In chapter 3 we used the scyther tool to verify our proposed security scheme. In 2007 Cas Cremers developed a protocol verification tool named Scyther [137, 138]. The main aim of developing this tool is for the formal analysis of protocols in which the cryptographic protocols are analyzed on the security properties (usually variants of authenticity and confidentiality). Unless and until an attacker does not know the decryption, key he cannot steal the information from encrypted message. Thus perfect cryptography is assumed by this tool. In Scyther security properties of a protocol are specified by the claims and role based depiction of protocol is the input of Scyther. Claims in scyther can be classified as form claim (Parameter, Principal, Claim) where security property is tartan for the term Parameter, Principal is User’s name and Claim is another security Property (for instance ‘secret’). Security Protocol description language (SPDL) is the language in which the protocol’s description is written. There are three ways in which we can use scyther to verify a protocol [137, 138].

- Verification Claim: Security properties can be verified or falsified using Scyther.
- Automatic Claims: If Security properties are not specified by a user as Claim Event then Scyther generates and verifies claims automatically.
- Characterization: Characterization of each protocol can be done using Scyther.
We wrote our proposed security scheme in SPDL language and then did the formal analysis of the scheme using scyther tool. Figure 27 shows the result of formal analysis of proposed security scheme and the proposed scheme was run for 30 rounds and result clearly shows that the scheme is verified and no attacks can be done to steal the information.

In Chapter 4 for simulation purpose we developed a WiMAX Network with four ASN gateways which are connected with a Base Station. 10 mbps link is used for the connection and constant bit rate is used as our traffic model as depicted in Figure 28. Four new MSs will arrive at every BS in a second. The maximum number of MSs is 1200 in the said network. To model the mobile stay time we used exponential distribution whose means are from 5s to 100s which shows that mean of mobile stay time for MS is generated randomly from [5, 100]. To make a decision that which ASN gateway will be visited by an MS we use uniform distribution.
We recorded the time taken by every mobility method for handover procedure and also observed the load on every ASN gateway and then a comparison was made between AMST based relocation and other available relocation methods. Following are the other methods with which we compared the performance:

- **Proper C3 Mobility Method**: In this type of mobility for inter ASN handover an MS always executes the CSN connected mobility.
- **Proper C4 Mobility Method**: In this type of mobility for inter ASN handover an MS always executes the ASN connected mobility and thus no gateway relocation is executed by the ASN gateway.
- **Predictive Relocation Method [135]**: Authors of [135] had proposed an algorithm in which an MS executes ASN connected mobility for inter ASN handover and if the load on the gateway increases it performs the predictive gateway relocation to get rid of the load.

Experimental parameters are shown in Table 5
Table 5 Experimental Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter handover inter arrival time of MS</td>
<td>1 sec</td>
</tr>
<tr>
<td>Number of MSs</td>
<td>1200</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.70</td>
</tr>
<tr>
<td>$P_{th}$</td>
<td>6</td>
</tr>
<tr>
<td>$L_H$</td>
<td>0.70</td>
</tr>
<tr>
<td>$L_M$</td>
<td>0.55</td>
</tr>
<tr>
<td>$L_L$</td>
<td>0.40</td>
</tr>
<tr>
<td>Detection Interval of MS</td>
<td>5 sec</td>
</tr>
</tbody>
</table>

The Load on each ASN gateway is shown in Figure 29, Figure 30, Figure 31 and Figure 32.

Figure 29 ASN Gateway 1 Loading
Figure 30 ASN Gateway 2 Loading

Figure 31 ASN Gateway 3 Loading
Among all the mobility methods the Proper C4 Mobility puts heavy load on the ASN gateway because it does not perform the relocation of connected MSs to release the load from the gateway. However, the load on an ASN gateway is very low in the case of Proper C3 Mobility because in this MSs always change the connected ASN gateway and thus the serving gateway and connected gateway are same for MSs. Authors of [20] proposed predictive gateway relocation in which MSs perform gateway relocation whenever the load on gateway increases but in this case the load on the gateway is very fluctuating and it goes up and down frequently and thus it is not stable. Now consider the case of AMST based gateway relocation scheme proposed by us which clearly shows that the load on ASN gateway is lower than that of the predictive gateway relocation method and variance of the load on ASN gateway is also lower than the predictive relocation method. Hence the gateway relocation based on AMST method is more stable than that of the predictive method.

During simulation the delay time for relocation and handover procedure is shown in Figure 33.

Figure 32 ASN Gateway 4 Loading
No relocation is performed by the C4 mobility method and thus it does not take time for relocation and the delay time will be smallest in this method. The largest delay time is in the C3 mobility method because movement of MSs will always trigger the relocation. AMST based mobility method has suitable strategy for relocation due to which unnecessary relocation can be avoided and thus it has the smaller delay time than that of the predictive method.

The relation between serving mobile station and ASN gateways average throughput is shown in Figure 34. If we compare all four methods we found that Proper C3 Mobility achieves the highest average throughput. When the number of mobile stations increases from 200 than Proper C4 Mobility’s average throughput falls significantly because ASN gateway is overloaded. The average throughput of the AMST based mobility is better than that of predictive mobility method.
Figure 34 ASN Gateway’s Average Throughput vs Serving MSs

Figure 35, Figure 36, Figure 37 and Figure 38 shows the mean and variance of load on each ASN Gateway for different mobility methods.

Figure 35 Load’s Variance and Mean in Proper C3 Mobility on every ASN Gateway
Figure 36 Load’s Variance and Mean in Proper C4 Mobility on every ASN Gateway

Figure 37 Load’s Variance and Mean in Predictive based Mobility on every ASN Gateway
Proper C4 Mobility method has the highest mean and variance for load whereas the Proper C3 Mobility method has the least mean and variance for load. AMST based mobility method has lower mean load for ASN Gateway in comparison to the Predictive Method of Mobility. Predictive method has an unstable load due to a fact that a proper strategy was not used to perform the relocations. Hence, the load variance of ASN Gateway is high in Predictive Method. The load variance of ASN Gateway is low with the use of AMST based mobility method and it is very near to the load variance of ASN Gateway with Proper C3 Mobility Method.

When MS switches between two ASN gateways frequently (Switching Phenomenon) a C3 channel between ASN gateway and CSN will be created with short lifetime. The average C3 channel lifetime will be very short if switching phenomenon occurs seriously. Figure 39 shows the average C3 channel lifetime for the relocation in four mobility methods.

Figure 38 Load’s Variance and Mean in AMST based Mobility on every ASN Gateway
No relocation is performed in the Proper C4 Method, thus the average C3 channel lifetime is extremely high in it and MSs never change their connected ASN Gateways and hence no switching phenomenon occurs. If we see the case of Proper C3 mobility method the average C3 channel lifetime is shortest as switching phenomenon occurs seriously in it. In the case of predictive mobility method switching phenomenon occurs as this method does not choose the suitable MS for relocation. In AMST based mobility method the C3 channel lifetime is longer than that of predictive because our method can choose proper MS strategically to perform relocation. MSs connect at the ASN Gateway where they have large AMST. Result of average C3 channel lifetime in AMST based method shows that C3 channel will be utilized longer and it can avoid switching phenomenon also.

Delay time in handover and relocation is shown in the Figure 40. The longest delay time is in proper C3 method due to a fact that whenever MS moves between ASN Gateways, relocation is always triggered by them. Proper C4 mobility has the shortest delay time as it does not perform any relocation. There is shorter time delay in AMST based mobility method than Predictive method because a proper strategy is implemented in it for relocation and thus it avoids unnecessary relocations.
Handover and Relocation Delay in Mobility Methods

![Handover and Relocation Delay in Mobility Methods](image)

**Figure 40** Handover and relocation delay in mobility methods.

Figure 41, Figure 42, Figure 43 and Figure 44 shows the average number of Mobile Stations on each ASN Gateway. Both connected and serving MSs are included in the number.

Average Number of MSs in Proper C3 Mobility Method on every ASN Gateway

![Average Number of MSs in Proper C3 Mobility Method on every ASN Gateway](image)

**Figure 41** Average Number of MSs in Proper C3 Mobility Method on every ASN Gateway
Figure 42 Average Number of MSs in Proper C4 Mobility Method on every ASN Gateway

Figure 43 Average Number of MSs in Predictive based Mobility Method on every ASN Gateway
Between all the four mobility methods the Proper C4 mobility method has the largest average number of MSs because it does not perform any relocation. On the other hand Proper C3 mobility method has the least average number of MS because it does not have any connected MS. The AMST based mobility method has lesser average number of mobiles than predictive mobility method because predictive mobility method only uses ASN connected mobility whereas AMST can choose suitable mobility method according to the load on ASN Gateway for relocation.

### 5.1 WiMAX Scenario

Figure 45, Figure 46, Figure 47 and Figure 48 shows the scenario of WiMAX network created in Qualnet.
Figure 45 WiMAX Scenario

Figure 46 WiMAX Scenario cntd
Figure 47 WiMAX Scenario cntd

Figure 48 WiMAX Scenario cntd
5.2 Survey regarding Deployment of WiMAX at BSNL Rohtak

BSNL Rohtak has deployed the WiMAX technology to provide the wireless broadband services to its subscribers. They only offer the fixed wireless broadband services to the users which do not offer the mobility. Only one BS is deployed at the roof of the BSNL head office of Rohtak which covers an area of around 10 Kms. The BS is provided by the Huawei Company and height of the tower is around 60 meters. Customer Premise Equipment is deployed at the subscriber’s premise which receives the signal sent by the BS. Free Spectrum is used by the WiMAX at BSNL Rohtak. Following are some of the merits and demerits of the WiMAX as told by the Sub Divisional Engineer:

Merits:

- Hundreds of users can be served with a single station.
- Deployment of new users is very fast as compared to wire networks.
- With Line of Sight users can get a speed around 10 Mbps within a radius of 10 Kms.
- WiMAX is standardized and thus equipments of same operating frequencies from different vendors can work together.

Demerits:

- For subscribers at a long distance needs Line of Sight.
- The signals can be interrupted by bad weather conditions.
- Interference can be caused by the other wireless equipment.
- It requires a strong electrical equipment as it is a power intensive technology.
- Very costly to install and operate.