Adaptive Application for Mobile Network Environment

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Abstract: In a mobile network environment, a Mobile Router (MR) has multiple communication interfaces to the Internet. It switches between or simultaneously uses these interfaces, causing network conditions within the MR to change. If the network conditions were shared with between nodes behind the MR (MNN) and their correspondent nodes (CN), it would be possible for applications to change its behavior accordingly. In this research, an application that has this ability is called Adaptive Application. We propose a new architecture of Adaptive Application, which allows allocating IDs to communication interfaces of MR and distributing those IDs to both CN and MNN. MNN and CN can be informed of the interfaces currently used on the MR. In a mobile network environment, a communication interface is a big determining factor in network conditions. This thus allows applications to adapt to network conditions. We also expose evaluation results obtained from a videoconference system that implements the proposed architecture. This application reacts to changes in the currently used interface and dynamically modifies its transmission rate. Finally, we conclude that dynamic adaptability of applications to the current network condition could be effective.

Keywords: Vehicle Communication, Network Mobility, Multihoming, Seamless Mobility.

1. INTRODUCTION

A Mobile Network is an entire network where a Mobile Router (MR) that belongs to the network provides movement transparency. Nodes inside a Mobile Network can connect to the Internet without being aware of the mobility. The concept that implements Mobile Network is called Network Mobility (NEMO) vis-à-vis Host Mobility known as Mobile IP. Applications of NEMO to Personal Area Network, automobile, airplane are examined in [1, 2, 3]. The IETF NEMO working group [4] has been setup in an effort to address issues related to NEMO. The working group has standardized the NEMO Basic Support protocol [5] recently.

A MR may have multiple communication interfaces to the Internet [3]. It switches between or simultaneously uses these interfaces, causing the network conditions within the MR to change. For example, in the case of a MR that is built into automobile, it uses Wireless LAN at parking lot or at gas station, and it uses cellular phone while moving around. Wireless LAN is a communication interface characterized by high bandwidth and low delay, whereas cellular phone is characterized by low bandwidth and long delay. Thus a network condition using Wireless LAN and using cellular phone differ largely.

But, current application within Mobile Network environment is configured to adjust to the low bandwidth that cellular phone has, and communication within the environment has become inefficient because current congestion control mechanisms cannot follow the change of network conditions. Network resources can be used efficiently if multimedia applications are capable of adaptation to changing network conditions.

Adaptation to changing network conditions can be implemented at several layers of the network protocol stack. At the network layer, dynamic re-routing mechanisms can be used to avoid congestion and mitigate variations in a mobile environment. At the transport layer, dynamic re-negotiation of connection parameters can be used for adaptation. Application can use protocols such as real-time streaming protocol (RTSP) [6] and real-time protocol (RTP) [7]. At the application layer, the application can adapt to changes in network conditions using several techniques [8] including hierarchical encoding, efficient compression, bandwidth smoothing, rate shaping, error control, and adaptive synchronization.

These techniques could also be applied nodes in the Mobile Network environment. But, the problem is, there is no straightforward trigger where end nodes of a communication know the changing of network conditions, because end nodes are not aware of the mobility in the environment.

The purpose of this research thus is to share the state of network condition with between end nodes of a communication, Correspondent Node (CN) and MNN. It would be possible for applications to change their behavior accordingly. In this research, this is defined as Dynamic Adaptability of Application and an application that has this ability is called Adaptive Application. It can apply to effective utilization of bandwidth and more efficient congestion control. Note that our discussion is based on the NEMO Basic Support because it's the only one standardized NEMO protocol.

The rest of this paper is organized as follow. Section 2 discusses approaches to archive our adaptive application architecture. An architecture based on the approach is designed. Section 3 gives an overview of the architecture. In order to evaluate the WHISTLE architecture, we implement a videoconference system. This application reacts to changes in the currently used interface and dynamically modifies its transmission rate. Section 4 and 5 give the overview and its evaluation results. In Section 6, we conclude.

2. APPROACH

Our adaptive application architecture is composed of two parts: 1) sharing the state of network conditions between CN and MNN, 2) changing behavior according to the state of network condition.

2.1. Sharing the State of Network Condition

A communication interface that a MR is currently using is a bottleneck of communications through the MR. The communication interface thus becomes a determining factor in the performance of the communications. We then propose a framework to share the information which communication interfaces the MR are currently using.

An extension to the Mobile IPv6 specification [9], which allocates Binding ID (BID) to each communication interface on Mobile Node, is proposed in [10]. The modified Binding Update sent to CN includes available BID. When multiple care-of addresses are registered bound to a single home address, BID is used to distinguish between the bindings. This could apply to adaptive application, because the CN can be informed of the interfaces currently used on the MR.

Our adaptive application architecture uses the similar approach, which allocates BID to each communication interface on the MR and distributes the BID of available communication interface to end nodes of a communication; it's CN and MNN in the targeted Mobile Network environment.

BID is an identifier, so itself does not include any information such as type, bandwidth, delay, and error rate about the communication interface. A mechanism that binds BID and such information is necessary. This helps more generic uses of the adaptive application architecture. But it is out of scope in this paper.

2.2. Changing Behavior According to the State of Network Conditions

A communication interface is characterized with bandwidth, delay, error rate, cost, service domain, and so on. Furthermore, a behavior of application can be defined with those parameters. For descriptive purposes, at this moment, the behaviors of application are defined by status (up/down) of communication interfaces that MR has in this paper. When MR has *n* communication interfaces, *n^2* way of behaviors can be defined.

The various behaviors of application that are changed with network conditions have been studied for a long time. It is also out of scope in this paper. Most prominent related work on friendly multimedia transmission over the Internet, based on a combination of system and network QoS feedback implementing equation-based adaptation is summarized in [8, 11]. For example, adapting to changing network conditions can be achieved by a number of techniques at the compression level (video encoder) including layered encoding, changing parameters of compression methods, and using efficient compression methods. At the application streaming level, adaptation techniques include layered encoding, adaptive error control, adaptive synchronization and smoothing.

When the MR changes interface, the correspondent BID is notified to end nodes of a communication. The nodes then search a database where behavior as described above is defined with the BID, and perform the behavior.

3. DESIGN

This section presents our adaptive application architecture that is designed based on the NEMO Basic Support protocol [5] and the approaches discussed at Section 2. We call the architecture WHISTLE. Figure 1 shows the overview of our WHISTLE notification architecture.

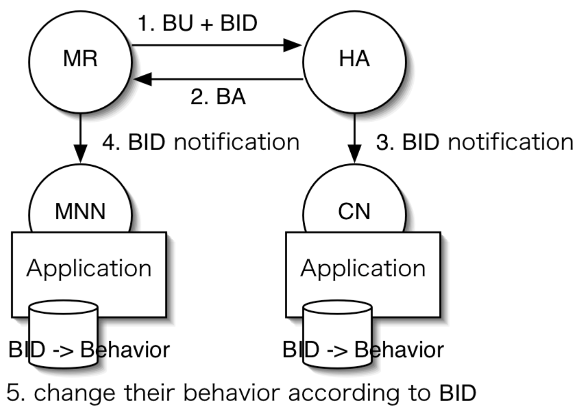

Figure 1: WHISTLE architecture

1. When a MR gets a new Care-of Address (CoA), it performs movement detection and sends Binding Update including the corresponding BID. 2. When HA succeeds to process the BU, HA returns Binding Acknowledgment (BA) to the MR. 3. HA then notifies the BID to CN. 4. When MR receives the BA, MR notifies the BID to MNN. 5. The application changes their behavior according to the received BID.

The notification of BID should be performed as soon as the Binding becomes valid. The timing, when it can judge that Binding became valid, differs in MR and HA: for MR, it is after receiving the BA, for HA it is just after sending the BA. It can be assumed that MR is the nearest from MNN, and HA is the nearest from CN because all communications are routed through a bidirectional tunnel between MR and HA in the NEMO Basic Support protocol. Additionally, sending BID notification from MR to CN is lacking in reliability and immediate because MR is generally using wireless access technologies to connect to the Internet. It has instability and long delaying than wired access technologies. Thus, although HA never concerns CN in the NEMO Basic Support Protocol, BID is notified from MR to MNN and from HA to CN.

BID notification is UDP/IPv6 and it must include HoA of MR, Mobile Network Prefix, and BID. Figure 2 shows the packet format. The notification is organized into tree part: main, MNP option, and BID option.

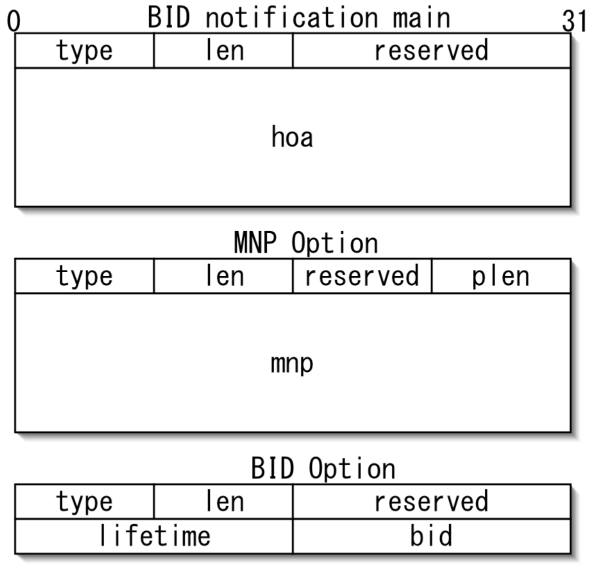

Figure 2: Packet format of BID notification

BID notification main

- *type* field: There are two message types, event (0x01) and regular report (0x11).
- *hoa* field: Home Address of a MR.

MNP option

When MR manages multiple mobile network prefixes, several MNP option can be added.

- *type* field: to identify MNP option. 0x21
- *plen* field: Prefix length of the Mobile Network Prefix.
- *mnp* field: Mobile Network Prefix

BID Option

When MR has multiple communication interfaces, several BID options can be added.

- *type* field: to identify BID option. 0x22
- *lifetime* field: Lifetime of the BID
- *bid* field: BID

4. IMPLEMENTATION

In order to evaluate the WHISTLE architecture, we implement a videoconference system with NEMO Basic Support protocol. This application reacts to changes in the currently used interface and dynamically modifies its transmission rate.

A Mobile Network provided by a MR that has Evaluation Data Only (EVDO) and Wireless LAN (IEEE802.11b) was constructed. This system is an extension of SHISA, which is open source NEMO Basic Support protocol implementation by KAME project [12]. With SHISA, it can obtain the information of the addition / modification / deletion of Binding by using the interface called Mobility Socket. Our BID notification daemon monitors the change of Binding using this framework

The SHISA movement detection daemon watches each communication interfaces and it notifies the changes of CoA to other SHISA related daemon via the Mobility Socket. This daemon is modified to have a binding between BID and communication interfaces. Thus, it is possible that MR learn a corresponded BID of a CoA. When a new CoA is detected, the Binding is immediately updated. Our BID notification daemon monitors the change of Binding via Mobility Socket. Furthermore, the destinations of BID notification are configured statically beforehand.

As a videoconference application, we use a MPEG-4 based Bi-directional Live Vide/Audio Transmission System called Quality Meeting (QM) by KDDI R&D Labs [13]. Beforehand, the configuration files for EVDO and Wireless LAN is prepared, QM restarts with the corresponding configuration when a BID is notified. At this time, the consumed bandwidth of videoconference is configured as 32Kbps for EVDO and 192Kbps for Wireless LAN.

5. DEMONSTRATION EXPERIMENT

The demonstration experiment was lunched at the ITS World Congress 2005 Nagoya Japan [14]. The passenger inside bus and the tourist navigator at exhibition booth had a live using this IPv6 videoconference system.

Figure 3 shows changes of effective bandwidth (dashed line) and encoding rate of the video streaming application (bold line). The effective bandwidth is measured in the resting state by using Iperf [15].

When MR changes its communication interface from cellular phone to Wireless LAN, it is observed that QM changes its encoding rate accordingly. In addition, even subjectively, the quality of animation and sound improves substantially in comparison with EVDO and wireless LAN. The delay to change the transmission rate is between about 3 seconds (maximum 8 seconds). This is because of the restarting of QM and delayed arrival of signaling due to the fact that band is consumed by the video streaming. This relay thus is not referable to the WHISTLE architecture.

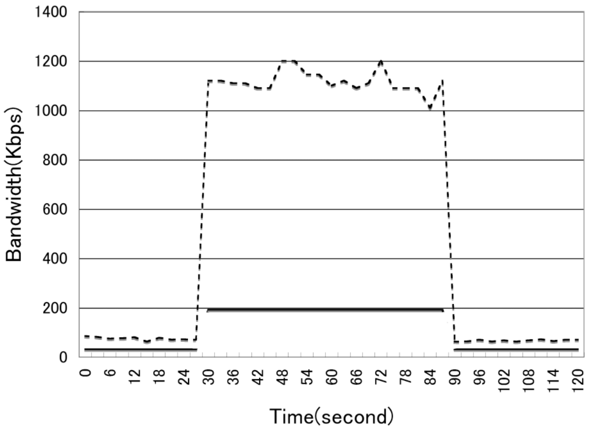

Figure 3: Changes of effective bandwidth and transmission rate of Video streaming

6. CONCLUSION

In order to make applications to adapt to changing network conditions, we proposed a new architecture called WHISTLE, which allows allocating IDs to communication interfaces of MR and distributing those IDs to end nodes of a communication in Mobile Network environment; it's both CN and MNN. MNN and CN could be informed of the interfaces currently used on the MR. In a mobile network environment, the interface is a big determining factor in the network condition. This thus allows application to adapt to network conditions. We also exposed evaluation results obtained from a videoconference system that implements the WHISTLE architecture. This system reacted to changes in the currently used interface and dynamically modifies its transmission rate. Finally, we conclude that dynamic adaptability of applications to the current network condition could be quite effective.

7. ACKNOWLEDGEMENT

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