VERTICAL HANDOFF DECISION ALGORITHMS FOR NEXT GENERATION WIRELESS NETWORKS: SOME ISSUES

Dr. Anita Seth*

Abstract: *In next generation wireless networks, the users may be connected to different radio access technologies like GSM, WiMax, WLAN, UMTS etc. In this heterogeneous environment, vertical handover process is involved that becomes complex as the users move between the different access networks. This makes the handoff mechanisms more challenging in heterogeneous environment as traditional mechanisms are not sufficient. Vertical handoff algorithms requires not only RSS measurement, but also additional parameters such as network conditions, interference power, monetary cost, QoS, terminal capabilities, user preferences and so on. As a result of which, the complexity of the vertical handover decision process is increased significantly. This paper presents an overview of handoff management process with a focus on vertical handover decision problem. In addition to this, open research issues in this area are also highlighted and an attempt is made to devise vertical handover (VHO) index that can be used to evaluate the VHO process. It would be quite helpful in making a comparison between the various VHO techniques proposed and do the evaluation of these techniques.*

Keywords: *Next generation wireless networks, vertical handover, decision process, vertical handover algorithms, vertical handover index.*

***Department of Electronics and Telecommunication, Institute of Engineering & Technology, Devi Ahilya University, Indore, India**

1. INTRODUCTION

Next-generation wireless networks relying on heterogeneous technologies allow the users to be connected to varied networks. Users may be connected to different radio access technologies like GSM, WiMax, WLAN, UMTS etc. as no single technology can fulfill users QoS requirements under all conditions. User mobility entails transferring an ongoing call or data session from one access point to another which is often termed as handoff is required. Traditional handoff process, which is called as horizontal handoff, takes place when a user moves between two adjacent cells supporting the same access technology in order to provide an uninterrupted service. However, in heterogeneous environment, vertical handover process is involved that becomes complex as the users move between the different access networks. In this scenario, supporting handoff process is a vital mechanism in order to provide ubiquitous wireless access and becomes necessary to integrate these different technologies.

Generally, horizontal handoff process is initialized when the link quality condition parameters such as received signal strength (RSS), signal-to-noise ratio (SNR), etc. drop below a specified threshold level. Compared to this, heterogeneous environment possess more challenges as traditional handoff mechanisms will not be sufficient. Vertical handoff algorithms requires not only RSS measurement, but also additional parameters such as network conditions, interference power, monetary cost, QoS, terminal capabilities, user preferences and so on. As a result of which, the complexity of the vertical handover decision process is increased significantly. The integration of heterogeneous wireless networks requires the design of vertical handoff decision algorithm to ensure seamless coverage and provide high quality of service for different applications.

This paper presents an overview of handoff management process with a focus on vertical handover decision problem. In addition to this, open research issues in this area are also highlighted and an attempt is made to devise VHO index that can be used to evaluate the VHO process. The rest of this paper is organized as follows. Sections 2 provide a general overview of handover process and vertical handover mechanism. Section 3 discusses open research issues for the development of efficient vertical handover systems. In Section 4, vertical handover (VHO) index for evaluating handover process is discussed. Finally, the main conclusions are presented in Section 5.

2. HANDOVER MANAGEMENT PROCESS IN HETEROGENEOUS WIRELESS NETWORKS

Handover, also know as Handoff takes place whenever a mobile node moves from one wireless cell to another, breaking the connection with the previous base station and getting attached to new base station. When a handover occurs within the domain of a single wireless access technology the process is known as horizontal handover. In contrast to this, vertical handover involves handover among heterogeneous wireless access network technologies such as between WLAN and UMTS; WiMax and UMTS etc (Nasser, 2007).

The handover procedure can be characterized in various types. Handover is termed as hard when the mobile station is connected to only one point of attachment at a time. It is also referred as break before make handover. On the other hand, it can be soft when MS is connected to more than one point of attachment for a while and it is referred as make before break handover. Handover process needs to be seamless in the sense that the transition to the new network point of attachment should be transparent to the user with no service degradation.

Handover decision mechanism can be located in a network entity or in the MT itself and handover decision depends on the measurement of some parameter involved (Zdarsky and Schmitt, 2004). So on the basis of this, there can be another type of the classification as:

- Network-Controlled Handover (NCHO), in which the network entity has the primary control over the handover.
- In Mobile-Controlled Handover (MCHO), MS take its own measurement and make the handover decision on its own.
- Mobile-Assisted Handover (MAHO), in this case the information and measurements from the MS are used by the network to decide when and where to handoff. It is used in GSM.
- Network-Assisted Handover (NAHO). Here the network collects information that can be used by the MS in a handover decision.

Handover process can be split into three phases (Stevens-Navarro, 2008) namely:

(i) Handover Information Gathering: In this phase, information required to identify the need for handover is collected. The information can be regarding network, network related properties, mobile devices, access points, and user preferences. The information is used and

processed for making decisions in the handover decision phase. For this reason, this phase is also called as handover information gathering (Kassar et al. 2007), system discovery (Singhrova and Prakash, 2007); system detection (Chen et al., 2004); handover initiation (Gupta 2006); network discovery (Siddiqui and Zeadally, 2006). The mobile device gathers the information from surrounding networks regarding services, data rates and power consumption etc. In addition to this, networks may also advertise their supported services and QoS parameters. Information concerning user preferences is also an important element to the decision-making process, because of its impact on the end user's satisfaction (Márquez-Barja et al. 2011). Information should be collected at each and every layer of the protocol stack (like applications, transport, network, data link and physical layer) in order to enhance the benefits of decision-making.

(ii)Handover Decision: this phase determines when and where to trigger handover by selecting the most suitable access network (based on some criteria such as user preferences) and giving instructions to the execution phase. It is also called as network or system selection (Kassar, et al., 2008; Goyal, and Saxena, 2008). When to trigger handover is an important issue and refers to the precise instant at which an optimal handover is made. While 'where' to handover involves selecting the best network fulfilling the requirements for switching. In a homogeneous network environment, decision regarding when to handover usually depends on received signal strength (RSS) values, while 'where' is not an issue as the same networking technology (horizontal handover) is being used. However, in heterogeneous network scenario, the process is quite complicated as it involves different radio access technologies. Thus, the criteria for vertical handoff have been updated. These can be grouped into following sub parts:

- Network-related: coverage, bandwidth, latency, link quality (RSS (Received Signal Strength), CIR (Carrier to-Interferences Ratio), SIR (Signal-to-Interferences Ratio), BER (Bit Error Rate), etc.), 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

These criteria can be static or dynamic depending on the frequency and causes of changes. Static criteria usually include user profile and the cost of the different access networks, whereas the mobile terminal velocity and RSS are dynamic criteria.

(iii) Handover Execution: Next phase of vertical handover involves handover execution in which handover procedure actually takes place. In this phase, change of channels in confirmation to the details resolved in decision phase takes place. After collecting the relevant information for handoff like RSS, etc., the execution phase trigger network binding update.

Overview of handover management process is depicted in Figure 1.

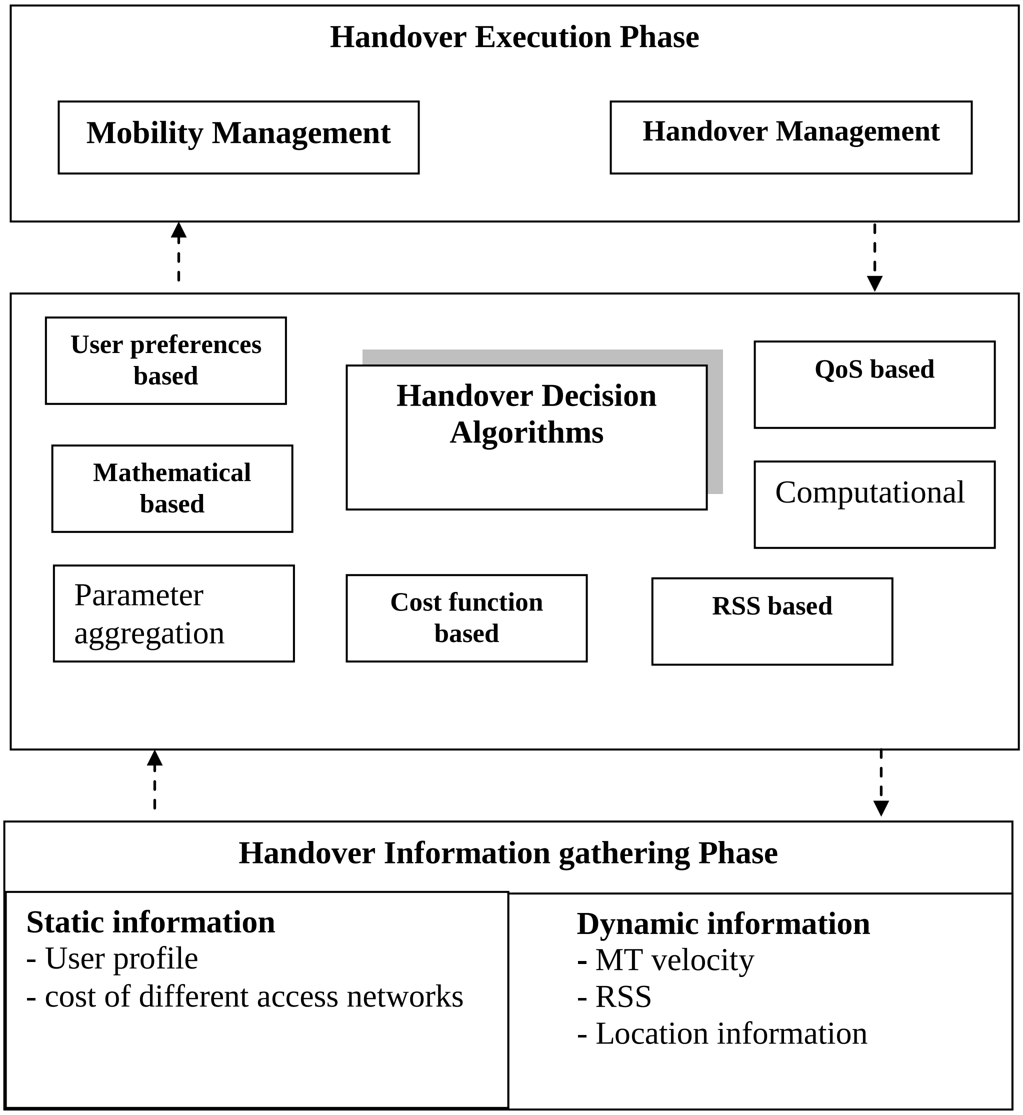

Fig. 1. Illustration of Handover management concept.

3. VERTICAL HANDOVER DECISION STRATEGIES

This section reviews various vertical handover decision strategies proposed in the literature. VHO algorithms have been designed in order to choose the best available network to connect to among the others. Based on the decision strategies and algorithms analyzed in the literature, vertical handover decision algorithms can be classified as per the taxonomy shown in Table 1.

Table 1: Summary of VHD algorithms

VHD Algorithm Category	**Author/year**	**Chief features of VHO algorithm**
User preferences based algorithms	Calvagna and Modica (2004)	Algorithm takes into account of user's preferences in terms of cost and QoS requirements and the model was tested for GPRS and WiFi networks.
	Ormond et al.(2006)	User-centric function is proposed that analyzes user satisfaction by using a utility function for non-real-time data services (FTP file transfer) for two WLAN networks.
Mathematical algorithms	Stevens et al. (2008)	Algorithm based on Markov decision process and used two types of functions: a link reward function is defined based on the applications' QoS requirements. The other is a signaling-cost function associated with the signaling overhead and latency when the vertical handover is performed. The performance of the algorithm is tested using voice and data traffic. The MDP model consists of five elements which include: decision epochs, states, actions, transition probabilities, and rewards. At each decision epoch, the MT has to decide whether to keep connected to its current network or to hand over to another one. The decision depends on the current status of the available access points which are maintained in the MDP states that carry information on network ID, bandwidth and delay in the co-located networks.
	Ying et al. (2008)	Proposed two Markov decision approaches based on rank aggregation. The top weighted network is selected on the basis of selection process that is similar to the multiple Criteria Decision Making (MCDM) technique for order preference.

VHD Algorithm Category	Author/year	Chief features of VHO algorithm
RSS based algorithms	Zahran and Liang (2006)	Algorithm is based on combining the RSS measurements and is proposed for handover between WLAN and 3G networks. MT continuously calculates the RSS average using the moving average method.
	Mohanty and Akyildiz (2006)	Vertical handover decision method based on comparison of the current RSS and a dynamic RSS threshold (S_{dth}) when a mobile terminal is connected to a WLAN access point. Algorithm is proposed for handover between WLAN and 3G network.
QoS based algorithms	Lee et al. (2005)	Residual bandwidth and user service requirements are taken into account in deciding whether to handover or not for WLAN and WWAN. When the MT is connected to a WLAN, the handover algorithm is initiated if the measured RSS is consistently below a threshold RSS_{T1}. Similarly, when the MT is connected to WWAN, handover process is carried out if consecutive beacons from the WLAN with RSS above a threshold RSS_{T2} are received.
	Yang et al. (2007)	VHD using Signal to Interference and Noise Ratio (SINR) for WLAN and WCDMA network. A handover is done to the network with larger value of SINR. The SINR calculation of the WLAN signals is converted to an equivalent SINR to be compared with the SINR of the WCDMA channel.
Cost function based algorithms	Zhu and McNair (2004)	VHD algorithm that is based on an optimized cost function is used to evaluate the cost of possible target networks. The algorithm prioritizes all the active applications and calculates the cost of each possible target network for the service with the highest priority. It is applied on two vertical handover policies, one for all the user's active sessions collectively (handed over the same target network) and one for each of the user's active sessions independently (with prioritization). Elimination constraints (RSS and channel availability) and a prioritized multi-

VHD Algorithm Category	Author/year	Chief features of VHO algorithm
		network scheme were introduced to reduce the delay and improve the throughput for an MT with multiple active sessions.
	Chen et al.(2004)	Proposed an adaptive scheme based on handover decision process. The authors used the utility function (higher utility is equivalent to target network), to evaluate the reachable wireless networks discovered (bandwidth and movement speed as factors) and to quantify the QoS provided by the wireless network on the MT. They introduced two adaptive handover decision methods adjusting the stability period according to the network resources and the running applications on the MT. One scheme measures several utility ratios (Utarget/Ucurrent) and other relies on the ratio of two measured utility ratios.
Computational algorithms	Nasser et al. (2007)	VHO algorithm based on artificial neural networks (ANNs). MT collects characteristics of available wireless networks and sends them to vertical handover manager. These network characteristics are used during handover decisions and include network usage cost, security, transmission range and capacity. The vertical handover manager consists of three main components: network handling manager, feature collector and ANN training/selector. A multilayer feed forward ANN is used to determine the best handover target wireless network available to the mobile device, based on the user's preferences.
	Pahlavan et al. (2000)	Proposed ANN based decision methods for vertical handovers for WLAN and General Packet Radio Service (GPRS) network. The ANN model consists of an input layer, two middle layers and an output layer. The mobile node performs periodical RSS measurements and detects if there is a drop in RSS value and makes handover decision. The output is a binary signal: value '1' leads to a handover to the GPRS, and the value '0' means that the mobile node should remain connected to the access point.
	Chan et al. (2002)	Proposed FL based solution in which terrestrial

VHD Algorithm Category	Author/year	Chief features of VHO algorithm
		(GPRS and UMTS) and satellite mobile networks operate alongside each other. The handover decision algorithm aims at selecting a network for a particular service that satisfy objectives based on criteria (such as low cost, good RSS, optimum bandwidth, low network latency, high reliability and long life battery) and taking into account the preferred access network.
	Celal et al. (2010)	Fuzzy logic-based handoff decision algorithm is introduced for wireless heterogeneous networks. The parameters; data rate, received signal strength indicator (RSSI), and mobile speed are considered as inputs of the proposed fuzzy-based system in order to decide handoff initialization process and select the best candidate access point around a smart MT.
	Xia et al. (2007)	If the MT is connected to the WLAN, and the velocity of the mobile terminal v is higher than the threshold velocity v_T, a handover to the UMTS is directly initiated. Otherwise, the pre-decision unit checks whether the predicted RSS from the WLAN (PR_W) is larger than its threshold (P_{rW}), or the predicted RSS from the UMTS (PR_U) is smaller than its threshold (P_{rU}), no handover is triggered. The three inputs, current RSS, predicted RSS and bandwidth, are fuzzified and normalized to generate performance evaluation values (PEV), and the VHD is made by comparing PEVs of the network candidates.
Parameter aggregation algorithms		
	Stevens-Navarro and Wong (2006)	Three models based on SAW, TOPSIS and GRA were compared on the basis of attributes like bandwidth, delay, jitter, and BER. Study showed that SAW and TOPSIS provided similar performance to the traffic classes used. GRA provided slightly higher bandwidth and lower delay for interactive and background traffic classes. AHP was used to determine the weights for the three models that required information about the relative importance of each attribute. Results also showed that all four

VHD Algorithm Category	Author/year	Chief features of VHO algorithm
		algorithms depend on the importance weights assigned to the parameters.
	Quiqyang and Jamalipour (2005)	A mechanism for network selection is proposed combining AHP (to achieve weighting of QoS parameters based on user preferences and service application) and GRA (to rank the network alternatives) techniques in order to find a tradeoff between user preferences, service application and network conditions. The mechanism involves three logical function blocks: ‘‘collecting data” to collect user preferences and network conditions; ‘‘processing data” to processes user-based data by AHP and normalizes network-based data by GRA, and ‘‘making decision block” that finalizes the process of balancing user preference, service application and network condition. The results revealed that it can work efficiently for an UMTS/WLAN system and also reduce the complexity of implementation significantly.

4. OPEN RESEARCH ISSUES AND PROPOSED VHO EVALUATION METHODOLOGY

Vertical handover mechanisms have undergone many enhancements and many new technologies have been introduced over the last few years. There are still some issues requiring further study. This section summarizes the issues that need further attention.

(i) When vertical handover takes place, providing the required QoS across the different wireless networks is a major issue and high levels of mobility possess further challenges. In order to guarantee the QoS, VHO techniques must carefully consider user mobility and network conditions in order to choose the best candidate network and perform a fast handover.

(ii) Guaranteeing the QoS is not enough in order to provide the best possible service to users Quality of Experience (QoE) is a concept that is gaining importance. It is related to users' satisfaction. Providing good networking performance need not always give total satisfaction to the end users. Hence there is a need to take into consideration of user preferences and mobile equipment as well while designing VHO strategies and techniques

(iii) Security is an important issue that is often overlooked in networking scenario. In order to enhance VHO techniques, there is a need for incorporating robust security solutions in heterogeneous networks that would allow security anytime and anywhere.

(iv) In heterogeneous environment, access networks need to be inter-connected in an optimal manner such that the users are always best connected. However, issues related to the inter networking including billing and pricing for the use of the networks, management of other such issues between operators must be addressed in order to facilitate the VHO and to guarantee QoE as well as Quality of Service (QoS). The inter-networking of these heterogeneous wireless networks has become a challenging and important area of research. Different access networks including 3GPP (e.g, EDGE, HSPA, UMTS, LTE) and non 3GPP (e.g, WiMax, WiFi) standards need to be inter connected in an optimal manner to provide users with a good QoS.

(v) There is a lack of homogeneous VHO evaluation methodology. Therefore, a common methodology is required so that the researchers, developers and users easily can compare and evaluate the diverse VHO techniques found in the literature. Hence, there is a need to release standard or guidelines on good practices for VHO evaluation.

4.1 Performance Requirements of Vertical handoff decision algorithms

From the review, it is revealed that there is a need for a methodology that can make a comparison between the various VHO techniques proposed and do the evaluation of these techniques. In light of this, paper proposes a method to calculate VHO index that would give an indication about effectiveness of vertical handoff management process. This index is can be calculated based on the following criterion derived from the literature:

(i) Seamless (S) : Handover is considered ‘‘seamless’’ when it is able to maintain the connectivity of all applications running on the mobile device, providing a continuous end-to-end data service within the same session during the switchover, offering both low latency and minimal packet loss.

(ii) Packet loss (PL): it is a measure of amount of packets dropped during VHO process. Mathematically, it can be expressed as,

Packet Loss for vertical handover = (1-no. of packets received)
Total no. of packets sent

Here packet loss is calculated for the hand over period only.

(iii) Throughput (TH): it refers to the data rate delivered to the mobile terminals during handover. It is usually desirable to get higher throughput during handover to a particular network.

(iv) Handover delay (HD): refers to the duration between the initiation and completion of the handover process. More complex is the VHO process; more handover delay would be there. Thus for delay-sensitive voice or multimedia sessions, reduction of the handover delay is important. Handover delay is the sum of all individual delays involved in handover (Shah et al., 2013). It can thus be written as

$T_{handover} = T_{L2} + T_{sig} + T_d + T_{IP}$; where T_{L2} is the time required to establish layer 2 connectivity between mobile node and access point or base station of new access point. T_{sig} is the time required for exchanging control messages, T_d is the one way delay for data packet in new network, T_{IP} is the IP address acquisition delay in new network.

Number of handovers (h): number of handovers involved should be low as frequent handovers would cause wastage of network resources.

(v) Handover failure probability (HF): A handover failure occurs when the handover is initiated but the target network does not have sufficient resources to successfully complete it. According to Volko and Campbell (2000), if h is the number of handoffs throughout the duration of call then, Handover failure probability is given as:

$1-(1-P_{h,j})^h$ where, $P_{h,j}$ denotes the probability that a handoff attempt for a call of type j is blocked.

(vi) Handover protocol overhead (PO): It represents the sum of overhead created by protocol for handover signaling and the overhead of the additional bytes sent with each data packet. Thus, PO = Overhead HO+ OverheadAD

(vii) Vertical handover process evaluation index would give the indication about the appropriateness and effectiveness of the handover process. This index can be calculated as:

$VHOI = w_s N(Sj) + w_{PL} N(1/PLj) + w_{TH} N(THj) + w_{HD} N(1/HDj) + w_{HF} N(1/HFj) + w_{PO} N(1/POi)$

Where, ws , w_{PL}, w_{TH}, w_{HD}, w_{HF}, w_{PO} represent weights assigned to the above mentioned criterion in accordance with their importance. While N(i) is the normalization function of ith criterion. Since each network parameter has a different unit, so normalization process is required.

By this method it would be possible to make a quantitative assessment of the various VHO algorithms in the literature. Higher the value of VHO index obtained for a particular VHO algorithm, more efficient is the handover decision process. This will be quite helpful to researchers in deciding whether a given VHO algorithm is suitable for a particular handover environment. Further, VHOI acceptable values may vary for different class of traffic types. As for instance, non-real time traffic (e.g. text data transfer, email etc.,) can tolerate large delays, so high value of handover delay is tolerable, that implies low scores for VHOI for such traffic types are acceptable. While real time traffic (e.g. video and voice) is highly delay sensitive, so high scores for handover delay are unacceptable.

5. DISCUSSION AND CONCLUSION

The next generation wireless systems would include several different radio access network technologies cooperating with each other. Therefore, study on vertical handoff mechanisms assumes importance. The paper covered the basic concepts relating to handover process and various vertical handover algorithms proposed in the literature. Furthermore, the most widely used vertical handover algorithms have been classified into different sub-groups depending upon the basic mechanism used for decision making. Further, paper proposed a methodology to calculate VHO index that would give an indication about the effectiveness of vertical handoff management process. It would be quite helpful in making a comparison between the various VHO techniques proposed and do the evaluation of these techniques.

Further, on reviewing the literature, it became clear that though much work in vertical handover algorithms design has been reported but still research in this area is still challenging. There is a further need for devising an algorithm that would be useful in wide ranging conditions and that would be incorporating user preferences as well. Most of the studies reported in the literature has focused on vertical handovers between GPRS, UMTS, WLAN, WCDMA interworking environments. Handover schemes can be extended for other interworking scenarios including WWAN, WMAN, UMTS, GPRS etc.

REFERENCES

1. Barcelo, F., (2004), "Performance analysis of handoff resource allocation strategies through the state-dependent rejection scheme", IEEE Transactions on Wireless Communications, Vol. 3, No.3, pp.900–909.
2. Calvagna, A., G. Di Modica, (2004), "A user-centric analysis of vertical handovers", in: Proceedings of the Second ACM International Workshop on Wireless Mobile Applications and Services on WLAN Hotspots, pp. 137–146.
3. Çeken, C., Serhan Yarkan , Hüseyin Arslan,(2010), "Interference aware vertical handoff decision algorithm for quality of service support in wireless heterogeneous networks", Computer Networks, Vol. 54, pp.726–740.
4. Chan, P., R. Sheriff, Y. Hu, P. Conforto, C. Tocci, (2001), "Mobility management incorporating fuzzy logic for a heterogeneous IP environment", IEEE Communications Magazine, Vol. 39, No.12, pp. 42–51.
5. Chan, P., Y. Hu, R. Sheriff, (2002), "Implementation of fuzzy multiple objective decision making algorithm in a heterogeneous mobile environment", in: IEEE Wireless Communications and Networking Conference, (WCNC 2002), Vol. 1, 2002, pp. 332–336.
6. Chen, L. J., T. Sun, B. Chen, V. Rajendran, M. Gerla, (2004), "A smart decision model for vertical handoff", in: Proceedings of 4th International Workshop on Wireless Internet and Reconfigurability, Athens, Greece, 2004.
7. Chen, W., J. Liu, H. Huang, (2004), "An adaptive scheme for vertical handoff in wireless overlay networks, in: Proceedings on the 10th International Conference on Parallel and Distributed Systems, 2004 (ICPADS 2004), pp. 541–548.
8. Goyal, P., S.K. Saxena, (2008), "A dynamic decision model for vertical handoffs across heterogeneous wireless networks", in: World Academy of Science, Engineering and Technology, Vol. 31.
9. Gupta, V., (2006), "IEEE 802.21 media independent handover tutorial, in: IEEE 802.21 Working Group Meeting, July 2006.
10. Hasswa, A., N. Nasser, H. Hassanein, (2006), "Tramcar: a context-aware cross-layer architecture for next generation heterogeneous wireless networks, in: Proceedings

of the 2006 IEEE International Conference on Communications (ICC'06), Istanbul, Turkey, June 2006, pp. 240–245.

11. Kassar, M., B. Kervella, G. Pujolle, (2007), "Architecture of an intelligent inter-system handover management scheme", in: IEEE Future Generation Communication and Networking Conference, Vol. 1,pp. 332–337. <http:// dx.doi.org/10.1109/FGCN.2007.70>.
12. Kassar, M., B. Kervella, G. Pujolle, (2008), "An overview of vertical handover decision strategies in heterogeneous wireless networks, Elsevier Computer Communications, Vol.31 No.10.
13. Kassar, M., B. Kervella, G. Pujolle, (2008), "Autonomic-oriented architecture for an intelligent handover management scheme", in: Proceedings of 6th IEEE Annual Communication Networks and Services Research Conference, pp. 139–146.
14. Lee, C.W., Li M. Chen, M.C. Chen, Y.S. Sun, (2005), "A framework of handoffs in wireless overlay networks based on mobile IPv6", IEEE Journal on Selected Areas in Communications, Vol. 23, No.11, pp.2118–2128.
15. Liao, H., L. Tie, Z. Du, (2006), "A vertical handover decision algorithm based on fuzzy control theory", in: IEEE International Multi-Symposiums on Computer and Computational Sciences, Los Alamitos, CA, USA, Vol. 2, pp. 309–313.
16. Mohanty, S., I.F. Akyildiz, (2006), "A cross-layer (layer 2 + 3) handoff management protocol for next-generation wireless systems", IEEE Transactions on Mobile Computing, Vol. 5, No.10, pp.1347–1360.
17. Nasser, N., S. Guizani, E. Al-Masri, (2007), "Middleware vertical handoff manager: a neural network-based solution, in: Proceedings of the 2007 IEEE International Conference on Communications (ICC'07), Glasgow, Scotland, June 2007, pp. 5671–5676.
18. Pahlavan, K., P. Krishnamurthy, A. Hatami, M. Ylianttila, J.P. Makela, R. Pichna, J. Vallstron, (2000), "Handoff in hybrid mobile data networks", IEEE Personal Communications, Vol. 7, No.2, pp.34–47.
19. Quiqyang, S., A. Jamalipour, (2005), "A network selection mechanism for next generation networks", in: International Conference of Communications, (ICC 2005), Vol. 2, pp. 1418–1422.

20. Siddiqui, F., S. Zeadally, (2006), “Mobility management across hybrid wireless networks: trends and challenges, Computer Communications”, Vol.29, No.9, pp.1363–1385.
21. Singhrova, A., N. Prakash, (2007), “A review of vertical handoff decision algorithm in heterogeneous networks”, in: 4th ACM International Conference on Mobile Technology, Applications, and Systems, New York, NY, USA, pp. 68–71.
22. Stevens-Navarro, E., V. Wong, (2006), “Comparison between vertical handoff decision algorithms for heterogeneous wireless networks”, in: Proceedings of IEE Vehicular Technology Conference (VTC-Spring), Vol. 2, pp. 947–951.
23. Stevens-Navarro, E., Y. Lin, V.W.S. Wong, (2008), “An MDP-based vertical handoff decision algorithm for heterogeneous wireless networks”, IEEE Transactions on Vehicular Technology, Vol.57, No.2, 1243–1254. <http://dx.doi.org/10.1109/TVT.2007.907072>.
24. Xhafa, A. E. O.K. Tonguz, (2004), “Dynamic priority queueing of handover calls in wireless networks: an analytical framework”, IEEE Journal on Selected Areas in Communications, Vol. 22, No.5, pp. 904–916.
25. Xia, L., L.-G. Jiang, C. He, (2007), “A novel fuzzy logic vertical handoff algorithm with aid of differential prediction and pre-decision method”, in: Proceedings of the 2007 IEEE International Conference on Communications (ICC’07), Glasgow, Scotland, June 2007.
26. Yang, K., I. Gondal, B. Qiu, L.S. Dooley, (2007), “Combined SINR based vertical handoff algorithm for next generation heterogeneous wireless networks”, in: Proceedings of the 2007 IEEE Global Telecommunications Conference (GLOBECOM’07), Washington, DC,
27. Ying, W., Y. Jun, Z. Yun, L. Gen, Z. Ping, (2008), “Vertical handover decision in an enhanced media independent handover framework”, in: IEEE Wireless Communications and Networking Conference, pp. 2693–2698.
28. Zdarsky, F., J. Schmitt, (2004), “Handover in mobile communication networks: who is in control anyway?” in: Proceedings of the 30th Euromicro Conference, pp. 205–212.