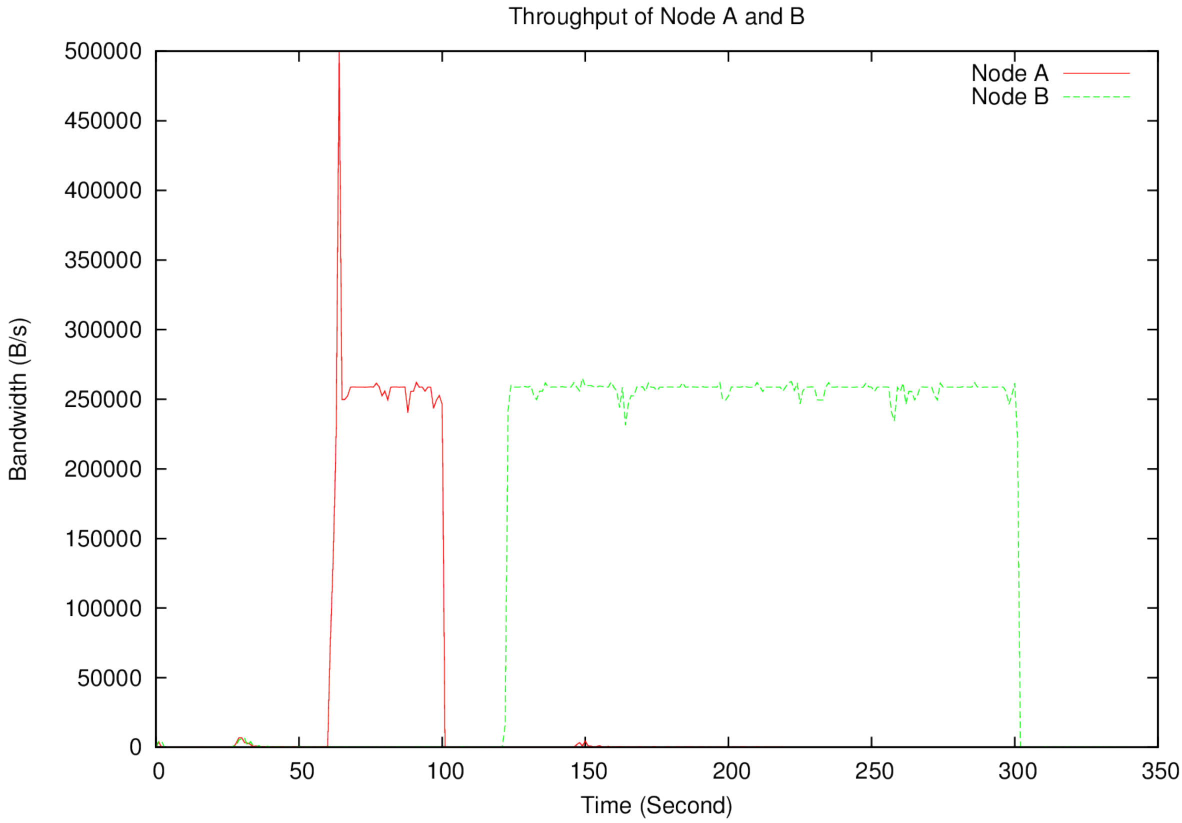

Figure 7.7: BABEL throughput graph

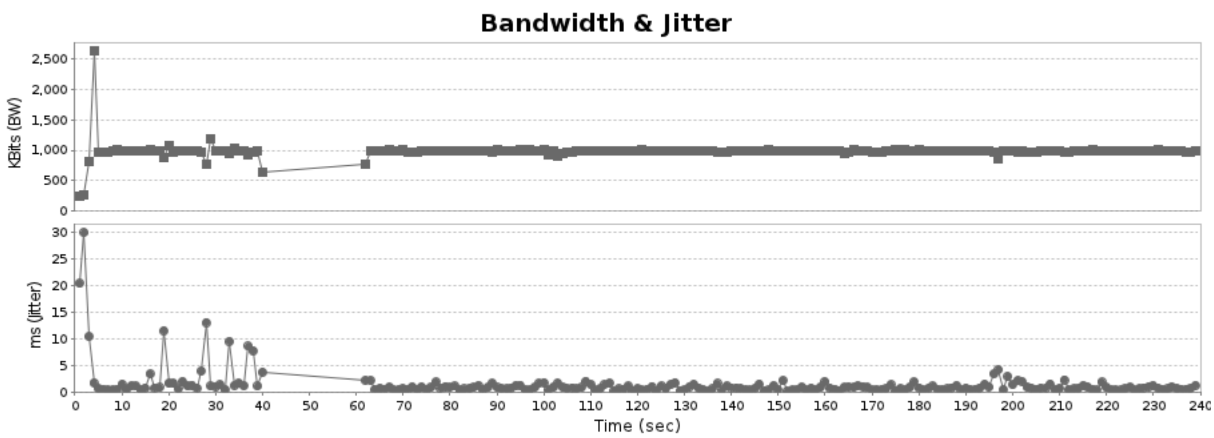

Figure 7.8: BABEL i-perf server graph

Not much improvements were observed in protocol II as compared to babel, but after node failure transmission continues in protocol II where as in babel there is no transmission in network.

7.4 Observed improvements

1. Packet drop ratio has decreased from 16 percent to 11 percent in protocol II.
2. Considerable reduction of jitter is observed, almost no jitter is observed in protocol II as compared to protocol I.
3. Less link switching in Protocol II as compared to B.A.T.M.A.N.-ADV.
4. Less fluctuation in bandwidth and increased reliability and stability.
5. Reduction in out of sequence packets.

Chapter 8

Scheduling

The Gantt chart describes the schedule followed during the implementation of project.

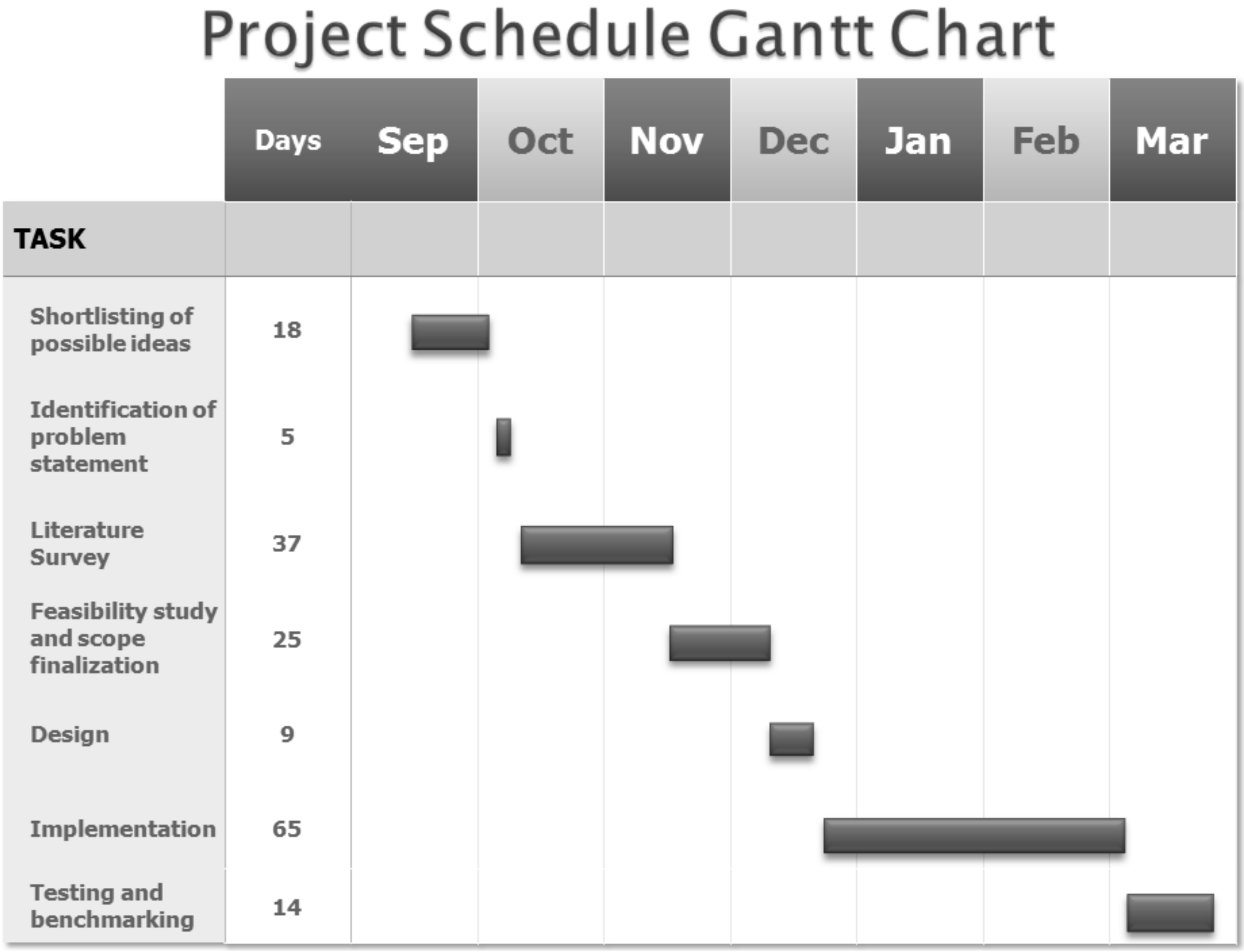

Figure 8.1: Project schedule

The project started with selection of wireless networking as domain and selection of possible ideas in mid-September.

By October there was collaboration with openmesh community on possible project implementations and the problem statement was finalized.This was followed by literature survey up to mid November.

The scope and feasibility of project was decided later followed by design finalization in December.

Actual implementation followed later up to start of March, which was followed by testing and benchmarking.

Chapter 9

Conclusion and Future Scope

9.1 Future Scope

B.A.T.M.A.N.-ADV and BABEL hybrid is an experimental protocol so there is a lot of scope for further modification and improvement. Listed below are some of major concerns which should be implemented in the next version of modified algorithm.

9.1.1 Overhead reduction

Currently our implementation runs both the protocols together with modification in cost metrics. Both the protocol do there own neighbor discovery and keeps sending broadcasts messages. Broadcasting of periodic messages and neighbor discovery is not necessary by both the protocols. Modification needs to done in one of the protocol which will handle neighbor discovery.

9.1.2 Metric tweaks to improve performance

There are a lot of possibilities for improvement in performance of the modified algorithm by making changes in the metrics. We have modified the cost metrics by studying the behavior of variation cost of both the algorithms by carrying out test experiments. An improved metrics can be made by carrying out some more tests and introducing a factor between the cost metrics of both the protocols. Even different metrics can be taken into consideration and studied . This area is limitless for explorations.

9.1.3 Resolution of physical and logical hop problem

B.A.T.M.A.N.-ADV makes a virtual switch to which all the nodes get connected. So in the hybrid all the BABEL nodes recognize every node as its neighbor, but in reality it may not be the case. So this needs to be resolved between the two protocols.

9.2 Conclusion

This research project proposes an approach to combine B.A.T.M.A.N.-ADV and BABEL in an effective way. It also compares both the protocols with and without any modification for a number of parameters. It could also be observed that link switching has been reduced as compared to B.A.T.M.A.N.-ADV. The result of this study suggests that B.A.T.M.A.N.-ADV and BABEL run with the proposed metric modifications outperform B.A.T.M.A.N.-ADV and BABEL run standalone without any metric modification.

Although, significant improvements have been observed over existing approaches the implementation is still not suitable for direct application in real world use case. The experiment has given some insight on how BABEL and B.A.T.M.A.N.-ADV can be improved and these findings should provide the impetus for further experimentation which will better suit for real world.

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