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Survey Paper: Mobility Management in Heterogeneous Wireless Networks

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Abstract

Ever increasing user demands and development of modern communication technologies have led to the evolution of communication networks from 1st Generation (1G) network to 4G heterogeneous networks. Further, 4G with heterogeneous network environment will provide features such as, “Always Best Connected”, “Anytime Anywhere” and seamless communication. Due to diverse characteristics of heterogeneous networks such as bandwidth, latency, cost, coverage and Quality of Service (QoS) etc., there are several open and unsolved issues namely mobility management, network administration, security etc. Hence, Designing proficient mobility management to seamlessly integrate heterogeneous wireless networks with all-IP is the most challenging issue in 4G networks.
Mobile IPv6 (MIPv6) developed by Internet Engineering Task Force (IETF) has mobility management for the packet-switched devices of homogeneous wireless networks. Further, mobility management of homogeneous networks depends on network related parameter i.e., Received Signal Strength (RSS). However the mobility management of heterogeneous networks, not only depends on network related parameters, but also on terminal-velocity, battery power, location information, user-user profile & preferences and service-service capabilities & QoS etc. Designing mobility management with all-IP, while, considering issues such as context of networks, terminal, user and services is the main concern of industry and researchers in the current era.

Keywords: MIPv6; Heterogeneous Network;Media Independent Handover;Vertical handoff.

1. Introduction

User’s interest and demands for the better service and/or ease life is the driving force for the evolution of new technology and enhancement in the existing technology. Ever increasing demands of the users for the wireless access of the services like voice, data and video while roaming leads to the challenging issues like mobility management, QoS, increase in coverage area, reduced data transfer cost, etc. Mehmet S. Kuran et. al., [25] summarized currently exist different wireless access technologies- Wireless Local Area Network (WLAN), WiFi (Wireless Fidelity), Worldwide Interoperability for Microwave Access (WiMAX), cellular technology- Global

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System for Mobile Communications (GSM), Code Division Multiple Access (CDMA), General Packet Radio Service (GPRS), Universal Mobile Telecommunication System (UMTS), and other earlier generation networks- Public Switched Telephone Network (PSTN), Integrated Services Digital Network(ISDN) so on, provided different nature of services with the different coverage, data rates, cost etc., to the end users as shown in the Table 1.

Table 1. Wireless Access Technologies characteristics

Network	Coverage	Data Rates	Cost
Satellite	World	Max. 144 kbps	High
GSM/GPRS	≈ 35 km	9,6 kbps – 144	High
IEEE	≈ 30 km	Max. 70 Mbps	Medium
IEEE	≈ 20 km	1-9 Mbps	High
UMTS	20 km	Upto 2 Mbps	High
IEEE	50-300 m	54 Mbps	Low
IEEE	50-300 m	11 Mbps	Low
Bluetooth	10 m	Max. 700 kbps	Low

Since the evolution of 1st Generation (1G) networks to 3G networks provided the users with different wireless access technology in each generation with different bandwidth, latency, coverage and cost. Increase in the popularity of wireless LAN-802.11 because of higher data transfer with low cost compared to cellular technology-GSM, GPRS and UMTS, the development in the IP-based applications (non-real-time or real-time) to have access to IP services anywhere at anytime from any network and evolution of multiple interfaces mobile devices with the capability to access more than one wireless technology is the driving force for the Beyond 3G (B3G) i.e. 4G [5]. Integration of wireless technologies namely Bluetooth, WLAN, GSM, GPRS, UMTS and WIMAX called “heterogeneous network” with all-IP is the communication environment in 4G as shown in Fig. 1. 4G with heterogeneous all-IP networks will provide the features, “Always Best Connected (ABC)”, “Anytime Anywhere” and seamless communication. 4G will differ with their presuccessor 1G, 2G and 3G networks interns of larger coverage area, faster data transfer, low latency, low data transfer cost etc. The main crucial issue for the 4G heterogeneous all-IP networks, in congregate network is the seamless mobility i.e. a flawless and proficient handoff scheme that supports the roaming of mobile devices from one wireless system to another.

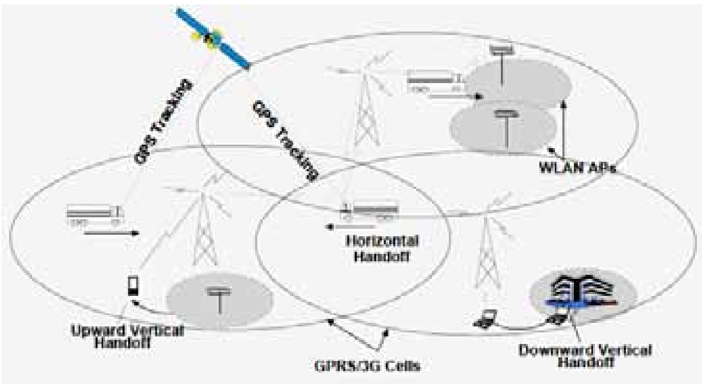

Fig. 1. Heterogeneous Network

In parallel to the evolution in cellular technology, in 1992 the Internet Engineering Task Force (IETF) working group added mobility at the network layer transparent to applications and higher level protocols like TCP resulting into Mobile IP, which is an add-on in IPv4. Mobile IPv4 (MIPv4) introduced the mobility concept at the network layer of TCP/IP by using two addressing concept for a mobile node (MN) i.e. Home Address (HoA) which is static, and is used to identify the home of a mobile node, and Care-of Address (CoA) which is the IP address to identify the MN current location in the foreign network. These two addresses are associated with Home Agent (HA) and Foreign Agent (FA) to assist the mobility management functionalities in MIPv4.

Higher handoff latency, packet loss and triangular routing were the main drawbacks of MIPv4, and hence it was not useful for real-time applications. To improve the drawbacks of MIPv4, IETF introduced mobility as an inbuilt feature in next generation Internet Protocol (IPv6) results into Mobile IPv6 (MIPv6) [1] as shown in Fig. 2 (a). MIPv6 eliminated the triangular routing problem and provided transparent packet's routing to and from MN while they are away from home network. Additionally, MIPv6 reduced the protocol complexity by removing the FA entity from the network architecture and relying on the mobile node itself to generate the CoA.

MIPv6 provides a lot of enhancements, but it still has some drawbacks in managing flawless and proficient handover of Mobile Nodes at the network layer, which affects the overall performance, causing packet loss, packet delay and signaling overhead. Variants of MIPv6 such as, Hierarchical MIPv6 (HMIPv6), Fast MIPv6 (FMIPv6) [2], Fast-HMIPv6 (FHMIPv6) [3], Proxy MIPv6 (PMIPv6) [4] have been attempted to solve the handover problem in Wireless LAN.

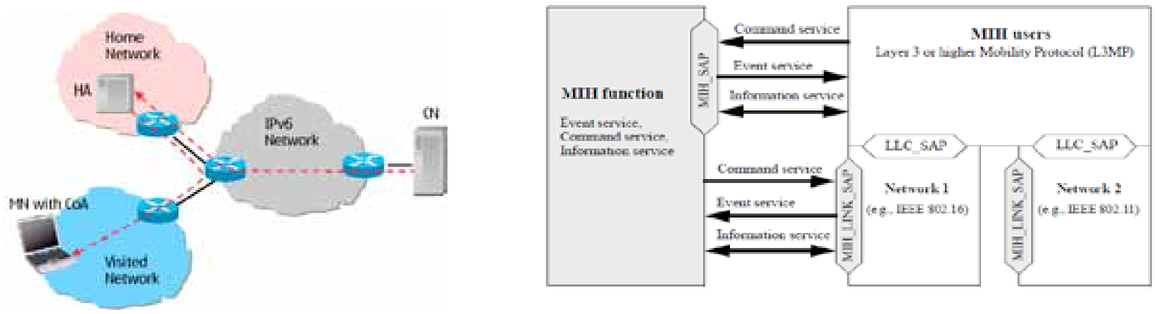

Fig. 2. (a) Mobile IPv6 Environment; (b) MIH services and their initiation [23]

MIPv6 developed for mobility management of homogeneous networks, which depend on network related parameter i.e., Received Signal Strength (RSS). However the mobility management of heterogeneous networks not only depends on RSS, but also on other parameters of network, terminal, user and services as shown below.

- **Network-related:** coverage, bandwidth, latency, CIR (Carrier-to-Interferences Ratio), SIR (Signal-to-Interferences Ratio), BER (Bit Error Rate), monetary cost, security level, etc.
- **Terminal-related:** velocity, battery power, location information, etc.
- **User-related:** user profile and preferences.
- **Service-related:** service capabilities, QoS, etc.

Designing mobility management for heterogeneous network with all-IP while, considering issues such as context of networks, terminal, user and services is the main concern of industry and researchers in the current era.

IETF with IEEE 802.21 Media Independent handover (MIH) [23] isolated the heterogeneous wireless access technologies from the network layer for the seamless mobility by providing the data related to the handover to IP layer. This is achieved in MIH by registering for the information required for the handoff in link layer as well as with other network elements as shown in Fig. 2 (b). MIH_LINK-SAP: MIH Service Access Point. LLC_SAP: Logical Link Control Service Access Point [23].

2. Background and Related Work

Features of the 4th Generation (4G) networks are to integrate wireless and cellular using all-IP, to provide "Always Best Connected", "Anywhere Anytime", seamless mobility.

MIPv6 and its variants like HMIPv6, FMIPv6, FHMIPv6 and PMIPv6 provides mobility to homogeneous network in Wireless LAN (WLAN) environment. In homogeneous networks handoff procedure is executed when MN moves away for the coverage area of the Access Point. Where as in 4G, handoff [9] procedure will be executed because of coverage area, better service availability, cost and so on. Because of the challenging features of the 4G [12] issues like, deciding the suitable handoff criterion, choosing the appropriate time to initiate the handover, selecting the most suitable access network for a specific service among those available and maintaining service continuity during the handoff are the challenging issues in heterogeneous networks [10, 13].

2.1 Mobility Management in Heterogeneous Networks

Handover in heterogeneous wireless network is referred to as vertical handoff which can be Mobile host controlled, network controlled, or mobile host assisted handover. Handoff decision algorithm is crucial part of the vertical handoff. Ian F et al., [26] current state of the art for mobility management in next generation all-IP-based wireless systems is presented. Jun-seok Hwang et al., [5] presented current trends and its underlying technologies to implement the 4G mobile technology and also showed some of the possible scenarios that will benefit the 4th generation technology. In [6] various vertical handover decision strategies have been proposed. Xiaohuan Yan et al., [7] presented a comprehensive survey of the VHD algorithms designed to satisfy the requirements required Quality of Service (QoS) to a wide range of applications while allowing seamless roaming among a multitude of access network technologies.

Ki-Sik Kong et al.,[8] starting by showing the validity of a network-based approach, presented qualitative and quantitative analyses of the representative host-based and network-based mobility management approaches (i.e., MIPv6 and PMIPv6), which highlight the main desirable features and key strengths of PMIPv6. Furthermore, a comprehensive comparison among the various existing well-known mobility support protocols is investigated. SuKyoung Lee et al., [9] developed a vertical handoff decision algorithm that enables a wireless access network to not only balance the overall load among all attachment points (e.g., Base Stations (BSs) and Access Points (APs)) but also to maximize the collective battery lifetime of Mobile Nodes (MNs). In addition, when ad hoc mode is applied to 3G or 4G wireless data networks, VANETs and IEEE 802.11 WLANs for more seamless integration of heterogeneous wireless networks, we devise a route selection algorithm to forward data packets to the most appropriate attachment point in order to maximize the collective battery lifetime as well as maintain load balancing.

Prakash S. et al., [10] presented a Handoff Management Unit (HMU) based on Mobile IPv6 (MIPv6). A. Dvir et al., [11] defined a system-wise decision function (DF) in which the system considers all the available network and user parameters (e.g., host velocity, battery status, Wi-Fi AP’s current load, and WiMAX BS QoS guaranties), and performs technology selection such that an overall system performance metric is optimized (i.e., throughput and capacity limitation), that is activated when a user is in an area with over-lapping access technologies and needs to decide what is the best technology to be used, where the entity performs technology selection in order to optimize the overall system performance metric in terms of throughput and capacity limitation.

Jiping L et al., [12] proposed a vertical handoff algorithm which enables a mobile node to intelligently select wireless access network among multiple access technologies, synthetically considering network characteristics and status, such as access bandwidth, response time, data loss, network congestion status, etc, along with access cost and received signal strength (RSS). Hanane Fathi et al., [13] to optimize the handover delay, proposed to use the adaptive retransmission timer. Young Hwan Kwon et al., [14] proposed an efficient handoff decision algorithm using differential Received Signal Strength Indicator (RSSI) in MPLS-based Mobile IP network. MPLS-based Mobile IP integrates Mobile IP and MPLS. The differential RSSI value is efficient to decide handoff because this value could represent the movement direction of MN. In their algorithm, a base station track the differential RSSI value of mobile node in overlapped region and release the reserved bandwidth of MN with the differential RSSI value. Fang Zhu et al., [15] proposed several optimizations for the execution of vertical handoff decision algorithms, with the goal of maximizing the quality of service experienced by each user. First, the concept of policy-based handoffs is discussed. Then, a multiservice vertical handoff decision algorithm (MUSE-VDA) and cost function are introduced to judge target networks based on a variety of user- and network-valued metrics.

In [16, 17] the target network is selected using a fuzzy logic-based normalized quantitative decision algorithm which, in addition to usual parameters such as the current received signal strength (RSS) and the available bandwidth, also takes a prediction of the RSS into account, resulting in a more accurate handoff. The RSS prediction is obtained using a differential prediction algorithm that has good accuracy. Furthermore, to reduce system load, a pre-decision method is employed before actual handoff decision to filter out users with high mobility or low RSS from using the Wireless Local Area Network.

Reza Farahbakhsh et al., [18] proposed a cross layer Fast handover solution able to optimize mobility management over mobile WiMAX networks in terms of handover delay and signaling load. Manzoor Ahmed Khan et al., [19] presented the user-centric network selection decision mechanism, where negotiation between users and network operators is carried out using game-theoretic approach.

Adiline Macriga et al., [20] presented heterogeneous handover fully controlled by the terminal, and network selection is user-centric, power-saving, cost aware, and performance-aware. Total mobility management, including interface management, handover decision, and execution, is also detailed. Abdul-Aziz et al., [21] quantified the vertical handoff delay from UMTS to WLAN based on Mobile IP under various configurations and enhancements, namely, the MIP with CoA, MIP with CCoA, MIP with route optimization, and MIP with IPv6 configurations. Hyo Soon Park et al., [22] presented a seamless vertical handoff procedure between IEEE 802.11 WLAN, which covers hotspot area such as offices, campuses and hotels, and the CDMA2000 cellular network that overlays the WLAN and also covers a larger area. A handoff algorithm between WLAN and CDMA2000 cellular network is proposed. In this algorithm, traffic is classified into real-time and non real-time services. Then, the beginning of handoff is decided by the handoff delay time and throughput according to the traffic classes

3. Seamless Mobility Management

Seamless mobility management is a set of activities that supports the movement of mobile nodes irrespective of the access technologies and transparent to applications and higher layer protocols like TCP. Handover management, one of the mobility management components, controls the change of the MN's point of attachment during active communication. Handover management issues include mobility scenarios, metrics, decision algorithms and procedures as shown in Fig. 3 (a).

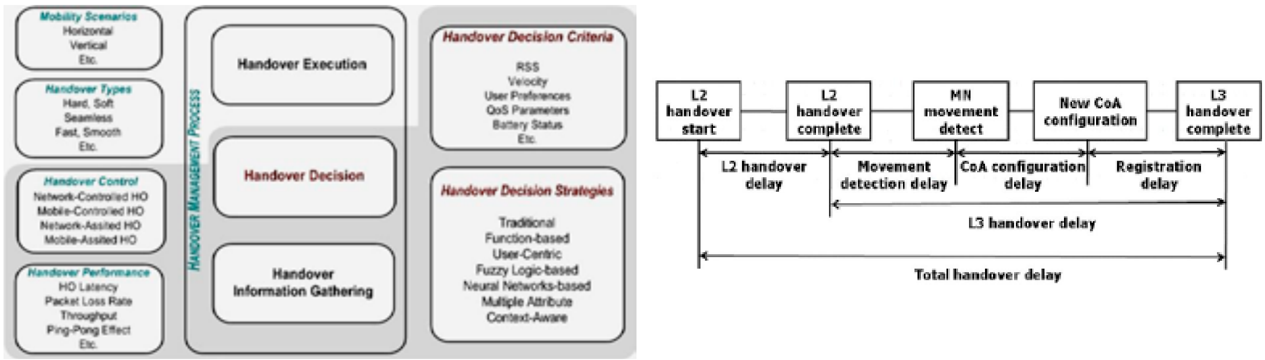

Fig. 3. (a) Handover management concept [6]; (b) Handover Delay

Seamless mobility in homogeneous network is achieved with the proper selection of handoff initiation time. Where as in, heterogeneous network, it not only depends on handoff initiation time, but also on selecting suitable candidate network and deciding the suitable criterion for the handoff.

MIPv6 mobility management for homogeneous network includes Layer-2 (L2) and Layer-3 (L3) handoff. L3 handoff which includes procedures namely movement detection, new CoA configuration, and Binding Update which are triggered by L2 as shown in Fig. 3 (b). Higher the time taken to finish these activities (more than 50 ms), is often unacceptable to real-time traffic such as voice and video.

Total Handover Delay = L2 Handover Delay + L3 Handover Delay

L3 Handover Delay = Movement Detection Delay + CoA Configuration + Delay + Binding Update Delay

The L2 handover delay in Mobile IPv6 is composed of the times for scanning and authentication of the Access Point (AP), re-association between mobile node and AP and sending the Medium Access Controller (MAC) address of the mobile node to the AP.

L3 handover begins with the L2 trigger, which includes detecting new Access Router (AR), generating new CoA, detecting CoA uniqueness in the network and updating its new CoA with the HA and Correspondent Node (CN) as a binding updates.

Seamless Handoff in homogeneous network is initiated because of the network related parameter – RSS. Comparison of RSS with threshold value is used by the device-mobile controlled handoff or network-network controlled handoff to initiate the handoff activity. Seamless handoff in heterogeneous network, not only depends on the RSS, but also on other parameters of network, as well as terminal, user and services to initiate the handoff, to select the suitable candidate network and to decide the handoff criterion [6, 28, 29].

Designing a mobility management for heterogeneous network which optimizes the handoff delay, packet loss, packet delay, handoff failure probability etc., is the challenging issue for the researchers.

4. Handoff Classifications

Handoff of a mobile node from one subnet/network to another, supported in different access technologies can be classified as shown in Fig. 4. Handoff classification depends on many factors like, network types involved, frequencies engaged, number of connections involved, administrative domains involved, necessity of handoff and user control allowed in the handover process.

4.1 Network Types Involved

Depending on whether a handoff takes place between a single type of network interface or a variety of different network interfaces type handoffs can be classified as either horizontal or vertical.

Horizontal handoff (HHO): It is the handoff process of a mobile terminal between access points supporting the same network technology. For example, the changeover of signal transmission (as the mobile terminal moves around) from an IEEE 802.11b base station to a geographically neighboring IEEE 802.11b base station is considered as a horizontal handoff process.

Vertical handoff (VHO): It is the handoff process of a mobile terminal among access points supporting different network technologies. For example, the changeover of signal transmission from an IEEE 802.11b base station to an overlaid cellular network is considered a vertical handoff process.

4.2 Frequencies Engaged

In cellular technology, handoff is the process of switching of signal from one frequency to another.

Intra-frequency handoff: It is the handoff process of a mobile terminal across access points operating on the same frequency. This type of handoff is present in code-division multiple access (CDMA) networks with frequency-division duplex (FDD).

Inter-frequency handoff: It is the handoff process of a mobile terminal across access points operating on different frequencies. This type of handoff is present in CDMA networks with time-division duplex (TDD) and is the only handoff type supported in GSM cellular systems.

4.3 Number of Connections Involved

Evolution in the mobile devices to support multiple interfaces, leads to handoff such as hard, soft, or softer depending on the number of connections maintained during the handoff.

Hard handoff (Break Before Make): In a hard handoff the existing connection with the current base station is released when the new connection is established with the new base station. In other words, using hard handoff, a mobile node is allowed to maintain a connection with only one base station at any given time.

Soft handoff (Make Before Break): Contrary to hard handoffs, in a soft handoff a mobile node maintains a radio connection with no less than two base stations in an overlapping handoff region and does not release any of the signals until it drops below a specified threshold value. Soft handoffs are possible in situations where the mobile node is moving between cells operating on the same frequency.

Softer handoff: A softer handoff is very similar to a soft handoff, except the mobile terminal switches connections over radio links that belong to the same access point.

4.4 Administrative Domains Involved

An administrative domain is a group of systems and networks operated by a single organization of administrative authority. Administrative domains play a significant role in 4G wireless networks as different networks which controlled by different administrative authorities, become available. Consequently, the classification of handoffs in terms of administrative domains is a crucial issue.

Intra-administrative handoff: a handoff process where the mobile terminal transfers between different networks (supporting the same or different types of network interfaces) managed by the same administrative domain.

Inter-administrative handoff: a handoff process where the mobile terminal transfers between different networks (supporting the same or different types of network interfaces) managed by different administrative domains.

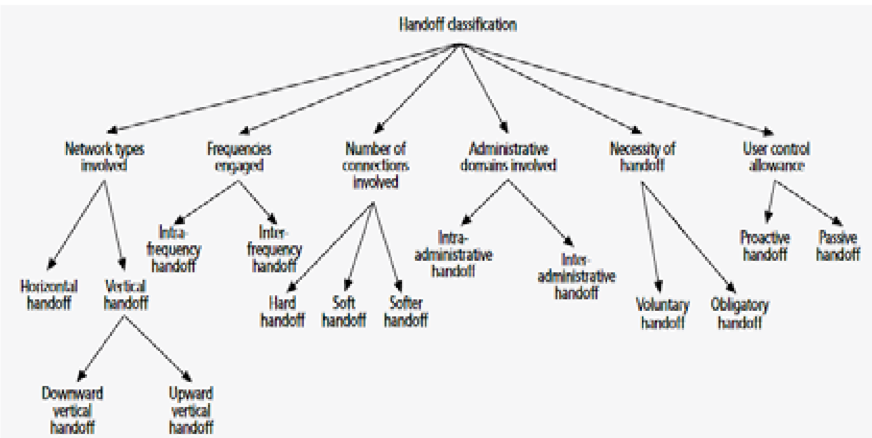

Fig. 4. Handoff Classifications [24]

4.5 Necessity of Handoff

Handoffs are initiated not only due to RSS, as in homogeneous networks but it also may be due to necessity of QoS requirements, cost, bandwidth and delay. Depending on the necessity, handoffs can be classified such as obligatory and voluntary.

Obligatory handoff: In some situations it is necessary for the mobile terminal to transfer the connection to another access point in order to avoid disconnection.

Voluntary handoff: In other situations transfer of connection is optional and may or may not improve the quality of service.

4.6 User Control Allowance

Depending on the users control in handoff, it can be classified as proactive or passive.

Proactive handoff: In a proactive handoff the mobile terminal's user is allowed to decide when to handoff. The handoff decision can be based on a set of preferences specified by the user. Proactive handoff is expected to be one of the radical features of 4G wireless systems.

Passive handoff: The user has no control over the handoff process. This type of handoff is the most common in first-, second-, and third-generation wireless systems. Handoff in heterogeneous network is called Vertical handoff because of roaming of mobile devices between different accesses technologies as shown in Fig. 1. Incase of multiple interface device, heterogeneous network support soft handoff.

5. Vertical Handover Decision Strategies

Depending on the different handoff decision criterions such as network related, terminal related, user related or service related, Meriem Kassar et al., [6], Xiaohuan Yan et al., [7] and Jun-Zhao Sun et al., [27] mentioned different handover decision strategies for vertical handoffs, like:

- **Decision-function based strategies:** calculate the weights of the accessible network based on certain policy.
- **User-centric Strategies:** Among the different criteria that a vertical handover decision takes into account, user preferences, in terms of cost and QoS, is the most interesting policy parameter for a user-centric strategy.
- **Multiple Attribute Decision strategies:** The handover decision problem deals with making selection among limited number of candidate networks from various service providers and technologies with respect to different criteria. This is a typical MADM (Multiple Attribute Decision Making) problem. In the study of decision making, terms such as multiple objective, multiple attribute and multiple criteria are often used interchangeably. Distinctions can be made between the different concepts: Multiple Criteria Decision Making (MCDM) is sometimes applied to decisions involving multiple objectives or multiple attributes, but generally when they both apply. Multiple Objective Decision Making (MODM) consists of a set of conflicting goals that cannot be achieved simultaneously. Multiple Attribute Decision Making (MADM) deals with the problem of choosing an alternative from a set of alternatives which are characterized in terms of their attributes.
- **Fuzzy logic and neural networks based strategies (FL/NN):** Fuzzy Logic (FL) and Neural Networks (NN) concepts are applied to choose when and over which network to hand over among different available access networks. These are combined with the multiple criteria or attribute concept in order to develop advanced decision algorithms for both non-real-time and real-time applications.
- **Context-aware strategies (CA):** The context-aware handover concept is based on the knowledge of the context information of the mobile terminal and the networks in order to take intelligent and better decisions. Thus, a context-aware decision strategy manages this information and evaluates context changes to get decisions on whether the handover is necessary and on the best target access network. The comparisons

between different handover decision strategies as shown in Table 2 [6, 30], demonstrate context-aware decision strategy is the most effective vertical handover decision strategy interms of efficiency, flexibility, implementation complexity.

6. Performance Measures of Handoff

Performance of handover management is measured by the parameters such as handover delay (latency), number of handovers, handover failure probability and throughput.

Handover delay: It refers to the duration between the initiation and completion of the handover process. Handover delay is related to the complexity of the handover management process, and reduction of the handover delay is especially important for delay-sensitive voice or multimedia sessions.

Number of handovers: Reducing the number of handovers is usually preferred as frequent handovers would cause wastage of network resources. A handover is considered to be superfluous when a handover back to the original point of attachment is needed within certain time duration and such handovers should be minimized (ping-pong).

Table 2. Comparison between VHO decision strategies [6]

Comparison between vertical handover decision strategies

Vertical handover decision strategy	Traditional (RSS-based)	DF	UC	MAD	FL/NN	CA
Multi-criteria	No	Yes	Yes	Yes	Yes (FL) No (NN)	Yes
User consideration	No	Low	High	Medium	Medium	High
Efficiency	Low	Medium	Medium	High	High	High
Flexibility	Low	High	High	High	Medium	High
Implementation complexity	Low	Low	Low	Medium	High	Medium
Service type supported	Non-real-time	Non-real-time and Real-time	Non-real-time	Non-real-time and real-time	Non-real-time and real-time	Non-real-time and real-time

DF, decision function; UC, user-centric; MAD, multiple attribute decision; FL/NN, Fuzzy Logic/Neural Networks, CA, context-aware.

Handover failure probability: A handover failure occurs when the handover is initiated but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage of the target network before the process is finalized. In the former case, the handover failure probability is related to the channel availability of the target network while in the latter case it is related to the mobility of the user.

Throughput: The throughput refers to the data rate delivered to the mobile terminals on the network. Handover to a network candidate with higher throughput is usually desirable.

The handoff performance metrics depends on the handoff decision parameters network related, terminal related, user related or service related [7] used to decide when and how to trigger the handoff.

7. Conclusions

Integration of heterogeneous networks with all-IP is the backbone of 4G to provide “Always Best Connected”, “Any Where Any Time”. Mobility management becomes the most challenging issue for the academia and industry because of heterogeneous characteristics of networks. Deciding the suitable time, suitable new point of attachment and suitable criterions to initiate the mobility management in heterogeneous networks is the challenge is 4G network. This survey papers focused the mobility management of heterogeneous networks with some of the challenging issues for the researchers.

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