An Approach to Structure the Handover Terminology

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Abstract—To meet the future demands on services and applications in wireless networks, a more advanced mobile terminal is needed. This terminal should be able to go between the different wireless cellular systems to get the best connection possible. When a handover between different wireless cellular systems is made, several types of decisions have to be done. In this paper the different terminology parameters that are needed to make the correct decisions are presented and the necessity of them are explained.

I. INTRODUCTION

The increasing number of mobile phones, laptops and personal digital assistants, set new demands on the future mobile systems. These mobile systems, beyond the third generation (3G), will be a combination of different wireless cellular systems.

To meet the demands of the new mobile systems, on capacity and coverage, a more advanced mobile terminal (MT) will have to be used. This MT will need to have the possibility to seamlessly go between different kind of technologies and systems. With the multifunctional MT it will be possible to hand over an ongoing connection from one type of cellular system to another. When handovers like this occurs different decisions need to be made. The handover parameters that these decisions are based on are discussed in the following section.

II. HANDOVER

Handover is the process in which the radio access network changes the radio transmitters or radio access media or radio system used to provide the bearer services, while maintaining a defined bearer service QoS [1]. When the handover is about to occur, different kinds of decisions have to be made. In Figure 1, the parameters are presented that are used to make the decisions. Most of these decisions have to be made during the handover process, but not all of the different combinations are possible to make. For examples can a MT that is connected to an operator that only can provide the GSM-technology, not make an intra-operator handover, when it change technology to a WLAN. The clouds in the figure, illustrate decisions that need to be made or at least be aware of, during a handover. The decisions in the figure are not given in a specific order, i.e., they can be in other arrangements, depending on the type of situation and systems involved.

The terminology used in the different clouds in Figure 1, can be related to the terminology described in [2], but the number of terminology parameters have been almost doubled.

The choice of parameter names could be argued, but the names in Figure 1, are the once we have decided to put forward.

A handover operation that can minimize or even eliminate the delay for establishing the new connection to the new base station (BS) or access point (AP), is called a fast handover. If the handover operation minimizes the data loss during the establishment of the new connection it is called a smooth handover. A handover that is both fast and smooth is called a seamless handover [3]. This is the key issue for the handovers between different technologies, to be seamless handover, i.e., the handover occurs without the user of the MT noticing it or have to make any arrangements for it.

Different systems have different terminologies for more or less the same function. For example, what we in this text refer to as a router, could in other a GSM-system be denoted a BSC. Below, we more thoroughly describe the parameters that are the decisions are based on.

A. Initiation

The handover can be initiated either by the network or the MT, depending on the circumstances. A handover can occur, due to limitations in the system/technology in use (QoS, capacity, frequency, coverage, etc.), to get a better connection, or due to the congestion in the cell in use, to make room for another MT. The handover can occur within the same system or technology, or can occur between different type of systems and technologies.
Network Initiated
A handover that is initiated by the network, can typically occur when congestion occurs in one cell. Then the network decides that one or several MTs need to leave that specific cell. The MT that needs to leave the cell is either handed over to another cell within the same technology, or handed over to another technology, depending on the MTs features. This is called load balancing, and is a common procedure to make room for another connection in the original cell [4].

Mobile Initiated
A MT can initiate a handover when it detects that the signal from the current sender gets to weak, i.e., when the C/I becomes to low. The MT can also be forced by the user to leave the technology in use, for example can the user by changing a parameter set make the MT use another technology.

B. Control
Network controlled handover and mobile controlled handover are the two basic types of handover protocols that are used to control the handover. These two protocols are often combined with the mobile assisted or network assisted feature, described below. If the decision process becomes more decentralized, i.e., goes from network controlled to mobile controlled, the time for the entire handover process decreases.

Network Controlled
In a network controlled handover protocol, the network makes the handover decision. If the handover is made with measurements that are assisted by the network, the decision of making the change could be based on measurements of the received signal strength of the MT at a number of BSs. This type of handover is not very useful when there is high congestion and rapid changes in the environment, due to the delay. The time it takes for the handover process is in general 100-200 ms that causes a click in a speech conversation that is noticeable, when the handover is made during a reasonable signal quality [5]. Since, the information about the signal quality is located at a single point, the time to complete the whole handover procedure might take up to seconds in time. This type of handover protocol was/is used in the first-generation analog systems. e.g., AMPS and NMT.

Mobile Controlled
In the handover protocol that is called mobile controlled, the MT is in control of the handover decision. The mobile can rely on measurements that come from either the network or the mobile itself.

C. Measurement
The decision-making process is becoming more and more decentralized. Not only the time decreases, also the measurement information that is used to make the handover decision decreases [5]. In [6], a comparison between the mobile controlled handover protocol and the network controlled handover protocol is made, when a mobile assisted handover occurs. The mobile controlled handovers, and mobile assisted, are found to have disadvantages when it comes to the inter-domain handover. On the other hand, for the MT to choose the optimal network, it needs to get capacity information from the networks that the operators normally do not disclose.

Network Assisted
The network is making the necessary measurements that the handover is based on. An advantage of the network assisted handover is that the network has knowledge of the network capabilities that the mobile is unaware of. A disadvantage is that it in most cases takes longer time than the mobile assisted.

Mobile Assisted
For the mobile assisted handovers the MT makes the measurements and, if it is network controlled, sends it to the network, where the decision whether to make the handover or not is made. This makes the handover process more distributed than the network assisted handover protocol.

Unassisted Handover
Sometimes the handover can be called unassisted. This happens when the same entity both controls and makes the necessary measurements, e.g., mobile controlled and mobile assisted handover.

D. Direction
When discussing the direction of a handover, we mean the direction in a hierarchical wireless system [7]–[9], i.e., if the user is connected to a base station at the same level, or not, after the handover is performed.

Vertical Handover
A vertical handover occurs when the MT changes between APs of different types [2]. A vertical handover occurs when the MT change from one level in the hierarchical structure to another. The levels in the hierarchical structure, can be of either the same or different technologies. It can also occur when the MT changes radio resources, e.g., from UTRAN-TDD to UTRAN-FDD [10]. Depending on which way the vertical handover is moving, it can also be classified into upward and downward [11]. It is called upward vertical handover if the MT is handed over from an underlay network to an overlay network, and, hence, downward in the other direction.

Horizontal Handover
A handover between BSs/APs of the same type (in terms of coverage, data rate and mobility) is called a horizontal handover, e.g., UMTS to UMTS [2]. In most cases the horizontal handover is an intra-technology handover, see Section II-H.

However, the definition of vertical and horizontal handover is rather vague, e.g., is a handover from an AP with IEEE 802.11b to an AP with IEEE 802.11g, considered to be vertical or horizontal [2]?
E. Creation
Both the MT and the network can be responsible for the creation of the handover. The creation defines if it was the pre-handover base station or the post-handover base station that started the handover.

Push Handover
A handover that is created by the old base station, or that is created by the MT via the old base station is called a push handover.

Pull Handover
The handover is called a pull handover when the new base station, or the MT via the new base station, creates the handover.

F. Process
The process illustrates in which order the handover is made. If it first loses the connection to the old base station or if it keeps the connection until the new is established.

Hard Handover
In hard handover, the connection to the old BS is broken before the connection to the new BS is made. During hard handover the MT does not only change BS, it also changes transmission frequency. For a short moment, while changing BS, the MT is not connected to any traffic channel. During this process, this is the moment where it is most likely that the connection is being dropped.

Soft Handover
In soft handover, the MT is connected to the old BS, during the time it takes to set up the connection with the new BS, i.e., a MT is temporarily connected to both the old BS and the new BS. Soft handover is, e.g., used in Code Division Multiple Access (CDMA) to reduce the interference to other cells [12]. Soft handover is most often related to CDMA systems, but can also be used in Time Division Multiple Access (TDMA) systems.

The soft handover can last during the remaining of the call if the MT stays in the area covered by the two BSs. The soft handover provides an undetectable handover. However, it also covers the difficult areas between the BSs effectively [13], i.e., the periphery area in the middle of two BSs that is covered by both. For this area, the signals are rather weak, due to the large distance to both BSs.

Softer Handover
A soft handover between two sectors, covered by the same base station, is called a softer handover.

G. Origination
The handover can be considered to be proactive or reactive, depending on if the handover was expected or not.

Proactive Handover
In an expected (proactive) handover, parts of the signaling can be made in advance before the MT decides to choose a specific new BS. The planning of the handovers can in some cases easily be made, e.g., when the user is in a car driving along the freeway using his MT or for a person that is using the MT on a train.

Reactive Handover
When an unexpected (reactive) handover occurs, the necessary signaling between the old BS and the new BS, cannot be made in advance, since no knowledge of its occurrence was present.

H. Equipment
Here the MTs use of technology, and if it is changed, decides which type of handover that should occur. This type of handover could easily be mixed up with direction handover, in Section II-D. The differences are that a horizontal handover can be an inter-technology handover. This occurs if the MT can make a layer 2 handover between two different technologies without changing the network interface seen by the IP layer [14]. The vertical handover can be an intra-technology handover if the MT has several network interfaces of the same type [14]. This distinguish could be essential for the decision to make the handover or not.

Intra-Technology Handover
When the MT uses the same technology after the handover as before the handover, e.g., UMTS to UMTS.

Inter-Technology Handover
As the handover occurs for the MT, it is handed over from one type of technology to another, e.g., from UMTS to EDGE.

I. Frequency
Different type of systems and technologies use different carrying frequencies. To better utilize hierarchical cell structures with macro, micro and indoor cells, inter-frequency handover is needed. The micro cells will have different frequencies than the overlaying macro cell. A hot-spot cell could have more frequencies than the neighboring cells, to increase the capacity. Inter-system, Section II-K and inter-technology handover, will in most cases make the MT change frequency. A change of frequency can also occur when a handover occur within the same system, e.g., when a GSM phone change from the 900 MHz bands to the 1800 MHz band.

Intra-Frequency Handover
The intra-frequency handover is a handover where the MT does not change frequency band.

Inter-Frequency Handover
During the inter-frequency handover the MT changes the frequency of the ongoing connection. The inter-frequency handover has its origin in the fact that the MTs have to be able to measure the quality of another carrier frequency, while the current connection is maintained.
Two methods are considered for making measurements on other frequencies while still having the connection running on the current frequency, dual receiver and slotted mode [12]. In dual receiver, one receiver branch switch to another frequency to do measurements to see if the new frequency is more favorable than the current. The other receiver continues to receive at the present frequency. Dual receiver is considered attractive for mobiles with antenna diversity and the advantage of this approach is that the current frequency connection is not broken. The slotted mode approach uses idle periods to do inter-frequency measurements and is suitable for MTs without antenna diversity.

J. Operation

A few wireless technologies, like UMTS, could be operated in different modes, e.g., UTRA-FDD and UTRA-TDD. This type of handover shall not be mixed up with the direction handover in Section II-D. Since both the vertical and the horizontal handover can be both intra- and inter-technology [14], the intra- and inter-mode handovers can be both vertical and horizontal.

Intra-Mode Handover
This type of handover can occur when the MT is handed over from one cell to another, within the UTRA-FDD. The handover can be soft handover, softer handover or hard handover. The hard handover may take place as intra- or inter-frequency handover [15].

Inter-Mode Handover
When the MT is handed over from, e.g., UTRA FDD to UTRA TDD it is called an inter-mode handover.

K. System

Depending on the definitions of the levels in a hierarchical structure, system is not always the same as technology. That is why the difference between the two categories has been made. With system it is here denoted a group of systems, that are placed on the same level in a hierarchical structure. Within the hierarchical structure the first level could for example be a GPRS or EDGE system. The next level could be any third generation system, e.g., UMTS. A WLAN of any kind, e.g., from the IEEE 802.11 family or HiperLAN/2, could be the system on the third level.

Intra-System Handover
For the user that has his MT associated to a specific system, with an ongoing connection to that system, the system in use will be of the same type after the handover, e.g., from one 3G-system to another 3G-system. Observe that this type of handover in most cases probably will be an intra-technology handover, but not by default.

Inter-System Handover
The type of handover that happens when a MT is handed over from one type of system, e.g., from a 3G-system to a WLAN-system, is called an inter-system handover. This type of handover is always an inter-technology handover.

L. Cell

A cell can be of different sizes depending on, e.g., the environment, the technology and the intention with the cells coverage area. The cell handovers differ from the frequency handover in Section II-I. Since cells within CDMA-systems use the same frequencies in the cells, an inter-cell handover can occur together with an intra-frequency handover.

Intra-Cell Handover
The MT is handed over from one physical channel to another physical channel within the coverage of the same cell. It is also called an intra-cell handover when, e.g., a change of sector or time slot, occurs within the coverage of the same cell.

Inter-Cell Handover
The handover occurs between two different cells. These two cells does not necessary have to be within the same system or technology.

M. Domain

Within a domain different kinds of technologies can exist. The network within a domain can include both wireless and wired core-networks.

Intra-Domain Handover
In most cases, handovers within the domain, do not need to control the QoS and AAA (Authentication, Authorization, Accounting), because within the same domain the security is in most cases the same and the parameters known.

Inter-Domain Handover
A handover between different domains, makes it necessary to make a control of the QoS-class and the AAA of the new domain. Also a security association could be set up to ensure that the information between the domains safely can be exchanged. This means that the handover duration is longer compared with the intra-domain handover.

N. Network

Within the network only one type of system or technology can exist. It can not be set equal to the equipment-type of handover, Section II-H, or the system-type of handover, Section II-K, since the handover can occur between the same type of technology and system, but with different operators. This means that the MT change network, but not the technology or system that it is currently using.

Intra-Network Handover
An MT makes the handover within the same network.

Inter-Network Handover
The MT changes the AP that it is connected to, from one network to another.

O. Router

In this section the router handover is described. Here it is denoted a router, like a router in an IP-network, but it can
also mean a BSC in a GSM-system.

**Intra-Router Handover**
The APs that the MT switches between are connected to the same access-router.

**Inter-Router Handover**
The different APs that the MT is handed over between are not connected to the same router.

**P. Access Point**
Here is an AP used, like an AP in an IP-network. In a GSM-system it would be called a base station. In this section they are used for the same purpose. The AP covers a specific area with its antenna.

**Intra-AP Handover**
When a MT changes frequency within the coverage of one AP, this type of handover occurs.

**Inter-AP Handover**
A MT that changes the coverage from one AP to another, makes an inter-AP handover.

**Q. Operator**
Different kind of operators will give the users the opportunity to use different type of systems. An operator can provide users with just one type of system or technology, or several. This will affect both the utilization and the accessibility.

**Intra-Operator Handover**
The handover occurs between systems, technologies and networks of the same operator.

**Inter-Operator Handover**
An inter-operator handover occurs between systems, technologies or networks that are not provided by the same operator.

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**REFERENCES**


