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Load Stabilization and Minimization of Handover Delay in IEEE802.16

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Abstract

To reduce the packet loss and handover delay IEEE 802.16 standard has described two layered mobility management. When a Mobile station moves between the Access Service Networks (ASN) and Base Stations in End to End WiMax Communication network then to minimize the handoff latency ASN connected mobility is adopted by the MS. But this process will increase the load heavily on ASN Gateway. Hence to reduce the load from gateway, relocation of gateway for connected gateway will be required. The standards only describe the procedures of the gateway relocation but they do not describe that when should gateway relocation be performed and how many number of Mobile Stations should be relocated. This problem is left for the researchers and service providers. In the article we will propose an algorithm based on average mobile stay time (AMST) in which a decision will be taken for the number of mobile stations to be relocated and to determine the appropriate time for the gateway relocation so that the load and handover delay can be reduced from ASN gateway.

Keywords: WiMax, IEEE802.16, ASN Gateway, Mobility, Resource management

INTRODUCTION

World Wide Interoperability Microwave Access is the full form of WiMax which is used to provide the Wireless Broadband internet services for an area of 40 to 50 miles. WiMax is defined by the IEEE 802.16 standard [1]. With time the Wimax Forum [2] made some amendments in the standard and one of them is IEEE 802.16e which provides the mobility to the subscribers at vehicular speeds. The Wimax Architecture standardizes only two layers i.e, MAC (media Access Control) Layer and PHY (Physical Layer), thus higher layers will be required to fabricate the complete system. WiMax Forum had proposed a communication network architecture which is also known as End to End WiMax Network Architecture [3][4]and it is shown in Fig 1. The main constituents of this architecture are CSN (Connectivity Service Network), ASN (Access Service Network), BS (Base Stations) and MS (Mobile Stations). There may be one or more ASN Gateways and BSs in an ASN and the main task of the ASN is to facilitate Wimax subscribers with wireless radio access. IP (internet Protocol) communication services are provided by the CSN and these are connected with ASNs. Wimax Forum has chosen MIP (Mobile IP) [5] to maintain IP Mobility. The location of the MS's HA (Home Agent) is in the CSN and MS's HNSP (Home Network Service Provider) is responsible to operate that. The location of FA (Foreign Agent) is in ASN gateway and its functionality is also supported by ASN gateway.

ASN mobility and CSN mobility are the two types of mobility management methods which are described by the Wimax Forum for End to End WiMax Network Architecture. Some procedures will be required when an MS moves between BSs and ASNs and it does not change the Communication Reference Point C3, and those procedures are referred by ASN connected mobility management. Mobile IP is adopted by the CSN connected mobility management to construct new C3 between latest ASN gateway and CSN. Both kind of mobility are shown in Fig1. Now let us assume that an MS wants to establish a connection to WiMax Communication Network and needs to access some web server also known as Correspondent Node (CN), thus in beginning a connection will establish between MS, BS-1, ASN Gateway-1, CSN and CN. We will name it as Data Flow 1 in Fig 1.

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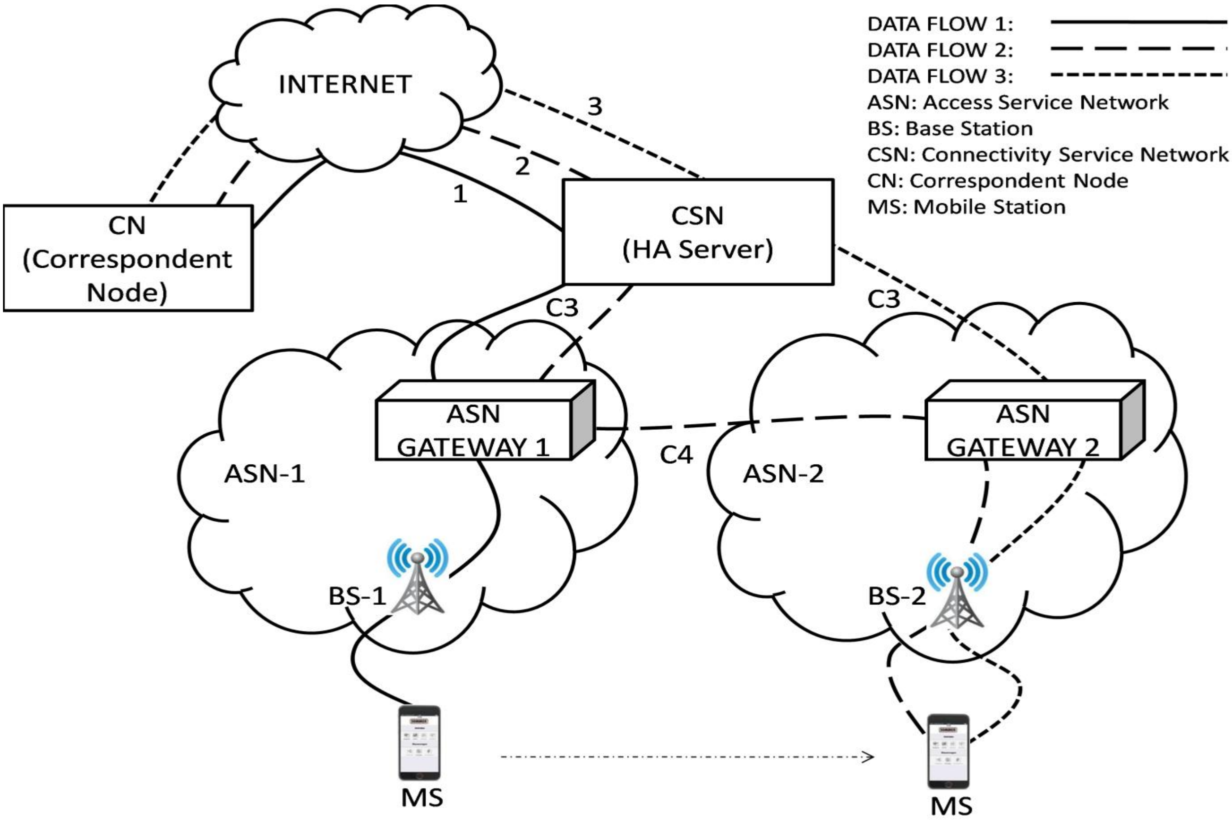

Figure 1: ASN connected and CSN connected Mobility in WiMax

In this scenario there can be two types of handover, one is intra ASN handover and other is inter ASN handover. Intra ASN handover means when there is a movement of an MS between BSs within ASN, and Inter ASN handover means when MS moves from one ASN to another ASN. Now suppose MS does an inter ASN handover and it does not prefer CSN connected mobility then Mobile IP will not be utilized and a data channel will establish between ASN gateway-1 and ASN gateway-2. ASN gateway-1 will be referred as connected ASN gateway and ASN gateway-2 will be referred as serving ASN gateway. Now a new connection will establish between MS, BS-2, ASN gateway-2, ASN gateway-1, CSN and CN. We represent this connection as Data Flow 2. Thus the Original Channel in C3 is still maintained between ASN gateway-1 and CSN. Hence, Handover Latency could be reduced by adopting this method but end to end delay might be longer. Now consider that many MSs got connected with ASN gateway-1 then load on this gateway would become very heavy and thus at some point ASN gateway Relocation must be performed by the system. ASN gateway relocation means that some of the MSs require performing the CSN connected mobility thus creating a new connection (Data Flow 3) between MS, BS-2, FA of ASN Gateway 2, HA of CSN to CN. A new data channel will establish between ASN gateway-2 and CSN in new C3 and thus ASN gateway-1 will not serve the MS. The old Data Channel between ASN gateway-1 and CSN in C3 is now removed. Thus Data Flow 2 is considered as ASN connected mobility and Data Flow 3 is considered as CSN connected mobility.

Consider a scenario in which MS performs CSN connected mobility during every inter ASN handover in which MS moves from ASN-1 to ASN-2 and the movement of MS is for a short period of time means the MS moves from ASN-1 to ASN-2 and stays in ASN-2 for a very short period and comes back to ASN-1 and stays there for a longer duration. In this scenario MS performs CSN connected mobility twice but it stills attached with ASN gateway-1 in the end. Thus the communication channel created between ASN gateway-2 and CSN is utilized by MS for a very short duration and if it performs ASN connected mobility the communication channel between ASN gateway-1 and CSN is always utilized. Thus performing ASN connected mobility is better in this scenario because in ASN connected mobility the handover delay and overhead is less than the CSN connected mobility. Now if the ASN connected mobility handover is performed by the MS than it remains connected to the older gateway and thus the number of MSs will not reduce and the load on the older gateway keeps on increasing. In this condition gateway relocation must be performed by the system. Thus the main problem is that when to perform the gateway relocation by the system as Wimax standard only defines the methods of gateway relocation and a decision should be taken that which MS should perform gateway relocation and how many number of MSs should be relocated. Another problem is that which type of mobility should be preferred ASN or CSN connected mobility whenever an MS performs the inter ASN handover.

For above said problems we will propose an AMST based algorithm in this article to choose appropriate mobility scheme and to decide when should gateway relocation be performed and which MS will perform it and how many number of MSs be relocated to reduce the load and handover latency from ASN gateway.

LITERATURE SURVEY

The basic outline of WiMax architecture and its technology has been presented by the authors of [6][7]. Various optimization methods for ASN connected mobility and the implementation of mobility management in WiMax has been discussed in [8]. They also discussed how the delay caused by handover is reduced by extending the data path from old ASN gateway to new ASN gateway. To maintain rapid and efficient handoff in WiMax , the authors of [9] suggest a cross layer handoff and fast intra network protocol. A seamless IP mobility Scheme is presented by the authors of [10] and evaluations were made for the flat WiMax architecture. Hierarchical MIP and two layered mobility management adopted by WiMax are similar [11][22]. To localize the signal traffic of MIP and to minimize the handoff latency, multiple levels of FA hierarchy is maintained in HMIP. A design for dynamically HMIP scheme was presented by the authors of [12] and it is for mobile IP networks. In this design every MS determine the hierarchy of Foreign Agents dynamically based on call to mobility ratio. When a threshold is achieved then the registration of MIP is executed and thus the signaling load due to MIP can be minimized appreciably. ASN gateways acts as the foreign agents in WiMax network due to the presence of two layered mobility management an MS can get serviced by two ASN gateways at most. The ASN gateway in WiMax is very similar to Serving Radio Network Controller (SRNC) in Universal Mobile Telecommunication Systems (UMTS) and the authors of [13] have proposed the SRNC relocation to reduce the load. SRNC relocation is performed immediately if an MS no longer remains connected with BS under SRNC and relocation is executed by the new SRNC. Whereas in the case of WiMax, MS only executes the ASN connected mobility if that MS connects to BS which lies in another ASN. This happens due to the fact that if ASN Connected and CSN connected mobility are executed by MS simultaneously then the time taken for handover procedure becomes very large. Load control and load balancing techniques have been presented for mobile IP in [14][15]. But the load of serving and connected ASN gateway will be affected if we use the techniques proposed in [14][15] in WiMax. Sometimes during inter ASN handover the MSs need to execute the CSN connected mobility and ASN connected mobility together but this will cause high packet loss and a large time will be taken for handover due to which the quality of service is degraded. To provide an excellent quality of service to subscribers the traffic in the network should be managed and Admission Control is a kind of technique used for network traffic management. Admission Control techniques are quite complex in wireless and mobile communication networks as MSs keep on changing their location from one network to the other network. If the resources in the target network are not at par or not well managed then link of MS possibly be dropped. A higher priority is given to the handover MS to use network resources due to the fact that an ongoing link is more essential than providing a new link to a new MS entering in the network. Different type of Admission Control algorithms has been proposed in [16][17][18][19]. Authors of [20] have presented two types of gateway relocation techniques for WiMax. One is predictive algorithm and another one is non predictive algorithm and these algorithms make a decision regarding the feasible time for gateway relocation and they also determine that how many of MSs connected should be relocated. In these algorithms load of connected MSs is only considered and depending on that load the gateway relocation is executed. If the load on ASN gateway due to serving MSs is high but load due to connected MSs is low then those algorithms will not perform gateway relocation. Moreover these algorithms just decide that how many numbers of connected MSs should perform relocation and does not decide regarding which connected MSs should perform relocation and that may cause unnecessary gateway relocations.

AMST BASED ALOGORITHM

A Selection of Mobility

In AMST based algorithm ASN gateway will register the arrival time of a serving MS and it also registers the departure time of the serving MS. Sample mobile stay time is calculated by the ASN gateway with the help of the arrival and departure times it already registered. AMST for an MS is adjusted by the ASN gateway whenever it receives a new sample mobile stay time. Generally AMST is recorded as a weighted average by ASN gateway and it uses new sample mobile stay time to manipulate the average slowly. Thus new AMST can be calculated as follows:

$$T_q = (1-\mu)\times S_q + \mu \times T_{q-1}$$

In above expression T_q is the new AMST, T_{q-1} is the old AMST, S_q is the new Sample Mobile Stay Time and $0 \le \mu < 1$. Let us assume that a WiMax Communication Network have $A_1, A_2, ..., A_m$ ASN gateways and $MS_1, MS_2, ..., MS_n$ number of mobile stations. Let T (x, y) is the current AMST for MS_y which is maintained in ASN gateway A_x and AMST threshold H_x for each A_x (x = 1, 2...m) is defined as:

$$H_x = \delta \times \left| T^x_{\max} - T^x_{\min} \right| + T^x_{\min}$$

Where

$T^x_{\min} = \min\{T(x, y) \mid y = 1, 2 \ldots n\}$,

$T_{\max}^{x} = \max\{T(x,y) \mid y = 1,2\ldots n\}$

and δ is a constant weighing factor (0≤ δ <1).

Now if Mobile Station MS_y performs inter ASN handover from A_y to A_x then ASN gateway A_x checks whether MS_y's AMST T (x, y) is larger than H_x or not. If it's larger than H_x than ASN gateway A_x will perform CSN connected mobility for mobile station MS_y else it will perform ASN connected mobility. It is quite difficult to select the value of weighing factor δ. ASN gateway A_x will always perform CSN connected mobility for MS_y if the value of H_x is close to $T_{\min}^{x}$ which means δ = 0. Such kind of condition will waste the bandwidth and resources of the ASN gateway network. If the value of δ = 1 i.e H_x = $T_{\max}^{x}$ then the load on ASN gateway will increase significantly as in this condition MSs will always perform the ASN connected mobility. In this article we recommend the value of δ as 70.

B Selection of Mobile Station

Let us assume a WiMAX Communication Network as depicted in figure 2 with nine mobile stations MS_1, MS_2 ... MS_9 and three ASN gateways A_1, A_2 and A_3 in which A_1 provides service to the MS_1, MS_2, MS_3, A_2 provides service to MS_4, MS_5, MS_6 and A_3 to MS_7, MS_8,and MS_9. Also MS_3, MS_8, and MS_9 are connected MSs of the ASN gateway A_2. Now the latest AMSTs T (x, y), x = 1, 2, 3 and y = 1, 2 ... 9 are as follows:

$$T(x,y) = \begin{bmatrix} 20 & 70 & 90 & 15 & 20 & 10 & 5 & 15 & 20 \\ 60 & 15 & 15 & 80 & 85 & 90 & 60 & 30 & 35 \\ 30 & 10 & 5 & 15 & 15 & 10 & 20 & 10 & 70 \end{bmatrix}$$

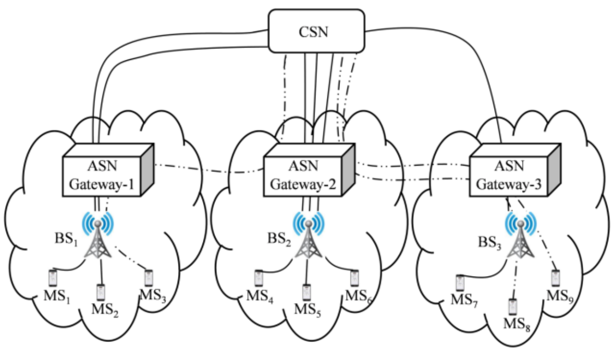

Figure 2: WiMax Network using three ASN Gateways

Consider that the load on A_2 is too high and thus system needs the relocation of ASN gateway to release that load from A_2. Now here comes the problem that which MSs among MS_3, MS_8, and MS_9 should perform the gateway relocation as they are connected with ASN gateway A_2. Thus to solve this problem we will consider the proportion of time PS_y which can be defined as the ratio of AMST in serving gateway to the AMST in connected gateway for each mobile station connected with ASN gateway. Thus PS_y for a mobile station MS_y which is connected in A_e, and served by A_f can be given as follows:

$$PS_y = \frac{T(f,y)}{T(e,y)}$$

Where *T (f, y)* is AMST of mobile station MS_y in serving gateway and *T (e, y)* is AMST of MS_y in connected gateway. By this expression we can calculate the proportion values of each MS which are connected with ASN gateway 2 i.e for MS_3, MS_8, and MS_9 as follows:

$$PS_3 = \frac{T(1,3)}{T(2,3)} = \frac{90}{15} = 6$$

$$PS_8 = \frac{T(3,8)}{T(2,8)} = \frac{10}{30} = 0.34$$

$$PS_9 = \frac{T(3,9)}{T(2,9)} = \frac{70}{35} = 2$$

From the obtained proportional values we can conclude that MS_3 will stay in serving gateway for a large duration of time as its PS_3= 6 whereas the PS_8 = 0.34 which shows that MS_8 will stay in servicing gateway for a smaller period of time and it will come back to its connected gateway. Thus the priority should be given to MS_3 to perform relocation of gateway. Hence PS_y is considered as criterion to select that which MS should execute the gateway relocation.

Another problem is the selection of an appropriate time to execute gateway relocation which is very essential to reduce the load from the ASN gateway and to avoid frequent gateway relocation. To deal with this problem we will define the load for the ASN gateway based on [20] and modify that accordingly. We will apply RED (Random early Detection) [21] for marking and dropping of the packets and the measurement will be defined on the basis of drop rate. If the load on the ASN gateway grows rapidly we will mark the packets randomly like that in RED so that those marked packets and some new arrived packets can be dropped if the queue becomes full. We will evaluate the drop rate at every interval *v* as follows:

$$d_v = \frac{m_v}{r_v}$$

where d_v is the drop rate ($0 \le d_v < 1$), m_v is the marked packets which are dropped in interval *v* and r_v is the total packets received in interval *v*. Hence we can evaluate the load on an

ASN gateway for a time t as a weighted moving average of d_v ($v = t, t-1, t-2 \ldots t-(z-1)$) as follows:

$$L_t = \frac{\sum_{v=t-(z-1)}^{t} w_v d_v}{\sum_{v=t-(z-1)}^{t} w_v}$$

where w_v is weighting factor for d_v and $w_t > w_{t-1} > \ldots w_{t-(z-1)}$. The load L_t will fall in interval [0, 1] and is measured by the newest drop rates. ASN gateway defines four conditions of the load depending on the three thresholds L_L, L_M, and L_H ($0 < L_L < L_M < L_H < 1$) and performs the following operations depending on these conditions.

- Condition 1: If the load on the ASN gateway is low i.e $0 \leq L_t < L_L$, than in this condition no relocation will be performed.
- Condition 2: If the Load on the ASN gateway is medium i.e $L_L \leq L_t < L_M$ then in this condition the ASN gateway can handle the traffic generated by MSs easily but it chooses the mobile station MS_y whose $PS_y \geq P_{th}$ to perform gateway relocation among the connected MSs where P_{th} is a threshold provided.
- Condition 3: If the load on ASN gateway is heavy i.e $L_M \leq L_t < L_H$ then in this condition also ASN gateway still chooses the mobile station MS_y whose $PS_y > P_{th}$ to perform gateway relocation among connected MSs. And if the load on ASN gateway keeps on increasing then the gateway will instruct all MSs to perform CSN connected mobility (C3 Mobility) when they moves to another ASN gateway.
- Condition 4: If the load on the gateway is very heavy i.e $L_H \leq L_t < 1$ then in this condition it is very difficult ASN gateway to handle the traffic generated by the MSs and ASN gateway will ask all the connected MSs to perform the CSN connected mobility (C3 Mobility) and thus all connected MSs get relocated to lower the load on the ASN gateway.

RESULTS AND DISCUSSIONS

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 Fig 3. 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.

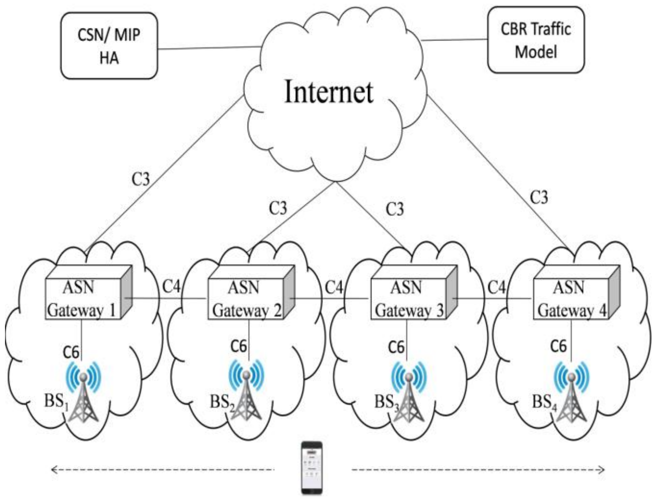

Figure 3: Experimental architecture

We recorded the 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 [20]: Authors of [20] 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 1

Table 1: Experimental Parameters

Inter handover inter arrival time of MS	1 sec
Number of MSs	1200
δ	0.70
P_{th}	6
L_H	0.70
L_M	0.55
L_L	0.40
Detection Interval of MS	5 sec

The Load on each ASN gateway is shown in Fig 4, 5, 6 and 7.

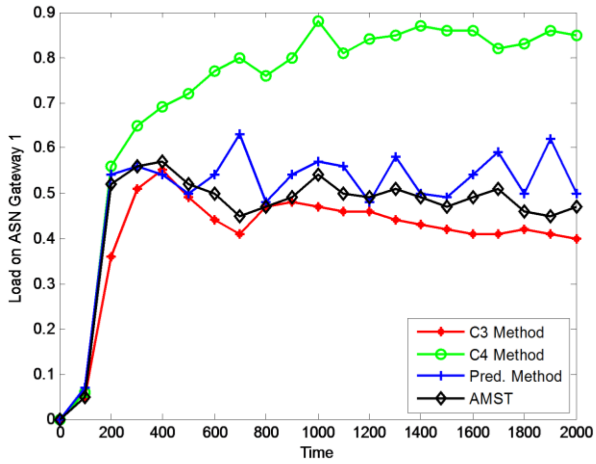

Figure 4: ASN Gateway 1 Loading

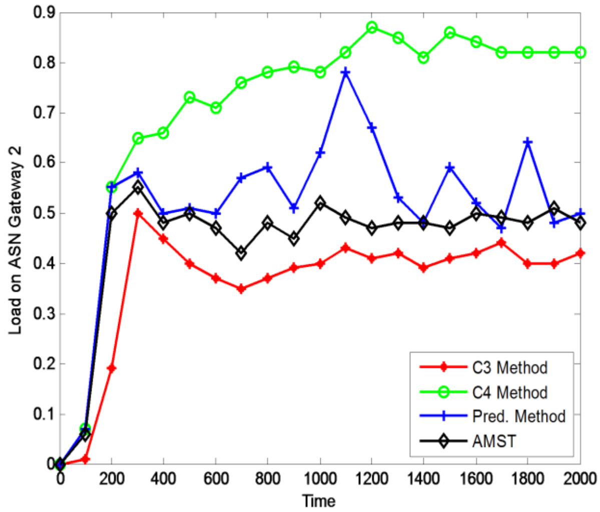

Figure 5: ASN Gateway 2 Loading

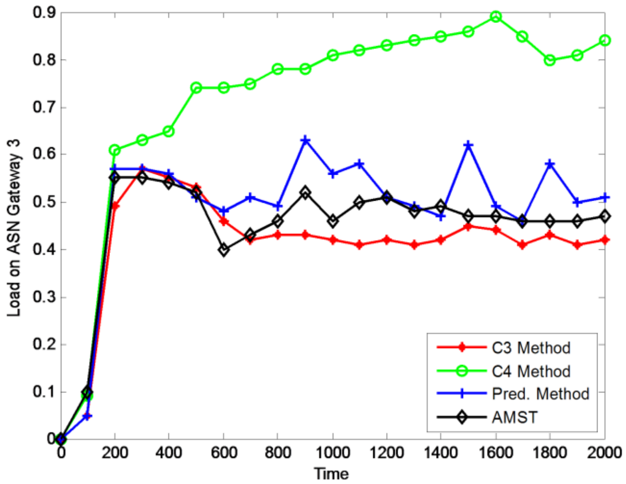

Figure 6: ASN Gateway 3 Loading

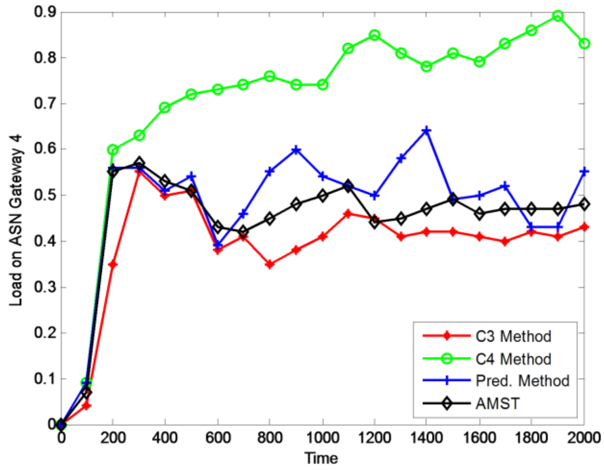

Figure 7: ASN Gateway 4 Loading

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 table II.

Table II: Handover and Relocation Delay

	Proper C3 Mobility	Proper C4 Mobility	Predictive Mobility	AMST Mobility
ASN Connected Mobility	0	54045.2 sec	53340.77 sec	34788.37 sec
CSN Connected Mobility	115504.5 sec	0	0	40911.9 sec
Relocation	0	0	34280.2 sec	4690.6 sec
Average	4.20 sec	1.96 sec	3.23 sec	2.95 sec

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 fig 8. 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 C4Mobility'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.

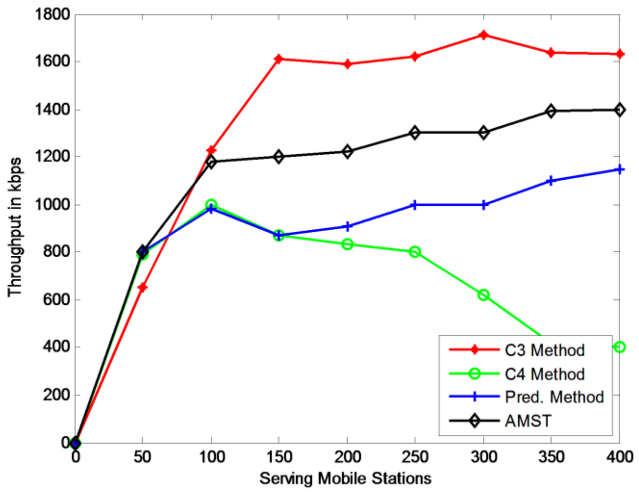

Figure 8: ASN Gateway's Average Throughput vs Serving MSs

CONCLUSION

Decision regarding gateway relocation can be taken by the ASN in WiMax network. A consideration is made in this article that the load is very heavy on the ASN gateway due to which gateway relocation will be performed by the connected MSs forcefully. This article proposes an AMST based algorithm for ASN gateway relocation which is used for proper selection of MSs to perform gateway relocation and also selects the appropriate time for gateway relocation. Suitable selection of mobility method (ASN or CSN connected mobility) can be selected by the ASN gateway depending on the AMST of MS and the load on the gateway. The results clearly shows that load on ASN gateway can be reduced using AMST based algorithm and load on gateway is more stable than the Proper C4 mobility and predictive ASN gateway relocation algorithm. Moreover it reduces the handover time compared to other Methods of mobility.

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