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A per-application mobility management platform for application-specific handover decision in overlay networks

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ABSTRACT

With the advance of various wireless access technologies, the demand for a mobile user equipped with multiple air interfaces simultaneously executing diverse applications emerged. In such network environments, *per-application mobility management* is a key to allow each application of an end user device to dynamically and fully take advantage of the most suitable access technology. In this paper, we devised a comprehensive architectural platform with cross-layer techniques to realize this disruptive technology, i.e., *per-application mobility management*. The proposed platform enables the triggering of vertical handover decisions based on the dynamic measurements from the entire protocol stack. For per-application, the handover decision as well as the mobility management and the transport/application protocol control adaptation for handover performance optimization are made with cross-layer techniques. Through the simulation results, it is shown that multi-layer handover triggering of the proposed platform enhances the QoS of the application services by making handover decisions when the QoS requirements of an application is not satisfied as well as when a mobile user moves out of the current access network in overlay network environments. It is also presented that per-application handover based on the proposed platform enhances the QoS of the application services compared to the handover approaches which make every on-going service flows handover together to the same access network.

1. Introduction

Rapid progress in wireless networking technologies has created different types of wireless systems such as Bluetooth, WiFi, WiMax, 3G Cellular Networks, and so on. An inevitable trend in the next generation wireless networks is coexistence of such different wireless access systems in a complementary manner. With this trend, it is foreseeable that all these various access technologies with significantly different capabilities (in terms of bandwidth, latency, coverage, security, etc.) will often be available in overlapping areas. The technologies for air interfaces of mobile devices are also evolving to enable the access of heterogeneous wireless technologies and/or the simultaneous access of multiple wireless networks [1]. Mobile nodes (MN) equipped with those kinds of air interfaces will execute diverse applications from voice services to multimedia services and data services.

Under these circumstances, critical to the satisfaction of service users is being able to select and utilize the best access technologies among the available ones. In this paper, we envision a comprehensive architectural platform for mobility management that allow end-users to dynamically and fully take advantage of different access networks. Assuming that an MN is equipped with an air interface capable of simultaneous access to multiple networks and running one or more applications at the same time, we propose the concept of *per-application mobility management*,

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that is, an access network is specifically selected for each application according to its different QoS perspective. Indeed, the concept of *per-application mobility management* is aligned with the motivation of the emergence of various access network technologies: no single network technology can satisfy all different QoS constraints of various applications.

All of the existing solutions only focus on *per-node mobility management*: an MN chooses a single access network at any given time regardless of how many different applications have connections to the network. With the air interface capability limited to the single wireless access technology and/or a single point of attachment at a time, and with the mobile devices targeted for a specific service and/or running a single application at a time, per-node based network selection is sufficient for obtaining best service available from the user perspective. However, with the advances in the technologies, if it becomes possible for an MN running one or more applications while attached through multiple wireless access technologies simultaneously, the *per-node mobility management* paradigm may no longer be considered as effective enough to deliver satisfactory QoS appropriate for each user application. Even though the air interface technologies to enable multiple simultaneous wireless accesses are important underlying technology, it is not the issue dealt with in this paper. We focus on the network protocol architecture which may take full advantages of those technologies.

Mobile IP (MIP) and its variants are widely accepted solutions as the network-layer approaches to the mobility management [2–5]. It is obviously difficult to implement *per-application mobility management* on top of these network-layer approaches because MIP concerns on host-level routing problems to find an IP host attached to a certain IP subnet. In order to implement, *per-application mobility management* based on MIP, home/foreign agents may need to be aware of multiple-points of attachments for all connections of an IP host. This, in fact, violates the original function of IP routing and can cause a scalability problem and ineffectiveness due to heavy burden on those agents. In addition, MIP based approaches generally cause a few undesirable characteristics [6]: network architecture complexity due to the additional mobile agents, overhead due to a triangular routing, and tunneling, etc.

Recently, there have been several works presented in the literature toward using end-to-end approaches for the mobility management [6–9]. Basically, the end-to-end handover scheme provides a network-independent solution. The solutions proposed in [6] and [7] are based on a specific transport protocol SCTP and its extensions. A solution based on a specific transport protocol, as proposed in [6] and [7], requires the modification of existing transport protocols and accordingly hinders general application of the approach. [8] and [9] avoids this kind of problem by deploying a protocol layer which maps the connection identification that is transparent to the mobility and is used by the user applications or by the transport protocol, into the IP addresses that the communicating end points are currently attached to. The main objectives of adopting the end-to-end mobility management approach in [8] and [9] are to reduce the handover latency and to handle the mobility without additional support from network elements. All of these solutions, though, discuss the problems still in the context of *per-node mobility management*.

In this paper, we also deploy an *end-to-end mobility management* technique that is similar to the ones proposed in [8] and [9]. However, our main objective of adopting an end-to-end mobility management is not just to achieve the objectives of [8] and [9], but to facilitate *per-application mobility management*. That is, in this paper, the end-to-end mobility management will be illuminated as one primary technique to realize the concept of *per-application mobility management*. Furthermore, we exploit the fact that mobility of a node is always explicitly notified to the communicating peer due to the end-to-end mobility management principle in order to provide appropriate protocol control adjustment for seamless handovers. Specifically, the objectives of the proposed architecture can be summarized as follows:

1. Enabling the triggering of handover decisions to effectively exploit the heterogeneous overlay wireless network environments in order to best serve the application and user requirements.
2. Enabling the handover decision that optimizes the handover performance in terms of each application requirements.
3. Enabling transport and/or application-specific control and adjustment during handover and after the handover.

These objectives require the gathering of dynamic status information across entire protocol stack as well as the dynamic adjustment of protocol parameters and controls accordingly. For instance, not only the information on the available wireless network interfaces and their characteristics but also the application level performance measures and requirements should be collected and considered together in order to make optimal handover decision for each user flow. Furthermore, if handover to a heterogeneous wireless access network environments actually occurs, transmission control adjustment for TCP like transport protocols or video encoding rate adjustment for a video stream should occur to deliver seamless QoS to each user flow. To this end, a *cross-layer* based dynamic performance optimization platform is proposed. The proposed platform enables a simple but powerful inter-layer communication to manage the complexity, especially when inter-layer communications are substantial. In the proposed platform, we take a completely modularized approach so that the impact on the existing protocols and infrastructures is minimized and the evolution from the existing layered protocol stack architecture can be smooth.

The rest of this paper is organized in the following way. Section 2 gives a detailed explanation on the architecture of the proposed platform. Simulations and its numerical results to illustrate the potential merits of the proposed platform and the algorithms are presented in Section 3. Finally, Section 4 concludes the paper.