Reducing Hand-off Latency in WiMAX network using Cross Layer Information

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***Abstract*— With the growing demand for wireless Internet services and advancement in broadband wireless technologies, seamless hand-off has become a crucial factor in quality of service aware networks. The hierarchical WiMAX network model gives low hand-off latency but requires centralized control approach which introduces system overhead and increased packet end-to-end delay. The flat architecture model reduces system overhead and packet end to end delay at the cost of higher hand-off latency. Hence, a scheme to reduce hand off latency in flat architecture model is proposed. The proposed scheme utilizes information provided by the Medium Access Control (MAC) layer regarding hand-off in order to minimize network layer hand off delay. With the help of simulation using OPNET Modeler, it is shown that the new scheme decreases the hand-off latency while causing no extra overhead to the WiMAX network.**

***Keywords*— MIP, WiMAX Hand-off,WiMAX Flat Model.**

I. Introduction

The IEEE 802.16 (WiMAX) network consists of the access services network (ASN) and connectivity services network (CSN) [1]. The core elements in the ASN are the base station (BS) and ASN gateway (ASN-GW). Currently deployed WiMAX networks adopt the traditional hierarchical architecture where multiple BSs are connected to CSN through ASN-GW (Fig. 1.a) facilitating resource management and mobility support in highly efficient manner [2][3].This architecture enables tight resource coupling where centralized controller (ASN-GW) manages all contexts of the Subscriber Stations (SS) attached to the BS under its supervision. Hierarchical network is well suited for high speed mobility network. Due to lack of scalability and high cost, the central controller becomes a performance bottleneck [3]. As the centralized node is involved in processing and initiating a call, call set up time is very high ranging from several seconds to tens of second [4]. This is not crucial for Voice over Internet Protocol (VoIP) as in that case, call set up is invoked at beginning of a call but very crucial for other data traffic (e.g. Internet application like FTP, HTTP etc) where call set up is done very frequently[4]. In this architecture bidirectional Generic Routing Encapsulation (GRE) Tunnel is established between the ASN-GW and each BS to exchange traffic between them through the IP Backhaul [5]. During the hand-off of Subscriber Station (SS) node from the access of Old BS to Target BS, it sends a HO_REQ (Handoff Request) message to the ASN-GW indicating need of handoff to Target BS. The ASN-GW checks the resources available at the Target BS by sending RES_REQ (Resource Request) and the Target BS confirms with RES_RSP (Resource Response). ASN-GW then initiates a session transfer process between the Old and the Target BS. Once session transfer is done, the ASN-GW sends HO_RSP (Handoff Response) to confirm Handoff and SS node replies HO_CMP (Handoff Complete) indicating completion of handoff.

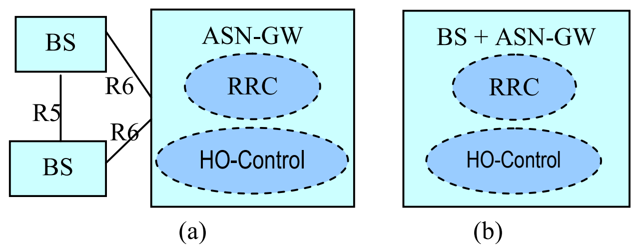

Figure 1. WiMAX network architecture (a) Hierarchical, (b) Flat

WiMAX flat architecture [6][4] consolidates the functionalities of the ASN-GW and the BS are merged together in a single node which can act as an independent router and these integrated elements are directly connected to the IP core network (Fig. 1.b). Here resource management is distributed which reduces call set up time. Thus flat architecture is better in terms of dealing with data traffic where call set up is done very frequently. When a Mobile Subscriber Station (SS) node roams from one Base Station (BS) to another, since there is no coordination at the link layer between BSs, a layer 3 handoff is triggered only after the serving link is dropped. Service is further regained by the slow Mobile IP [7] protocol which leads to large hand off latency. After completing layer 2 hand-off, SS is now attached to Target BS and it must receive the MIP Agent Advertisement (Agent Adv) message (broadcast over the newly connected radio link) from the Foreign Agent (FA) situated at target BS. Receiving Agent Adv, SS node sends a Registration Request (Reg_Req) to FA which relays this message to SS node's HA. HA updates its mobility binding table and send a Registration Reply (Reg_Rep) to the FA which update its visitor list table and send the message to SS node. Now HA forward all the traffic intended to SS through Newly connected Target BS's FA.

The flat model of WiMAX offers low network latency as number of nodes between SS and IP core network is reduced to one and provides high scalability as there is no centralized bottleneck. Thus, single point failure may not affect greatly. It

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avoids costly and complex inter-node interfaces (R6,R8, etc). Where as, in case of hierarchical architecture, failure of centralized controller may disrupt large area. Most significant challenge for flat architecture is hand off latency. Hierarchical network gives fast hand-off through only layer 2 hand-off but flat architecture requires network layer mobility which causes significant delay and thereby affecting real time application. Hence, flat model though advantageous lies behind mainly due to poor handoff performance. Most of the research works have concentrated on enhancing the MAC layer to reduce handoff latency [8]. In this article we propose a scheme that reduces the handoff latency without any extra overhead on WiMAX network. Detailed description is given in the subsequent section.

The rest of the paper is organized as follows. In section II we present our proposed scheme to reduce hand off latency in flat architecture. Section III presents the performance analysis and results followed by conclusion in section IV.

II. PROPOSED HAND-OFF SCHEME

In flat architecture, network layer handoff is initiated after finishing the data link layer handoff causing slow hand-off. The network layer is unaware of the data link layer handoff. MIP handoff begins only when the mobile node receives Agent Advertisement message over the newly connected radio link. To overcome this shortcoming we have modified the WiMAX MAC and MIP protocol in the SS node. After completing the layer-2 hand-off procedure, mobile nodes start periodic ranging. At this time SS node is connected to Target BS over the newly connected WiMAX radio link. In our proposed scheme, at this stage, mobile node agent sends an Agent Solicitation message broadcast over the newly connected radio link. The FA at the Target BS replies Agent Advertisement message with its own address to the SS node. Receiving the Agent Advertisement, the SS node registers with the FA at the new BS. Thus the SS node does not need to wait for Agent Adv as in normal procedure. Fig 2 shows the schematic representation of proposed hand-off process. To implement our proposed model, we have modified WiMAX-MAC and MIP process models of the SS node (wimax_ss_wkstn) in OPNET. Here MAC layer sends an interrupt to the MIP Mobile Node Agent situated at the SS node itself giving information about completion of layer 2 hand-off. This interrupt triggers the MIP agent to send the Agent Solicitation message.

The interrupt processing is internal so it will take negligible time (of the order of micro second). Time delay for message transfer is usually in the range of microsecond while average time to get the Agent Advertisement is in range of second. By default, MIP Agent Advertisement is sent with an interval of 5 secs [5]. An SS node may receive Agent Advertisement just after entering the new cell or after 5secs. On an average it will get the message after 2.5secs. The Layer 2 handoff latency (98ms as per our simulation) is in the order of ms where as waiting time for getting Agent Advertisement is in the order of second. In our proposed scheme, after completing the L2 hand off, then SS node need not wait for the agent advertisement from target BS to initiate the L3 handoff, instead it sends Agent Solicitation message to trigger L3 handoff. Thus the waiting time is eliminated which reduces the handoff latency greatly.

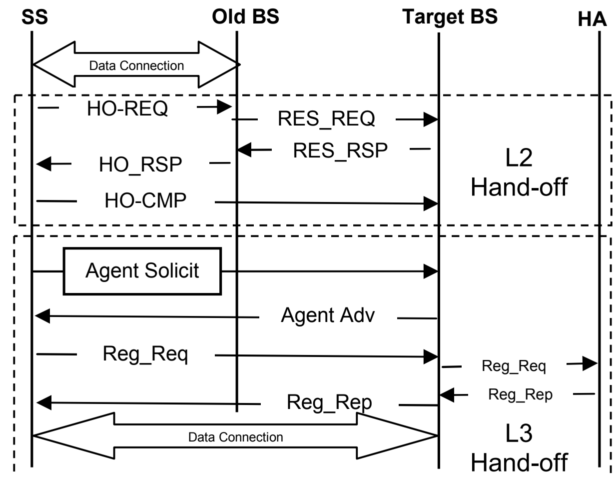

Figure 2. Message flow during hand-off in proposed scheme

III. SIMULATION RESULTS

We have used OPNET modeler version 15 for simulation to compare the Handoff delay and overall QoS of the conventional models and our proposed scheme. We built our proposed SS node model using 'wimax_ss_wkstn' node model present in the simulator. To simulate the 3 models we have constructed 3 simulation scenarios separately with common attributes as given in the Table 1.

TABLE I. COMMON ATTRIBUTES FOR SIMULATION

Attributes	Values
Base Station Model	wimax_bs_router
Subscriber Station Model	wimax_ss_wkstn
Link model	PPP_DS3
IP Backhaul model	Router_slip64_dc
Application traffic demand	96Kbps (100 packets/s)
Scheduling type	ertPS

The network architecture, shown in Fig. 3 is used for simulation. Here, we concentrate on Mobile_1_1 which is moving along the path marked by white line. Base Stations are connected to IP Backhaul using Point to Point link. 3 GRE tunnels (denoted by dotted lines) are configured among the BSs and the ASN-GW (for hierarchical model only). For flat model, WiMAX interface of Base Station_1 is configured as HA for Mobile_1_1 and other 2 Base Stations as Foreign Agents. Minimum MIP Agent Advertisement Interval is set as 5sec.

It is clear from the Packet end-to-end delay graph that flat model gives good performance in terms of delay. Our proposed scheme gives the same result as Conventional flat model. From Fig. 5 we see, hierarchical architecture gives very fast handoff, so interruption time is negligible compared to flat models. Proposed scheme gives better handoff performance and interruption time is minimal compared to the conventional flat architecture. We can also see that average throughput (Fig. 6) is less in case of conventional flat architecture because during handoff its throughput is zero which affects average throughput. We also find average throughput of conventional flat architecture is 78225 and for proposed scheme is 85775 in our set of architecture.

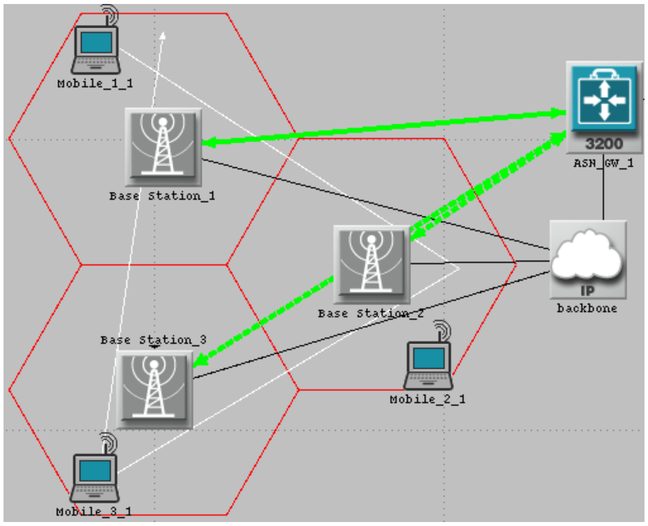

Figure 3. Network architecture for simulation

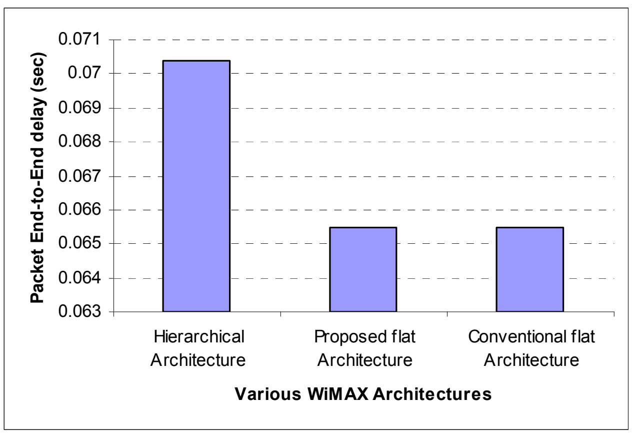

Figure 4. Average packet End-to-End delay comparison

IV. CONCLUSIONS

In this paper, the benefits and challenges of flat architecture network model over Hierarchical model have been discussed. Flat architecture network model is a promising option for next generation all-IP networks, but costs more hand-off latency which is also very crucial for QoS aware data communication. In this paper, we present a scheme to reduce the hand-off latency for flat architecture. The simulation model based on OPNET modeler confirms that our proposed scheme exploits the benefits of hierarchical network with reduced handoff delay maintaining the less signal overhead and end-to-end delay features of flat network without any network overhead.

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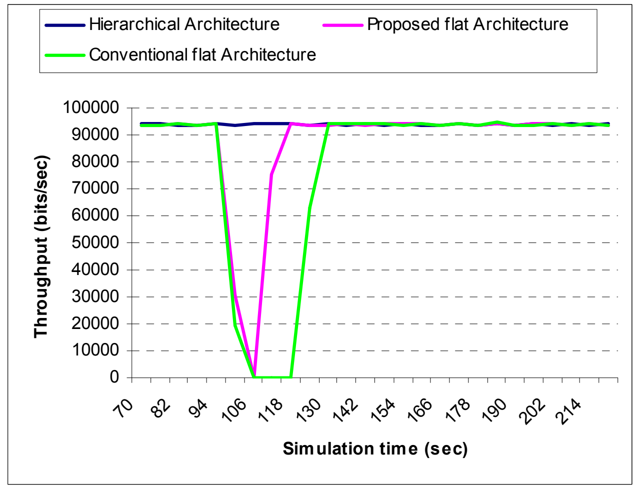

Figure 5. Throughput comparison with respect to simulation time

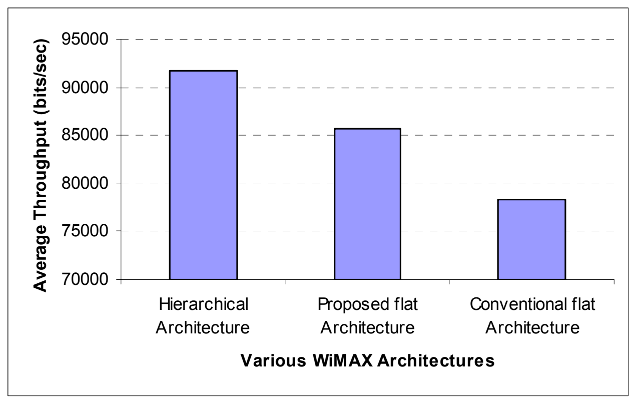

Figure 6. Average throughput comparison

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