ENHANCEMENTS FOR SIMULTANEOUS ACCESS IN NETWORK-BASED LOCALIZED MOBILITY MANAGEMENT

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ABSTRACT

Network-based Localized Mobility Management (NetLMM) is considered as the future solution for the IP mobility management confined within the access network, as well as a solution for inter-access system handover between 3GPP and non-3GPP. In this paper, we enhance NetLMM to support simultaneous use of radio interfaces in 4G environments consisting of multi-interface mobile nodes and heterogeneous access technologies. All issues on how to manage and to use multiple interfaces simultaneously in NetLMM are identified. We present necessary enhancements for the network attachment and network detachment processes. It is pointed out that IP tunneling is not suitable for simultaneous access in NetLMM. Consequently, a new tunneling method, which is based on Stream Control Transmission Protocol (SCTP) and its extensions, referred to as *virtual SCTP tunneling*, is proposed. We show that that the new tunneling method is advantageous to both mobile users and network operators with the consideration of two scenarios, load-balancing and wireless bandwidth aggregation. Some simulation results are also provided in this paper as an early estimation of the new tunneling method.

I. INTRODUCTION

The Always Best Connected (ABC) concept is considered as the vision behind vertical handover between heterogeneous access technologies (e.g., from UMTS to WLAN) [1][2][3][4]. ABC has always been about multi-interface mobile nodes and multi-access networks in which the simultaneous use of access technologies is foreseen as a key feature of 4G.

Network-based Localized Mobility Management (NetLMM) [5][6] is currently standardized by IETF for Localized Mobility Management (LMM) inside a localized mobility domain (LMD). The NetLMM protocol is also used to interconnect heterogeneous systems as described in [7]. We consider an LMD composed of Access Routers (ARs) controlling heterogeneous radio access technologies. A Mobile Node (MN) can have multiple interfaces of different radio access technologies; each interface has its own IP address that is kept unchanged within this domain.

The objective of this study is to enhance NetLMM for an ABC vision in which flows of a MN are mapped to different interfaces. The enhanced NetLMM allows a MN to use different interfaces simultaneously to increase the QoS while moving.

We identify all issues on how to manage and to use multiple interfaces simultaneously. For maintaining multiple bindings, we point out necessary enhancements in the network attachment and network detachment processes with a *selective deregistration* procedure and a *keep-alive* procedure. For simultaneous access, we indicate that with the use of IP tunneling in NetLMM, the binding granularity is limited to the address (i.e. mobility binding). We present a new tunneling method, referred to as *virtual SCTP tunneling.* This tunneling method allows MN flows to be distributed through different ARs on a per-packet basis or on a per-flow basis (i.e. flow binding). Therefore, a mobile user can have an aggregated wireless bandwidth to increase the QoS; while an operator can have the load-balancing to increase the system utility.

This paper is organized as follows. Section II provides a review on related work, including the Localized Mobility Management problem and its current NetLMM architecture, the inter access system handover between 3GPP and non 3GPP, and current work of Monami6 on multiple interfaces. Section III identifies related issues. Section IV presents our enhancements and the new *virtual SCTP tunneling* method. Section V provides an analysis of enhancements with some scenarios and an early estimation on the new tunneling method. Finally, section VI concludes the paper.

II. FRAMEWORK AND RELATED WORK

A. Network-based Localized Mobility Management

While moving, Global Mobility Management (GMM) and LMM assure the session continuity between the Correspondent Node (CN) and the Mobile Node (MN). LMM is used for the mobility inside an LMD; while GMM is used for the global mobility between LMDs. The GMM protocol can be MOBIKE, HIP, or Mobile IP [8].

NetLMM is principally based on an assumption of "unmodified" MNs in the sense that no NetLMM specific software support is present on MNs. The NetLMM architecture consists of the following components: Localized Mobility Anchors (LMAs) within the backbone network maintain a collection of routes for individual MNs within the LMD; Access Routers (ARs), also known as Mobile Access Gateways (MAGs), terminate a specific edge link and tracks mobile node IP level mobility between edge links. The routes point to ARs managing the links on which the MNs currently are located. Packets for a MN are routed to and from the MN through tunnels between the LMA and ARs. When a MN moves from one link to another, the AR sends a route update to the LMA.

NetLMM defines two interfaces. The first one defines the interaction between MNs and ARs while the second one defines the interaction between ARs and the LMA (see Fig. 1)

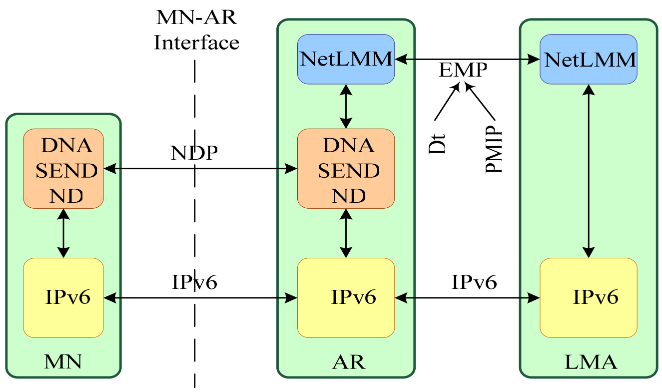

Figure 1: Protocol stack for Network-based Localized Mobility Management

The MN-AR interface [9] is used between MNs and ARs. In the absence of link-layer specific mechanism, it allows the AR to detect the network attachment of a MN and update routing at the LMA so that the MN stays reachable when it roams across the NetLMM domain. The IP layer MN-AR interface fulfills these requirements by using the SEND public key [10] as the MN identifier, while being solely based on standard track IPv6 protocols, including Detecting Network Attachment (DNA) [11] and SEcure Neighbor Discovery (SEND), implemented by non-NetLMM MNs.

The simplest AR-LMA interface between the LMA and the AR is Edge Mobility Protocol (EMP) [12]. It is used as a base protocol for the design process of the AR-LMA interface. The first descendant of EMP is done by the Design Team. This Design Team's protocol [13] is constructed from zero in hope that it will optimize the mobility management. The next candidate for the AR-LMA interface is Proxy Mobile IP [14], which is an extension of Mobile IP. In this paper, we chose the Design Team's protocol to be the referral protocol.

As for the traffic delivery, NetLMM allows the LMA and ARs to choose the right tunneling methods specified in the HELLO message. The tunneling methods can be: IP-in-IP, GRE, MPLS, Null method. Note that current NetLMM does not consider multi-homing provision as a goal.

B. Inter access system handover between 3GPP and non 3GPP

3GPP Access System is regarded as an *edge domain* within which the MN acquires and keeps the same IP address. Non-3GPP access networks (WLAN) also have their own edge domain mobility solutions. Possible edge domain mobility solutions applicable to non-3GPP access are MOBIKE, NetLMM or Proxy Mobile IP.

The proposed solution for inter-working between 3GPP and non 3GPP access system at user-IP layer, through an IP-based global mobility management protocol, could be the Mobile IP or a fully network-based protocol like NetLMM [7].

C. Mobile Nodes and Multiple Interfaces in IPv6 (Monami6)

The objective of Monami6 Working Group (WG) [15] is to deal with the simultaneous use of multiple addresses for either MNs using Mobile IPv6 or Mobile Routers (MRs) using NEMO Basic Support [16]. Monami6 WG provides a protocol extension to support the registration of multiple Care-of Addresses at a given Home Agent address. In this WG, the concepts of *flow* and *flow binding* are also presented. A *flow* is defined as one or more connections having the same flow identifier. A single connection is identified by the source and destination IP addresses, transport protocol number and the source and destination port numbers. A *flow binding* is a mobility binding extended with a flow identifier; it associates a particular flow to a care-of address without affecting other *flows* using the same home address. Binding Updates are sent to the Home Agent by the MN.

III. PROBLEM DEFINITION

The objective of this study is to enhance NetLMM for the ABC provision. We consider LMD as an autonomous system under the control of an operator. The LMD is composed of different ARs controlling heterogeneous radio access technologies. From this point of view, NetLMM can be used for inter access system handover within an operator while GMM will be responsible for the handover between LMDs of the same operator or between operators. A MN can have multiple interfaces of different radio access technologies; each interface has its own IP address within the LMD. Without loss of generality, we consider here only 3GPP and WLAN access networks for the simplicity. We can identify here three issues that need to be solved.

The first issue relates to the network attachment process of the MN. The standard NetLMM protocol currently allows ARs to detect the network attachment of a MN and update bindings at the LMA and the ARs. However it assumes that the MN will detach from the old ARs. The LMA will send *location* deregistration message to all old ARs. As a result, all the bindings for the MN in old ARs and in the LMA are removed and replaced by the new binding. To allow multiple bindings, NetLMM should provide a way so that *location deregistration* messages only affect old ARs having the same radio access technology as that of the new AR. This enhancement requires modifications in the LMA and ARs.

The second issue relates to the network detachment process of the MN. It is how to inform the LMA to remove a binding when the corresponding access technology becomes unavailable. This issue must be solved without introducing any changes in the MN except triggering predefined procedures.

The third issue is that NetLMM must allow multi-interface MNs to benefit from all advantages by allowing the LMA to distribute flows or packets dynamically to different access technologies within the LMD. Though, the simultaneous use of multiple interfaces for MNs can be done in GMM (e.g. using flow binding as mentioned in Monami6 WG), the simultaneous use in GMM is out of synch with the MNs movement within the LMD because the NetLMM signaling messages (e.g., Binding Updates) are not routed outside the LMD to avoid the side-effect and to minimize the signaling volume. Using IP tunneling between the LMA and ARs, the traffic can not be distributed over simultaneous interfaces because the flow binding using IP tunneling is not directly applicable inside NetLMM. The flow binding is built on top of static routing that needs information to identify MN flows while the LMA and ARs have no knowledge about MN flows. Consider the following example. Assume that tun_i denotes the IP tunnel between the LMA and the i^{th} access router AR_i. Given that the MN has 2 interfaces with $@_1$ and $@_2$ respectively to be the edge IP addresses of the first interface and the second interface in the LMD. At one given moment, the first interface has access to AR_1, and the second interface has access to AR_2. Without information of MN flows (source IP address, transport protocol number and the source and destination port numbers, etc.) to identify flows, there exists only one routing entry (mobility binding) for each interface in the LMA. Routing entries in the LMA for the MN must look like the following:

Source	Destination	Next hop
any	@1	tun1 (for AR1)
any	@2	tun2 (for AR2)

All flows having $@_1$ as the destination address follow the first routing entry and chose tun_1 as the next hop; the same explanation is applied for the second routing entry. There is no particular routing entry for each flow. As a result, the LMA can not balance the load on two interfaces.

IV. SOLUTION

In this section, we propose our solutions to address each of the above issues.

A. Selective Deregistration Procedure

The first issue is how to make location deregistration messages affective only to a subset of old ARs having the same radio access technology as that of the new AR. We propose a *selective deregistration procedure* in which we classify ARs within the LMD into groups by using *group identifier*. ARs in the same group are exclusive; this means that only one AR is valid for each group for each MN. On power up, the AR notifies its group identifier to the LMA through the *association procedure*. The *group identifier* is also included in the *location registration* message so that *location deregistration* messages are only valid for ARs of the same group; ARs of other groups use those messages for updating the bindings.

The group assignment is static and can be manually done by administrators when deploying the system. Such extension can be easily realized by employing some unused fields.

B. Keep-alive Procedure

The second issue is how to inform the LMA and ARs to remove a binding when one access technology becomes unavailable. We propose to repeat the network attachment process on all active interfaces. Messages are propagated from the MN to ARs and then to the LMA. Note that this time the ARs and the LMA already have the forwarding state for the MN; therefore they do not need to send back the acknowledgment. The LMA uses those messages as *keep-alive* messages. On receiving the first *keep-alive* message, the LMA turns on a timer for the MN. The LMA marks ARs having sent *keep-alive* message as reachable for the MN; other ARs are considered as unreachable for the MN. On timeout, the LMA deletes bindings to unreachable ARs and activates the *selective deregistration procedure* to remove forwarding state at unreachable ARs or to update forwarding state at reachable ARs.

C. Virtual SCTP tunneling method

The third issue deals with simultaneous use of ARs for one MN in the downlink from the LMA to the MN. Without MN's flow binding information, the LMA is unable to create flow bindings but only mobility bindings. We provide a new tunneling method, based on Stream Control Transmission Protocol (SCTP) [17] and its extensions [18][19], as an alternative.

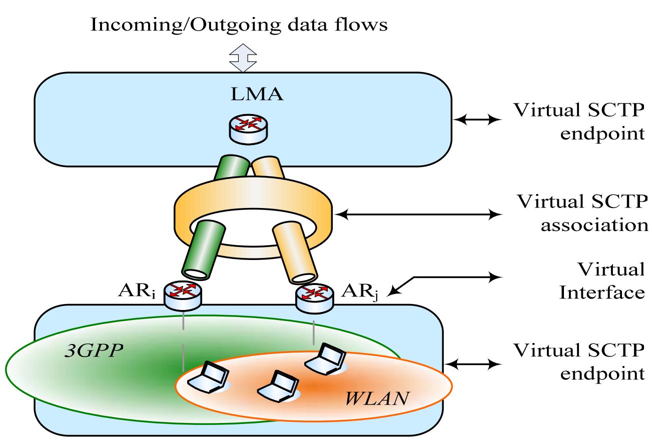

Figure 2: Virtual SCTP endpoint and virtual SCTP association concepts

The solution comes from the observation on the SCTP that supports multi-streaming and multi-homing features. In [19], SCTP is extended to transmit data chunks over simultaneous active paths and provides a bandwidth aggregation technique that is very beneficial for networks with limited bandwidth and high loss rate.

We consider the tunnel as a virtual SCTP association between two virtual SCTP endpoints as shown in the Fig. 2. One virtual SCTP endpoint is the LMA, and the other virtual SCTP endpoint, comprising multiple virtual interfaces, is a set of ARs. Each AR is considered as a virtual interface. Note that those ARs have different *group identifier*. The new tunneling method, referred to as *virtual SCTP tunneling*, allows multiple simultaneous endpoint addresses. The tunnel is fixed between the LMA and a set of ARs, allows the collaboration between ARs, and is shared by different MNs.

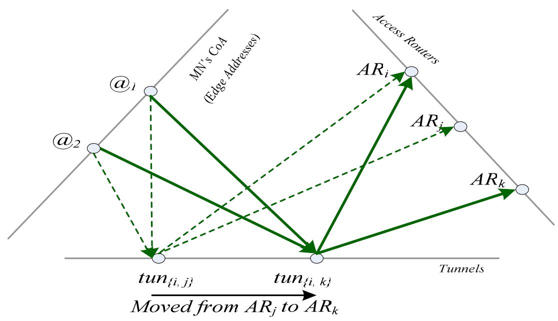

Figure 3: Mappings between different spaces

Fig. 3 shows the mapping between different spaces: MN's edge IP addresses space, tunnels space, and ARs space. Routing entries for $@_1$ and $@_2$ point at the same tunnel, each tunnel distributes data to a subset of ARs. Assume that $tun_{\{i,\ j\}}$ denotes the tunnel between the LMA and the set of $\{AR_i,\ AR_j\}$. Packets addressed to MN having access to AR_i and AR_j will go through the $tun_{\{i,\ j\}}$. Given that this MN has moved from AR_j to AR_k. On receiving the *location registration*, the LMA updates its routing table to redirect MN's packet to the $tun_{\{i,\ k\}}$. The tunnel is responsible for dynamically distributing MN's flows or packets to the most suitable AR. Those tunnels can be manually created by administrators or incrementally created by observing *location registration* messages and the forwarding state in the LMA and ARs.

V. ANALYSIS OF ENHANCEMENTS

This section analyzes the enhancements, especially the new *virtual SCTP tunneling* method, with some scenarios and some simulations to cover both qualitative analysis and quantitative analysis.

A. Packet bundling with virtual SCTP tunneling

The transmission of traffic in the backhaul network, from the LMA to ARs, is realized by using the *virtual SCTP tunneling* method. In case of small-size packet networks, such as

VoIP network, the *virtual SCTP tunneling* can bundle multiple small packets in one SCTP datagram.

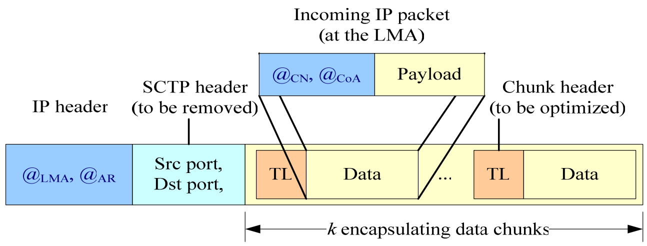

Figure 4: A simple encapsulating SCTP datagram

Fig. 4 shows a simple schema of SCTP tunneling in which we put the whole original IP packet in an encapsulating data chunk. This simple schema has advantage of not changing the incoming packets; therefore it is usable even for encrypted IP packets.

We carried out an observation of this schema under ns2 version 2.29. We constructed a simplified NetLMM infrastructure using IPv6 as described in the original IETF drafts [6][13]. For the first step, the interaction between ARs and the LMA follows the standard. The capacity and the propagation delay of the AR-LMA links are respectively 10 Mbps and 10 ms. We measure the tunneling goodput and the average tunneling delay while varying parameters such as the number of flows, the incoming IP packet size and the number of encapsulating data chunks *k*.

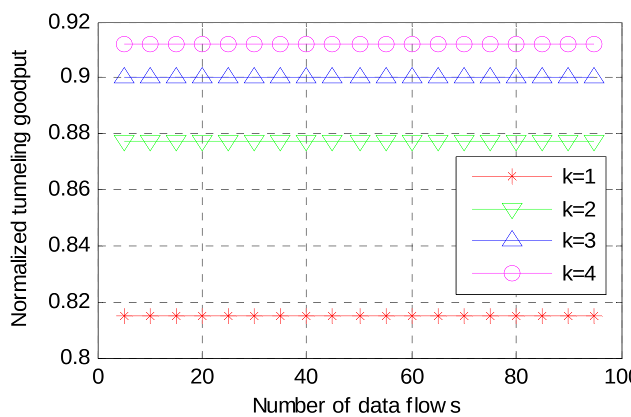

Figure 5: Normalized tunneling goodput vs. number of flows

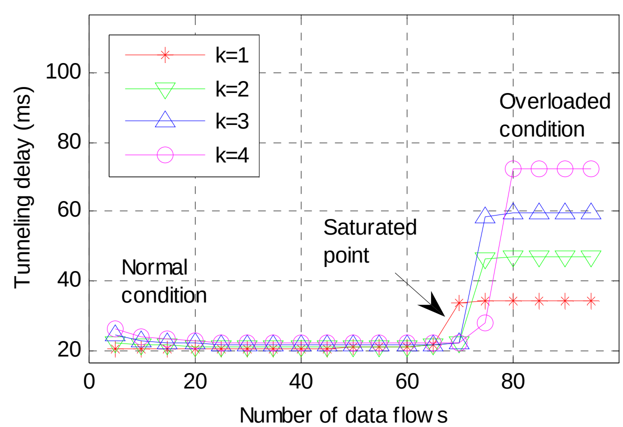

Figure 6: Tunneling delay vs. number of flows

Fig. 5 shows tunneling goodput normalized by the throughput of encapsulating packets versus the number of flows when the inter-arrival time of each flow is 20 ms and the incoming packet size is 300 bytes, that is enough for VoIP packets (e.g., if G.711 is used, the VoIP packet size is only 220 bytes). It shows that larger *k* provides better efficiency than smaller *k*. Fig. 6 points out that, in normal condition, larger *k* slightly increases the average tunneling delay. In conclusion, the number of encapsulating chunks *k* may be set to one to have the smallest tunneling delay but can be maximized for applications that tolerate to the jitter and delay to have better efficiency. The choice for this value requires further studies.

B. Per-packet dynamic distribution

Virtual SCTP tunneling provides per-packet dynamic distribution that is useful and more advantageous than IP tunneling in some scenarios, e.g. a Mobile Router (MR) in NEMO [16] plays the role of a MN in NetLMM. In this scenario, the traffic between the Home Agent (of GMM) and the MR is composed of many different flows and is encapsulated at the Home Agent. The traffic is seen as a single flow to NetLMM but should be distributed through different radio interfaces on a per-packet basis to increase the overall NEMO network throughput.

C. Wireless bandwidth aggregation for MNs

From the point of view of MNs, the use of such *virtual SCTP tunneling* in NetLMM provides a larger wireless bandwidth, of which the capacity is the total capacity of the two wireless links. Assume that a MN has two flows: one for the file transfer and the other for the audio/video stream. The *virtual SCTP tunneling* allows the LMA to use the WLAN AR for the file data flow and the 3GPP AR for the audio/video flow. This scenario can also be extended to per-packet basis, on which, different packets of the same flow are distributed through different interfaces.

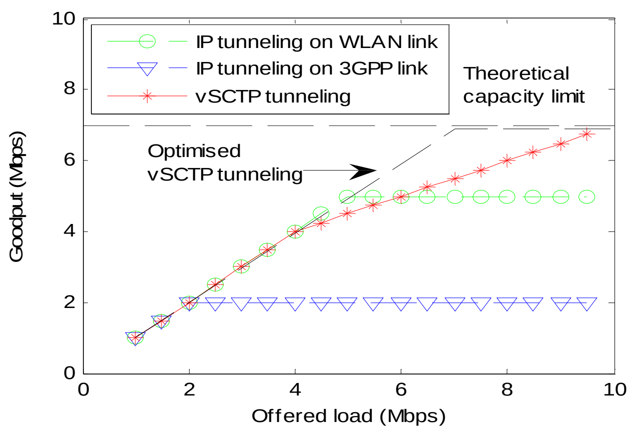

Figure 7: Aggregated bandwidth with virtual SCTP tunneling

Consider the following simulation. The 3GPP link capacity is 2 Mbps and the WLAN link capacity is 5 Mbps. The *virtual SCTP tunneling* is scheduled so that the traffic is distributed to different links on a per-packet basis, and in a simple manner with the Round-robin algorithm. We define the offered load as the total traffic volume sent to the MN and measure the MN goodput that is the total traffic volume received by the MN. Fig. 7 illustrates the aggregated wireless bandwidth feature with the use of *virtual SCTP tunneling*.

D. Load-balancing for operators

Continuing with the above scenario of aggregated wireless bandwidth: Provided that at one moment, the number of served MNs in the 3GPP coverage increases so that the load on the 3GPP link is going to be saturated, The tunnel can switch the traffic of certain MNs from the 3GPP link to the WLAN link to improve the global performance in term of number of "satisfied" MNs (with regard to the MN profile and the QoS). From the point of view of operators, the use of *virtual SCTP tunneling* provides load-balancing mechanism that allows the network operators to manage the load in their network.

VI. CONCLUSIONS AND PERSPECTIVES

This paper presents NetLMM in a context of Always Best Connected where the simultaneous use of interfaces and the dynamic change of IP addresses are inseparable. We enhanced NetLMM with the *selective deregistration* procedure and the *keep-alive* procedure for maintaining multiple bindings in the LMA and ARs. We point out that IP tunneling is not suitable for simultaneous use of radio interfaces in NetLMM. We proposed a new *virtual SCTP tunneling* method as the alternative to IP tunneling. The early analysis shows that the new tunneling method is advantageous for both the user and the operator. From the user perspective, the bandwidth, the QoS are improved with wireless bandwidth aggregation. From the operator perspective, the system utility can be improved by switching flows/packets to the right radio interface.

We implemented the first proof-of-concept for validating the scenario of wireless bandwidth-aggregation under ns2. In the next phase, we will optimize the *virtual SCTP tunneling* to achieve better bandwidth utilization. We will use the above architecture to define and model an intelligent interface selection algorithm that should satisfy both network operators and mobile users while considering the impact of different factors such as mobility, network traffic characteristics, limited coverage area, etc.

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