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A novel network mobility handoff scheme using SIP and SCTP for multimedia applications

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ABSTRACT

In a heterogeneous wireless environment, seamless mobility is the basis of network support with which mobile users who roam between or among various wireless access networks are able to fully enjoy uninterrupted wireless services. When users are in a mass transportation vehicle, e.g., a bus or a train that provides network service, the vehicle can be regarded as a network which is serving users as it moves from one location to another. The movement of a network is called network mobility (NEMO). The network mobility protocol based on Mobile IPv6 as proposed by the Internet Engineering Task Force (IETF) in 2005 has some fundamental drawbacks, such as header overhead and the pinball problem. In this paper, we propose a novel hybrid method for network mobility called Hybrid-NEMO, which provides a soft handoff scheme at the transport layer basically utilizing SIP and SCTP protocols to ensure a lossless packet-transmission environment and less handoff-delay variation, which are critical in providing QoS voice and multimedia applications. Experimental validation and performance evaluation were also conducted in this study.

1. Introduction

Wireless networks of the next generation have been envisioned as an integration of various wireless access networks (Katz, 1998), e.g., wireless wide area networks and wireless local area networks (Salkintzis et al., 2002; Buddhikot et al., 2003), that can give users a convenient wireless environment to access an abundance of network resources. Thus, users are able to ubiquitously access these resources from anywhere at any time with their own mobile devices to further facilitate and enrich their lives.

Additionally, the rapid growth of wireless technologies has not only greatly attracted people's interest in a new era of cyberspace, but has also propelled researchers to propose various business models using different technologies, such as location-based service (LBS) (Choi and Tekinay, 2003) and push mail (http://en.wikipedia.org/wiki/Push_e-mail). In such an environment, seamless mobility support is the basis for providing uninterrupted wireless services to mobile users who often roam between or among various wireless access networks. We call the movement of mobile users "host mobility". On the other hand, if users are in a mass transportation vehicle, e.g., a bus or a train that provides network service, the vehicle can be regarded as a network, which is serving users as it moves from one location to another. The movement of a network is called network mobility (NEMO), and the network itself is called a mobile network (Ernst and Lach, 2007; IETF Network Mobility (NEMO) Working Group; Ng et al., 2007). Several seamless mobility approaches have been proposed (Perkins, 2002; Johnson et al., 2004; Rosenberg et al., 2002; Johnston et al., 2003; Stewart et al., 2000; Kim and Copeland, 2003; Vidales et al.; Fu et al., 2005; Atiquzzaman and Ivancic; Chowdhury et al., 2007). The basic ideas of the approaches are based on Mobile IP (Perkins, 2002; Johnson et al., 2004), session initiation protocol (SIP) (Rosenberg et al., 2002; Johnston et al., 2003), stream control transmission protocol (SCTP) (Stewart et al., 2000; Fu et al., 2005; Atiquzzaman and Ivancic; Chowdhury et al., 2007) or TCP-based protocol (Kim and Copeland, 2003; Vidales et al.). Basically, these approaches have relatively longer handoff delays and/or higher packet-loss rates, even though the authors tried to mitigate or eliminate the impacts of the drawbacks.

NEMO has been one of the most popular research topics in recent years because of its importance in military and vehicular applications (Stewart et al., 2001; Lim et al., 2005). A mobile network can be viewed as a single unit which usually consists of one or several central points and attached nodes (named mobile network nodes, MNNs for short) that connect themselves to their central point through wired or wireless interfaces. A mobile network may enter the communication range of another mobile network and become an attached node of the latter. The aggregated hierarchy of such a mobile network structure is called a nested mobile network. The key difference between host

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mobility and network mobility lies in whether a mobile network has a central point or not. For network mobility, handover is handled by a central point. For host mobility, migration of a mobile user among APs is managed individually by mobile terminal devices. The advantages of network mobility are as follows (Perera et al., 2004a):

(1) *Migration transparency*: Permanent connectivity to the Internet is often required by all MNNs for global reachability via their permanent IP addresses (IPs for short). Hence, sessions should be uninterruptedly maintained when an underlying mobile network migrates from one AP to another.
(2) *Power efficiency*: The radio transmission distance between a mobile device and its central point is often much shorter than that between the device and the access point directly connected to the Internet. Consequently, when the device is communicating with a host (e.g., a web server), which is outside an underlying mobile network, transmission power can be dramatically reduced if the connection is directly to the central point instead of directly to the access point, particularly when the device is powered by batteries.
(3) *Handoff reduction*: Once the MNNs of a mobile network establish links with their central point, only the central point needs to handle handoffs when the mobile network migrates.
(4) *Increasing manageability*: Only the central point needs to manage the mobility of its mobile network. If any additional features are needed in the future, updating software or policies on the central point will be much easier than updating those on MNNs.
(5) *Complexity reduction*: When a mobile network changes its point of attachment to the Internet, only the central point needs to reconfigure its address. No MNNs need to be changed. Hence, software and hardware manipulation and the maintenance complexity of network nodes can be greatly reduced.

Although the network mobility protocol based on Mobile IPv6 (MIPv6-NEMO) (Wakikawa et al., 2003) has been enforced by the Internet Engineering Task Force (IETF), MIPv6-NEMO still inherits basic features from Mobile IPv6, such as tunneling and registering with a home agent (HA). When a mobile node moves to a foreign network, several fundamental problems arise, such as header overhead due to tunneling and routing redundancy resulting from packet forwarding. In this paper, we propose a novel hybrid method for network mobility called Hybrid-NEMO, which provides a soft handoff scheme at the transport layer basically utilizing SIP and SCTP protocols to ensure a lossless packet-transmission environment and less handoff delay and delay variation, which are critical in providing QoS voice and multimedia applications (Gu and Zhang, 2003; Hardman et al., 1995; Perkins et al., 1998; Leu et al., 2005; Xiao, 2003). Further, this paper is an advanced version of our previous work (Leu and Ko, 2008). Several key functions and mechanisms, e.g., nested network handoff, the relation between overlapped signal regions and network moving speed, comparisons of related network mobility schemes and Hybrid-NEMO, and so on, are not addressed in that previous work.

The contributions of this study are as follows:

(1) We demonstrate that the mechanism Hybrid-NEMO that we propose can perform better than several existing NEMO schemes in, e.g., packet loss during handoff, the pinball problem, header overhead, and lack of congestion control inside a mobile network.
(2) We analyze and compare the advantages and disadvantages of the four NEMO schemes tested.
(3) We demonstrate that the existing correspondent nodes (e.g., VOD servers) do not need to be modified when applying Hybrid-NEMO.
(4) We propose that the quality of transmission of multimedia data packets through SCTP is better than that via UDP due to the restrictions of a mobile network.

The rest of this paper is organized as follows. Section 2 briefly introduces the background of this paper and reviews currently available handoff techniques. Section 3 describes the Hybrid-NEMO architecture, various operations of its entities and three types of handoffs. Simulation results and discussion are presented in Section 4. Section 5 concludes this paper and addresses our future research.

2. Background and related work

2.1. SCTP

In 2000, the IETF Signaling Transport (SIGTRAN) working group defined SCTP as a transport layer protocol. SCTP inherits congestion and flow control mechanisms from TCP, but improves several features to make its signal transmission more efficient. A connection in SCTP is referred to as an association. An association is established through a four-way handshake, which can protect a server from Denial of Service (DoS) attacks using a spoofed IP (Camarillo et al., 2003).

To increase the robustness of communication, an SCTP server is often equipped with multiple network interfaces, each with its own IP. Such a server is called a multi-homed server. During the establishment of an association, an SCTP endpoint can provide its peer with a list of IPs or domain names. Among them, one address is marked as the primary, which is used to send data to and receive data from the peer under normal circumstances. When the primary address is unavailable or its performance is poor, communication will be switched to another address in the list. This can greatly increase the reliability of the SCTP association.

SCTP has been specified by the third Generation Partnership Project (3GPP) to carry call signaling traffic in the universal mobile telecommunications system (UMTS) (O'Mahony, 1998). Using a base version of SCTP, endpoints after establishing their association cannot switch the two addresses currently used before the association is released. Hence, this version is unable to support soft handoff for a mobile node.

Mobile-SCTP (mSCTP), an extension of SCTP, is used for mobility management in a wireless environment. It allows an endpoint to add, delete and change IPs by sending address configuration (ASCONF) messages to its peer while their SCTP association is still active. An SCTP-based handoff scheme, which is designed by using the mSCTP protocol, has several limitations. For example, SCTP is often employed to provide client-server services in which a client needs to initiate a session to connect itself with a fixed server, i.e., a peer. To support peer-to-peer services, mSCTP should provide additional location management schemes, but it does not do so.

2.2. Session initiation protocol

Four logical entities are defined by SIP, including user agents, registrars, proxy servers, and redirect servers. Descriptions of their major functions can be found in Schulzrinne and Rosenberg (2000). SIP also defines six basic requests whose specifications are