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Evaluation of IEEE 802.21 handover between IEEE 802.11 and UMTS networks

Abstract

The paper presents IEEE 802.21 – the ongoing standard for network handovers – illustrating its functional features, and considering and simulating a set of scenarios of mobile stations moving between IEEE 802.11 and UMTS networks. In order to evaluate the performance of IEEE 802.21 handover packet loses and switching delays caused by handover procedures are investigated. The authors discuss example results of simulation experiments and suggest further extensions to the standard.

Keywords: IEEE 802.21, handover, IEEE 802.11, UMTS, simulation, ns-2

Introduction

The history of IEEE (Institute of Electrical and Electronics Engineers) 802.21 standard begins in 2003 along with discussion on IEEE 802.x network series handover techniques. This discussion led to IEEE 802.21 workgroup initiated in 2004 to address handover-related problems in 802 networks and 3GPP/3GPP2 (Third Generation Partnership Project) systems. The main objective of the standard is to define media access independent mechanisms that enable optimization of handovers for both mobile and stationary users. The experiments presented in the article are based on the last standard draft published in April 2007 [7].

The IEEE 802.21 introduces Media Independent Handover (MIH) Function that is considered a shim layer in the network stack of both network node and the network elements that provide a mobility support [2]. MIH Function provides abstracted services to the upper layers and communicates with lower layers through technology-specific interfaces.

The article presents the results of simulation experiments related to handover between IEEE 802.11 [6] and UMTS networks [1]. The handover is performed along to IEEE 802.21 standard. The conducted experiments aim at performance evaluation of handover depending on packet size and velocity of mobile stations. Next sections describe handover architecture, simulation scenario and example results. The article is completed by discussion of results and final conclusions.

Handover Design

Handover describes a mechanism when a user moves through the coverage of different wireless cells. A handover between wireless cells of the same type is referred to as horizontal handover, while a handover between cells of different type is known as vertical handover 3. Because IP protocols were designed for stationary systems, some extensions have been proposed to introduce mobility support.

There are some solutions to the mobility problem in IP networks, e.g. IETF Mobile (MIP) IPv4 [10], IETF Mobile IPv6 [8], Cellular IP and HAWAII. Because IPv6 is not often used in today's networks, Mobile IPv4 is perceived as an appropriate current solution. The protocol aims at continuous TCP connections even though the IP address changes when the handover occurs.

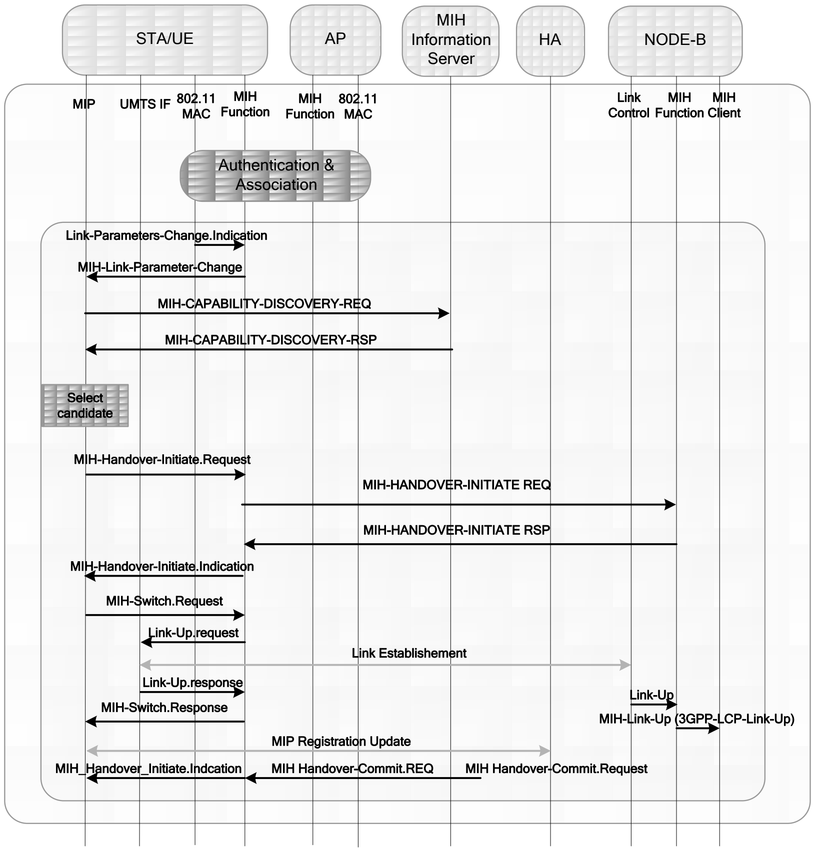

Fig. 1. IEEE 802.21 handover between IEEE 802.21 and UMTS networks

The IEEE 802.21 handover procedure is illustrated in Fig. 1. The figure presents mobile station moving from IEEE 802.11 network to UMTS network. Before the handover is performed the station is authenticated and associated with IEEE 802.11 AP, and is able to send and receive data. When the station is about to leave WLAN coverage, the indication is triggered by MAC layer. The design of the triggers is critical to the performance of the handover and is the subject of detailed research [5][4]. The event "Link Parameter Change" is forwarded to MIP entity which is registered as MIH Client. The capability discovery procedure provides the information about available networks. Handover initiate procedure reserves resources for mobile terminal (e.g. DCH channel for UMTS access). In the next step handoff is performed and MIP registration with HA is refreshed.

Simulation scenario

The simulation experiments were conducted with the use of ns-2 simulator [9], extended with MIH Function support and simplified UMTS network model. The simulated network architecture consists of two radio access networks, namely the UMTS and 802.11b/g networks, connected via Internet.

The 802.11bg radio access network consists of a single access point (AP), connected to a 100Mbit Ethernet LAN, which is in turn connected to the Internet through a gateway, using a 2Mbps link (e.g. DSL). Other APs can be connected to the same LAN (and the same gateway, which is not simulated), forming a geographically larger wireless radio access network. The simulated network data rate is constant: 11 Mbps for user data and 2 Mbps for control data.

The UMTS architecture adheres to UMTS Release 4 specifications. The simulated UMTS Terrestrial Radio Access Network (UTRAN) consists of a single Radio Access Network (RAN) controlled by a Radio Network Controller (RNC). One Node-B (operating in FDD mode) connected to Internet via a 2Mbps link. Only a part of the packet switched (PS) domain is simulated. AAL2 is used for transport between RNC and Node-B and AAL5 between RNC, SGSN and GGSN. The simulated network is considered a pico cell that offers 2 Mbps download data rate.

Mobility management is performed by means of a Mobile IP mechanism. The Home Agent (HA) is located somewhere in the Internet (where the mobile host obtained its address) and Foreign Agents (FA) are located in the WLAN's gateway and in the SGSN. MIP entity is registered as MIH client in relevant nodes.

A scenario with overlapping UMTS and WLAN coverage, which is the most common in urban environment, is also considered. For the open space propagation modeling TwoRayGround model is applied. In the simulation scenario the station moves from IEEE 802.11 network coverage to UMTS network coverage and returns back. In both experiments the overlapping coverage area is crossed. The handover decision is based on Lazy Cell Switching algorithm [10] i.e. the mobile station switches the network when the connection with current network is lost. It is assumed that the mobile terminal is equipped with either two wireless interface cards, or a dual UMTS/802.11bg interface card.

It was accepted that during simulation experiments, the mobile user watches a movie which is simulated as CBR traffic over UDP. The model makes it possible to measure handover performance not influenced by flow control introduced by connection-oriented protocols (e.g. TCP). The movie server is located in the Internet.

Simulation results

The number of packets lost during handover is presented in Fig. 2. The handoff includes detection of deteriorated link state, authentication and association procedures, resource reservation (when switching to UMTS network) and MIP registration update procedure. The number of lost packets is measured from the moment of losing the connection until the communication is restored in L3. The goal of experiments was to measure the statistics experienced by the application, as observed by a user.

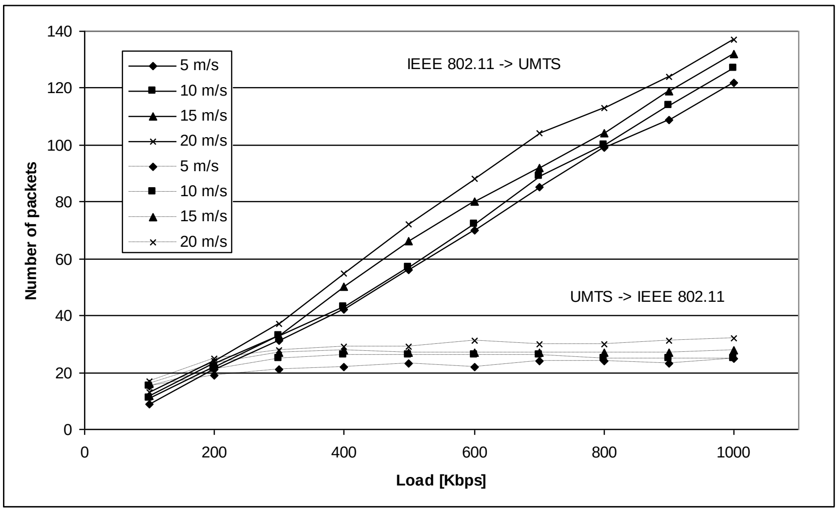

Fig. 2. Number of packets lost during handover in relation to station speed and traffic load

The simulation model assumes that capability discovery is not performed after the connection with the previous network is lost. The expectation is that capability information is up-to-date. For example the discovery procedure has been performed just before the link is down, not to influence handover delay which is a crucial parameter for multimedia applications. The simulated solution is expected to be implemented in future IEEE 802.21 implementations.

Fig. 2 presents two groups of statistics for a station moving from IEEE 802.11 network to UMTS network and in reverse direction. The experiments were conducted for four selected movement speeds: from bicycle speed (5 m/s) up to vehicle speed in urban area (20 m/s). The CBR traffic consisted of UDP packets that carry 1000-byte payloads. The load is increased by lowering interval between data packets; the packet size is constant. The handoffs statistic is not symmetrical, i.e. the number of lost packets is generally higher when moving from IEEE 802.11 to UMTS network, comparing with station moving in reverse direction. The reason is that data throughput of IEEE 802.11 network (11 Mbps) is higher than UMTS network (2 Mbps). When the link is down packets destined for a station are queued in the network until communication with a station will be restored. In case of full queue the newly arrived packets are lost. When the handover is completed the queued packets are forwarded to the new network attach point of the station. If the new network data rate is relatively low the high number of packets will be lost until transmission queue is empty.

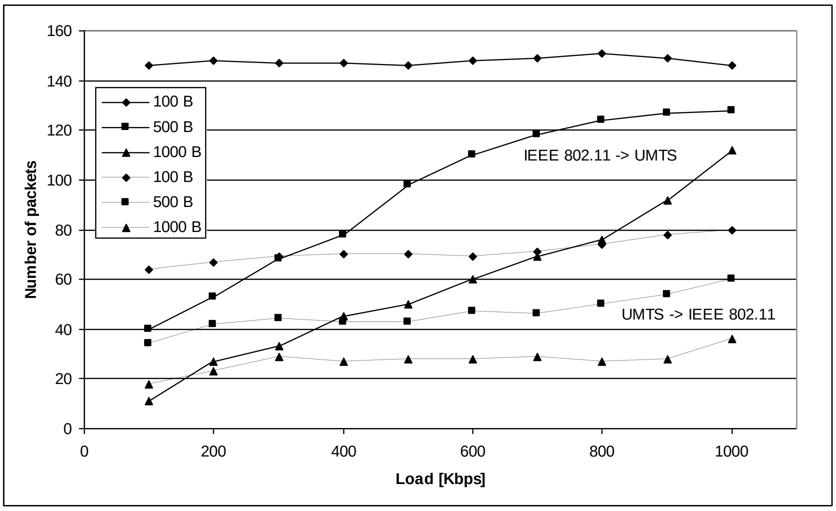

Fig. 3. Number of packets lost during handover in relation to packet size and traffic load

As observed in Fig. 2 there is no strong relation between the number of packets lost and the station speed. When the station is moving faster the number of lost packets is higher. The reason for that is that handoff time is longer when the station moves faster (see Fig. 4).

Fig. 3 presents the influence of packet size on the number of packets lost during handover. Because the interface transmission queues store the fixed number of packets (64) the amount of lost 100-byte-long data is higher than 1000-byte-long packets for the same traffic load. The second observation is that when station is moving from IEEE 802.11 to UMTS network the number of long packets (500-byte and 1000-byte-long) lost during handover increases dynamically when load is higher. The number of small packets lost is nearly constant in function of traffic load. The reason for that observation is that when 100-byte-long packets are transmitted the transmission buffers are always instantly overfilled during handover, even if traffic load is small. The video server sends 125 short frames per second to obtain load 100 Kbps. The handover in simulated scenario takes at least 800 ms (see Fig. 4) and transmission queue size is 64. For this reason some packets are always dropped on the queue. When longer data packets are transmitted the transmission queues are not always filled completely so the total number of lost packets is smaller.

Fig. 4 presents measured switching time i.e. interval when packets cannot be delivered to the mobile station because of handover procedure observed at application layer. When the station is moving from IEEE 802.11 network to UMTS network the switching time grows as the traffic load increases. This is caused by lower data rate of the UMTS network, as explained before.

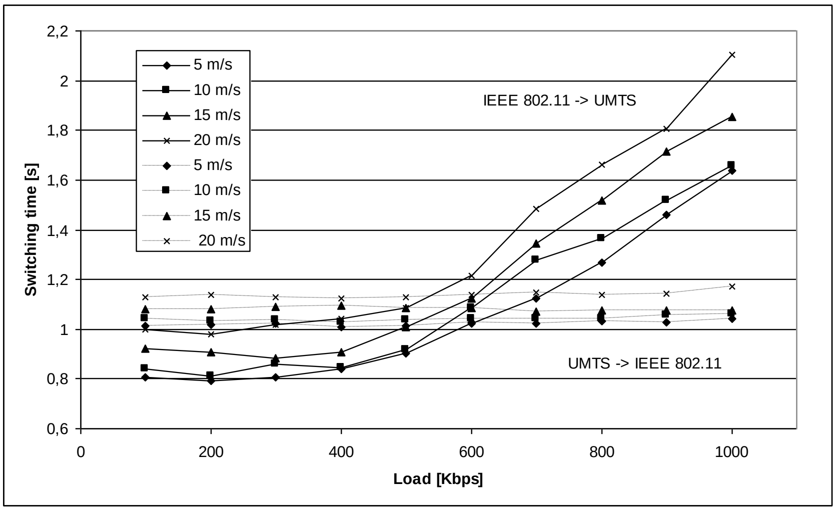

Fig. 4. Switching time in relation to station speed and traffic load

Conclusions

The article presents example results of simulation experiments carried out for IEEE 802.21 controlled handover. The measured switching time and packet lost is acceptable for "best-effort" services (e.g. www) but will significantly influence the performance of multimedia application.

A suggested improvement is to simultaneously register with the new network before the connection with the old network becomes unavailable (which is referred as soft handover). For example during a handover from WLAN to UMTS, the mobile station can be authenticated and authorized in the UMTS network and a dedicated channel (DCH) can be allocated while data transfer is performed by the 802.11b interface. During a handover from UMTS to WLAN, the terminal is first registered, authenticated and authorized by the AP in the WLAN while the data is still transferred using UMTS. After successful registration, the handover (when assumed profitable) takes place and UMTS channels are released. However, for such a scenario the reliable trigger "Link going down" must be provided in both networks. The design of that trigger is not obvious because of not stationary nature of wireless channel.

In future implementation the handover decision algorithm can take into account network data rate or similar dynamic parameter that describes network load. For example the station can proactively switch to faster network when entering its range. Moreover, different applications can use different interfaces to access the service. For example wireless device user can watch movie through WLAN and have a voice call via UMTS at the same time. This usage scenario will introduce new requirements on handover algorithms.

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