A Multi-Interface Proposal for IEEE 802.21 Media Independent Handover

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Abstract

In Next-Generation (NG) wireless networks, hybrid handover techniques are expected to enable the integration of heterogeneous networks, e.g. 3G cellular networks and 802.11 Wireless LAN (WLAN). Media Independent Handover (MIH) has begun to be discussed in the latest IEEE 802.21 to accommodate multiple disparate interfaces in mobile handset. Multiple interfaces can come in a variety of ways to facilitate hybrid handover, and may result in different requirements on protocols and performance. In this paper, we classify multi-interface schemes for handover in heterogeneous wireless networks. We propose a multi-interface scheme for IEEE 802.21 MIH. The scheme is proposed to be able to work with standard TCP and Mobile IPv4 agent routers without particular configuration. Based on this scheme, we implemented a dual-interface Mobile Host (MH) model in Network Simulation 2 (ns2) to evaluate how it performs in comparison with single-interface MH.

1. Introduction

In Next-Generation (NG) wireless networks, hybrid handover techniques are expected to enable the integration of heterogeneous networks, e.g. 3G cellular networks and 802.11 Wireless LAN (WLAN). Hybrid handover is the process, in which Mobile Host (MH) is switched between domains of different access technologies, or between domains of multiple operators.

Figure 1 illustrates the procedures involved in a hybrid handover in the integration of 3G Public Land Mobile Network (PLMN) and WLAN. Generally, hybrid handover involves network selection from a list of discovered Point of Attachments (POA). The Mobile Host's (MH) association with newly selected POA can be established while keeping an ongoing session with the current POA. To support hybrid handover, MH must have multiple network interfaces for accessing disparate networks. The multi-interface solutions of MH have been studied in a number of papers [1, 2]. Single-interface solutions for accessing multiple networks were also addressed in [3, 4]. In hybrid handover, dealing with the heterogeneities of multiple access technologies in a consistent manner would be a challenge for multi-interface design. Media Independent Handover (MIH) was recently proposed in IEEE 802.21 for discussion. The IEEE 802.21 [5] is a developing effort to enable handover and interoperability between heterogeneous networks.

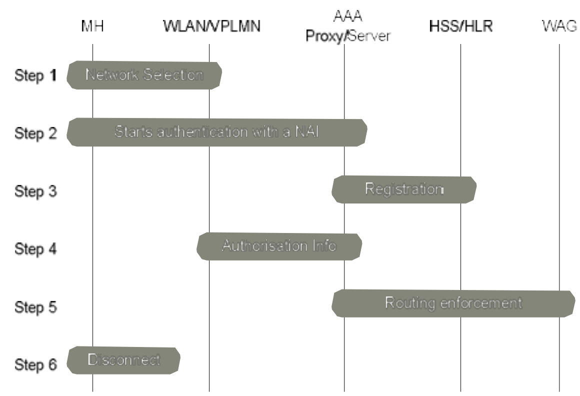

Figure 1 Handover Procedures in the Integration of 3G PLMN and WLAN networks

IEEE 802.21 framework defines three different services to facilitate information exchange for network discovery and selection in hybrid handover. Media Independent Event Service (MIES) provides events notification in response to changes in network conditions. Media Independent Command Service (MICS) is used to manage and control link behavior relevant to handover. Media Independent Information Service (MIIS) provides a model for information gathering.

Although IEEE 802.21 MIH defines an effective framework for enabling multiple disparate interfaces in mobile handset, the different implementation may result in varied performance in handover. The multiple interfaces can be simultaneously used to facilitate the so-called soft handover, which requires corresponding processing at upper layers. While, in another approach of hard handover, multiple interfaces can be alternatively used, and thus keep compatible with network layer protocols being widely used. In this context, we propose a multi-interface scheme for 802.21 MIH, and evaluate its handover performance on Network Simulation 2 (ns2) [6].

The rest of the paper is organized as follows. The multi-interface schemes of MH for hybrid handover are classified in Section 2. Section 3 describes a multi-interface scheme proposed for 802.21 MIH. In section 4, we introduce the implementation of dual-interface MH model in ns2. The simulation scenario and experimental results are demonstrated in Section 5. We conclude the paper in Section 6.

2. Multi-Access Schemes

Multiple interfaces in mobile handset can come in a variety of ways to support accessing heterogeneous wireless networks. Some selective terms on multi-interface design are explained as follows:

- Simultaneous communication: refers to the ability of having multiple interfaces carry data communication simultaneously.
- Address management: host mobility management has been addressed in both Mobile IPv4 [7] and Mobile IPv6 [8]. MH can acquire multiple Care of Address (CoA) for accessing multiple visited domains. The related IP address assignment on each interface is referred as address management.
- Traffic redirection: the ongoing sessions/traffic can be redirected from one interface to another due to handover.
- Network selection: is the process of selecting next POA with handover decision algorithms.

In this section, we classify and compare multi-interface schemes for accessing heterogeneous wireless networks. In addition, we also demonstrate a single-interface scheme for accessing different network domains, which may belong to multiple operators.

2.1 Multi-Interface Simultaneously Used

Mobile handset may use multiple interfaces simultaneously to support a soft handover, which means MH always keeps at least one radio connection with POAs. The corresponding handover allows more than one interface to carry traffic flow so as to redirect ongoing sessions seamlessly. Mobile handset with multiple IP addresses is referred to as multihomed [9]. Because data stream would be carried through multiple network domains, multihoming solutions need support at both network and transport layers. Mobile IPv6 provides necessary mechanisms for multi-interface related address management and the corresponding solutions on nomadism of users for IP layer services. In [10], a number of transport multihoming protocols have been addressed. Basically, the transport protocol in multihoming should be able to deal with the packets originating from the same session being multicast on multiple paths. Additional signaling and data traffic would be loaded on networks. The problem with this scheme is its incompatibility with TCP, which has huge user base. This scheme requires the multihoming support in visited agent routers as well, which may not be available in heterogeneous environments.

2.2 Multi-Interface Alternatively Used

Multiple interfaces can also be alternatively used to support hard handover in heterogeneous networks, which is also known as "break before make". Because only one interface gets involved in data transmission, lower layer interface switching can be made transparent to upper layers, e.g. TCP. Multiple interfaces can be integrated for ubiquitous access, but may result in a longer handover delay in data transmission due to excess time required for setting up new connections. The network interfaces other than the one carrying traffic can be used for network discovery, and gathering information on potential POAs. Multi-interface alternatively used scheme has less traffic burden on networks than the simultaneously used multi-interface scheme. This scheme still uses mobile IP protocols for address management and location services. However, it doesn't require the mechanisms, such as multiple CoAs' binding, which may need special setting in home agent. Morever, no particular configuration is need in agent routers. This scheme can work well even in standard Mobile IPv4.

2.3 Single Interface for Multiple Access

Single network interface is used for accessing one specific network domain in most cases. However, under some circumstances, single network interface, e.g. IEEE 802.11, can be multiplexed to simultaneously connect to multiple network domains. In the MultiNet scheme proposed in [3], single IEEE 802.11 wireless card can support infrastructure and ad-hoc mode of communications at the same time. The basic idea behind the MultiNet is to multiplex wireless network card across multiple wireless networks. MultiNet-enabled mobile handset maintains several virtual adapters in its network stack, which act as virtual wireless interfaces. Another scheme called SyncScan [4] explores the freedom of beacon sending time to synchronize wireless node with the timing of AP beacons. SyncScan aims to reduce probing delay in scanning multiple channels, and has the potential to track beacons from nearby APs while carrying on communication with the current AP. But, similar to MultiNet, it also requires synchronization with networks and modification to network protocol stack.

3. A Multi-Interface Scheme Proposed for Media Independent Handover (MIH)

To support handover in heterogeneous wireless networks, we propose a multi-interface scheme that is compatible with the transport protocols already in use. It is based on the second multi-access scheme aforementioned in Sec. 2.2. The proposed scheme supports network interface selection, and is one implementation of the IEEE 802.21 framework [5] still in discussion. The scheme adopts the concept of cross-layer design, and proposes an intermediate layer that gathers information through different network interfaces to assist handover decision making. All the functions with the intermediate layer are implemented in a Handover Management Module (HMM). The HMM is proposed to make upper layers independent of the heterogeneities of multiple network interfaces. Some handover decision algorithms for hybrid handover, such as policy-enabled handoff [11] and AHP network selection [12], can be implemented in HMM to assist handover decision making. The communication between HMM and other layers can use 802.21 MIH defined services. Each network interface can work in either primary mode or standby mode. However, only the interface in primary mode is activated for carrying traffic streams as well as signaling. Other interfaces in standby mode are only allowed to receive signaling from new POAs.

Figure 2 illustrates the main functional components and their interaction with the HMM. The HMM obtain handover metrics information, such as signal strength, QoS and service type, from both lower layers and upper layers using “HMM Metrics” services. The “HMM Metrics” services are the implementation of 802.21 MIH Information/Event services of information gathering and event notification. To trigger interface switching after decision making, the HMM sends “HMM commands” (implementing 802.21 MIH Command Services) to both upper layers and lower layers. The corresponding operations in different layers would be followed. The HMM commands for lower layers are used to activate or deactivate network interfaces for interface switching. To achieve a fast handover, the HMM can also inform upper layers of any changes made to physical connections. For example, in 802.11 WLAN, when MH activates a standby interface for attachment to a new POA, the HMM can send up HMM commands to mobile IP layer to start registration/solicitation immediately so as to avoid waiting time for next advertisement’s arrival.

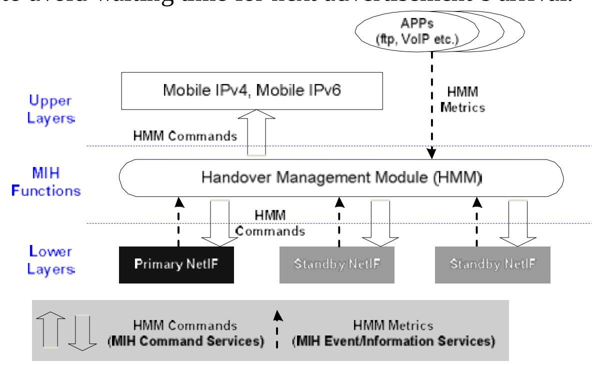

Figure 2 A Multi-Interface Scheme Proposed for 802.21 MIH

4. Implementation Issues

Based on the proposed multi-interface scheme shown in Figure 2, we implemented a dual-interface MH model in ns2 [6]. In this model, the HMM functions are implemented in a Handover Manager (HOMgr). We assume MH is equipped with two IEEE 802.11 interfaces. Its structure is illustrated in Figure 3. The simulation was developed on ns 2.29, with the following modifications:

- Support for multiple wireless channels on MH;
- Handover metrics probing at lower layer objects for information gathering;
- Modification to NO Ad-Hoc Routing Agent (NOAH) to be used as the routing agent for dual-interface MH;
- Proactive triggering mechanisms in mobile IP protocol.

Because ns2 lacks the implementation of dealing with multiple interfaces, we also developed the following new components/functions for controlling and managing multiple interfaces:

- Handover manager with handover decision algorithms;
- Functions for network interface switching;

In dual-interface MH. We use the NOAH [13] to direct communication between MH and APs. Two 802.11 interfaces have been tuned to different wireless channels, and both of them interact with the HOMgr. Mobile IPv4 was introduced to test MH’s compatibility with legacy IP networks. Foreign Agent (FA) Care-of-Address (CoA) is enabled on both interfaces when connecting to visited networks. Dual-interface MH is implemented such that: at anytime if the standby interface is activated, then the primary interface goes into standby mode. This would be followed by the termination of the data traffic on the previously activated interface. Upper layers (TCP/Applications) stay unknown to what happened at lower layers. HOMgr can regularly retrieve metric information through "Metric Probe" process, which is embedded at different layers. In the current implementation of HOMgr, we apply the signal power based handover decision algorithm [14].

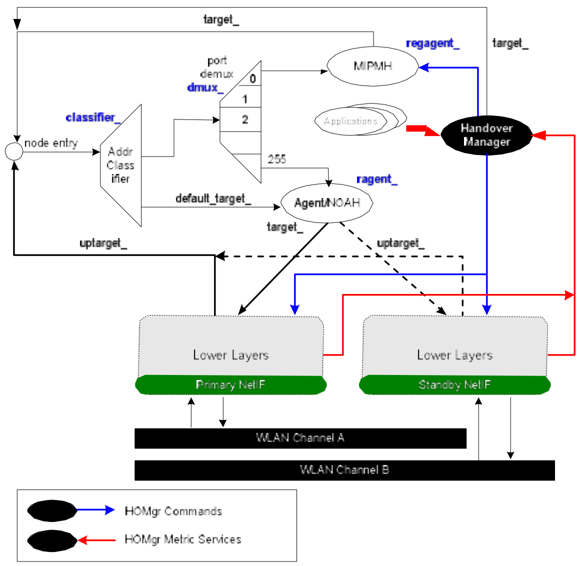

Figure 3 Dual-Interface Implementation in ns2

In implementation, we assume that MH skips channel scanning process in finding new POAs, which has been well studied in [4]. Authentication is also not implemented for handover association. HOMgr based multi-interface architecture can well accommodate other interface modules, such as GPRS and UMTS.

5. Simulation and Results

A. Simulated Scenario

In the simulated scenario, the Correspondent Node (CN) is connected to two separated 802.11 WLAN domains through a fixed link of 5Mbps. The AP of Home Agent (HA) is denoted as AP-HA, and AP-FA refers to the AP of Foreign Agent (FA). AP-HA and AP-FA are tuned to different wireless channels. Their radio coverage is made partially overlapped. As illustrated in Figure 4, MH was initially moving from AP-HA towards AP-FA at the speed of 20m/s, and then went back to AP-HA.

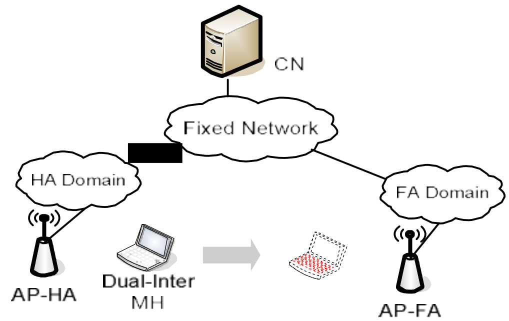

Figure 4 Wireless Overlap Scenario under Study

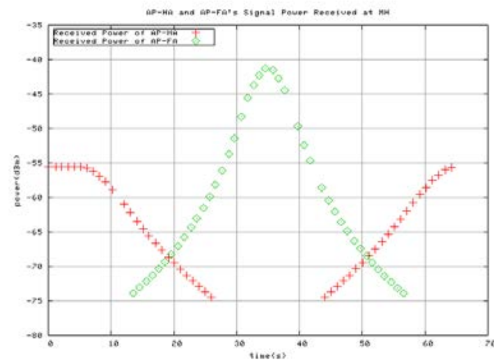

Figure 5 Received Signal Power at MH

The radio coverage of AP-HA and AP-FA is a circle of 450m in radius. TCP is the transport protocol applied between network nodes, through which constant bit rate (CBR) traffic is carried at the rate of 672Kbps (a 210-byte packet is sent every 2.25ms). Two handover events expected in this scenario are HAÆFA and FAÆHA respectively. The scenario of Figure 4 would be run for both dual-interface and single-interface MH so as to get a comparison result. Figure 5 shows the received signal power at MH for AP-HA and AP-FA.

B. Simulation Results

To evaluate the performance of the proposed multi-interface scheme, we simulated the above scenario on ns2 for both dual-interface MH and single-interface MH scenario. The simulation results of dual-interface MH would be compared with that of single-interface in the following three aspects.

- Data Throughput

The data throughput of dual-interface and single-interface MH in the simulation is demonstrated in Figure 6. Both dual-interface and single-interface MH show common data transmission characteristics in homogeneous domains (non radio overlap areas). In the overlap areas, the dual-interface MH was able to conduct a faster handover to associate with new POA than the single-interface MH. MH was set to allow the missing of just two consecutive advertisements. For single-interface MH, the break time of TCP data transmission in both directions is 5.14s for “HAÆ FA” and 2.64s for “FAÆHA” respectively. In comparison, the dual-interface MH took just 67ms to recover data transmission through visited FA in a handover, and 547ms to have data transmission handed back to HA.

• End-to-end Packet Delay

The end-to-end packet delay is defined as the packet traveling time from traffic source (CN) to traffic destination (MH) for each confirmed TCP packet. From Figure 7, we noticed that the end-to-end packet delay during handover is in proportion to transmission breaking time. In the dual-interface scenario, handover still caused longer end-to-end packet delay compared with normal packet delivering time. However, the delay has been noticeably reduced to 700ms if dual-interface is enabled on MH, in comparison to over 5s delay for single-interface MH.

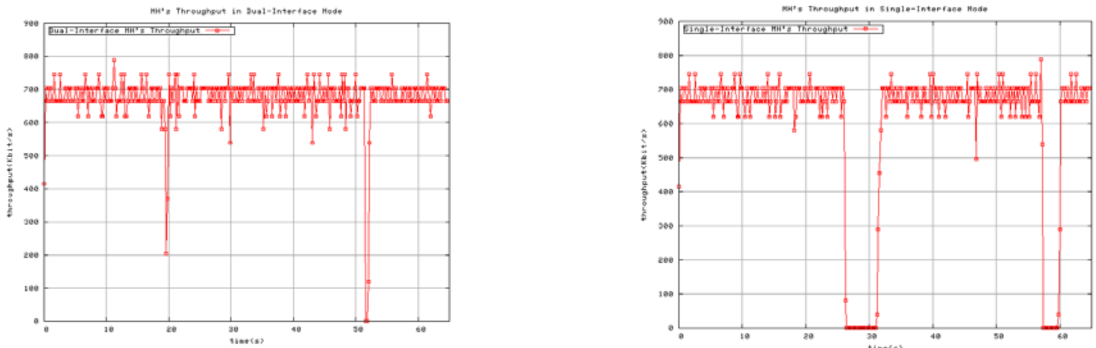

Figure 6 MH’s Throughput (Dual-Interface vs. Single-Interface)

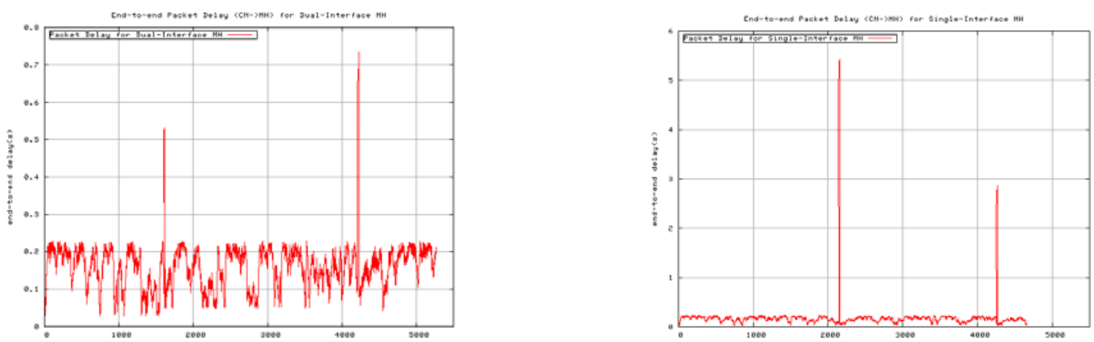

Figure 7 End-to-end Packet Delay from CN to MH (Dual-interface vs. Single-Interface)

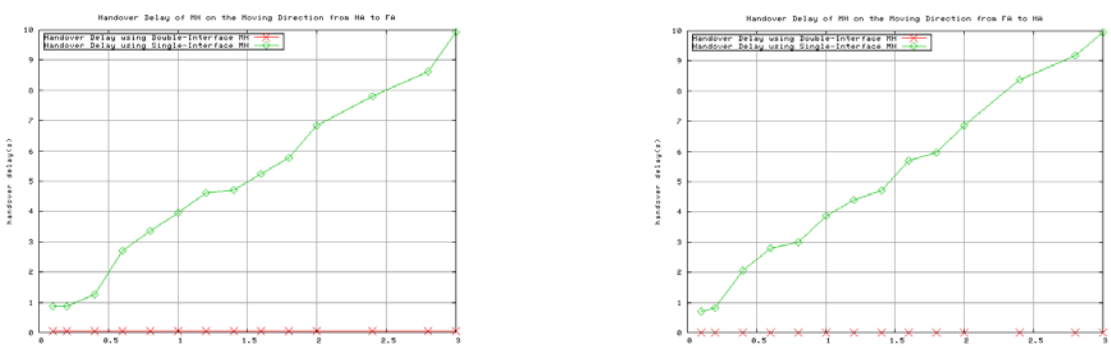

Figure 8 Handover Delay of MH with varying Advertisement Interval (HAÆFA vs. FAÆHA)

• Handover Delay

Handover delay is defined as the time interval between the correctly receiving of the last packet from old POA and the completion of association with new POA. In the simulation, we set the agent advertisement (ads) interval (I_{ads}) to be one-third of the advertisement lifetime (L_{ads}) according to [7]. We measured handover delay incurred in both movement directions of MH. I_{ads} was increased in the simulation, and thus its impact on handover delay can be evaluated. The simulation results show that single-interface MH generally took much longer time to complete a handover than dual-interface MH. Single-interface MH always waits until the ads from the currently attached AP expire before trying to find a new AP. In the simulation, an average 0.84s handover delay was seen when $I_{ads} = 0.2$. While, when I_{ads} was 1s, handover delay reached 3.91s. For dual-interface MH, handover delay was apparently independent of I_{ads} as demonstrated in Figure 8. The dual-interface is able to deal with handover in an proactive way, and thus appears not influenced by the variation of I_{ads} . The average handover delay of dual-interface MH in the simulation is 39.9ms for HA ÆFA movement, and 4.7ms in the reverse direction.

6. Conclusions

In this paper, we have presented a multi-interface scheme for IEEE 802.21 media independent handover. The proposed scheme is compatible with transport protocols already in use, e.g. TCP and UDP, It works well with Mobile IPv4 without particular setting in agent routers. A dual-interface MH model has been designed and implemented in ns 2.29 to validate the proposed scheme. The comparison results (with single-interface MH) show that dual-interface can effectively decrease data transmission break time and end-to-end packet delay in handover. Moreover, dual-interface can eliminate the influence of the advertisement interval on handover delay. This would make end-to-end packet delay independent of access domain in handover. Such a feature would especially favor NG heterogeneous networks that may be based on disparate technologies and run by multiple operators.

7. References

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