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Exploring Efficient Imperative Handover Mechanisms for Heterogeneous Wireless Networks

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***Abstract*—The Next Generation Internet will provide ubiquitous computing by the seamless operation of heterogeneous wireless networks. It will also provide support for quality-of-service, QoS, fostering new classes of applications and will have a built-in multi-level security environment. A key requirement of this new infrastructure will be support for efficient vertical handover. Y-Comm is a new architecture that will meet the challenge of this new environment. This paper explores the design of efficient imperative handover mechanisms using the Y-Comm Framework. It first looks at different types of handovers, then examines the Y-Comm Framework and shows how Y-Comm maps unto current mobile infrastructure. It then explores support for different handover mechanisms using Y-Comm. Finally, it highlights the development of a new testbed to further investigate the proposed mechanisms.**

***Index Terms*—Next Generation Internet, Vertical Handover, Architectural Framework, Mobility**

I. INTRODUCTION

The Next Generation Internet (NGI) will provide ubiquitous computing via the seamless operation of heterogeneous wireless networks including WLAN, 3G, WiMax, Ultrawideband, etc. Using these networks, users will be continuously connected to the Internet as they move around. Vertical handover [1] which allows mobile nodes to seamlessly switch their connections from one network to another is a key mechanism that must be supported in NGI. In order to do this effectively, it is necessary to gather extensive information about various system parameters including the state of individual wireless network interfaces as well as the state of transport connections.

In a broader context, the widespread use of wireless technologies has highlighted a significant evolution in the architecture of the Internet. In terms of performance, it is now possible to divide the Internet into two distinct parts: a core network and edge or peripheral networks. The core network consists of a super-fast backbone and fast access networks which are attached to the backbone. Peripheral networks will be dominated by the deployment of different wireless technologies. This means that the characteristics of the core network will be very different to the peripheral wireless networks on the edge.

This change needs to be reflected in a new networking architecture which attempts to clearly define the functions, their order and the interlocking relationships that are necessary to support heterogeneous networking. Recently, a new architecture called Y-Comm [2] has been designed to capture this new reality. This paper shows in some detail how different types of imperative handovers can be supported using the Y-Comm architecture. The rest of paper is structured as follows: Section 2 looks at a classification for vertical handovers. Section 3 looks at previous work while Section 4 describes the Y-Comm Framework. Section 5 shows how Y-Comm maps unto current mobile infrastructure while Section 6 discusses vertical handovers in Y-Comm. Section 7 explores current work and the paper concludes with a section of conclusions and future work.

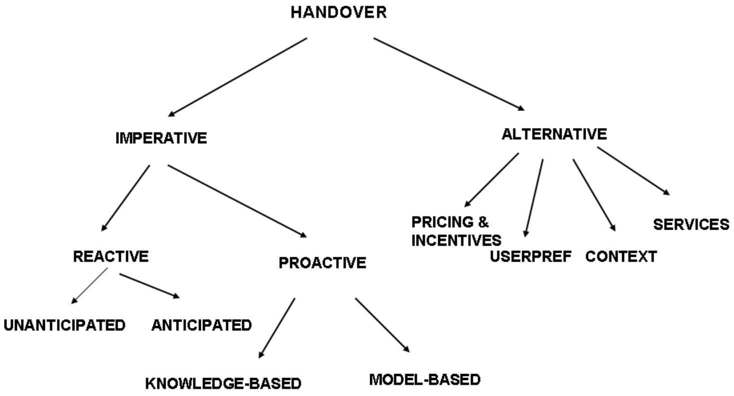

Fig. 1: Vertical Handover Classification

II. VERTICAL HANDOVER - A DETAILED CLASSIFICATION

In this section we take a detailed look at vertical handover to pinpoint its different classes. Firstly we introduce the concepts of **hard** and **soft** handovers. Hard handovers occur when the current attachment is broken before the new connection is established while in soft handovers, the current connection is broken after the new connection is established.

Another important operational factor is the entity that makes the decision to do a vertical handover. The options basically are network-controlled handover in which the decision to implement handover is taken by the network(s) to which the mobile node is currently attached. The second is called client-based handover in which the client is the deciding entity. Though Y-Comm can facilitate network-controlled handover, client-based handover is favoured as a more elegant solution [3]. This is because client-based handover is more scalable as the mobile node can easily monitor the necessary parameters from its wireless interfaces. In addition, client-based handover allows the mobile node to look at other issues such as the state of its TCP connections. A general classification of handover is shown in Figure 1.

Imperative handovers occur due to technological reasons only. Hence the mobile node changes its network attachment because it has determined by technical analysis that it is good to do so. This could be based on parameters such as signal strength, coverage, the quality-of-service offered by the new network. These handovers are imperative because there may be a severe loss of performance or loss of connection if they are not performed. In contrast, alternative handovers occur due to reasons other than technical issues [4]. Hence there is no severe loss of performance or loss of connection if an alternative handover does not occur. The factors for performing an alternative handover include a preference for a given network based on price or incentives. User preferences based on features or promotions as well as contextual issues might also cause handover. Finally there may be other network services that are being offered by certain networks. In this paper we concentrate on imperative handovers.

Imperative handovers are in turn divided into two types. The first is called **reactive handover**. This responds to changes in the low-level wireless interfaces as to the availability or non-availability of certain networks. Reactive handovers can be further divided into anticipated and unanticipated handovers [5]. Anticipated handovers are soft handovers which describe the situation where there are alternative base-stations to which the mobile node may handover. With unanticipated handover, the mobile is heading out of range of the current attachment and there is no other base-station to which to handover. These handovers are therefore examples of hard handovers.

The other type of imperative handover is called **proactive** handover. These handovers use soft handover techniques. Proactive handover policies attempt to know the condition of the various networks at a specific location before the mobile node reaches that location. Proactive policies allow mobiles nodes to calculate the **Time Before Vertical Handover** (TBVH) which will allow the mobile node to minimize packet loss and latency experienced during handovers. Proactive handovers therefore represent a mechanism that could be used to support seamless handover as it allows the system and applications more time to deal with handover issues. Presently, two types of proactive handovers are being developed. The first is knowledge-based and attempts to know by measuring beforehand the signal strengths of available wireless networks over a given area such as a city. This could involve physically driving around and taking these readings [6]. The second proactive policy is based on a mathematical model which calculates the point when vertical handover should occur and the time that the mobile would take to reach that point based on its velocity and direction [7].

III. Previous Work

Work on handovers has been going on for sometime. Most of the research done by the mobile operators focused on network-controlled horizontal handover where handover is done between adjacent cells of the same network. The development of models to understand whether handover should be done given the relative load on individul cells based on on-going calls, new calls being made within the cells and incoming calls due to handover from nearby cells was a major goal.

With the introduction of Mobile IPv4 and Mobile IPv6 [8], client-based handover began to be investigated. For these mechanisms, handover latency is high because they only work at the network level as they are based on Router Advertisements (RAs) which are relatively slow. In order to reduce this latency, Fast Mobile IPv6 (FMIPv6) [9] makes use of L2 events and triggers to reduce handover latency.

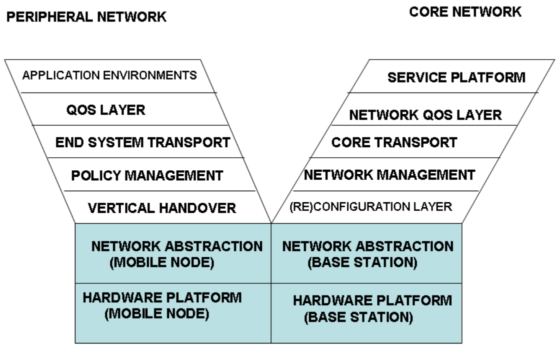

Fig. 2: The Y-Comm Framework

The study of vertical handovers was greatly enhanced with the deployment of the Cambridge Wireless Testbed [10], which was the first testbed to study client-based vertical handovers. The testbed used the Vodafone 3G Experimental network, with Home and Foreign WLANs and a wired IPv6 LAN. Using the testbed, PROTON [11], a policy manager for reactive handovers was developed. PROTON was implemented using a 3-layer structure. Y-Comm is a direct follow-on from the Cambridge Wireless Testbed. It should improve the handover process by dynamically supporting all types of handover including proactive ones which allow the system to acquire resources long before handover will occur and so prevent a loss of performance.

IV. THE Y-COMM ARCHITECTURE

The Y-Comm Architecture is a new architecture to support heterogeneous networking. It uses two frameworks. The first is called the **Peripheral Framework** and deals with operations and functions on the mobile node. The other framework is called the **Core Framework** and shows the functionality required in the core network to support the Peripheral Framework. The structure of the Y-Comm architecture is shown in Figure 2. A brief explanation of Y-Comm is now attempted starting with the lowest layer. A more detailed explanation can be found in [12], [13].

A. The Peripheral Framework

The **Hardware Platform Layer** (HPL) is used to classify all relevant wireless technologies. Hence different wireless technologies which are characterised by the electromagnetic spectrum, MAC and modulation techniques make up this layer. The **Network Abstraction Layer** (NAL) provides a common interface to manage and control all the wireless networks. These first two layers for both frameworks are similar in functionality. In the Peripheral Framework, the Hardware Platform and the Network Abstraction layers run on the mobile to support various wireless network technologies while in the Core Framework these two layers are used to control the functions of base stations of different wireless technologies.

The **Vertical Handover Layer** (VHL) executes vertical handover. So this layer acquires the resources for handover, does the signalling and context transfer for vertical handover. The **Policy Management Layer** (PML) decides whether and when handover should occur. This is done by looking at various parameters related to handover such as signal strength and using policy rules to decide both the time and place for doing the handover.

The **End Transport Layer** (ETL) is used to provide network and transport functions to the mobile nodes in peripheral networks. It allows the mobile node to make end-to-end connections across the core network. The **QoS Layer** (QL) in the Peripheral Framework supports two mechanisms for handling QoS. The first is defined as Downward QoS. This is where an application specifies its required quality-of-service to the system and the system attempts to maintain this QoS over varying network channels. The other definition is Upward QoS where the application itself tries to adapt to the changing QoS. This layer also monitors the QoS used by the wireless network as a whole to ensure stable operation. The final layer of the Peripheral Framework is called the **Applications Environments Layer** (AEL). This layer specifies a set of objects, functions and routines to build applications which make use of the framework.

B. The Core Framework

As previously mentioned, the first two layers of the Core Framework are engaged in controlling base-station operations. The third layer is called the **Reconfiguration Layer** (REL). It is a control plane to manage key infrastructure such as routers, switches, and other mobile network infrastructure using programmable networking techniques [14]. The **Network Management Layer** (NML) is a management plane that is used to control networking operations in the core. This layer can divide the core into a number of networks which are managed into an integrated fashion. It also gathers information on peripheral networks such that it can inform the Policy Management Layer running on mobile nodes about wireless networks at their various locations.

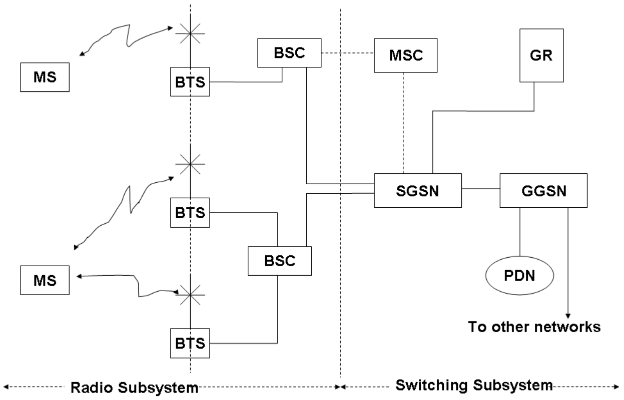

Fig. 3: The GSM/GPRS Network

The next layer, called the **Core Transport System** (CTS), is concerned with moving data through the core network. Where the peripheral networks join the core network is called a **core endpoint**. Core endpoints are usually situated in access networks and several peripheral networks may be attached to a single core endpoint. CTS is concerned primarily with moving data between core endpoints with a given QoS and a specified level of security.

The **Network QoS Layer** (NQL) is concerned with QoS issues within the core network especially at the interface between the core network and the peripheral networks. A main concern of this layer is to prevent overloading. In this regard, admission control techniques are applied by the NQL to prevent new streams or mobiles doing vertical handovers from overloading core endpoints or associated peripheral networks. Finally the **Service Platform Layer** (SPL) allows services to be installed on various networks at the same time.

V. MAPPING Y-COMM ONTO MOBILE INFRASTRUCTURE

In this section we show the relationship between Y-Comm and current mobile infrastructure. We believe that Y-Comm can easily be mapped onto well-established networks such as the GSM/GPRS architecture [15]. The GSM architecture was developed by the European Telecommunications Standards Institute (ETSI) and remains the most popular mobile infrastructure ever deployed. The GSM/GPRS infrastructure is shown in Figure 3. The mobile node runs the GSM/GPRS protocol stack while the required network functionality is distributed using several core entities. The Base station transceivers (BTS) interact directly with the mobile node using specified radio channels. Each BTS is controlled by a Base Station Controller (BSC) while each BSC is controlled by a Mobile Switching Centre (MSC) for voice traffic or a Service GPRS Support Node (SGSN) for data traffic. The Gateway GPRS Support Node (GGSN) serves as a gateway to other networks with the help of the Gateway Register (GR).

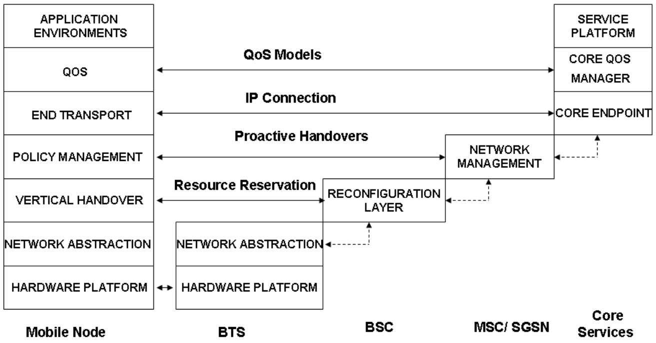

Fig. 4: Mapping Y-Comm onto Mobile Infrastructure

We can now show how the functions of Y-Comm can be mapped onto the GSM infrastructure making possible the transition from GSM to Y-Comm. This is shown in Figure 4. The Mobile Node (MN) runs the entire Peripheral Framework as shown. The Core Framework is distributed throughout the core network in a similar way to the GSM/GPRS infrastructure. The Hardware Platform and Network Abstraction Layers run in the Base Transceivers. Y-Comm however, supports BTSs of different wireless technolgies including 3G base-stations, Wi-Fi and WiMax APs, etc. The Reconfiguration Layer of Y-Comm runs in the Base-station Controllers for GSM or access routers in WLANs and LANs. This layer uses programmable techniques on the Network Abstraction Layer to control the resources on individual BTSs. It is expected that each Y-Comm BSC would control one wireless technology. The Reconfiguration Layer on the BSC allocates resources to do a handover to a particular BTS.

The Network Management Layer (NML) manages different wireless networks and runs at the level of the MSC/SGSN level in current mobile infrastructure. In Y-Comm, a local NML manages all the BSCs in a local area and knows the status of each wireless network and its topology. This information can be shared with the Policy Management Layer on the mobile node. The core endpoint is used by the mobile node to connect to the wider Internet. For a given connection, IP packets to and from the mobile node are tunnelled through the core network using core endpoints. Finally when an application on the mobile node wishes to make a connection through the core network, the QoS layer running on the mobile node interacts with the QoS manager in the core network with regard to QoS requirements for the new connection. The QoS manager will return two core endpoints which can be used for the new connection.

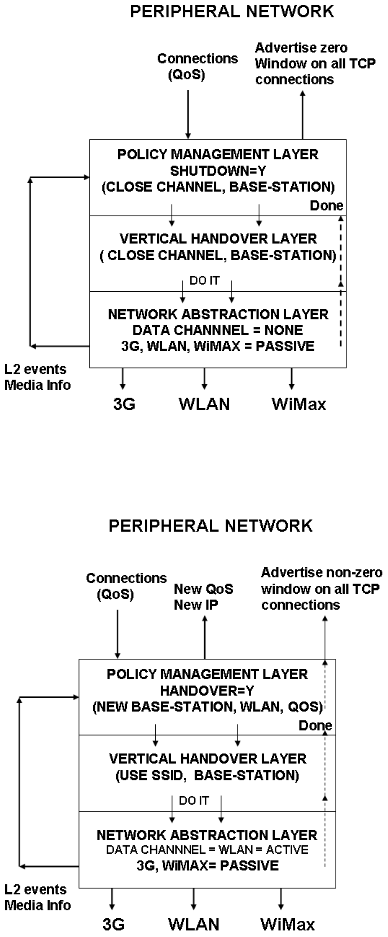

Fig. 5: Unanticipated Handover: Stages 1 and 2

VI. VERTICAL HANDOVER IN Y-COMM

In this section we look at the various layers of Y-Comm that are involved in vertical handover. Y-Comm supports both reactive and proactive handovers.

A. Reactive Handovers

With reactive handovers, the main inputs into the Policy Management layer are the L2 events and Media Information from the Network Abstraction layer which monitors the different network interfaces. The state of ongoing TCP connections and their required QoS are also monitored. The mobile node makes the decision to handover based on these factors only.

1) Unanticipated Handovers: Unanticipated handovers result in a two-stage interaction. The first stage occurs when the Policy Management Layer is informed that the signal strength from the current base station is fading fast and there is no other base station in the vicinity. The PML will first instruct the TCP connections to advertise a zero receive window on all its connections. This stops senders from sending data while the mobile node is unconnected from the network. It then instructs the Vertical Handover Layer to close the present channel. This is shown in Figure 5.

In the second stage of the unanticipated handover occurs when the mobile node finds a new base-station as its next point of attachment. It first signals to the vertical handover layer to acquire a channel if it is a 3G base station or obtain the SSID of the WLAN network. It is worth noting that for reactive unanticipated handovers the core network cannot be involved as there is no current connection to the core network. Hence the mobile node must acquire an unreserved channel on the BTS. Once this is done, a new IP address and a new QoS are communicated to the upper layers. The system then tells the TCP connections to advertise a non-zero window. This is shown in Figure 5.

2) Anticipated Handovers: In this section we explore anticipated handovers in which there are alternative base-stations to which to handover. In Figure 6, we look at an anticipated handover to a WLAN workstation. In this example, it decides to handover to a WLAN base-station from which it is already receiving beacon frames. The Vertical Handover Layer which is responsible for the handover, uses the Reconfiguration Layer to obtain the valid SSID for the network. The REL uses its programmable interface to get the SSID key from the base-station. It passes it back to the vertical handover layer which then does the handover. This sequence can be represented by the message exchange diagram shown in Figure 7.

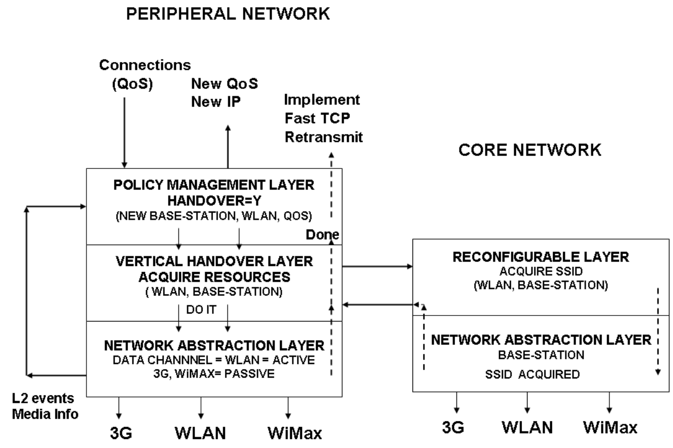

Fig. 6: Anticipated Handover

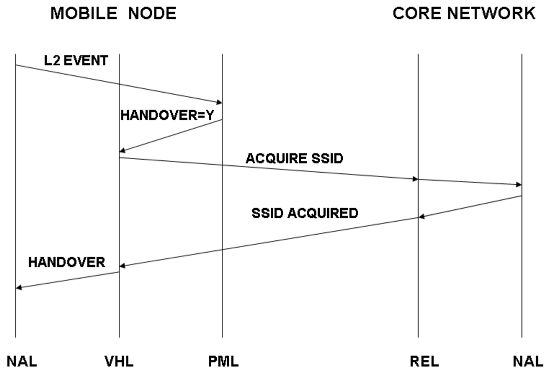

Fig. 7: Anticipated Handover Sequence

The new QoS and new IP address are signalled up to the End Transport and QoS layers. When the handover has occurred, each layer signals to its upper layer that handover has been completed. In order to quickly restore communications in anticipated handovers, the transport level keeps a copy of the last TCP acknowledgement for each connection. After handover, the previous channel is released and the mobile node implements a fast retransmit algorithm, i.e., it sends the last TCP acknowledgement 3 times and this results in fast retransmission where any packets lost during the handover are retransmitted.

B. Proactive Handovers

This section looks at proactive handovers. This is shown in Figure 8. Since proactive handovers attempt to determine when and where handover should occur, it is necessary to have a knowledge of networks in the local area where the mobile is located. In addition, in order to perform vertical handover using a mathematical model approach, it is also necessary to know the topology of these local networks. In Y-Comm, this information is managed by the Network Management Layer in the Core Framework. The mobile node therefore polls the NML to obtain information with regard to all local wireless networks, their topologies and QoS characteristics. This information along with the direction and speed of the mobile as well as the QoS of on-going connections are used by the Policy Management Layer to determine where and when handover should occur. The PML calculates TBVH - the period after which handover will occur. This information is communicated to the Vertical Handover Layer which immediately requests resources to do a handover. Even though the resources are acquired early, handover actually takes place when TBVH expires. This sequence is shown by the message exchange diagram shown in Figure 9.

In addition, once the PML decides to handover, the new IP address, the new QoS as well as TBVH are communicated to the upper layers. Given TBVH, the upper layers are expected to take the necessary steps to avoid any packet loss, latency or slow adaptation. For example, it may be possible for the End-

Transport Layer to signal an impending change in the QoS on current transport connections and to begin to buffer packets ahead of the handover. After handover, the previous channel used by the mobile node is released.

VII. CURRENT WORK

Reactive policies were explored using the Cambridge Wireless Testbed. However, proactive policies have only been investigated using simulations. Detailed results were presented in [16] and show improvements in handover performance. The proposed mechanisms need to be tested in a real environment. Work has begun on a Y-Comm testbed which will be used to test algorithms and mechanisms needed to implement the Y-Comm architecture including the vertical handover mechanisms discussed in this paper. The testbed will initially support vertical handover between WLAN, 3G and LAN systems.

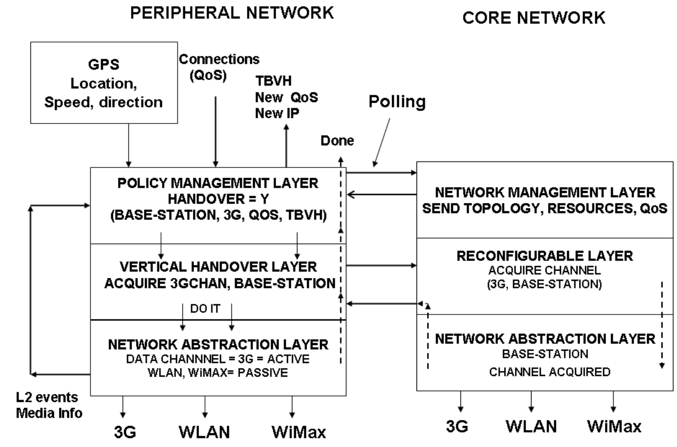

Fig. 8: Proactive Handover

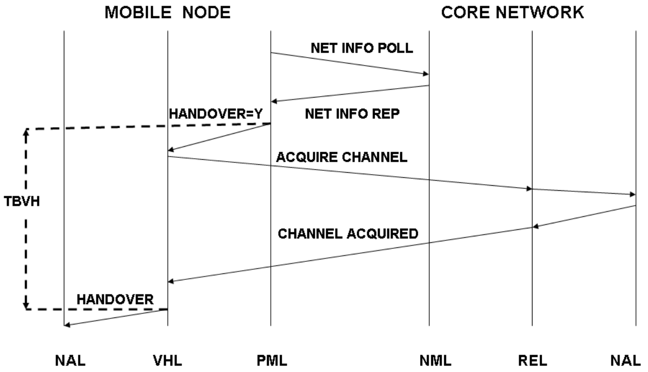

Fig. 9: Proactive Handover Sequence

VIII. CONCLUSIONS AND FUTURE WORK

This paper has detailed the mechanisms to support efficient vertical handover using the Y-Comm Framework. We believe that the adoption of proposed mechanisms will enhance seamless connectivity. Work is proceeding to build a testbed to test the working and performance of these algorithms in real environments.

ACKNOWLEDGMENTS

We would like to thank the Brazilian Research Funding body, FAPESP, for bestowing a grant on ICMC, USP which facilitated a four-week visit by Dr. Glenford Mapp to ICMC USP as a Visiting Research Fellow in August 2008.

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