Location History based Energy Efficient Vertical Handover Scheme

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Abstract:

Nowadays, there is a growing demand for accessing information anywhere and anytime due to the proliferation of mobile devices. According to the availability of different overlapping wireless technologies such as 3G and WLAN, handover between these wireless technologies is also available. Energy efficiency in handover process is an important aspect due to the battery problems of mobile devices. In this paper, we propose a smart and energy efficient vertical handover method based on user location pattern. The proposed method uses Media Independent Handover (MIH) for triggering information and Stream Control Transmission Protocol (SCTP) for mobility management.

Key words: Media independent handover, energy efficiency, vertical handover, user pattern, location

1. Introduction

In the last several years, demand for access to information anywhere and anytime has been growing with the proliferation of mobile devices and availability of different wireless technologies. Therefore, while a mobile user is on the move, connecting to different networks is possible in different environments such as indoor and outdoor with different kind of wireless network technologies such as 3G and wireless local area network (WLAN).

In general, handover is a technique that sustains communication by transferring session from one network to another. Mobile user is detached from one wireless network or access point (AP) and attached to another one without connection loss. There are two types of handover technique, horizontal and vertical handover. In the former method, mobile device alters its communication within homogeneous wireless network technology such as from a GSM base station (BS) to GSM BS. In the latter one, vertical handover technique (VHO) allows mobile user to stay connected to the Internet by switching to a different wireless network such as from Wi-Fi to 3G when it is necessary. Overlap of these wireless technologies necessitates handover to provide session continuity and better quality of service (QoS) depends on both user demands and application requirements. Thus, VHO between different wireless networks may be advantageous depending on the circumstances. It is also possible to make VHO between more than two different wireless technologies, if they are supported by the mobile device [8].

Vertical handover process has three main parts. In the first part, information collection process is handled for providing information to the next step. In the second step which is decision making, candidate wireless networks are evaluated according to selected metrics in order to choose the best one among them. These decision algorithms must be fast and energy efficient. Finally,

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seamless handover needs to be executed for sustaining communication between communicating nodes. This can be in layer 2 [12], layer 3 [13] or layer 4 [14].

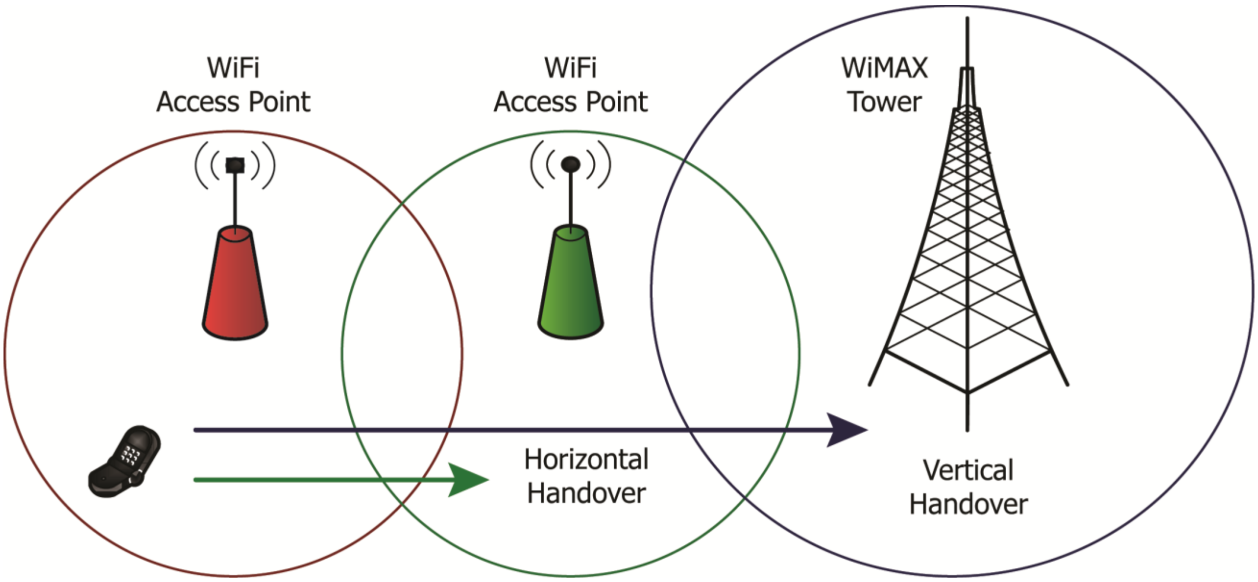

Figure 1. Illustration of handover types

Nowadays, one of the major issues of mobile devices is battery lifetime. It is possible to replace batteries with extra backup battery. Although it seems to be a good feature, it may be costly and impractical in daily life. Therefore, methods that consume less energy and take power consumption into consideration while making handover must be investigated. In our daily lives, most of the time, we follow a pattern. Every person has a location change pattern. For example, adults use specific roads or visit specific locations, while they are going from home to work or vice versa. Even students have a pattern in weekdays as adults. That shows us that majority of the people has a location change pattern. Therefore, these patterns can be used for energy efficient handover where networks in specific locations are known.

In this paper, a history based handover approach is adopted. In the proposed method, candidate network selection decision is made by considering user's early location change patterns and reputation values of APs in location where user stands. MIH framework is used to get information for available candidate networks and link events. Moreover, SCTP [16] with Dynamic Address Reconfiguration (DAR) extension [17] (mSCTP) is used to provide mobility. The rest of the paper is organized as follows. In section II, we provide a brief overview about proposed energy efficient handover mechanisms. In section III, we give background information for better understanding of the proposed method. Section IV describes our history based handover mechanism and we conclude our work in section V.

2. Related Works

There are several energy efficient handover mechanisms proposed in the literature. Recently, [3] proposes two advanced energy efficient decision making algorithms. Both of the algorithms use RSS, throughput, CPU load and calculated power consumption in candidate networks. Excepted power consumption is calculated for all available networks such as WLAN and Universal Mobile Telecommunication System (UMTS) considering all running TCP or UDP applications in mobile device. The first proposed algorithm is fuzzy logic based decision making algorithm. It evaluates all networks by described energy function. The second algorithm periodically monitors received signal strength (RSS) of all available networks and then calculates excepted energy consumption in candidate networks. Authors in [7] propose an optimized handover decision between WLAN and Worldwide Interoperability for Microwave Access (WiMAX) technologies. In this work, two energy models are generated for each wireless technology. The proposed algorithm decides when to perform VHO and do network scanning by taking channel coherence time which is time duration that the communication channel is expected to last into account. In Ref [5], a mobile terminal based handover framework is proposed. Mobile device collects parameters and evaluates each available network including power consumption per interface. The number of parameters can be dynamically change by intelligent handover manager. Therefore, context can be adjusted dynamically based on needs. Study [6] mentions to NIC (Network Interface Card) management for energy efficiency. NICs belong to WLAN and 3G consume different power in different modes such as transmit, receive and idle. NICs are not turned on for network discovery. In order to do that, network informs mobile device for available networks. In this work, applications are classified in two categories, best-effort and real-time. Fuzzy logic based method is applied to find out values of each AP based on these categories. In [9], IEEE802.21 Media Independent Handover Services standard is modified for prolonging battery lifetime by providing interface management as in previous study. This model also considers sleep mode of interfaces for consuming much less power. Authors in [8] investigate cost function based network selection while taking minimal user involvement into account. Minimal user involvement is provided by Media Independent Information Services in 802.21 standard. This service provides different available network information near the mobile user without network scanning with query/response mechanisms. Furthermore, smart triggering system is developed for when to make handover. Finally, in [1], each mobile user rates its connected AP. These rates are then collected, aggregated and assigned to each APs by an overlay manager. Therefore all APs are rated based on mobile satisfaction values of mobile users. When a mobile user wants to make handover, overlay manager offers the best reputated network that mobile user covers.

3. Mobile Handover Basics

3.1. IEEE 802.21 Media Independent Handover Services

The standard defines exchange of information, events and commands but not actual execution method due to the support of mobility management in different layers. The word “media” indicates communication type such as cable or radio. There are several abstract elements in this standard such as MIH function (MIHF), service access points (SAPs) and MIH users (MIHU).

MIHF resides in layer 2.5 and contains 3 entities. The media independent event service (MIES) detects changes in the link layer and reports events occurred in the lower layers such as physical layer and link layer. MIHF informs MIHUs about changes. The media independent command service (MICS) is used to control lower layer by upper layers in the protocol stack or a remote entity such as MIHF of network controller. The media independent information service (MIIS) acquires information related to neighbor networks in the surrounding area. The information such as location and properties of candidate networks can be used by local or remote entity as in the MICS. Information is formed by Information Elements (IEs) and query/response mechanism is used for communication. SAPs, which define both media dependent and independent interfaces, are used to provide MIHF services to MIHUs. There are three types of SAPs. MIH_SAP stays between MIHF and MIHUs. Communication between these entities is provided by MIH_SAP. MIH_LINK_SAP stays between lower layers and MIHF. MIH_LINK_SAP interfaces are dependent to specific wireless access technologies such as 802.11x, 802.16 and 3GPP. Finally, MIH_NET_SAP is used to provide information exchange between remote MIHFs.

3.2. Stream Control Transmission Protocol

Stream Control Transmission Protocol is a connection oriented transport layer protocol. It has been developed by IETF SIGTRAN working group [18] to provide requirements of telephony call control signaling called Signaling System 7 in RFC 2960 [19]. The original protocol is, then, standardized for serving as general transport layer protocol in RFC 4960 [16] with several extensions such as in RFC [17]. SCTP resembles to the two well-known transport layer protocols TCP and UDP in many ways but has some additional features. The features similar to TCP are that SCTP is a reliable connection-oriented transport layer protocol. It has window based congestion control and flow control mechanisms. SCTP offers selective acknowledgement mechanism and provides non-duplicated packet transfers. Although TCP does three-way handshaking, SCTP does four-way handshaking to prevent DOS attacks. SCTP divides application messages into meaningful frames so called chunks so as to preserve message-framing boundaries. In addition to this, it delivers messages in order as in TCP, unordered as in UDP and partially ordered mode which is provided in multistreaming mode. Multistreaming is a method of transmission where messages are exchanged in more than two logically independent streams. Therefore, partial ordering is only available within streams but not in between. Moreover, SCTP supports multihoming so as to improve path availability and reliability. For each NIC, an IP address is held in both sides if available and these lists of IP addresses are exchanged among peers while connection is setting up. Only one IP address called primary path is used for communication. Other paths are reserved for backup or being alternative. When the primary path fails, SCTP automatically switches to an alternative path and traffic is rerouted. Backup paths are checked for availability in a specific period of time with HEARTBEAT messages. If peer node sends HEARTBEAT ACK back, that path remains. After pre-determined unacked HEARTBEAT messages, node removes the backup path. Although primary path can change, port number does not change during the communication. The basic SCTP does not allow an end point to alter its IP addresses list during the life time of communication. DAR [17] extension has been introduced to overcome this limitation. Therefore it is allowed to add or remove IP addresses for both sides during the communication and which allows any end point to make handover both horizontally and vertically.

4. History Based Media Independent Handover Mechanism

The proposed reputation scheme allows mobile user to make seamless handover, both horizontal and vertical, by considering previous experiences. These experiences come from previous visits of the same geographical location where each access network has a rank value. In each visit, connected network is evaluated and its rank value is updated. The scheme is implemented in mobile terminal. Therefore neither early system training because of history based approach nor distributed network manager is necessary. System gradually converges to better power consumption value and better average network information over time due to reducing network scanning and advanced NIC management. The scheme consists of two modules and a system manager. MIH Module (MIHM) and Network Evaluation Module (NEM) are helper modules. VHO Manager (HOM) which controls the overall handover process resides at top of the scheme.

4.1. Media Independent Handover Module

Media Independent Handover Module realizes MIH with some additional features. This module provides information for available networks. The required information for NEM to evaluate access networks is provided by MIHM. It collects predefined parameters such as bandwidth (BW), RSS, data sending rate (DSR) and delay (D). Finally MIHM sends them to NEM to find out the best suitable network for required conditions. Additionally, this module notifies HOM for link events such as MIH link detected or MIH link handover complete events. Therefore, necessary actions are carried out by HOM in order to sustain communication. To provide seamless handover, mSCTP is used within MIHM. After determination of new network, HOM informs MIHM for link change by sending MIH handover commit event. Therefore, mSCTP alters primary path of the association to the path of new network. Old association remains for a specific period of time for precautionary action in order to reduce extra computation if mobile device needs to connect previous network.

4.2. Network Evaluation Module

Network Evaluation Module gets a list of available access networks within coverage of mobile user using query/response mechanism of MIIS. Later, it evaluates and grades each of these networks and returns back the list to HOM by using an Analytical Hierarchical Process (AHP) based algorithm.

Each single network is evaluated by considering its RSS, BW, D and expected power consumption (PC) values. Each of which has different weights based on access network and applications in device. Each weight of parameters for each category is listed in Table 2. To find out expected power consumption average number of bytes in the queue P is divided to sending bit rate of candidate network N_i. Consequently, it is multiplied by unit power consumption value UP_x of network technology type. The expected power consumption simply calculated as follows:

$$PC_i = (P / N_i) . UP_x \tag{1}$$

Table 1. Power consumption values in transmit, receive and idle modes for 3G and WLAN NICs.

Modem	Transmit	Receive	Idle
3G - CDMA 1x Wireless Modem	2.8 W	495 mW	82 mW
WLAN - Orinocco IEEE 802.11 B	1.3 W	900 mW	740 mW

Table 1 shows the power required to send and receive data [6]. Primarily, applications are classified in two categories, real-time and best-effort. Therefore, the required network quality is decided by classifying running application in mobile device. Required quality and quality of each available candidate network are found by the following two formulas 2 and 3. The former equation calculates required network quality and the latter one is used for evaluating networks:

$$Q_{reqired} = W_{RSS}.N_{required} + W_{BW}.N_{required} + W_{D}.N_{required} + W_{PC}.N_{required} \quad (2)$$

$$Q_{i} = W_{RSS}.N_{i} + W_{BW}.N_{i} + W_{D}.N_{i} + W_{PC}.N_{i} \quad (3)$$

Table 2: This table indicates weights for each parameter per application category.

Application Type	RSS	BW	D	PC
Real-time	0.34	0.17	0.42	0.07
Best-effort	0.36	0.36	0.13	0.15

Each time a mobile node needs to make handover, first it calculates required quality for sustaining communication smoothly. Afterwards, each quality of network n_i is computed. Finally, networks which are equal or greater than required quality is stored from the highest to the lowest and sent back to HOM for continuing handover process.

4.3. Handover Manager

Handover Manager is responsible from handover initiation, network scanning, querying and updating Network History Table (NHT). NHT is a structure in which some specific information about each of previously connected access network is stored. NHT stores an access network's ID, geographical location information, average network grade, rank value, its technology such as 3G and WLAN. Access network ID is required to identify each visited network. Geographical location information provides fast querying to gather candidate networks within the next location. It also reduces overall power consumption gradually because visited APs belong to that location is checked before scanning all available networks that mobile user covers. After a period of time, with each visit, an access network will dominate other access networks where its rank value is the highest for that location. Rank value indicates the precedence of a network among others. This value is calculated as follows:

$$RV(t)_{AP[i]} = \begin{cases} rv_{AP\,[i]}, & t = 1 \\ \left(\propto * RV(t)_{AP[i]}\right) + \left((1-\propto) * rv(t)_{AP[i]}\right), & t > 1 \end{cases} \quad (4)$$

$$rv_{AP\,[i]} = \begin{cases} +1, & Q_i \geq Q_{req} \text{ and connects } (positive) \\ -1, & Q_i < Q_{req} \quad (negative) \end{cases} \quad (5)$$

In this formula, $RV_{AP[i]}$ is a rank value in NHT and $rv_{AP[i]}$ is +1 or -1 according to the equation 5. The value $rv_{AP[i]}$ is determined by checking whether network value taken from NEM for candidate AP is equal or greater than currently connected AP. Temporary rank value $rv_{AP[i]}$ is +1 when mobile user checks for its requirements and connects to that AP. The value is -1 when checking fails. If access network is not checked, rank value in NHT table does not change. There is a little chance that rank values of two APs for specific location can be the same. Therefore, their average network grade is compared and AP with the highest average grade is chosen. To improve power saving, network technology information is stored in NHT. First of all, the same access networks are queried in order not to turn on other NICs. If access networks with the same technology do not satisfy required conditions, in other words if values of candidate networks calculated by NEM is less than currently connected network, alternative NIC is turned on and NHT table is queried again. If both fail, then network scanning to find out an access network which is not visited and satisfies requirements is made.

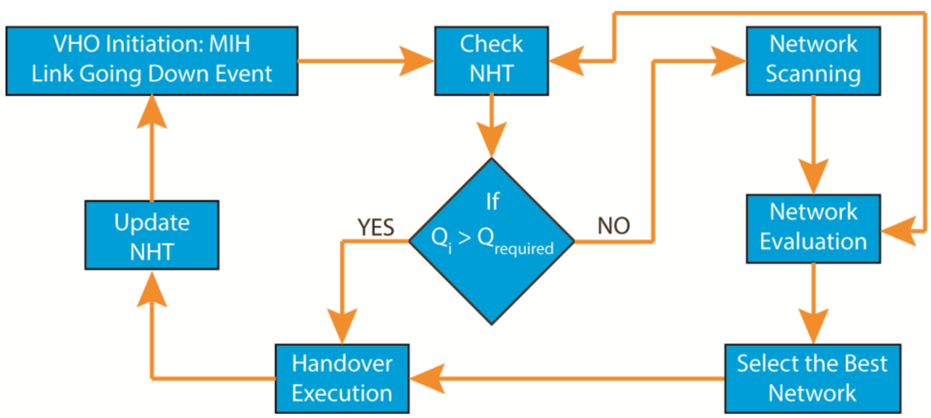

Figure 1. Illustration of handover types

Handover is initiated when MIH link going down event is received from MIHM. Subsequently, NHT is checked given by mobile user location. If there are available networks previously connected, then no network scanning is necessary. Therefore, networks in the NHT are evaluated in case of network condition changes. For example a network with high reputation value may be not ideal when a temporary event such as festivals occurs because of network load. Afterwards, if an access network in table satisfies required conditions, handover is executed by changing primary address of mSCTP connection to new network IP. This provides a seamless connection. Meanwhile, if there is no network for that location visited before or networks in table do not satisfy given requirements, then network scanning is required to find out a new network for sustaining communication. When a suitable connection is found and handover is executed, reputation process steps in. The new network is stored in the NHT for later probable connections. Overall handover algorithm is depicted in Figure 2.

Conclusions

Energy efficient network selection is relatively a major issue for mobile devices. Most of the existing approaches require modification both in network and user side. Additionally, there are only few studies that use the developing standard IEEE802.21. To address these issues, we proposed user location history based energy efficient handover mechanism. The proposed method considers both power consumption in candidate network and NIC management for efficient power usage. Expected power consumption is calculated by considering queued packets in target network. NICs stay turned off unless it is not necessary and only activated when scanning is the only option. In our schema, IEEE 802.21 provides required information and link event notifications. Seamless handover is handled by mSCTP. In this work, studies will be made only for WLAN and 3G networks. For the future work, the study will be extended for other wireless networks such as WiMAX. Meanwhile, expected energy consumption can be developed for better prediction and speed of mobile user must be considered.

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