Multiple Network Interfaces Management for Mobile Routers*

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Abstract: *In recent years we have witnessed the development and the deployment of a multitude of wireless access networks, including IEEE 802.11a/b/g WLAN, IEEE 802.15 PAN, IEEE 802.20 MBWAN, or 3G WWAN. In this heterogeneous environment the IPv6 network layer is widely accepted as being the much-needed convergence layer to accommodate various kinds of technologies. Thus, mobility management procedures have been designed for the IPv6 layer, comprising the mechanisms for network mobility (NEMO) that support the mobility of entire networks. Moreover, the Mobile Routers that connect these mobile networks to the Internet will be equipped with several wireless interfaces, and therefore they have to make decisions about which interfaces to use for each mobile node or application. Our current work focuses on the issues related to the interface selection decisions and their applicability in the case of Mobile Routers.*

Keywords: network mobility – NEMO, multi-interface mobile routers, always best connected, multihoming

1. INTRODUCTION

As IPv6 has become the convergence layer used when integrating the heterogeneous access networks, providing seamless access to the Internet is one of the important tasks within the Internet Engineering Task Force (IETF). Consequently, protocols such as Mobile IPv6 [1] and its suite have been recently engineered in order to cope with the mobility management issues. Nonetheless, the need to displace a number of hosts collectively known as a "mobile network" and "network mobility (NEMO)" (for instance on cars, trains or airplanes, see [11]) has imposed the extension of the Mobile IPv6 protocol from handling a single mobile node to supporting a complete mobile network. This is necessary in order to avoid the change of addresses inside mobile networks, especially for nodes with no mobility support capabilities (i.e., LFN, see [12]), or to minimize signaling overhead during handovers. If the internal addressing within a mobile network changes, each node inside the network has to inform its Home Agent (HA) and its correspondent nodes (CNs) each time the mobile network moves; this could lead to a large amount of signaling traffic on the radio link which is a scarce resource by excellence. Therefore, the IETF NEMO working group has designed a mechanism that maintains the connections between the Mobile Network Nodes (MNNs) and their Correspondent Nodes regardless of the end-nodes' movements. The effort to provide NEMO support was divided into two parts, namely NEMO Basic Support [2] and NEMO Extended Support. NEMO Basic Support is an extension of the Mobile IPv6 protocol. A mobile network preserves its connectivity by dynamically constructing bi-directional tunnels between the Home Agents and the Mobile Routers (MRs) acting as gateways between the mobile network and the rest of the Internet. Then, the HA is responsible for forwarding all the traffic designated to the mobile network prefixes (MNPs) toward the current position of the mobile network, i.e., the Care-of Address (CoA) of the Mobile Router. Thus, the HA manages a list of MNPs (the prefix table) which is associated to the Home Address (HoA) of the Mobile Router. The MR interfaces connected to the visited link are called egress interfaces (E-faces), whereas the ones connecting the mobile subnet to the MR are designated as ingress interfaces (I-faces). A NEMO may have several MRs connected to the Internet or it may use several E-faces simultaneously in order to gain access to the Internet (as explained in [10]). A simple network mobility scenario with three Access Routers is presented in Figure 1.

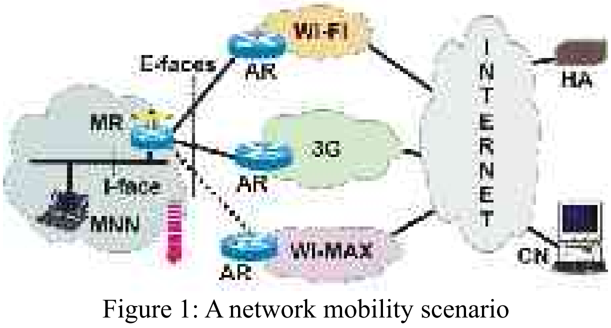

Figure 1: A network mobility scenario

Besides typical NEMO functionalities (see [2]), we suggest that the Mobile Router act as a policy decision and enforcement point when several E-faces are present. Thus, the MR may choose just one E-face when several

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access networks are available, or it may simultaneously use several E-faces in order to perform load balancing and map the communication flows on E-faces depending on the administrator and the network operators' preferences, or to improve the handover management. Some work has been carried out on the multihoming issues raised in NEMO context (see, e.g., [3] and [4]); however, they were more focused on the evolution of the network stack architecture needed to support multihoming. Nevertheless, it is necessary to make a decision, i.e., to choose an E-face and an IPv6 source address for the tunnel towards the HA, and also to feed this decision process with the appropriate parameters. There are several research activities (see [5] for a survey) that deal with this problem but in the context of a mobile node. We have contributed to this area of research by designing and implementing a multi-interface mobile terminal architecture [6]. Nonetheless, in this paper we explore the use of our architecture in the NEMO context and we show the benefits we could get by applying our solution. We will also give suggestions on how to improve the MR behavior by taking into account the various actors' requirements (as our architecture does in the mobile terminal context).

The rest of the paper is organized as follows. First, we briefly review the benefits and the issues concerning the Mobile Routers equipped with multiple egress interfaces (i.e., multihomed). Then, we introduce a novel Mobile Router architecture that takes into account different profiles when selecting the egress interfaces to be used for simultaneous or successive connections to the Internet. Next, we describe the test-bed we have set up for the network mobility and we discuss a typical use-case. Finally, we explain what is missing and what has to be done in order to take advantage of multiple interfaces availability on Mobile Routers; this leads us to present the most interesting perspectives and our plan for future work. As usual, the concluding remarks will be provided at the end.

2. MULTI-INTERFACE MOBILE ROUTERS – ISSUES AND BENEFITS

A typical Mobile Network will be connected to the Internet through various wireless access technologies that are using different and/or complementary radio technologies. Therefore, to overcome the well-known drawbacks of these technologies, the main idea is to equip the Mobile Routers with several egress interfaces using different technologies. Even if some extensions to the NEMO protocol are required (see [4]), the benefits of the multi-interface approach are obvious. These benefits have been presented, for example, in [10] and [13]; we just give a brief description of them in the following paragraphs. First, it will be easier for the Mobile Routers to offer a ubiquitous access because several access technologies may be available within a location at any given time. Moreover, the redundancy can be guaranteed in a more effortless manner if several egress interfaces are employed for communication. Then, diverse load-sharing and load-balancing schemes can be applied for spreading the traffic on several interfaces. Finally, various policy/preferences routing mechanisms can be imagined in order to let the mobile end-users and/or the applications to choose amongst the MR's egress interfaces based on their requirements in terms of QoS, cost or security.

To have these functionalities implemented and take advantage of them, a number of improvements are currently under discussions within the IETF. Unfortunately, even if their importance is recognized (e.g., see [10]), the decision mechanisms for selecting "best" egress interface (also known as path selection) are not within the scope of the IETF work. Nevertheless, the optimum interface selection problem within the multi-interface mobile nodes communicating in heterogeneous radio environments has already been in the researchers' view for a while (e.g., see [7], [8]).

Following this trend, we have recently developed a novel mobile terminal architecture (see [9]) that uses profiling and selection decision mechanisms to support the simultaneous use of several interfaces and vertical handovers. For example, this architecture allows us to automatically select the "best" interface for each application flow by taking into account different requirements, such as: users/administrators preferences, surrounding context, or applications needs. Moreover, our architecture has integrated a number of adaptation mechanisms at different layers, e.g., including the support for adaptive applications or the interactions with various L2 triggers (see, e.g. [17]).

Therefore, inspired by this modular architecture, we propose a new Mobile Router architecture supporting several egress interfaces within different network mobility scenarios. Likewise, to fully benefit from such an advanced architecture, the missing mechanisms and protocols on the MR need to be thoroughly investigated.

3. MOBILE ROUTER ARCHITECTURE

In this section we describe in details the proposed architecture for the Mobile Routers and we focus on two of its components: the Profile Manager and the Selection Decision modules.

3.1. Architecture Overview

In order to let the users and the network operators take advantage of the different access interfaces existing on the Mobile Routers, we have designed and implemented an advanced middleware. Our middleware allows the Mobile Routers, which may have simultaneous or successive connections to several access technologies, to automatically configure and select the "best" suitable egress interface according to the defined various preferences. Figure 2 shows the envisaged Mobile Router architecture, its components and the interactions among them.

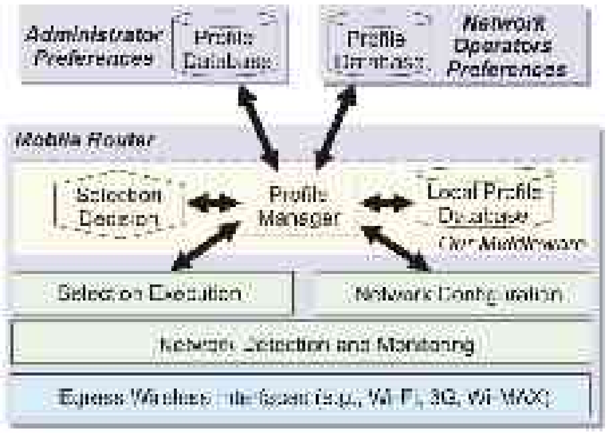

Figure 2: Overview of mobile router architecture

Accordingly, in a structured way, we gather the preferences given by the administrator or the network operators, and the capabilities of wireless interfaces and access networks in well-defined profiles. Then, the decision to use or not an egress interface is based on these profiles; our aim is to select the "best" access option. Consequently, an important part of the Mobile Router architecture is dedicated to the definition and the management of profiles existing within our middleware. Generally, the profiles are files stored in profile databases and they summarize key information about the components of the system and its interactions with the environment, that is the mobile users, the network operators, or the service providers. Therefore, the Profile Manager determines if the Selection Decision module needs to be informed or not about the changes within the Mobile Router. Finally, based on the triggers received from the Profile Manager, the Selection Decision component queries various Profile Databases and suggests the "best" egress interface be employed for communication.

Besides the middleware, we also need a set of three supporting lower modules (see Figure 2); the first one detects the available networks and provides real-time information about the interfaces and access networks capabilities; the second "lower-layer" module makes on-demand network interface configuration; and, the third one handles the selection execution process, i.e., it actually maps the network traffic on the preferred egress interfaces. Finally, we stress the fact that our middleware controls all these "lower-layers" modules by initiating network configurations and performing interface selection decisions.

3.2. Profiling Mechanism

In order to capture the most of the characteristics and the capabilities of the Mobile Router we have designed a Profile Manager module and three kinds of profiles within the Profile Database:

1) Preferences and Resources Profile (PRP): we noticed that one's preferences depend on the currently existing resources or the present situation; thus, the PRP specifies how the Mobile Router should behave depending on the current context, such as geographical location or end-user role; the preference parameters considered within the PRP are, e.g., cost, security level required, and preferred and forbidden access networks.

2) Network Interface Profile (NIP): it comprises network interface parameters that can be obtained from technical specifications (e.g., maximum theoretical throughput), or that can be found through measurements (e.g., average throughput and typical delay).

3) Access Network Profile (ANP): it specifies all the necessary information required to successfully configure and use an access network; for example, the ANP contains the mandatory parameters required to associate with the network, such as WEP keys for IEEE 802.11a/b/g hotspots, PIN codes for Bluetooth or Access Point Names for GPRS networks; in addition, the ANP may contain information related to the cost and the security parameters specific for each known access network.

It can be pointed out that the Profile Manager acts as a dispatcher within our architecture: it interacts with all the entities which supply the profiles, it knows which information needs to be stored in the Profile Database, and it determines if the Selection Decision module should be triggered or not. The described interactions amongst the constituent modules and the various existing profiles are depicted in Figure 3.

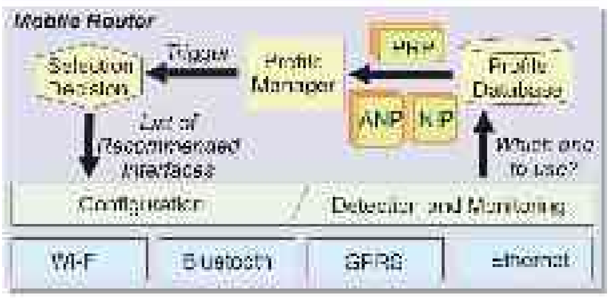

Figure 3: Modules interactions

3.3. Selection Decision

After receiving a trigger from the Profile Manager the Selection Decision module uses various profiles for choosing the most suitable egress interface to be used for communication. Thus, in our approach the Selection Decision entity does not need to know how the parameters are collected within profiles or how the selection decisions are enforced.

The outcome of the Selection Decision module consists of a list of recommended interfaces. This list contains two parts. The first part comprises the preferred interfaces that are already configured and can be employed for communication immediately; the second part contains the interfaces that may be activated and employed only if the configured interfaces do not suffice.

The suggestion to employ or not an interface is currently made for all existing traffic (i.e., a single egress interface at a time). Nevertheless, in our future work we will also deal with a Selection Decision module that proposes the “best” interface for each mobile end-user or even for each application, and thus, several egress interfaces may be used simultaneously on the MRs. This was already worked out for Mobile Nodes (see [9]); however, as we will see later on in Section 4.3., integrating such strategies within the proposed architecture requires some changes and improvements on Mobile Routers.

4. IMPLEMENTATIONAND USABILITY

This section deals with implementation issues and it also presents a typical use-case. Moreover, in order to take full advantage of the proposed MR architecture, the missing mechanisms are reviewed and possible improvements are discussed.

4.1. Implementation Details

To implement and test the proposed Mobile Router architecture we have chosen a laptop running FreeBSD 5.3; to support the MIPv6 and NEMO mobility we have installed the SHISA stack (see [14]), which is an extension of KAME (see also [15]).

Then, as access technologies, we have used IEEE 802.11b, Bluetooth, Ethernet and a GPRS network. To detect and configure these networks, we have used various scripts together with standard OS commands.

The information stored within all these profiles is managed in a uniform and extensible manner using the XML and the Ruby language; this language has many built-in libraries for handling XML files and for inter-modules communication.

The proposed mechanisms allowed us to emulate various scenarios such as: the choice of the fastest or the cheapest interface, “always on”, the selection of the most appropriate interface when combining several goals (e.g., QoS vs. Cost), etc.

4.2. A Typical Use-Case

To better understand how our Mobile Router architecture works, we present one of the use-cases we have simulated in our laboratory. In this use-case let us imagine a taxi car with two actors inside: the taxi driver and a businessman. Thus, various Preferences and Resources Profiles (PRPs) may exist in the Profile Database, for example, the PRP of the car fleet administrator and the PRP of the taxi driver. Moreover, the administrator is able to define a PRP profile for regular clients or for business clients. The arbitration mechanism amongst these different PRPs was described in [9]. Typical parameters within PRPs are, for example, the cost and security preferences, and the preferred and forbidden access networks. In our example, we consider that the taxi fleet administrator has set up the highest priority for the business clients PRPs and has specified the security as the most important requirement.

The taxi is equipped with a Mobile Router that has GPRS and Wi-Fi network interfaces with their own Network Interface Profile (NIP).

Furthermore, these interfaces may use distinct access networks in time; thus, several Access Network Profiles (ANPs) exist within the Mobile Router’s database. Let us see what happens inside the Mobile Router (see also Figure 4).

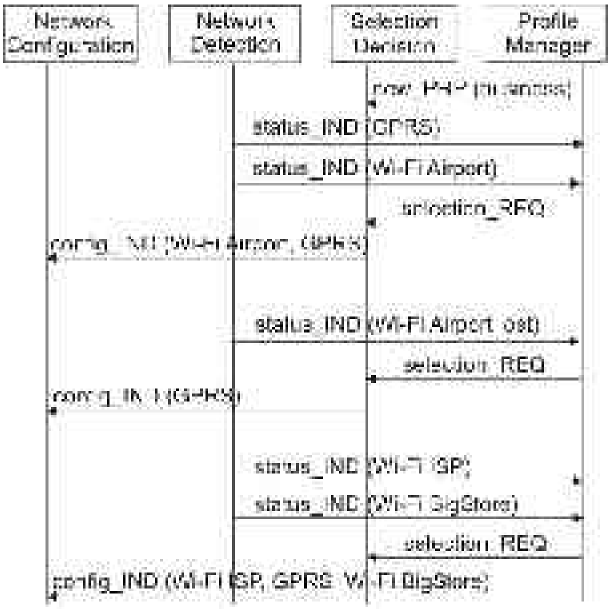

Figure 4: A typical use-case

When the taxi begins the trip at the airport the Network Detection module informs the Profile Manager about the existence of two access networks, namely a commercially available GPRS network and the Wi-Fi hotspot of the airport. Thus, the Selection Decision entity suggests the use of Wi-Fi and GPRS network interfaces in this order. Additionally, to allow the Network Configuration module to set up the interfaces, the corresponding Access Network Profiles are also provided.

While departing from airport, the Network Detection component notifies the Profile Manager about the lost of Wi-Fi coverage. Thus, the Selection Decision module proposes only the GPRS network in the list of preferred interfaces.

Let us suppose that during the trip, somewhere in the town center, the availability of two Wi-Fi networks is detected, i.e., one of an ISP and one of the Big Store. Therefore, the Profile Manager triggers again the Selection Decision module which, based on preferences from PRP, suggests the use of Wi-Fi ISP, GPRS, and Wi-Fi Big Store in this preferred order (e.g., the Big Store hotspot is less secure than the ISP access point).

The purpose of this typical use-case was to show how our middleware, that contains the Profile Manager and the Selection Decision modules, behaves and how it manages common situations that come up when several interfaces are employed within the Mobile Routers.

4.3. What is Missing in Mobile Routers?

We underline the fact that in our approach the Mobile Router may dynamically interact both with the MR's administrator and with Network Operators in order to gather their specific preferences or requirements. For example, our proposal allows the administrator to easily configure an entire fleet of Mobile Routers (e.g., for a taxi company) by remotely providing them with the specific preferences profiles. However, the work for such protocols is ongoing within our projects.

Moreover, in order to allow the MR to select the most appropriate egress interfaces, the applications executing on the Mobile Network Nodes (MNNs) may wish to inform the Mobile Router about their service requirements (i.e., QoS needs), or to be informed about the MR's capabilities in order to adapt their behaviors. Thus, the profiles may be distributed amongst different entities, and therefore a protocol between the MR and the MNNs is required to handle them. Moreover, in the common case of multiple applications running on the MNN, the arbitration mechanisms amongst the several applications' flows require to be designed and implemented on the Mobile Router. The typical scenario with several MNNs complicates even further this arbitration because each end-user may have her/his specific preferences.

We can also mention the fact that multihoming is not supported by the current NEMO protocol, and thus, we could only use one egress interface at a time. However, the work on this issue is ongoing at IETF (e.g., see [16]) as well as its implementation within SHISA stack. Additionally, when fast handover mechanisms (such as those based on L2 triggers [17]) are to be implemented on the Mobile Routers, we will be able to have more advanced selection strategies that can distribute the traffic on several interfaces in a more expeditious manner.

Finally, from other point of view, we can also have scenarios where multiple Mobile Routers exist (see, e.g., [10]) and, therefore, negotiations between the MRs on how to select the most appropriate egress interfaces need to be considered in future.

5. CONCLUSIONS

We have applied our architecture originally designed for multi-interface mobile terminals to a Mobile Router supporting multiple egress network interfaces. This allowed us to automatize the configuration of the network interfaces and to solve the interface selection problem for simple cases (i.e., one interface at a time). Our main goal was to allow the mobile users to always employ the "best" access option. Thus, based on a profiling mechanism we are able to propose the most suitable interface to be used for communication when several access networks are present.

Our ongoing work focuses on further refinement of the profiles and on the investigation of more selection strategies; these strategies will evolve as several egress interfaces will be supported simultaneously in future NEMO releases. Finally, more tests need to be carried out in order to grasp all the benefits of the proposed Mobile Router architecture.

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