Seamless Vertical Handover for Efficient Mobility Management in Cooperative Heterogeneous Networks

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Abstract The inter-networking cooperation among different wireless networks will help the operators to improve the overall throughput and resource utilization of the wireless networks. During this inter-networking, a mobile node switches among various access networks to satisfy QoS as well as QoE. The next-generation networks require seamless handover among different networks to maintain the connection. In future wireless networks, a mobile node with a multi-interface may have network access from separate service providers using different protocols. Thus, with this heterogeneity environment, spectrum handover decision making must be introduced to take benefit of cooperative support for handover and mobility management in heterogeneous networks. In first stage, an extensive review of the heterogeneous network environment and vertical handover is presented. In second stage, system functionalities and spectrum switching decision making for the vertical handover process are explained. In third stage, architecture and the simulation testbed used for system validation and implementation of the system modules in QualNet simulator are presented.

Keywords Vertical handover · Heterogeneous networks · Mobility management Inter-networking scenario · Decision making schemes

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1 Introduction

The users are witnessing the requirement for a network that has capability of handling the traffic in a different perspective. Thus, a pressure is put on the homogeneous network operators to provide seamless handover to the users with both maintained Quality of Service (QoS) and Quality of Experience (QoE). Since wireless network technologies are now becoming a compulsory part of daily work, so this pressure will continue in the coming future. Vertical handover must be performed regardless of the data transmission through network. Service provider may have to combine several networks seamlessly in order to provide uninterrupted services to the users with anywhere, any time, and anyone support. High competitive market competition for users, along with ever-increasing availability of unlicensed networks, like WiFi, MANET, will give mobile users the freedom for network selection to make cost-effective handover decision making. The presence of a heterogeneous wireless network is related with low-cost deployment of low power access points (called relay node) and service provider's approach to provide coverage in small areas at minimum cost [1]. This femtocell-based approach enhances indoor coverage and maintains reliable connectivity without the requirement for the infrastructure-based network which may be cost-inefficient [2, 3]. In highly populated regions, mobile nodes very commonly identify signals from other service providers and access points. In future, these highly dense areas will be served by a combination of networks and form heterogeneous network architecture. Thus, vertical handover and seamless mobility are needed to maintain the same QoS parameters in different–different networks [4].

Different networking protocols and features need specific handover techniques. For example, a mobile node having high mobility, received signal strength is one of the main parameter for triggering handover process. On the other way, for less mobility node, other factors like bit error rate, cost, QoS will be probable factors to initiate handover process.

The rest of this paper is structured as follows. Section 2 explains mobility environment to support vertical handover stages and its technical aspects used for network switching decision making. In Sect. 3, QualNet-simulated sample scenario for mobility management in heterogeneous network and its results are discussed. Finally, the conclusion is drawn from the work given in Sect. 4.

2 Mobility Environment in Heterogeneous Network

The all-IP backbone provides the paths to merge different wireless networks to form heterogeneous network for coming generation. This supports seamless mobile and ubiquitous communication. In a cooperative heterogeneous networks environment, an intelligent mobile node having multiple interfaces can perform handover process seamlessly among different networks to support multimedia real-time services. Thus, future network's mobile node would be capable to move freely across different

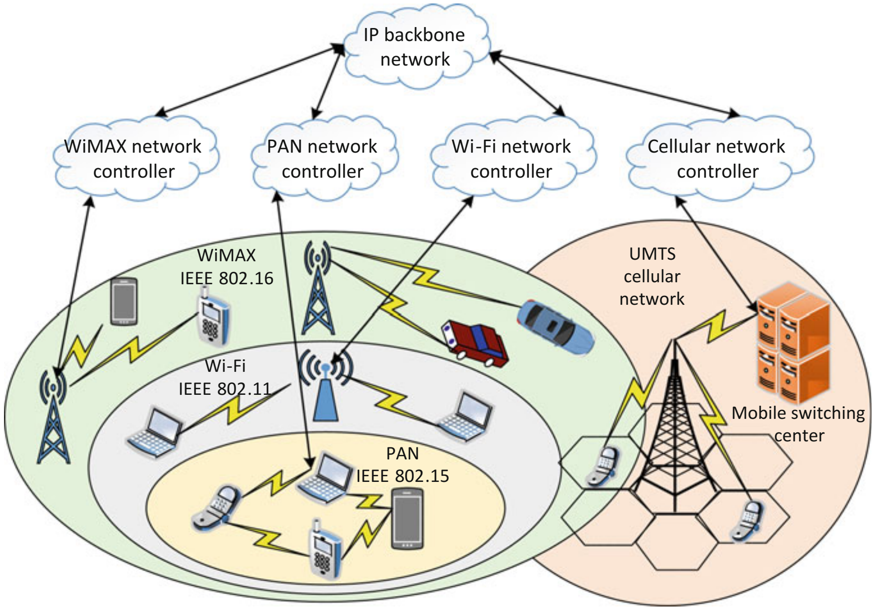


Fig. 1 Cooperative heterogeneous networks environment

wireless access networks like cellular, WiFi, WiMAX, MANET and Bluetooth [5]. Figure 1 represents a heterogeneous roaming scenario network which consists of several different wireless access networks.

2.1 *Vertical Handover Phases*

Seamless transfer of user's service from existing network to a new network bearing dissimilar radio access technology and protocols is called vertical handover (VHO) [6]. Figure 2 represents three main phases in handover process, namely handover initiation, handover triggering, and handover execution. In first phase, mobile node or an access point starts searching for new available network link; if detected, it

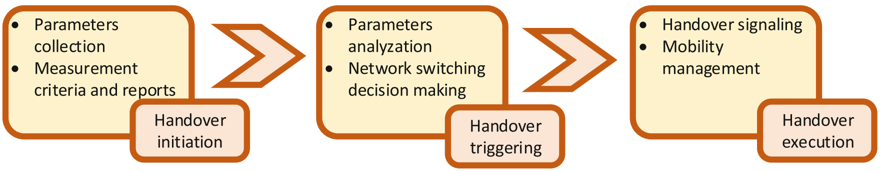


Fig. 2 Handover phases

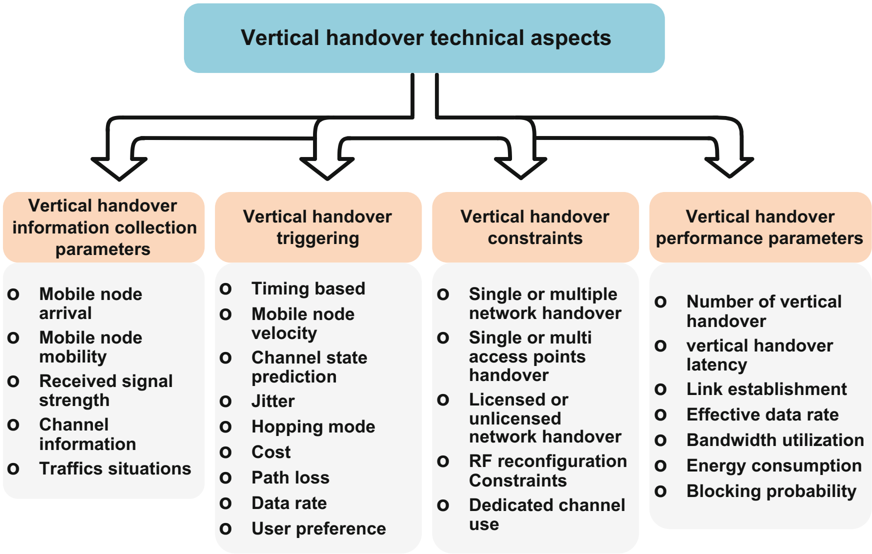


Fig. 3 Various technical aspects of vertical handover

makes the measurements for initiating a handover toward a new network or new access point. In second phase, measurement information is compared with fixed threshold value to take network switching decision whether to perform the handover or not. In third phase, new network or access point is added, all the parameters are adjusted, and active set is updated for mobility management.

2.2 *Vertical Handover Technical Aspects*

The technical aspects deal with vertical handover-related issues in heterogeneous networks [7]. The vertical handover is the integrating part of mobility management framework. The occurrence of vertical handover initiates with movement of mobile node. The technical aspects related to vertical handover are summarized into four main subgroups as shown in Fig. 3.

2.3 *Network Switching Decision-Making Schemes*

2.3.1 Simple Additive Weighting (SAW)

SAW is very popular and mostly used in network switching decision making using cost/utility function as an attribute [8]. It can be calculated as

$$K_{\text{SAW}} = \sum_{j=1}^{M} w_j d_{ij} \tag{1}$$

where w_j represents the weight of jth attribute and d_{ij} denotes the value of jth attribute of the ith network.

2.3.2 Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS)

TOPSIS scheme includes the range from evaluated network to one or several reference networks [9]. The cost or utility function for this scheme is calculated as

$$K_{\text{TOPSIS}} = \frac{T^{\alpha}}{T^{\alpha} + T^{\beta}} \tag{2}$$

where

$$T^{\alpha} = \sqrt{\sum_{j=1}^{M} w_j^2 \left(d_{ij} - D_j^{\alpha}\right)^2} \quad \text{and} \quad T^{\beta} = \sqrt{\sum_{j=1}^{M} w_j^2 \left(d_{ij} - D_j^{\beta}\right)^2}$$

This equation represents the Euclidean distances from the typical network to the worst and best reference networks, where D_j^{α} and D_j^{β} denote the measurement of jth attribute of the worst and best reference networks, respectively.

2.3.3 Gray Relational Analysis (GRA)

The GRA is an analytical process derived from the Gray system theory to analyze discrete data series [10]. The main difference between TOPSIS and GRA is that, for the calculation of utility function, GRA uses only the best reference network. A utility function is given as

$$K_{\text{GRA}} = \frac{1}{\sum_{j=1}^{M} w_j \left| d_{ij} - D_j^{\beta} \right| + 1} \tag{3}$$

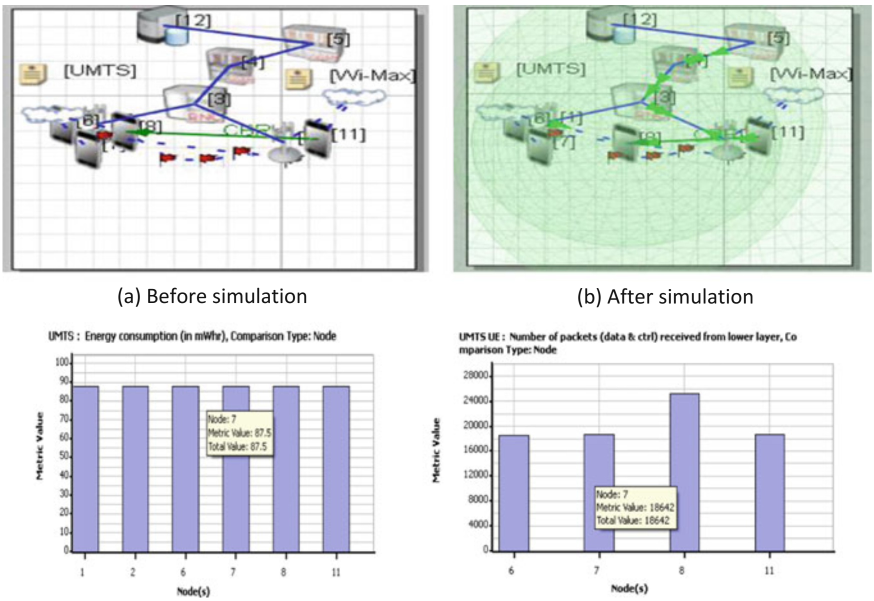
Data processing, mathematical modeling, decision making, control, prediction, and systems analysis are the main fields of Gray relational analysis.

3 Deployment and Implementation of Scenarios in QualNet

In this work, vertical handover is performed considering two different heterogeneous network scenarios, namely UMTS–WiMAX and WiFi–MANET–WiMAX. Simulation is performed in QualNet software. By calculating the quantity of transferred packets from one mobile node to another mobile node, the performance of transmission control protocol (TCP)-based application is observed. If a large number of packets are transferred, then it shows the high performance of TCP at network layer. For monitoring the performance of user datagram protocol (UDP), the packet loss and end-to-end packets delay variation (called jitter) are analyzed. If these two has minimum value, then it shows the better performance of the UDP.

3.1 Scenario-1 (UMTS–WiMAX Inter-networking)

Figure 4a represents the scenario that consists of 12 nodes. Node 6, 7, 8, and 11 are mobile nodes, and remaining nodes are with dual-radio interfaces acting as a part of UMTS and WiMAX networks. For example, node 3 is represented as radio network controller (RNC), node 12 as a mobile switching center (MSC). All the

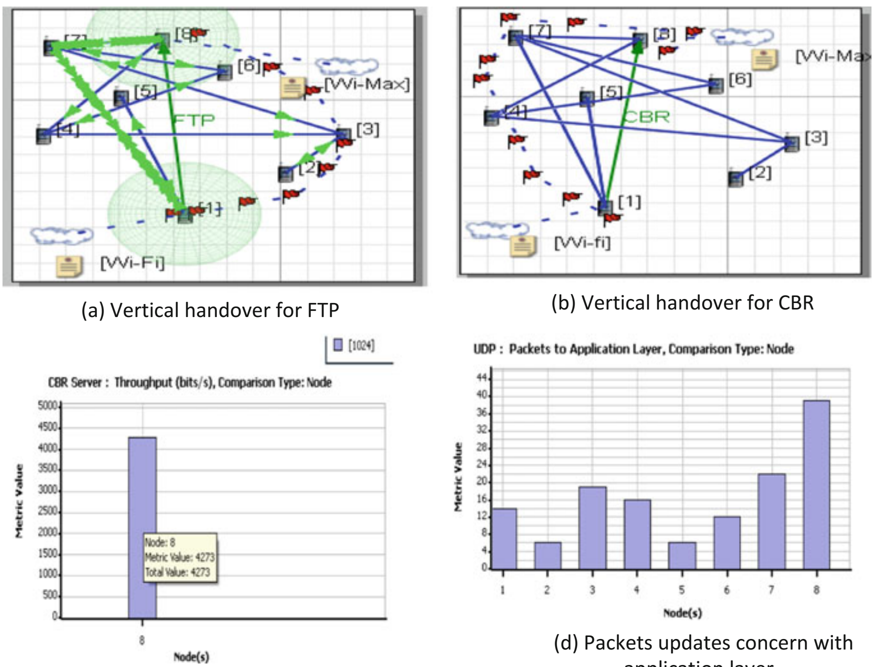


(a) Before simulation (b) After simulation

(c) Energy consumption at different nodes (d) Number of packets received from lower layer

Fig. 4 UMTS–WiMAX inter-networking

points of attachment are connected through a wired backbone. Node 11 maintains a constant bit rate (CBR) application with node 8. This scenario was simulated as shown in Fig. 4b in order to demonstrate the effectiveness of the implementation. The routing protocol used is Bellman–Ford which is a reactive routing protocol, meaning that it provides a route to a destination node only on demand. Also, the connection setup delay is minimum. Node 11 roams from the area covered by node 8 which is connected with UMTS network. Figure 4c shows that each node consuming almost same energy level which makes it energy-efficient. During this time, vertical handover exists, so each time the packets are received and updated at lower layer as shown in Fig. 4d. In this, RNC node receives these handover requests and triggers a local link-layer command to find out the channel parameters, and when it receives the confirm primitive, it forwards the real-time channel occupancy information to the MSC. For now, the handover is executed by MSC based on the information solely on channel occupancy and received signal strength (RSS).



(a) Vertical handover for FTP

(b) Vertical handover for CBR

(c) Throughput of server node 8

(d) Packets updates concern with application layer

Fig. 5 WiFi–MANET–WiMAX inter-networking

3.2 *Scenario-2 (WiFi–MANET–WiMAX Inter-networking)*

In this scenario, node 8 act as a destination, node 1 as a source, and it uses FTP protocol between them as shown in Fig. 5a. Node 8 is connected to WiMAX network. Node 1 which is connected to WiFi sends data to mobile node 8 via MANET which is formed by node 2-3-4-5-6-7. Once this scenario has established, then mobile node 1 travels toward WiMAX coverage area and vertical handover takes place between WiFi and WiMAX. Now data transmission takes place from node 1 to node 8. In Fig. 5b, same model is simulated for CBR application. Figure 5c represents a throughput measured at node 8. This throughput graph indicates a slight declining trend in case of the traditional vertical handover approach which is desirable for the faster handover. Figure 5d represents the packet updates concerned with application layer. Therefore, all the nodes are participating in packet reception and forwarding to the next node and these nodes are connected with different–different networks. This shows that vertical handover is taking place among the different access networks.

4 Conclusion

Cooperative heterogeneous networks have a great potential to handle inevitable demands of extra spectrum in next-generation wireless networks. In the upgradation to future networks, convergence of IP-based core networks with heterogeneous network is inevitable. Thanks to the rapid growth in communication technologies, the users are becoming more dominant in their traditional choice. In this paper, an overview of heterogeneous network and vertical handover with network switching decision-making schemes is introduced. This work considers a mobility management framework in which two different inter-networking scenarios have been analyzed for the purpose of comparing the performance of vertical handover in UMTS–WiMAX and WiFi–MANET–WiMAX hybrid integrated architectures. Furthermore, empowering best nomadic applications via plug-and-play-type connectivity and always best connected (ABC) network in an autonomous fashion is a new research direction for seamless mobility management in heterogeneous network environment. It is believed that cooperative heterogeneous networks need to learn about network parameters and proper coordination among different networks to work correctly and efficiently with cooperation. Therefore, a common infrastructure is required to provide such heterogeneous networks with information and technology at low cost for real-time multimedia applications.

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