Advantages of Flow Bindings: an embedded mobile network use case

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ABSTRACT

This paper reports a demonstration of embedded communication systems on bicycles, and shows the advantages of Flow Bindings associated with the Network Mobility Basic Support (NEMO BS) protocol to distribute traffic along various paths.

In June 2007 we demonstrated a new E-bike system by using the ANEMONE Mobile IPv6 testbed. In practice, three bicycles equipped with user terminals evolved on the university campus named Beaulieu in Rennes, France. All user terminals were connected to the IPv6 Internet via a mobile and multi-interfaced router with Network Mobility Basic Support protocol. This protocol included for the first time the Flow Bindings support in order to optimize the different network accesses. In this paper, we show why it is important to install flow policies on an embedded mobile network in order to distribute and filter applications according to the connectivity of the mobile network.

Categories and Subject Descriptors

C.2.0 [**Computer-Communication Networks**]: General—*Data communications*; C.2.1 [**Computer-Communication Networks**]: Network Architecture and Design—*Network communications, Wireless communication*

General Terms

Design, Experimentation, Performance

Keywords

Next Generation Wireless Network Testbeds, IPv6 Mobility, NEMO Basic Support, Flow Bindings, embedded applications

1. INTRODUCTION

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The increasing popularity and improving characteristics of wireless technologies stimulated the appearance of new types of user behavior and expectations. The concept of pervasive connectivity (i.e. being connected anywhere, anytime) is, among others, of crucial importance. The users expect to benefit from their usual network applications or services while on the move. Unfortunately, heterogeneous wireless Internet access has increased the complexity of user terminals. Various wireless chipsets are now included in such terminals, which requires intermediate or sometimes advanced configuration skills from the users as each wireless technology has its own characteristics. Furthermore, several wireless networks can be available at the same time, and it is up to the users to select the best interface according their needs and requirements (e.g., minimize the cost or maximize the bandwidth).

In order to simplify the access to heterogeneous IPv6 networks [1], we can move the mobility management to a distinct network entity, and access the Internet from a simple user terminal. This is one of the ideas lying behind the Network Mobility Basic Support (NEMO BS) protocol [2]. This protocol introduces the notion of Mobile Routers (MR) which are IPv6 routers in charge of the mobility management of an entire network, called a mobile network. As a result, every network movements are handled by the MR, and are fully transparent to the nodes located inside the mobile network. For example, public transportations may benefit from NEMO BS to provide Internet connectivity to their customers during their journey.

Thanks to the Multiple Care-of Address (MCoA) extension [3], a multi-interfaced MR may use several network interfaces simultaneously connected to the Internet. Such MR is commonly said multihomed. However, neither the NEMO BS protocol nor MCoA defines how to select the interface the MR should use to forward the data packets to or from the Internet. To fully benefit from these multiple paths, the Internet Engineering Task Force (IETF) [1] is currently designing the Flow Bindings scheme [4]. This is a set of NEMO BS extensions allowing MRs to bind one or more flows to a specific network interface. By this mean, the operators of the MRs could define routing policies to redirect efficiently each flow among all network interfaces currently in use regarding their needs and requirements (e.g. cost, bandwidth, security, or quality of service).

[1] http://www.ietf.org

In this article, we present the results from the E-Bike demonstration held within the Pracom conference [5] in Brest, France. E-Bike is a generic name used for periodic demonstrations organized by the Nautilus6 Working Group [6] to show new trends and new protocols in a mobile environment. This new demonstration is the first experiment in a real environment of a fully functional NEMO BS testbed implementing the Flow Bindings scheme. This demonstration was hosted by the French site of the FP6-IST ANEMONE project [7].

The rest of the article is organized as follows. First, in Section 2, we present the motivations and expectations of performing a new E-Bike demonstration. Section 3 provides an overview of the demonstration scenario followed by Section 4 where we present and analyze the advantages of Flow Bindings. Finally, conclusions and future works are presented in Section 5.

2. DEMONSTRATION PURPOSE

The purpose of this demonstration is to experiment in a real environment the first implementation of the Flow Bindings scheme. A previous demonstration performed at the Tour de France [8] illustrated the NEMO BS protocol [2] in a real life use and environment. Thanks to the MCoA extension [3], the presented MR was multi-interfaced, it could simultaneously establish several concurrent paths to the Internet (one Home Address to several Care-of Addresses). These concurrent paths enable a simple flow redirection feature: when a path is no longer available (e.g. due to an outage), all of the traffic is redirected from the failed interface to an active one. By this mean, the latency experienced by communications is drastically reduced as other paths are operative (the establishment of the tunnels between the MR and its Home Agent are already set up). However, only one network interface was used at a given time to forward the flow to or from the mobile network. This limitation is due to the NEMO BS and MCoA specifications that do not address how the traffic could be distributed simultaneously among all available network interfaces.

In addition, during this past demonstration we observed that the most critical issue was the limited capacity of the first hop of the mobile network, which is the egress interface of the MR that connects the mobile network to the IPv6 Internet.

New proposals such as Flow Bindings [4] overcome these limitations by introducing the support of routing policies in NEMO BS. In the case of a multi-interfaced MR, the Flow Bindings scheme enables the use of routing policies to bound flows to different network interfaces regarding the characteristics of the flows such as the bandwidth, constraints latency, etc. and the availability and the state of the mediums.

The new E-Bike demonstration presented in this article therefore extends the previous one by highlighting the benefits of the Flow Bindings scheme in a practical deployment of NEMO BS.

3. DEMONSTRATION SCENARIO

3.1 Targeted Scenario

Our scenario presents the advantages of Flow Bindings scheme in a mobile network environment with NEMO BS. This demonstration is composed of three bicycles (see Figure 1). Each one embeds different devices such as a user terminal (i.e., Tablet PC), a camera and a GPS sensor. In addition, one special bicycle carries a MR. The user terminals and the MR are connected together with Wi-Fi ad hoc connection and compose a mobile network. The MR is connected to the IPv6 Internet through both Wi-Fi and GPRS technologies.

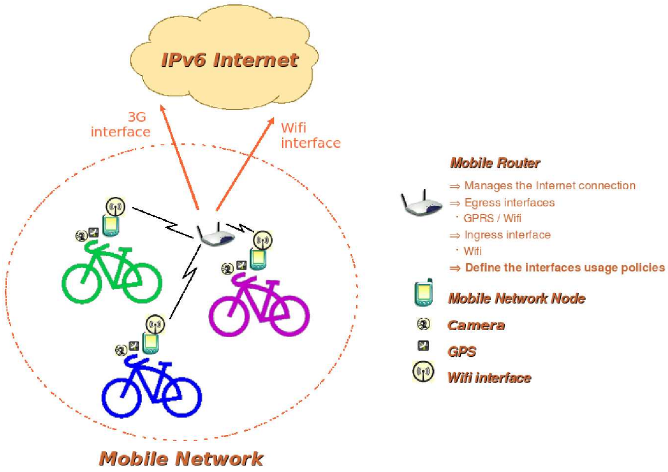

Figure 1: The mobile network in demonstration: three bicycles and one Mobile Router with two paths to reach the Internet

The bicycles move through an itinerary across the university campus called Beaulieu in Rennes, France (see Figure 2) where both GPRS and Wi-Fi connectivity is available. The bicycles move from the Telecom Bretagne laboratory to the IRISA/INRIA's one. The itinerary is fully covered with a GPRS access. In addition, an outdoor Wi-Fi access is deployed near both laboratories. The outdoor Wi-Fi coverages are represented by the dark areas in Figure 2. During the trip, the MR (which is the only equipment directly connected to the Internet) crosses different access networks. It starts with both Telecom Bretagne's Wi-Fi and GPRS accesses, then it looses the Wi-Fi connection and only has the GPRS access turn on between both laboratories, and it finishes with IRISA/INRIA's Wi-Fi and GPRS accesses again.

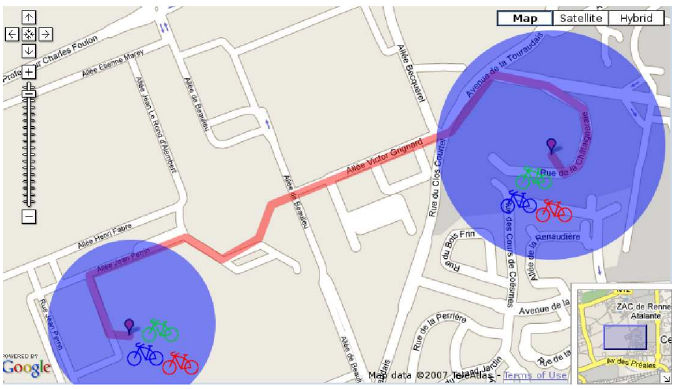

Figure 2: The mobile network moves and crosses different access networks (Wi-Fi, GPRS)

For public monitoring from the Internet, a set of data of each component of the mobile network is periodically sent to a web server. As the bottleneck of the path between the mobile network and the potential users accessing the mobile network information is on the first hop from the mobile network to the Internet, the MR only sends the data to a central point in the Internet (i.e., the web server). Then the web server distributes the data to any users who follow the demonstration over the Internet, without introducing more traffic on the MR egress interface.

These data concern pictures from the cameras, GPS coordinates of each bicycle and network flow rates of every wireless interface. The targeted audience of the demonstration, i.e., the assistance of the Pracom seminar, is localized 300km far away from the demonstration in Brest, France. They were able to follow the demonstration remotely by seeing on a web interface the bicycles on a satellite map, pictures of the landscape and the mobility monitoring of the MR. In addition, a Voice over IP (VoIP) and Instant Messaging (IM) sessions were established between every bicycle and the Pracom audience.

The VoIP service is provided by a conference bridge hosted on a bicycle. This bridge provides a conference room for the bicycles and remote participants from the Internet. The conference bridge is embedded in the mobile network in order to maintain the communication between the bikers even if the connection to the Internet is broken. Thus, the bikers can always communicate together even if the mobile network is not connected to the Internet. This is a very important feature, as the wireless connectivity of the mobile network to the Internet is sporadic, and subject to outages. Each bicycle establishes a VoIP flow with the conference bridge. In addition, one VoIP call has been set up between the Pracom audience and the mobile network.

The VoIP flow between the mobile network and the Pracom audience requires a particular attention. When the mobile network is connected through Wi-Fi, the quality of the VoIP session is good. However, once the MR looses its Wi-Fi connection, it only uses the GPRS interface for all traffic. However, the characteristics of GPRS do not match those required by the VoIP session and thus the transmission of such an amount of data over GPRS is likely to oversaturate the medium. Therefore, we propose to install filter rules on the MR to prevent the transmission of VoIP flows through the GPRS interface. The VoIP session between the mobile network and the Pracom audience is thus interrupted as long as the Wi-Fi connectivity is not available. As a consequence, the other flows between the mobile network and the Internet (including mobility signaling messages) are not affected by a medium congestion due to the VoIP session.

3.2 Key Components

3.2.1 The ANEMONE Testbed

ANEMONE is an ongoing european project which aims to set up an open testbed based on IPv6 mobility technologies. The french part of the ANEMONE testbed is located on the university campus Beaulieu in Rennes, France. When the ANEMONE testbed will be fully set up, the overall campus will have a Wi-Fi indoor and outdoor IPv6 access. At the moment of the demonstration, there was only a Wi-Fi IPv6 access around the Telecom Bretagne and IRISA/INRIA laboratory buildings. The rest of the campus was covered by a GPRS access. As this GPRS network only provides IPv4 connectivity, an IPv6 over IPv4 tunnel is set up in the ANEMONE testbed.

3.2.2 The Mobile Router (MR)

All mobility aspects are managed by the MR, which permits to keep the mobility transparent from the mobile network nodes without any modifications on their software. The MR is a terminal running the Ubuntu GNU/Linux operating system. It has two egress network interfaces (Wi-Fi and GPRS) and one ingress network interface (Wi-Fi).

The MR integrates the NEMO BS protocol [2] to manage IPv6 mobility. Moreover, the MR implements the MCoA [3] and Flow Bindings [4, 9] extensions in order to handle the multiple network interfaces of the MR and define the interface usage policies. These policies are configured to preferably use the Wi-Fi access. If only the GPRS access is available, the policies are configured to filter the VoIP flows to the Internet.

Figure 3: The web interface provides the mobile network monitoring

3.2.3 INESS

INESS (IPv6 Network Set of Services) [10] is a modular application written in JAVA which offers to the end-users a single graphical interface to manage a set of applications. INESS is important here because the bicycles are equipped with user terminals with a limited screen width, and the bikers have restricted physical movements. In addition, the bikers only have a stylus to control the application, and a virtual keyboard to type the text.

INESS integrates the VoIP and IM modules to allow the communication between each biker and the Pracom audience. In addition, INESS integrates a monitoring module including the type of network access in use (GPRS, Wi-Fi), and several network parameters related to the IPv6 mobility management.

3.2.4 Web Interface

In addition, a web interface has been developed to allow anyone from the Internet to monitor and follow the demonstration without the need to install any software or system. The web server receives all information of each mobile network component. This web interface (see Figure 3) displays a description of each bicycle, the localization and the itinerary followed by the bicycles, the pictures from the cameras, and several parameters on each network interface of the mobile network components during the trip.

Thus, this collection of data allows the Pracom audience (located in Brest) to follow the demonstration and each bicycle. The web interface is based on PHP and Javascript application and is available at [11]. The offered tracking system is based on the service from Google Map [2]. As this service only support IPv4 remote hosts, an IPv6 web proxy has been set up in order to be reachable by the bicycles which have only IPv6 connectivity.

4. RESULTS AND DISCUSSIONS

This section analyzes the advantages of the Flow Bindings scheme in conjunction with NEMO BS. Three main categories of data flows are going through the MR: (1) the VoIP flow, (2) the IM flow and (3) the monitoring flow. In this section, we focus on the most important one in term of bandwidth, the VoIP flow between the mobile network and the audience.

[2]http://maps.google.com

4.1 Throughput analysis

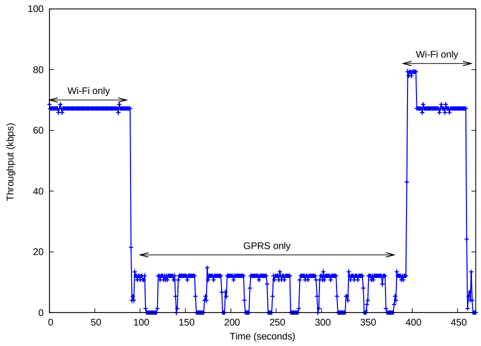

Figure 4: Throughput without Flow Bindings support

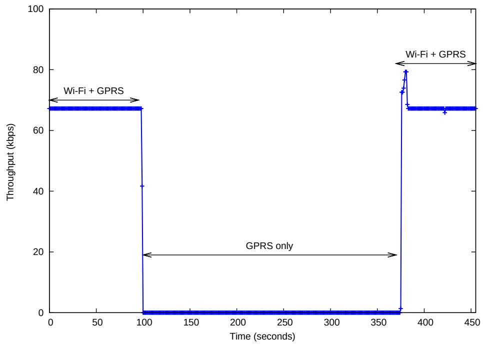

Figure 5: Throughput with Flow Bindings support

Figures 4 and 5 show the overall throughput (Y-Axis) regarding the time (X-Axis), respectively without and with Flow Bindings support, during the mobile network trip. The bicycles move from the Telecom Bretagne laboratory to the IRISA/INRIA 's one. The campus is fully covered by a GPRS access and both laboratories have an outdoor Wi-Fi coverage around the buildings.

As we can see, when the MR uses the Wi-Fi access, the throughput is stable at the nominal bitrate of the VoIP flow. Without the Flow Bindings support, when the MR uses the GPRS access, we observe that the maximum value of the GPRS throughput is reached. This maximum value is smaller than the nominal bitrate of the VoIP flow shown when the MR uses the Wi-Fi access. In this case, the throughput is not stable and has lot of fluctuations during the time. With the Flow Bindings support, when the MR uses the GPRS access, the throughput is null because the VoIP flow is filtered.

When the GPRS access is used, the throughput fluctuations show a saturation of the medium. This medium saturation means that a large number of packets are lost, which is confirmed by the next analysis. Moreover, this saturation does not only affect the VoIP flow but the others as well. As a consequence, the quality of the communication is significantly degraded, and some instant messages, monitoring informations and mobility signaling packets are lost. Obviously, the VoIP session is unusable.

4.2 Packet loss analysis

Figures 6 and 7 show the packet loss (Y-Axis and continuous line) regarding the time (X-Axis), respectively without and with Flow Bindings support, during the mobile network trip. Moreover, the figure 7 shows the packets filtered (Y-Axis and dotted line) re-

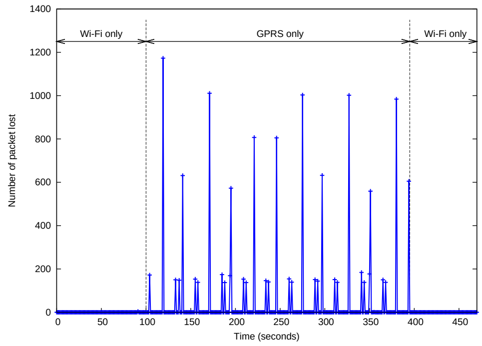

Figure 6: Packet loss without Flow Bindings support

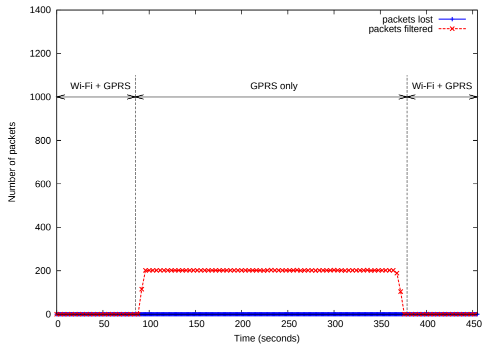

Figure 7: Packet loss and filtering with Flow Bindings support

garding the time (X-Axis). When the MR is using the Wi-Fi interface, the observed packet loss rate confirms that the Wi-Fi medium is able to transport all the packets without any loss. By comparison, without the Flow Bindings support (Figure 6), we can see a large number of lost packets on the VoIP flow whenever the MR uses the GPRS access.

When the GPRS interface is used, the packet loss is due to the saturation of the medium. This saturation affects other flows as well, in particular the mobility signaling messages. As a consequence, the stability of the tunnel between the MR and its Home Agent is also degraded. Some mobility messages are received after the binding lifetime. Thus, the tunnel is not continuously maintained and the MR can not send any packets to the Internet.

With the Flow Bindings support (Figure 7), no packets are lost as the VoIP flow is filtered. The number of packet filtered is about 200 per seconds and represents an important safe of bandwidth for other flows. In our case, we prefer to interrupt the VoIP communication rather than having bad performances in all flows.

4.3 Limitations

In a mobile environment, resources are usually very scarce and need specific management. The management used in this demonstration is based on the Flow Bindings scheme in order to define the interface usage policies; the results show that this support is very valuable. The interface usage policies are configured to filter the VoIP flow which is too greedy in bandwidth to be carried out via the GPRS access. However, these policies could be further extended to filter other kind of traffic, or the definition and enforcement of such policies could even be dynamic.

The policies affect only the VoIP flow depending on the availability of the access network. This application flow is drastically affected by the quality of the medium, especially because the VoIP application has real time constraints. By comparison, the monitoring data are more flexible regarding to the real time constraints. For instance, the policies could impact the monitoring flow instead of the VoIP flow or both according to a timer or dynamic parameters.

In our configuration the difference between the nominal bitrate of the VoIP flow (approximately 65 kbits/s) and the bandwidth available on the GPRS access is too important.A solution could be to use different VoIP codec with lower bitrate to allow the VoIP flow to be transmitted through the GPRS interface but the control on the VoIP server was limited.

In addition, all camera pictures from each bicycle are sent to the web server, but they are not all usable. Some camera pictures are impacted by the brightness of the outside, and show nothing. These camera pictures could be sent to the web server only if they have a good quality.

5. CONCLUSION AND FUTURE WORKS

Quick development of wireless technologies have made possible for users to communicate while on the move. Such mobile nodes, however, have to support mobility in order to be able to maintain ongoing communications. Various mobility management protocols especially designed for next generation wireless network have been recently (or are currently being) standardized. Among them, there is the NEMO BS protocol which is designed to manage the mobility of an entire IPv6 network. Numerous existing studies have evaluated this protocol (often based on theoretical analysis or simulations) and have shown that this protocol appears to be very efficient, especially in a transportation usage. Yet, before large scale commercial deployments, this protocol has to be experienced in real environments. That was the purpose of our previous demonstration held at the Tour the France cycling competition [8].

Currently, a new extension to NEMO BS, called Flow Bindings [4, 9] is being standardized. This proposal allows a multi-interfaced MR to fully benefit from all of its network interfaces. Thanks to Flow Bindings, the operators of MRs could define routing policies to redirect efficiently each flow among all network interfaces currently in use according to their needs and requirements (e.g., cost, bandwidth, security, or quality of service). We have therefore extended our previous testbed with the first implementation of Flow Bindings and performed a new demonstration.

Results presented in Section 4 have shown that Flow Bindings is a mandatory add-on in case of a multihomed MR. First of all, Flow Bindings allows a MR to fully benefit from its several active network interfaces (Wi-Fi and GPRS in our testbed). It can thus increase the overall bandwidth of the mobile network by sharing the load among all active interfaces. In addition, the Flow Bindings support enables the definition of policies corresponding to specific interfaces or traffic. As presented in 3, when the MR does not implement Flow Bindings, it redirects all ongoing traffic to its GPRS interface whenever it loses its Wi-Fi connection. However, the GPRS link provides lower performances than the Wi-Fi link (in terms of bandwidth, latency, etc.). Therefore, we observed that the GPRS link is instantly saturated as the VoIP flow used in our experiment requires high bandwidth availability (approximately 65 kbits/s). As a result, the voice of every correspondent was inaudible and most of mobility signalling messages were lost leading to several mobile network deconnections from the Internet (i.e., every node located in the mobile network becomes unreachable from the Internet). Furthermore, the GPRS connection is generally very expensive and most of the users expect to use it only to transmit a few amount of data. Thanks to Flow Bindings, we can overcome such problems by defining appropriate routing policies. For example, we have chosen to filter all VoIP flows when only the GPRS connection is available. Although in this case the VoIP session is also stopped, the GPRS link is not saturated and thus no mobility messages are lost.

Our future works are to use Flow Bindings scheme in a mobile environment with dynamic interfaces usage policies. These dynamic policies are defined from the quality of service available on the medium. When the ANEMONE testbed will be fully set up at Rennes, the pervasive Wi-Fi coverage will offer more facilities to make these experiments.

Acknowledgments

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