Demonstrating Seamless Handover of Multi-Hop Networks

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ABSTRACT

Traditionally, global network mobility problem is addressed at networking layer. However, none of these solution is designed for supporting seamless horizontal and vertical handover. The demonstrated solution, called WiOptiMo, provides always-on, continuous and optimized network services, whenever possible, to the applications independently from lower layers. The whole network can move and all network nodes can continue to work with the optimal connection, until some possible connection exists. This paper shows how the network mobility can be handled at application layer with WiOptiMo and presents a demonstration scenario with a mobile network, whose nodes access audio and video application without being affected by the fact that the network moves and switches from one network access to another.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless communication

General Terms

Experimentation

Keywords

seamless handover, network mobility, performances

1. INTRODUCTION

Rapid advances in radio technologies and the increasing user demand to be always-on even when traveling are giving impetus to the large-scale deployment of wireless services. It is not far the moment when users will be put in the conditions to experience the *"all the time, everywhere access"* foreseen in the view of pervasive computing [6]. In current and near future scenarios, access to the global Internet is granted by a set of heterogeneous wireless technologies, such as Bluetooth, 802.11x wireless local area networks (WLANs), WCDMA 3G cellular networks, and satellite networks, all relying on the use of the IP protocol. There exists several scenarios in which a whole network can move, and we must provide all the nodes in this network with *seamless connectivity respectful of their expectations in terms of received QoS and costs.* For a mobile network, seamless connectivity means that network mobility is transparent to the users in terms of IP connectivity. The mobile network can change its point of attachment to the Internet while still being reachable with the same IP addresses and without incurring in the disruption of ongoing communications. This means that, while moving, (re)connection with the Internet must be automatic and transparent, and correct routing of the IP datagrams must be ensured. This problem is already hard for a single mobile node, especially in case of high mobility and/or demanding applications, and becomes even more difficult when it is a whole network that moves. During the *handover* from one network connection point to another, service provisioning might incur in significant interruptions and delays, such that the users might experience undesired falls in the received QoS. For example, we can consider a group of colleague or friends that is traveling by train, and one of them, say Bob, is connected to the Internet via GPRS. The others can all access their remote PC by being connected in ad hoc mode with Bob, who works as Internet access point. Another scenario can be the case where just one node can access a private or a filtered network. Similarly to previous scenario, the other nodes can connect in ad hoc mode with the enabled node, and they can use it as access point to access the Internet. A similar multi-hop scenario was used to provide access to attendees at WONS 2005, during some hours when the WiFi of the conference was not working, even if, in this case, the multi-hop network was not moving. The work mainly performed in the IETF Network Mobility WG (NEMO) has addressed so far the different aspects of network mobility management and seamless handovers [4]. The large majority of the proposed solutions for network mobility are built on *Mobile IP* [2], which is a network layer protocol designed to add mobility management capabilities for a single user to the basic IP. However, similarly to Mobile IP and related solutions, inherently present a number of flaws, limitations, and/or major deployment problems. In this paper we present *WiOptiMo*, an integrated application layer solution that has been firstly adopted for single node, but that has been further extended for network mobility management and seamless handovers across heterogeneous IP

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networks. When used for a mobile network, WiOptiMo has the following advantages: (i) fully supports network mobility across wired and wireless networks equipped with different technologies by providing seamless and persistent connectivity, (ii) offers to the mobile network both fully automatic and semi-automatic (assisted) ways to choose among the different available network accesses according to the users preferences and QoS expectations, (iii) avoids unnecessary networking overhead in order to optimize performance and favor scalability, (iv) runs unchanged on the majority of the most popular commercial and network devices. As presented in other works [3, 1], we pragmatically followed the approach to design a middleware that rely only on *existing technologies, deployed standards, lightweight calculations, and minimal network overhead*. This implies that the installation of WiOptiMo's components do not require any modification or addition to the current standard implementations of the TCP/IP protocol stack, nor impose constraints on the side of the mobile network in terms of computational power, operating system, characteristics of network interface cards (NICs), or on-board radio technology. The core of WiOptiMo's architecture is empowered by the active and passive *cross-layer monitoring* of variables of interest, and by the use of *autonomic* components to provide transparent adaptivity and basic self-tuning and self-configuration capabilities.

2. MOBILE AD HOC NETWORK SEAMLESS HANDOVER

The switching between two different types of networks is called *vertical handover*, while *horizontal handover* refers to the case of networks of the same type. The handover can be either *soft* (or *alternative*) when it is executed for the sole purpose of *optimization* of the connection cost or QoS, or *hard* (also termed *imperative*), when it is executed due to imminent or present loss of connectivity. The handover process is traditionally decomposed in three functional components (e.g., see [5]): (1) *Handover Initiation*, (2) *Network Selection*, (3) *Handover Execution*. Handover Initiation consists of the *proactive monitoring* of the current connection and/or of possible alternative connections in order to: (i) effectively *anticipate* or explicitly deal with imperative handovers, or (ii) trigger alternative handovers in order to *optimize* costs and performance. In our case, the CNAPT *Search* and *Check Activities* (see Section 3.2) both participate to process (1), mostly focused on the treatment of imperative handovers. Network Selection comprises the procedures to select the new connection point according to *decision metrics* like quality of the signal, cost, bandwidth. etc.. In our case, Network Selection is supported by the results provided by the Search Activity. Handover Execution stands for the set of procedures to be carried out for the authentication and reassociation of the MT. This pertains to the WiOptiMo CNAPT/SNAPT switching procedure (see Section 3.1).

3. THE WIOPTIMO SYSTEM

WiOptiMo [3, 1] is a solution for seamless handover among heterogeneous networks/providers. It transparently provides persistent connectivity to users moving across different wired and wireless networks. WiOptiMo detects the available network access points and provides, in automatic or semi-automatic (assisted) way, the best Internet connection in terms of estimated QoS (e.g., bandwidth, reliability, and security) and/or cost effectiveness among all the available connections at a certain time and location. The optimized handover is executed without interrupting active network applications or sessions and avoiding or minimizing user intervention. Further, if the current connection becomes no longer available and if no other connections can be established (e.g., inside an uncovered area), the system hibernates the applications to perform re-establishment when the current or a new connection becomes available again (obviously, if the reestablishment exceeds the application timeout, the application may detect a network problem). WiOptiMo's behavior is summarized in the diagram of Figure 1. From this figure it results evident that, by decoupling the traditional client/server application from the network connection, WiOptiMo acts as a distributed proxy. Thus, for example, it is possible to use networks like IPV6, ATM, etc.., between the CNAPT and the SNAPT, and to continue to use IPv4 for the application sides.

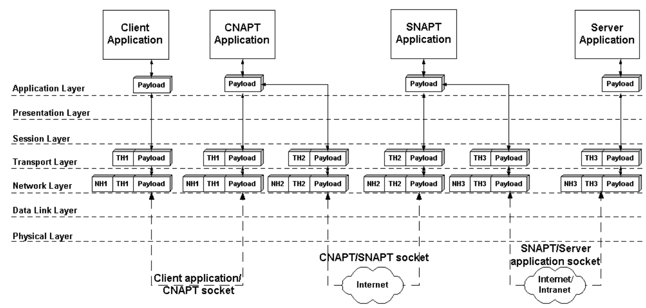

Figure 1: CNAPT and SNAPT components. The role of the single socket between Client and Server application is played by three sockets: (1) a local (reliable) socket between the Client and the CNAPT: *Client application/CNAPT socket*; (2) a (unreliable) socket between the CNAPT and the SNAPT: *CNAPT/SNAPT socket*; (3) a (reliable) socket between the SNAPT and the Server application: *SNAPT/Server application socket*

3.1 WiOptiMo Application Layer Solution

The WiOptiMo system does not require any modification of the layers of the OSI protocol stack and it does not introduce any additional sub-layer. The seamless handover is realized by interfacing the application processes by a pair of applications (OSI Layer 7), the *CNAPT* (Client Network Address and Port Translator) and the *SNAPT* (Server Network Address and Port Translator). The CNAPT and the SNAPT collectively act as a *middleware* and interface the communication between the Client and the Server applications hiding the mobility to them. In this way Client and Server applications do not realize that they are communicating via the Internet since CNAPT and SNAPT let them believe that they are running on the same device, or on different devices belonging to the same network. The CNAPT is an application that can be installed in the same device as the Client application or in a different device in the same mobile network. In the demonstration scenario, where a group of nodes require mobility while working together, the CNAPT is installed just in one of the mobile devices of the mobile network and the whole network can share the seamless handover provided by it. The SNAPT is an application that can be installed in the same device as the Server application or in a different device of the same network or in any Internet server (e.g., in a corporate front-end server, in the home PC, or in any Internet node or router). This flexibility allows to handle the mobility of multiple users either in a centralized way, with a star topology, or using a distributed topology, in which every user manages its mobility by installing the SNAPT on the accessible nodes (e.g., in the home PC if directly connected to the Internet), saving in terms of transmission costs.

3.2 WiOptiMo Handover Initiation and Network Selection: *Search* and *Check* Activities

The CNAPT application acts as an application relay system, and also activates a decision task in order to provide persistent and optimized Internet connectivity. The decision task consists of two main activities: the *Search Activity*, for soft handovers, which proactively searches for new network providers and connectivity, and the *Check Activity*, for hard handovers, which continuously monitors reliability and performance of the current connection.

4. DEMONSTRATION EXPERIMENTS

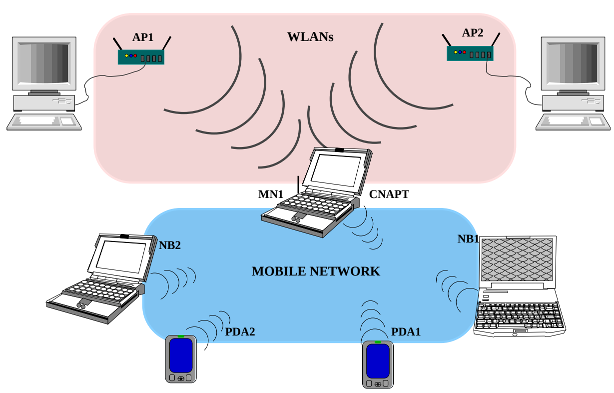

Figure 2: Configuration used for demonstration.

Figure 2 illustrates the topology of the demonstration scenario. The CNAPT is installed on the mobile node MN1 that is equipped with a built-in WiFi card, a second external WiFi card and a GPRS card. The SNAPT is installed on a machine that reside in a remote network accessible via Internet. The mobile node MN1 is the Internet access point for the mobile network, composed by two more laptops and two palmtops. These nodes are connected to the MN1 with an ad hoc connection, and then access Internet in multi-hop way. There are two access points (AP1 and AP2) that act as two different Hot-spots. They are WaveOS access points from RT Networx, which have the fundamental characteristic of being able to vary the emission power, and that show at display the evolution of a large number of parameters (greater than the set foreseen for the 802.11k standard). The demonstration applications are voice and video. For the voice demonstration, we run skype on the palmtops. The video demonstration is performed by accessing a web page with real time video streaming. The Clients applications on the nodes of the mobile network, depending on the physical connection selected by WiOptiMo, can connect in multihop fashion either through one of the access points, or through GPRS to the Telco bridge and then get on the server via the Internet. During the demonstration, we reduce the transmission power of the access points, such that we can simulate the network mobility without moving. We will show that with WiOptiMo solution, we are able to maintaining the application quality, of both video and audio, while MN1, and thus the mobile network, changes its point of attachment.

5. CONCLUSIONS AND FUTURE WORK

Widespread availability of wireless services and their use by mobile devices is becoming a reality and is expected to play an ever increasing role in our daily life. Seamless mobility of a whole network is already a real issue, and most of the current solutions based on network layer approaches fail to reach these objectives. An application layer solution like WiOptiMo can overcome most of the network layer solutions limitations and can provide efficient and effective network mobility management in heterogeneous, multi-technology, networks. Future work includes the investigation of peer-to-peer approach for WiOptiMo network mobility. Currently, the system requires a reliable connection between any client application of nodes in the mobile network and the CNAPT (localhost or wireless PAN). At the same time, the CNAPT could be connected in an unreliable wireless way (WiFi, WWAN) to a SNAPT and the SNAPT must have a reliable Internet connection (e.g. ADSL, T1 etc). Finally, the SNAPT is connected in a reliable way to the server application. The idea is to install the CNAPT and the SNAPT on the same device and to consider the SNAPT as a normal application like a browser. In this case the local CNAPT can use its connection to a remote SNAPT (on a different mobile device) to provide a reliable connection to the local SNAPT. This way any client application on mobile device can surf the Internet in a peer-to-peer way also if there is not an Internet connection by using another node as a bridge to reach a SNAPT on reliable Internet.

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