Cross Layer Based Mobility Management in Wireless Networks

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***Abstract* - Mobile users are demanding anywhere and anytime access to high-speed data, real and non-real time multimedia services from wireless systems. Most of the wireless networks have been divided into independent layers and each layer has its specified job without any interaction. But for mobility management during handover (HO), layered architecture leads to inefficiency. So cross layer schemes are proposed for mobility management in wireless networks to improve HO performance in terms of delay, BW and QoS. This paper presents an overview of various cross layer mobility management (CLMM) techniques and also categorized them as Timely trigger based CLMM, Multi-entity based CLMM, Cross module based CLMM, Technology integration based CLMM, velocity-adaptive CLMM, and security enhanced CLMM considering the HO delay as performance metric. Each one of these techniques reduces HO delay but limited by some constraints related to real time applications. In this paper, a predictive LGD trigger scheme is proposed.**

***Keywords*- Handover, Cross layer mobility management, wireless networks, delay.**

I. INTRODUCTION

Most of the current work on Wireless Networks protocol analysis and design is mainly based on a layered approach. The layered approach is actually suboptimum for the overall system performance of Wireless Networks. The performance of one layer affects other layers. For instance, bad resource scheduling in MAC layer can lead to interference that affects the performance of the PHY layer due to reduced signal to interference-plus-noise-ratio (SINR) and ultimately deteriorates the overall network performance. Therefore, Cross-layer design has been focused in this paper to improve the performance of a wireless network during handoff in which there is no strict boundary between different layers.

Most of the cross layer architectures fit out into one of the two categories: direct or explicit cross-layer communications and indirect or implicit cross-layer communications via a common entity[1][2]. The first category, direct communications should be used when only a single cross layer optimization is planned. A combination of the cross-layer signalling ' methods can be optimized using CLASS(Cross-Layer Signalling Shortcuts) as shown in figure 2. CLASS serves as a generic interface to enable the interactions among non-neighboring layers using light weighted messages.

The second category indirect communications is realized with a common cross-layer entity or Cross Layer Manager (XLM), which acts as a mediator between the layers[3]. In order to achieve inter-working of Internet with wireless networks, and to meet the requirement of seamless handoff for real-time and multimedia applications, mobility management needs careful attention. The cross layer scheme has been proved effective to improve a network performance during a HO. Handoff management maintains active connections for roaming mobile terminals. There are a number of competing micro-mobility protocols like Mobile IP (MIP), Hierarchical MIPv6 (HMIPv6) [3], Handoff Aware Wireless Access Internet Infrastructure (HAWAII), and Cellular IP (CIP). An empirical analysis of handoff performance for SIP, Mobile IP and SCTP protocols running over different type of wired/wireless access networks is presented in [7]. Mobile IP yields the highest handoff delay among the three mobility protocols and SIP and SCTP yield 33% and 55% lower handoff delays respectively compared to Mobile IP.

Traditional handoff mechanisms used in MIP and micro mobility protocols fail to provide advanced mobility support required in wireless networks due to the following shortcomings:

1) No efficient movement detection mechanism leading to long handoff delays and packet loss.
2) No support for best network selection for the MT in an overlay network environment. Since the decision metric is only signal strength, the MT cannot migrate to other networks available which can provide better network experience in terms of cost, bandwidth, power consumption, etc.
3) The MT cannot make multimedia aware handoffs which respond to the types of applications and their QoS requirements.

Terminal mobility decisions should be taken at the network layer with the contribution of useful information from other layers cooperating through a well designed cross layer platform to facilitate these functions. The advanced mobility support calls for a coordination of all the layers. The performance of a CLMM can be measured in terms of various parameters like HO delay or latency, BW and resource management, power consumption, HO cost, packet loss, QOS. These parameters can be optimized using different CLMM techniques. In this paper, these techniques are categorized based upon strategy used named as Timely trigger based CLMM, Multi-entity CLMM, Cross module based HO, Technology integration based CLMM, which will be discussed in section II.

Various researchers have been made use of cross layer to optimize various parameters during handover. We will study these aspects in this paper which is organized as follows. Various optimizing CLMM techniques are listed and categorized in section II. A comparative study of these techniques and research gap is discussed in section III. The proposed work is explained in section IV and finally conclusion and future work is given in section V.

II. Optimizing CLMM Schemes

A. Timely trigger based CLMM

The mobility management modules include algorithms for handover prediction and decision algorithms for fast handover with handover preparation, handover coordination and optimization algorithms for best performance. These also include information to decide the appropriate time to initiate and execute the handover procedures. The next step in mobility management is to collect information from various event sources from each layer and processing the collected events to a standardized trigger format. These triggers can be further used to feed handover decisions to enable seamless handovers assuming that the decisions are based on information available at MN. A Trigger Management architecture for a vertical handover controller (VERHO) system has been presented in [8] which supports the application of different triggering policies and integrates them to feed HIP, Mobile IP, and Session Handovers. The HO decision is made based upon predefined rules or parameters like cost, power consumption, support for wireless QoS or bandwidth assigned weighted numerical values. Each interface gets a calculated preference value based on the values of different parameters. Trigger Management may also use a different policy at different times or when in different contexts, without having to regenerate rules. Also triggers can be formed depending on the system or application context instead of mobility management procedures. Effective and timely link-layer trigger mechanisms can significantly influence the handover performance. An LGD trigger should be fired at least in the required handover time before the Link_Down (LD) event. The required handover time is different according to the topologies, layer 3 HO protocols and policies of the neighbor networks and dynamic in nature due to mobility [9]. If HO initiation is on appropriate time, HO latency and service disruption time is reduced as well as preceding interface is utilized at the maximum.

B. Multi-entity CLMM

The authors of [10] introduced a Planned Multicast Group (PMG) approach to strategically arrange all the mesh routers to form a scalable wireless mesh backbone which can facilitate efficient intergateway handoff supports from multiple layers. The information obtained from the L2, such as the link quality of the new channel and the IP address of the new AP after a handoff, to predict the L3 and L5 handoffs is utilized in advance so that part of the handoff procedures can be carried out parallelly before an MN completes a L2 handoff.

Previous Access Router (PAR) can also be made to validate the proposed new IP address before MN disconnects from PAR to remove Duplicate Address Detection (DAD) delay in [11]. Dynamic RSS(Sth) is calculated using collective information from HO signaling delay estimation units, speed estimation units present in different layers.

C. Cross module based HO

2. RNG_REQ of 802.16e and FNA of FMIPV6 are combined and sent as FNA_ RNG_REQ.

MIPV6 and SIP are the most widely deployed protocols for handling mobility and for session control respectively as discussed in previous sections but some functions are same leads to inefficiency in session setup signaling when jointly used. As most of the inefficiencies stem from SIP/SDP's unawareness of layer3 mobility so cross layer scheme can be utilized for minimizing the end to end HO delay in case of integrated SIP and MIPV6 techniques as suggested by [5] and [12]. The direct use of the Care-of Addresses in some messages (short-lived message transactions in call initiation) and few cross-layer interactions, (including layer 3 location information in session setup signaling) are proposed by [5] as a solution for these inefficiencies. While in [12], a cross module is introduced between home agent and serving-Call Session Control functions(S-CSCF), a database function of control plane of IP Multimedia Subsystem （IMS). Through the cross-layer module, the binding update message received by HA can be translated and forwarded to S-CSCF to trigger the registration procedure in IMS. So the signaling between mobile node and home network can be reduced dramatically and can provide better mobility management for real-time service in IMS and has good scalability.

D. Technology integration based CLMM

Because of numerous advantages of cross layer approach, Most of the recent standards like IEEE 802.11WLANs (Wi-Fi), IEEE 802.16 WMANs(WiMAX), IEEE 802.21 are adopting cross layer design to refine the existing HO procedures. The authors of [14] summarized the various cross layer techniques for HO adopted by various standardization bodies like IEEE, IETF, and 3GPP for seamless HO. The HO can be optimized in WiMAX by exchanging security keys between BS and SS during scanning phase prior to HO thus neglecting the need of authorization. Another option to reduce HO latency is the coordination between SS and serving BS which allows the SS to maintain multiple associations at a time. IETF adopted sophisticated mobile IP schemes such as FMIPV6 or HMIPV6 or a combination of both(F-HMIPV6) to yield end to end based mobility support. FMIPv6(Fast handover for Mobile IPv6) protocol uses the L2 trigger information which can solve the unacceptable HO (Handover) latency and the data loss problems of MIPv6. The authors of [15] proposed an IPv6 based fast handover scheme for seamless macro-mobility(within different domains) support over WiBro (Wireless Broadband) Internet networks. Another cross layer HO scheme was suggested by [4][16] having integration of 802.16e and FMIPV6 to reduce HO delay. In this procedure, some modifications are done in following 802.16e HO messages :

1. MOB_HO_IND of 802.16e and FBU of FMIPV6 are combined and sent as FBU_MOB_HO_IND.
2. RNG_REQ of 802.16e and FNA of FMIPV6 are combined and sent as FNA_ RNG_REQ.
3. MOB_NBR_ADV of 802.16e and PtRtAdv of FMIPV6 are combined and sent at once.
4. Fast Ranging IE and FBack of FMIPV6 are combined and sent at once.

The Hierarchical MIPv6(HMIPv6) introduces the Mobility Anchor Point (MAP) to reduce the signaling overhead and delay concerned with Binding Update for micro mobility(within same domain). Fast Handover for Hierarchical MIPv6 (F-HMIPv6) can also be combined with 802.16e to achieve a better transmission performance in terms of HO latency and HO disruption time as shown by equations 1 and 2[17].

$D_{FMIPV6} = T_{L2(C)} + T_{MN\_NAR}$ (1)

Where $T_{L2(C)} = T_{SYNC} + T_{cont\_resol} + T_{rng} + T_{auth} + T_{reg} + T_{frame}$

$D_{CLFS} = T_{L2(O)} + T_{MN\_NAR}$ (2)

Where $T_{L2(O)} = T_{SYNC} + T_{FRAME}$

By reducing number of messages, the HO delay is significantly reduced. This method has also been applied to the case where an MN moves to 3GPP(UMTS) and 3GPP2(CDMA2000) networks[16]. Measurement Control L2 message in 3GPP network and Neighbor List L2 message in 3GPP2 network contain the L3 information about GGSN and PDSN, respectively, and RtSolPr/PrRtAdv messages are omitted. In addition, RAB Setup Complete L2 message of 3GPP system passes MN's LLA, instead of Fast Neighbor Advertisement L3 message and LCP/IPCP messages in PPP setup procedures of 3GPP2 system play the same role. If FBACK is received before disconnection, HO is predictive, or it is reactive otherwise[6]. The concept of a predictive mode fast handover can also be applied to a reactive mode fast handover procedure, except for the following: Since FastNeighborAdvertisement L3 message in a reactive mode plays the role of passing a NCoA (New Care-of-Address) of an MN, DSA-REQ, RABSetupComplete, and LCP/IPCP L2 messages in each
case should contain the NCoA of an MN. Thus more functionality in the standard L2 signaling messages are cluded to reduce the handover latencies, packet delay and packet loss as shown in equations 3 and 4.

$T_{CLHS} = 8d1 + 4d2 + 2d3$ (3)

$T_{original} = 10d1 + 6d2 + 2d3,$ (4)

where d1 denotes the message delay between MN and BS, d2 is the delay between BS and ASN GW, and d3 is the delay between ASN GW and HA.

E. Velocity-adaptive CLMM

An architecture for the seamless roaming from the WiMAX to the UMTS network is proposed by [18] which introduces a new common sublayer named IW (InterWorking) sublayer and SR ARQ mechanism to resolve several typical inter-RAT(radio access technologies) handover problems, such as packet loss, high handover latency, false fast retransmit. In addition, an enhanced TCP proxy is introduced on the RNC (Radio Network Controller) to resolve BDP (Bandwidth Delay Product) mismatch and spurious RTO (Retransmission Time Out)/premature timeout problems. With the help of the movement prediction achieved by linear regression model with keeping track of the signal strength of mobile users, layer-3 handover activities are able to occur prior to layer-2 handover. Such a scheme is proposed by [19] to reduce total handover latency by Δt (prediction interval) in mobile WiMAX. Refer to [13] for performance comparison of various HO mechanisms in WiMAX listed as:

- Link-layer HO algorithm [20]
- Pre-coordination HO scheme [21]
- Passport HO scheme [22]
- FINCH(fast intra network and cross layer HO) [23]

Each of above managed to reduce the HO latency during downlink(DL) but not during uplink(UL). Except for FINCH[23], they do not consider the scenario of HO between BSs that belongs to different ASN-GWs (macro mobility) which causes extra HO latency as in FINCH. For high velocity applications in mobile WiMAX, the HO threshold is set variably according to the the Received Signal Strength Indicator (RSSI) as well as MS mobility, named as velocity-adaptive handover scheme [24]. This scheme adopts dynamic handover threshold according to different velocity to skip some unnecessary handover stages, reduces handover delay and enhances the network resource utilization.

SEARCH GAP

Many researchers have used cross layer for optimizing HO performance in terms of latency, throughput and packet loss. In [5], an integration of SIP and MIPV6 is used to improve HO performance but MIPV6 is less efficient than FMIPV6. According to [2], instead of exporting information between layers, it is more useful to import information into a separate management database visible across all layers and threshold RSS should be adaptive for inter and intra HOs but it has not been implemented in this paper. The authors of [18] included an interworking (IW) layer to resolve a number of HO problems simultaneously and also discussed some open issues for further research. The limitation of [18] is that it considered only DL traffic and the integration of tightly and loosely coupled cross layer is opted which is very complex. The authors of [16] have reduced the total service disruption time in heterogeneous networks but the delay between ASN-GW and HA is not reduced. [10] purposes the idea of L3 and L5 HO preparation during L2 HO process using planned multicast group(PMG) but it shows tradeoff between PMG overhead messages generated during HO and total HO delay. Trigger Management for collecting and processing the cross layer information is shown in [8] but it has nowhere described any predefined or adaptive threshold for trigger producers or event sources. A velocity adaptive HO is proposed in [24] in which the threshold RSS varies according to the velocity but it is proved to be effective for high velocity applications only and there is no improvement for low velocity vehicles. Another approach is proposed in [17] to improve HO performance by integrating the 802.16e and FHMIPV6 but the selection mechanism of an appropriate BS is not considered. The HO latency of FMIPV6 HO mobile WiMAX is optimized in [25] by using a network level protocol called context transfer. It transfer connection info between ARs and omit the re-registration and re-entry procedure but DAD delay, return routability procedure and queuing is ignored in this work. In [9], a timely effective trigger based HO is proposed and reduced the HO latency greatly from 450ms to 55ms which is a great improvement. The accurate network conditions are provided timely by LL triggers that are fired at MAC sublayer and timely firing of link triggers influence HO greatly. The limitations of [9] are following:

- The shadow fading effects are not included in RSS estimation.
- The RSS of target network is not calculated to verify the threshold condition.
- The HO required time is not varying with the speed of mobile.
- The cross layer information is utilized very less such as the information about the new channel can be taken in advance after deciding HO to do Pre-HO work in advance.

III. Proposed Work

In this section, mathematical structure for the HO management is developed. The proposed steps to be followed are given below:

1. HO Initialization
2. HO time estimation
3. Trigger generation

1. HO Initialization

The received signal strengths $P_{ri}(d)$,i=c,t, received by MS from BSs at a distance of d from BSc(current) and BSt(target) is calculated by

$$P_{rc}(d)=K_{1c}-K_{2c}\log_{10}(d)+P_{sfc}(d) \qquad (5)$$
$$P_{rt}(d)=K_{1t}-K_{2t}\log_{10}(D-d)+P_{sft}(d) \qquad (6)$$

Where K_{1i} and K_{2i} are the path loss parameters. K_{1i} = transmitted power.$K_{2i}=10^{\gamma_i}$ where $^{\gamma}{}_{i}$ denotes the path loss exponents. D is the distance between BSc and BSt. Note that $P_{sfc}(d)$ and $P_{sft}(d)$ are zero mean stationary Gaussian random processes that model lognormal shadow fading. Shadow fading is modeled as follows:

$$P_{sfi}(d)= \rho P_{sfi}(d-1)+\sigma_i\sqrt{(1-}\ \rho^2)W_i(0,1) \qquad (7)$$

Where σ_i and ρ are the standard deviation and the autocorrelation between consecutive measurement samples. $W_i(0,1)$ represents truncated normal random variable. The average signal strength is measured to remove the fluctuations given by:

If $P_{rc}(d)<P_{min}$ and $P_{rt}(d)>P_{min}$

Where $P_{min}>P_{th}$.

Go to Step2.

2. HO time estimation

The target network is to be discovered after obtaining the neighbor information. The MS can decide the HO type, number of channels to be scanned and whether the L3 HO is required or not using this information. The time required to complete HO procedure is estimated using the following equation.

$$T_h = t_{L2C\_nbr}+t_{L2T\_scn}+\max\{t_{L2C\_ind}+t_F,t_t^*\} \qquad (8)$$

t_{L2C_nbr} : Meassage exchange time to obtain the neighboring information.

t_{L2T_scn} : maximum channel scanning time for the target network type.

t_{L2C_ind} : HO indication message exchange time to the current BS.

t_F : fast HO execution time.

t_t^* : HO execution time with target network BS.

3. Trigger generation

Predictive Link going down(LGD) trigger is generated at the appropriate time so that service disruption time is minimized. T_h ahead prediction is done using linear slope estimation. If after T_h a Link_Down event is expected, then a predictive LGD trigger is generated to initiate the required HO procedure. If $P_{rc}(t+T_h) < P_{th}$

Link going down(LGD) trigger is generated using any trigger generation mechanism.

IV. Conclusion And Future Work

Mobile wireless networks are capable of delivering services to the users anywhere at any time. However, mobility management is one of the critical aspects which can influence the quality of service during handover. This paper reviewed various cross layer mobility management (CLMM) schemes, their optimization to improve HO performance. This paper offers a simple method to analyze optimizing CLMM schemes by putting them under different categories. By analyzing these schemes, we may conclude though a lot of work has been done to improve HO performance but a great research gap is still present in this area to fulfill the demands of real time multimedia applications. For instance, LL and network layer information is nowhere used combined to generate trigger. In L2 trigger, sudden link loss conditions are not considered in the related work so FMIPV6 should reduce the dependence on L2 triggers. In most of the papers, the HO latency is reduced at the cost of increase in overhead so we may aim to device a mechanism to reduce latency without affecting overhead greatly. Also the target network for HO should satisfy the minimum requirement of signal strength for a certain period of time. It is concluded that the proposed predictive LGD trigger technique will improve the HO performance. In future work we will prove the proposed work by simulations and aim to device some techniques which can overcome the above limitations.

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