CHAPTER 4

PERFORMANCE ANALYSIS OF PROTOCOL INDEPENDENT MULTICASTING IN HETEROGENEOUS ENVIRONMENT

4.1 INTRODUCTION

Video conferencing is becoming extremely popular in wired and wireless network, efficient utilization of the network bandwidth is important to achieve Quality of Service (QoS). Internet Protocol (IP) multicast is a routing technique that allows IP traffic to be sent from one source or multiple sources and deliver to multiple destinations. Instead of sending individual packets to each destination, a single packet is sent to a multicast group, which is identified by a single IP destination group address.

For multicast sessions to be successful, the network must transport data in these sessions using minimal network resources. A multicast session in the network is established by creating a multicast tree along which the data is transferred. The construction of the tree using specific algorithms is called as multicast routing algorithms. Group applications demand a certain amount of reserved resources to satisfy their QoS requirements such as end-to-end delay, jitter, loss, cost, throughput to name a few (Chen et al 1998). Since resources for multicast tree are reserved along a given path to each destination in a given multicast tree, it may fail to construct a multicast tree to guarantee the required QoS if a single link cannot support the required resources. So, an efficient
multicast communication solution includes a multicast tree construction with the best chance to satisfy resource requirements (Wang et al 2000).

As future networks are anticipated to be heterogeneous networks, upgrades will not be instantaneous due to their sheer size (Internet). Hence heterogeneity is a must, meaning that instead of attempting a solution, networks should be heterogeneously designed. This study investigates such heterogeneous network architectures and the effect of multicasting in such networks.

In this chapter, it is proposed to evaluate the performance of multicasting in a heterogeneous network using Protocol Independent Multicasting Sparse Mode (PIM-SM) under different link scenarios. The network contains both wired and wireless nodes. The Wireless nodes are one hop away from the Access point of the infrastructure based network.

4.2 HETEROGENEOUS NETWORKS

Second-generation mobile communication services have expanded explosively globally from the late 1980’s. Many wireless communication systems like IEEE 802.11a/b wireless LAN, Bluetooth, IMT-2000, and Fixed Wireless Access (FWA) systems today provide easy internet access for improved communication. There are many digital communication systems independently designed, implemented, and operated to meet mobility, data rates and services mobility. Some provide services at specific locations thereby creating a heterogeneous wireless environment in overlaid service areas. Seamless heterogeneous wireless systems integration is expected to use in a wireless communications industry revolution affecting vendors, service/application/context providers, policy makers, and users.
Wireless communications advances expanded application possibility from simple voice services in early cellular networks (first and second generation, 1G and 2G) to new integrated data applications. IEEE 802.11 family based wireless LANs (WLANs) are currently popular due to the possibility of high data rates at low cost. WLAN access points (APs) ensure hotspot connectivity at airports, hotels, shopping malls, schools, university campuses, and homes. Future advances in Software-Defined Radio (SDR) and possibly cognitive radio technologies will make multi-interface, environment-aware, multimode, and multiband communication devices very common.

An integrated heterogeneous environment enables users access specific networks based on applications and types of radio access networks (RANs) available (cellular network, WLAN, wireless personal area network (WPAN)). For example, in a scenario where a user downloads a large video file through multimode phone cellular interface, availability of higher-data-rate and lower-cost connection through home IEEE 802.11b ensures that the connection automatically switches over from cellular network to home AP. Automatic connection and seamless network migration for a single call can be anticipated in the future.

The beginning in providing efficient data services is by integrating WLANs (e.g., IEEE 802.11a/b/g and HiperLAN/2), wireless WANs, WPANs (e.g., Bluetooth, 802.15.1/3/4), and wireless MANs (e.g., IEEE 802.16) through the observance of a common one-hop (single-hop or infrastructure) operation mode, by which users access a system via a Base Station (BS)/AP connected to wired infrastructure. The next step extend this to multi-hop communication environment through a MANET which includes wireless devices serving as routers. Router connectivity may change frequently in a MANET leading to the multihop communication paradigm which allows
communication without BS/AP, and includes provision of alternative connections inside hotspot cells. Although MANET devices communicate through WLAN/WPAN interfaces, multihop operations include many associated issues, not considered in single-hop operation mode. So, MANETs and WLANs/WPANs which operate in single-hop mode should be differentiated in integrating solutions designs.

![Heterogeneous networks architecture of this work](image)

**Figure 4.1 Heterogeneous networks architecture of this work**

Figure 4.1 shows a heterogeneous network consisting of wired nodes communicating via router and to the wireless side using gateway. The wireless nodes are either one hop nodes or multi hop to reach the gateway. The end to end delay in the wireless side is higher than the wired side.
4.3 PROTOCOL INDEPENDENT MULTICAST SPARSE MODE

PIM-SM (Fenner et al 2002) has been designed as a multicast routing protocol for a sparsely populated network. The definition of a region as sparse requires any of the following conditions to be true (Paul 1998):

- The number of networks/domains with members is smaller than the total number of networks/domains in a region.
- Group members are widely distributed.
- The overhead of flooding all the networks with data followed by pruning networks with no members in them is significantly high.

In addition, the groups are not necessarily small and hence dynamic alteration of the groups with a large number of members must be supported.

The features of PIM-SM design include (Paul 1998):

- Low-latency data distribution if the application requires low end-to-end delay;
- Independent of the underlying unicast routing protocol;
- Inter-operability with other multicast routing protocols, like DVMRP or CBT;
- Robustness - avoiding single point of failure, and to adapt gracefully to changes in network topology; and,
- Scalability - the control message overhead should not exceed a certain percentage of the link bandwidth, irrespective of the size or distribution of the group.
To satisfy the above design requirements, PIM-SM supports both shared tree and the shortest path trees. PIM-SM uses the concept of a central node for a multicast group, like CBT. The central node in PIM-SM is called the Rendezvous Point (RP). A unique RP for each group is determined based on the multicast group address. The selection of the RP is done by a router that is called the BootStrap Router (BSR). The BSR is dynamically elected within a PIM domain.

![Shared RP tree in PIM-SM](image)

**Figure 4.2 Shared RP tree in PIM-SM**

In PIM-SM, the routers responsible for managing group membership in the leaf subnets are called the Designated Routers (DRs). When any receiver wants to join the multicast group, its DR sends an explicit
“join” request to the RP. The join message is processed by all the routers between the receiver and the RP; the routers save the state information for the group. Thus a branch of the multicast tree for the new member is set up as seen in Figure 4.2.

The “Join” message for new receiver is sent by its DR towards the RP till it reaches an on-tree router. The DR for source S initially unicasts encapsulated packets to the RP, which de-capulates the packets and forwards them to all receivers along the shared tree.

When a sender wants to multicast to a group, its DR initially encapulates the data packets and unicasts them to the RP, which then forwards the de-capulated data packets to the receivers along the shared multicast tree (Figure 4.2).

![Figure 4.3 Source-specific shortest-path tree in PIM-SM](image-url)
If the sender’s traffic increases beyond a pre-determined threshold, then the shortest path tree is created rooted at the sender. All the routers on the shared tree between the RP and the receivers send a “join” message towards the source and a ”prune” message towards the RP, thereby creating the source-rooted SPT as shown in Figure 4.3.

The RP itself joins the SPT. Once the source-rooted tree is created, the source forwards the data packets along the SPT, and not the RP-Rooted Shared Tree (RPT). The RP continues to receive a copy of the multicast data packet (in native format), and forwards the packet along the shared RP tree. This is done because there might still be receivers who are receiving from the shared tree. It also ensures that new receivers who join the group are able to receive data packets for the group till the time they switch to the SPT.

All the receivers switch to the shortest path tree when the data rate of the source exceeds a threshold. The RP also receives the data packets in native format from the shortest-path tree.

The PIM-SM forwarding uses RPF check on the incoming interface to trace looping packets. The unicast routing information is derived from the unicast routing tables, independent of the unicast routing protocol that constructed them. PIM-SM uses “semi-soft” states - the state information in each on-tree router has to be periodically refreshed (by sending join/prune message for each active entry in the PIM routing table). The periodic messages can reflect changes in topology, state or membership information. If the periodic update message is not received from a downstream router within the pre-set timeout period, the state entry is deleted from the upstream router’s local memory. Since the state information is periodically refreshed, PIM-SM does not need an explicit tear down mechanism to remove state when a group ceases to exist.
PIM-SM is a complex routing protocol; the amount of detail in the operation of the protocol is extensive. It creates large routing tables and requires significant memory at the routers to store the multicast state. The complexity of processing at the routers is also high. However, the protocol has many attractive features such as fast join to the multicast tree, low latency for high data rate sources, robustness to loops and node failures that have led to its wide deployment.

### 4.4 EXPERIMENTAL SETUP

The experiments are carried out in a heterogeneous network consisting of both wired and wireless nodes. The wireless nodes are one hop away from the Access point of the infrastructure based network. OPNET was used for the experimental setup.

Figure 4.4 IP Statemachine wireless node
OPNET is a versatile simulation tool to model devices in the network, protocols and architectures. Using OPNET it is possible to simulate the performance of the designed network. OPNET uses state machine diagram to represent the simulation process. Figure 4.4 shows the state machine diagram of the wireless node’s Internet Protocol (IP).

The node designed is capable of handling multicast traffic using the ip_dispatch_handling routine.

Figure 4.5  UDP Statemachine of router

Figure 4.5 shows the state machine of the router and Figure 4.6 shows the state machine diagram of the intermediate router. It is seen from Figure 4.6, the router monitors the node’s state connected to it. The router is capable of maintaining and monitoring the routing table and the link status.
Figure 4.6 Statemachine for intermediate router

Figure 4.7 shows the overall state machine diagram of the gateway capable of handling wired and wireless node’s.

Figure 4.7 Statemachine of the gateway

Simulations are conducted using varying number of senders and are varied from 1, 5, 10, 20, 30, 40 and 50 senders. The number of receivers is 30 to 60 nodes and consists of a combination of both wired and wireless nodes. The combination of the wired and wireless nodes for which the simulations were conducted as follows:
Network without wireless one hop group members

Number of wireless single hop members = 0.5 x number of wired group members

Number of wireless single hop members = 2 x number of wired group members

Network with only one hop group members

The performance of the heterogeneous network is studied in the terms of Packet Delivery Ratio (PDR), End to End delay and Jitter.

4.5 RESULTS AND DISCUSSION

Simulations were carried out to compare the performance of data transmission for multicasting on the basis of PDR, end to end delay and jitter. Simulation results are shown in Table 4.1.

Table 4.1 Performance of the network with all receivers in wired side of heterogeneous network and without wireless one hop group members

<table>
<thead>
<tr>
<th>Number of senders</th>
<th>Avg PDR</th>
<th>End to End delay in second</th>
<th>Jitter in second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9861</td>
<td>0.0072</td>
<td>0.000221</td>
</tr>
<tr>
<td>5</td>
<td>0.9433</td>
<td>0.0089</td>
<td>0.000258</td>
</tr>
<tr>
<td>10</td>
<td>0.9104</td>
<td>0.0134</td>
<td>0.000286</td>
</tr>
<tr>
<td>20</td>
<td>0.9027</td>
<td>0.0162</td>
<td>0.000294</td>
</tr>
<tr>
<td>30</td>
<td>0.8985</td>
<td>0.0178</td>
<td>0.000304</td>
</tr>
<tr>
<td>40</td>
<td>0.8746</td>
<td>0.0216</td>
<td>0.000365</td>
</tr>
<tr>
<td>50</td>
<td>0.8618</td>
<td>0.0274</td>
<td>0.000382</td>
</tr>
</tbody>
</table>
Figure 4.8 Packet delivery ratio with only wired nodes

From Figure 4.8 it can be seen that as the number of sender increase, the throughput starts decreasing linearly with the PDR reducing by 14.42% when the number of sender in the group is about 50 compared to a single sender in the group.

Figure 4.9 End to end delay
Figure 4.9 shows the end to end delay. Though the variation is about 28% between one sender and 50 senders, the QOS does not get affected as 27.4ms delay does not affect even multimedia traffic. Figure 4.10 shows the jitter in the network.

Figure 4.10  Jitter with all receivers in wired side of heterogeneous network

Table 4.2  Performance of the Network with the Number of wireless single hop members = 0.5 x number of wired group members

<table>
<thead>
<tr>
<th>Number of senders</th>
<th>Avg PDR</th>
<th>End to End delay in second</th>
<th>Jitter in second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9674</td>
<td>0.0103</td>
<td>0.000417</td>
</tr>
<tr>
<td>5</td>
<td>0.9401</td>
<td>0.0126</td>
<td>0.000458</td>
</tr>
<tr>
<td>10</td>
<td>0.9005</td>
<td>0.0262</td>
<td>0.000462</td>
</tr>
<tr>
<td>20</td>
<td>0.8942</td>
<td>0.0286</td>
<td>0.000498</td>
</tr>
<tr>
<td>30</td>
<td>0.8145</td>
<td>0.0302</td>
<td>0.000517</td>
</tr>
<tr>
<td>40</td>
<td>0.8021</td>
<td>0.0312</td>
<td>0.000568</td>
</tr>
<tr>
<td>50</td>
<td>0.7968</td>
<td>0.0368</td>
<td>0.00061</td>
</tr>
</tbody>
</table>
When 50% of the nodes are one hop wireless nodes, the PDR decreases by 1.93% in the case of single sender compared to a network with only wired nodes. However when the number of senders increases to 50, the PDR difference between wired network and heterogeneous network with 50% of nodes being wireless is 8.15%. It can be seen that the PDR starts decreasing as the number of senders increase. Similarly within the heterogeneous network the PDR decreases by 21.41% when the number of sender is increased from 1 to 50. This is illustrated in Figure 4.11.

![Graph](image)

**Figure 4.11 Average packet delivery ratio**

The end to end delay is shown in Figures 4.12. Compared to network without one hop nodes the end to end delay increases by 10.2% in the case of heterogeneous network when the number of senders in the network is 50. Since the maximum end to end delay is 36.8 ms, the QoS of the packet is not affected even if the data is of multimedia in nature.
Figure 4.12 End to end delay

Figure 4.13 shows jitter and it can be seen that the jitter increases by 46.28% when the number of senders increase from 1 to 50. The increase in jitter is linear across the number of senders.

Figure 4.13 Jitter with Number of Wireless single hop members=0.5 x number of wired group members
Table 4.3 shows the third scenario of the experiment. Experiments were carried out with the number of senders increased from one to fifty.

Table 4.3  **Performance of the network with number of wireless single hop members = 2 x number of wired group members**

<table>
<thead>
<tr>
<th>Number of senders</th>
<th>Avg PDR</th>
<th>End to End delay in second</th>
<th>Jitter in second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9576</td>
<td>0.0121</td>
<td>0.00048</td>
</tr>
<tr>
<td>5</td>
<td>0.9331</td>
<td>0.0227</td>
<td>0.000562</td>
</tr>
<tr>
<td>10</td>
<td>0.8988</td>
<td>0.0284</td>
<td>0.000594</td>
</tr>
<tr>
<td>20</td>
<td>0.8342</td>
<td>0.0317</td>
<td>0.000735</td>
</tr>
<tr>
<td>30</td>
<td>0.7963</td>
<td>0.0387</td>
<td>0.000793</td>
</tr>
<tr>
<td>40</td>
<td>0.7584</td>
<td>0.041</td>
<td>0.000834</td>
</tr>
<tr>
<td>50</td>
<td>0.7642</td>
<td>0.0463</td>
<td>0.000892</td>
</tr>
</tbody>
</table>

When two third of the nodes are one hop wireless nodes, the PDR decreases by 2.976% in the case of single sender compared to a network with only wired nodes. However when the number of senders increases to 50, the PDR difference between wired network and heterogeneous network with 33% of nodes being wireless is 12.77%.

It can be seen that the PDR starts decreasing as the number of senders increase. Similarly within the heterogeneous network the PDR decreases by 25.30% when the number of sender is increased from 1 to 50. This is illustrated in Figure 4.14.
End to end delay is shown in Figures 4.15. Compared to network without one hop nodes the end to end delay increases by 25.8% when the number of senders in the network is 50.
Figure 4.16 Jitter for number of wireless single hop members = 2 x number of wired group member

Figure 4.16 shows the jitter and with the increase in the number single hop members the jitter starts increasing as the number of senders increases beyond 20.

Table 4.4 shows the performance of PIM-SM with only one hop nodes connected via gateway.

Table 4.4 Performance of the network with only one hop group members

<table>
<thead>
<tr>
<th>Number of senders</th>
<th>Avg PDR</th>
<th>End to End delay in second</th>
<th>Jitter in second</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9521</td>
<td>0.0218</td>
<td>0.000872</td>
</tr>
<tr>
<td>5</td>
<td>0.9287</td>
<td>0.0287</td>
<td>0.000882</td>
</tr>
<tr>
<td>10</td>
<td>0.8973</td>
<td>0.0304</td>
<td>0.000985</td>
</tr>
<tr>
<td>20</td>
<td>0.7846</td>
<td>0.0392</td>
<td>0.001001</td>
</tr>
<tr>
<td>30</td>
<td>0.7622</td>
<td>0.0417</td>
<td>0.001087</td>
</tr>
<tr>
<td>40</td>
<td>0.7187</td>
<td>0.0463</td>
<td>0.00112</td>
</tr>
<tr>
<td>50</td>
<td>0.6953</td>
<td>0.0498</td>
<td>0.001432</td>
</tr>
</tbody>
</table>
When all the nodes are one hop wireless nodes, the PDR decreases by 3.57% in the case of single sender compared to a network with only wired nodes. However when the number of senders increases to 50, the PDR difference between wired network and heterogeneous network is 23.95%. This becomes significant and shows PIM-SM is not ideally suited for wireless network. This is illustrated in Figure 4.17.

**Figure 4.17 Average packet delivery ratio**

**Figure 4.18 End to end delay**
Figure 4.19 shows the jitter for the various senders. The jitter is within the QOS parameters for multimedia traffic.

![Jitter Network with only one hop group members](image)

**Figure 4.19 Jitter Network with only one hop group members**

Similarly within the one hop wireless network the PDR decreases by 69.53% when the number of sender is increased from 1 to 50. However the end to end delay is within the QoS parameter values as shown in Figure 4.18.

### 4.6 CONCLUSION

To evaluate the performance of the multicasting in a heterogeneous network using Protocol Independent Multicasting Sparse Mode (PIM-SM) under different link scenarios is proposed in this chapter. The network contains both wired and wireless nodes. The Wireless nodes are one hop away from the Access point of the infrastructure based network. It is seen that performance of real time streaming is not affected by nodes using wireless network in the last mile. Further work needs to be done to measure the QoS in networks consisting of MANET connected to Legacy wired system using gateway with PIM-SM on the wired network side and MAODV on the MANET side.