Mobility Management in Next Generation Mobile Networks

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***Abstract*—In this demo we propose a novel architecture suitable for deployment in future mobile networks based on the distributed mobility management (DMM) paradigm. In DMM, the IP anchoring point gets closer to users, with the aim to flatten the architecture and to truly enable the fixed/mobile convergence.**

DMM allows operators to tackle the explosion of data traffic without burdening the core part of the network, offering a common IP framework for mobility and heterogeneous access.

As a use case scenario, this demo has shown a possible deployment for a content delivery network's nodes, in order to exploit the DMM benefits.

I. Introduction

In recent years, we have witnessed a steep increase of data traffic in mobile networks. This *mobile revolution* has been pushed by the high rates reached by current wireless technologies, the vast penetration of modern high-end handheld devices and the successful proliferation of applications based on Internet services. More, this trend is expected to be further boosted in next years with the current deployment of the so-called 4G technology and the consequent All-IP design.

In order to cope with the foreseen huge amount of traffic, mobile network operators are currently seeking and designing innovative solutions to reduce data transmission costs while maintaining a good service perceived by subscribers. For instance, some of these solutions are the WLAN traffic offload and the Local IP Access and Selected IP Traffic Offload (LIPA-SIPTO) [1], under study within the 3GPP[1]. The WLAN offload mechanism primarily aims at reducing congestion in the access part of the network, while the LIPA-SIPTO technique is mainly focused in mitigating the traffic aggregation at the core's gateways.

Following up on these topics, the IETF[2] community started investigating new ways of approaching the IP mobility problem space. Representatives of the industry stress the need for flexible mobile solutions, simplifying the deployment model while addressing new requirements in terms of offloading and optimal routing. DMM [2] is therefore one of the key technologies allowing distribution of mobility functions so far centralized at single and expensive points. In fact, traditional IP mobility solutions, e.g., DSMIPv6 [3] and PMIPv6 [4], rely on the existence of central mobility servers that anchor the IP address used by the mobile node (MN).

[1] 3rd Generation Partnership Project: http://www.3gpp.org/
[2] The Internet Engineering Task Force: http://www.ietf.org/

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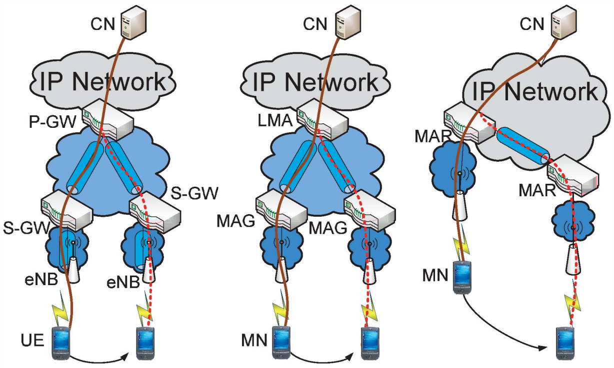

(a) EPS (b) PMIPv6 (c) **DMM**

Fig. 1. Network layout.

In this work, we present a prototype for next generation mobile networks. We show the implementation of a DMM solution carried out as proof of concept of the DMM paradigm. The solution is validated through a use case scenario highlighting the advantages brought by DMM combined with the deployment of Internet service, as for example video content delivery. In this document, Section II presents an overview of DMM with respect to centralized scheme and Section III gives a walk-through of the demo.

II. Distributed Mobility Management: an Overview

The mobility protocols currently adopted in cellular networks follow the traditional centralized model, where users' data traffic is dispatched by a gateway interfacing the IP network and the operator's one. Such gateway is on top of a tree-based hierarchy, whereas the basis consists in the radio access network.

For instance, in the Evolved Packet System (see Fig. 1-a), a packet data network gateway (P-GW) connects the IP network with a number of serving gateways (S-GW), which in turn handle several eNodeBs (eNB), the base stations for LTE radio access. The GPRS tunneling protocol (GTP [5]) is used as data and control plane to deliver subscribers' data packets, and also to manage user equipment (UE) mobility. The UE can start IP communications after having established a packet data network (PDN) session with the P-GW. In GTP, packets are encapsulated in the access network between the eNB and the S-GW and also between the S-GW and the P-GW. In this way, when the UE enters the domain of a new S-GW, the IP flows are still anchored at the P-GW, which simply redirects traffic to the appropriate tunnel.

Alternatively to GTP, the P-GW/S-GW interface can be substituted by Proxy Mobile IPv6 (PMIPv6 [4]), an IP based mobility protocol standardized by the IETF (see Fig. 1-b). The PMIPv6 operations are pretty similar to GTP. Simply put, the P-GW is renamed as local mobility anchor (LMA) and the S-GW into mobile access gateway (MAG). Also, following Mobile IPv6 (MIPv6 [6]) terminology, the moving host is renamed in mobile node (MN). Still, in PMIPv6, the users' traffic is encapsulated between the LMA and the MAG, and, in case of movement, IP flows are anchored at the LMA, which delivers MN's traffic using the corresponding tunnel.

It can be observed from these examples that the centralized IP gateway suffers from some limitations: *i)* as the P-GW/LMA aggregates traffic for a vast amount of users, it has to be provisioned with large equipments and transport links, reducing scalability; *ii)* since data packets need to traverse such IP gateway, routing paths might result to be non-optimal; *iii)* mobility support is offered as a default service to subscribers, even for those IP flows that do not necessarily need it (e.g., HTTP), incurring in encapsulation overhead that can avoided; *iv)* the mobility anchor represents a single point of failure.

In order to tackle such limitations, the IETF community is currently re-designing mobility protocols following a distributed paradigm, thus the DMM working group has been chartered for this purpose[3].

In this work, we have implemented the network-based partially distributed solution described in [2]. The solution consists basically in decoupling the PMIPv6's control and data forwarding planes, applying the following changes. The local mobility anchor is no longer traversed by user traffic, but still it is responsible to store the users' mobility sessions (bindings). Due to its simplified role, it is renamed into central mobility database (CMD). The mobile access gateway is modified to become the only agent in the data plane. It is enriched with additional functionalities so that, besides being the access router for the MNs connected to its access links, it is also the anchor for the MNs' data traffic. This node is called mobility access router (MAR). More, the solution inherits the same control messages and data structures defined by PMIPv6, extending them to accommodate the operations for a distributed design.

Our DMM protocol envisages a more dynamic traffic anchoring than PMIPv6: a MAR acts both as standard router (i.e., no IP tunneling) when a MN connected to it starts new data sessions, and as mobility anchor for ongoing connections when the MN moves to another MAR by establishing an IP tunnel with the new MAR (see Fig. 1-c).

[3]http://datatracker.ietf.org/wg/dmm/

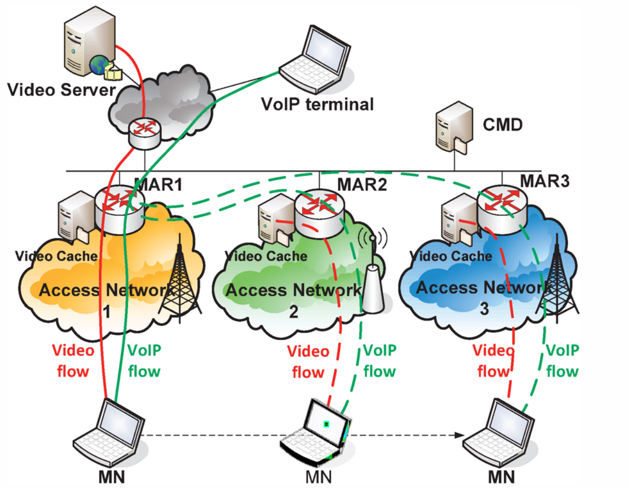

Fig. 2. Network layout.

A. Use case: content caches co-located with MARs

Content delivery networks (CDN) have gained success in recent years to optimize the delivery of the data requested by users. By deploying content caches co-located with MARs, our architecture enables a mobile operator to deliver content to the user without congesting its core network with the traffic generated by the users. Also, users benefit from an extremely low latency when accessing those caches, as they are placed one IP hop away from the MN's current location. Mobile operators have the chance to play an active role in offering multiple services to the subscribers, and not only the mere IP connectivity. In this work, we deploy as example a CDN for video services, showing that, at every MN movement, the video chunks are streamed from the MAR that is currently serving the MN.

III. Demo Walk-Through

In the following, we provide a high-level walk through of the demo with focus on functionalities enabled by DMM (see Figure 2).

We consider an MN moving around in a mobile network composed of three MARs, each offering a different radio access, respectively 3G, WiFi, and LTE[4]. An additional node acting as CMD is deployed to form the mobility domain. Video contents are available at a remote server and replicated in caches co-located with the MARs.

In our prototype, the entities running the mobility domain (the three MARs and the CMD), are realized using ASUS WL-500G miniPCs, running OpenWRT as operative system. These boxes provide WiFi connectivity by default (IEEE 802.11 b/g). In case LTE and/or 3G is available from a commercial

[4]The LTE and 3G access technologies during live events are subject to the availability of such in the venue where the event is celebrated. In case a technology is not available, it will be replaced by WiFi access.

operator, an IPv6-in-IPv4 tunnel is established between the MN and the box over the LTE (3G) link, so that the box is seen as the first IPv6 hop and default gateway by the MN on that link. A Ubuntu 12.04 laptop acts as mobile node. An additional Ubuntu laptop is used to host the video server, a web server, as well as a VoIP client to show a voice call with the MN. The DMM solution is written in C for Linux platforms, based on the code developed within the UMIP project[5].

The MN is accessing both a video service (Video flow) and a VoIP flow when connected to MAR1, that offers 3G connectivity. The user is playing the video using VLC Media Player with DASH (Dynamic Adaptive Streaming over HTTP, an HTTP-based adaptive bit-rate streaming technology where a multimedia file is partitioned in segments/chunks). A media presentation description (MPD) provides the URLs for the segments and, once downloaded, the player starts requesting the chunks listed in it. All HTTP requests pass through the HTTP proxy server[6] co-located within the MAR, which intercepts and analyzes all requests. If the video chunks are available in the local cache, they are directly streamed to the MN. Otherwise the HTTP requests are forwarded to the video server which can serve them.

All along, the user is moving and eventually attaches to MAR2. The chunk which is currently in download is tunneled from MAR1 to MAR2 according to the DMM protocol. This is necessary to guarantee that the video stream is not disrupted due to excessive packet loss. However, as next chunks are requested in individual HTTP sessions, the proxy server intercepts the requests and in case the chunks are available locally they are delivered by MAR2, hence the video flow is no longer anchored at MAR1. Conversely, the VoIP flow is always anchored to MAR1, so the traffic is tunneled between MAR1 and the MAR currently serving the MN. This happens because the VoIP flow is not segmented as the video, and the communications endpoints (and consequently the source and destination addresses of the connection) cannot be changed as easily as for the DASH video.

Finally, the user moves out of WiFi coverage and goes under LTE coverage. VoIP is still anchored at MAR1 but the video now is streamed by MAR3.

For the sake of better visualizing the benefits of the DMM architecture during the demo, the local caches in the MARs contain all the chunks for the requested video and thus the video is always streamed by the MAR serving the MN.

In the entire demo, the user is transparent to the dynamics happening in the network.

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