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ORIGINAL RESEARCH

An optimized MCHVD approach to curtail handover failures in wireless networks

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Abstract The applications of wireless local area networks (WLAN's) are highly accepted by mobile terminals (MT's) due to their high transmission bandwidth and reduced costs. However, in such high speed networking platforms, there is a possibility of unnecessary handover failure (UHF) due to limited coverage of WLAN's. Therefore, the given paper provides a multi-criteria hysteresis vertical handover decision (MCHVD) approach for wireless systems in order to minimize handover failure by analysing and validating its performance with conventional received signal strength (RSS) scheme of source and target cells. Using OPNET simulator, the proposed approach is tested over 60 samples, which are divided equally among networks such as Wi-Fi, Worldwide Interoperability for Microwave Access (WiMAX), and Universal Mobile Telecommunication System (UMTS) based on parameters like G power as 0.8, threshold energy limit as 0.05%, and confidence interval as 95%, thereby keeping the maximum accepted error as 0.05 and beta as 0.2. An independent sample *T*-test is done, which reveals that the probability of handover failure (p) is 0.01 ($p < 0.05$), which is found to be statistically significant in the MCHVD approach when compared with the conventional RSS scheme. The results show that the handover failure rate for MCHVD is significantly lower than that for conventional RSS-based methods with respect to 20 iterations.

Keywords RSS · Wi-Fi · WiMAX · UMTS · Vertical handover · Wireless networks

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1 Introduction

The growing demand from consumers for wireless communication services has fuelled the rapid development of wireless technologies and facilities for mobile users [1]. Users expect continuous and reliable connectivity to ensure the quality of their communication services [2]. In order to meet these demands, a novel MCH Vertical Handover Decision (MCHVD) technique has been developed to enable seamless vertical handover (VHO) between different wireless technologies in different coverage areas [3]. The ultimate goal of providing uninterrupted inter-system handover in cellular networks is to enhance the user experience of mobile terminals (MT) by allowing for network switching while maintaining session continuity [4].

To optimize handover between different wired and wireless media in vertical handover, it is important to develop specification that provides link layer intelligence and related network information to upper layers [5]. This will help to estimate the necessity for vertical handover and making the final decision about when and where the handover should occur [6, 7]. The finalization of vertical handover in novel MCHVD depends on various factors related to the network, and failure to manage these factors can result in issues such as high latency and lack of control [8–10]. This finalized cell is generally different from a previous cell and the difference is obtained based on different factors for example anticipated interference, load balancing etc. [11]. Once the handover failure is experienced, the cell can return to a previous frequency and an appropriate cell can be determined [12]. Instruction of the cell that should be used can be determined by user equipment as well as from a network entity [13]. To overcome the above limitations and minimize the handover failure, MCHVD model is used in heterogeneous networks. The given paper is organized into following sections. Section 2 presents a review of studies with existing gaps in the context of the prediction of handover failures in wireless and cellular networks. Section 3 discusses the proposed MCHVD approach, which considers three types of vertical handover scenarios. Section 4 presents results and discussions, followed by a conclusion, future scope, and references.

2 Related works

The given section describes a concise overview of existing studies as shown in Table 1.

3 Proposed approach

The study considered three network models namely Wi-Fi-WiMAX, WiMAX-UMTS, and UMTS-Wi-Fi, each with 20 samples [21] making a total sample size of 60. The required sample size for the analysis was determined using power

Table 1 Comparative analysis of existing studies

Cited works	Purpose	Techniques / Approaches used	Gaps identified
[14]	Designed patient monitoring system using heterogeneous networks	Fuzzy logic	The given system exceeds a significant probability value of handover failure ($p > 0.05$), which leads to instability and loss of bandwidth in wireless networks.
[15]	Travelling distance prediction scheme to minimize handover failures	Fourier transformation and trigonometric functions	The gap between two consecutive RSS values is so high that it leads to deadlock and less accuracy.
[16]	Network lifetime based handover strategy	NS2 simulator is used	The given approach exceeds the threshold energy limit of 0.05%, thus increasing the signaling load on the system.
[17]	Vertical handover approach between WLAN and cellular networks	Hidden Markov Model	Failed to predict the radio link failure rate, which eventually results in handover delays.
[18]	Predictive method to estimate hysteresis margin by considering signal thresholds	Hysteresis margin based handover algorithm	The algorithm does not consider handover aspects between WiMAX and UMTS, which eventually leads to a single-criteria handover approach.
[19]	Selection of suitable value of signal strength	MIPv6 handover protocol	The signal strength received by mobile networks is less than threshold handover probability.
[20]	Computation of probability of handover failure	Window size optimization and triggering technique	The given approach exceeds the threshold energy limit of 0.05%, thus increasing the signaling load on the system.

calculation. The minimum power was set at 0.8, and the maximum acceptable error was set at 0.05, with a beta value of 0.2 [21]. In (MCHVD), vertical handover necessity estimation is considered using multiple criteria such as RSS, Quality of Service (QoS), Link quality, gateway, path quality, and network availability, cost, and data rate [22]. In the proposed work, a novel MCH vertical handover decision approach is considered and compared with Conventional RSS scheme. The ratio of handover failure was obtained for three network models in which WIFI WiMAX is considered as group 1 with a sample size of 20, WiMAX-UMTS is considered as group 2 with the sample size of 20 and UMTS-Wi-Fi is considered as group 3 with the sample size of 20. Wi-Fi, UMTS, and WiMAX are connected or linked to the Internal Server (IS). Three types of vertical handover scenarios are described in Fig. 1 as shown.

- Type 1**:** Vertical handover between *Wi-Fi and WiMAX* is considered. When the user moves from the handover region, all the nearby base stations allocate the channels for the user in the handover region and it leads to handover failure over the network. To overcome the resource constraint, MCHVD was proposed and it is used to calculate the priority ranking of the available network based on multi-criterion such as RSS, link quality, data rate, gateway, and power. During the handover process, the decision-making was based on multi-criteria and user preference.
- Type 2: It considers handover between *WiMAX and UMTS* where the proposed MCHVD is used to rank the available networks based on multiple criteria such as RSS, link quality, data rate, gateway, and power. This approach results in seamless intersystem handover with no packet loss and minimum latency, providing uninterrupted service for end-users.
- Type 3: It involves handover between *UMTS and Wi-Fi* where the proposed MCHVD is again used to rank the available networks based on criteria such as RSS, link quality, gateway, data rate, and power. The Wi-Fi and UMTS networks are implemented using OPNET 14.5 software, and handover between the networks can occur when the received power is higher than the specified threshold. Simulation and testing of the proposed architecture are conducted using OPNET 14.5 software, with a basic system configuration of an i3 processor, 5th generation Intel with 4 GB RAM and 32-bit processor, and 8 MB cache up to 1.60 GHz.

Each server is connected to the gateway and the gateway is connected to the IP Cloud or Third-Party Server. The proposed model makes use of Application configuration, Profile configuration, Quality of Service, and Mobility configuration when the nodes move from one network to another network.

4 Results and discussions

Table 2 displays the results of the statistical analysis of handover failure for two groups, namely MCHVD as Group

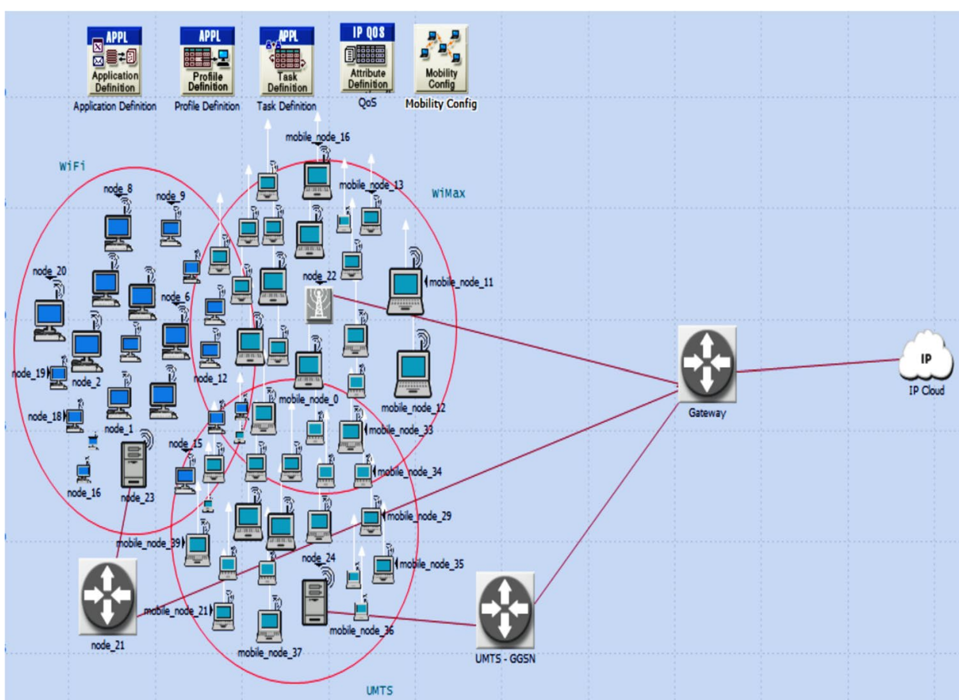

Fig. 1 Interconnection between Wi-Fi, WiMAX and UMTS with Internal Server (IS)

Table 2 *T*-test analysis for UHF1, UHF2 and UHF3

	Group	*N*	Mean	SD	SE
UHF1	MCHVD	20	0.15	0.366	0.082
	Conv.RSS scheme	20	0.55	0.510	0.114
UHF2	MCHVD	20	0.70	0.470	0.105
	Conv.RSS scheme	20	0.90	0.308	0.069
UHF3	MCHVD	20	0.49	0.046	0.010
	Conv.RSS scheme	20	0.34	0.082	0.018

1 and the features of conventional RSS scheme as Group 2. In the UHF1 frequency band, MCHVD has a mean value of 0.15, a standard deviation of 0.366, and a standard error value of 0.82 while conventional RSS has a mean value of 0.55, a standard deviation of 0.510, and a standard error value of 0.114.

In UHF2, MCHVD has a mean value of 0.70, a standard deviation of 0.470, and a standard error value of 0.105 while conventional RSS has a mean value of 0.90, a standard deviation of 0.308, and a standard error value of 0.69.

In UHF3, MCHVD has a mean value of 0.49, a standard deviation of 0.46, and a standard error value of 0.10 while conventional RSS has a mean value of 0.34, a standard deviation of 0.082, and a standard error value of 0.812.

In Fig. 2, the ratio of handover failure between Wi-Fi and WiMAX is computed on *Y*-axis and time (ms) on *X*-axis. MCHVD approach minimizes the resources utilization as compared to conventional RSS scheme (Fig. 3).

Figure 4 describes the ratio of handover failure and time variance in both MCHVD and Conv.RSS scheme. For MCHVD, the ratio of average handover failure is 0.29 and for Conv. RSS, the ratio of average handover failure is 0.92 with respect to 20 iterations.

It depicts that the ratio of handover failure for WiMax-UMTS is higher as compared to WiFi-WiMax and UMTS-WiFi, which indicates that the proposed MCHVD approach works much better in the case of WiMAX-UMTS (Figs. 5, 6, 7).

The higher mean difference in the conventional RSS scheme shows that the values are largely scattered from the threshold probability of handover ratio.

4.1 Discussions and limitations

Based on geometrical models, the probability distribution of traversal length provided a linear approximation [23, 24] whose closed-form integral can be obtained from handover failure. Linear approximations are used to keep the threshold values (0.82) to find the probability of handover failure within the pre-designed limits. This work explores different criteria for vertical handovers including RSS, link quality, data rate, and power, and proposes a novel MCH Vertical Handover Decision (MCHVD) approach. The results show that the handover failure rate for MCHVD is significantly lower than that for conventional RSS-based methods. Other studies have also emphasized the need for advanced evaluation functions and optimized architecture to improve handover decision-making and network resource utilization for better user satisfaction. In heterogeneous networks, the probability of handover failure is found to be low and the number of handovers needed for mobile terminals decreases with increasing speed.

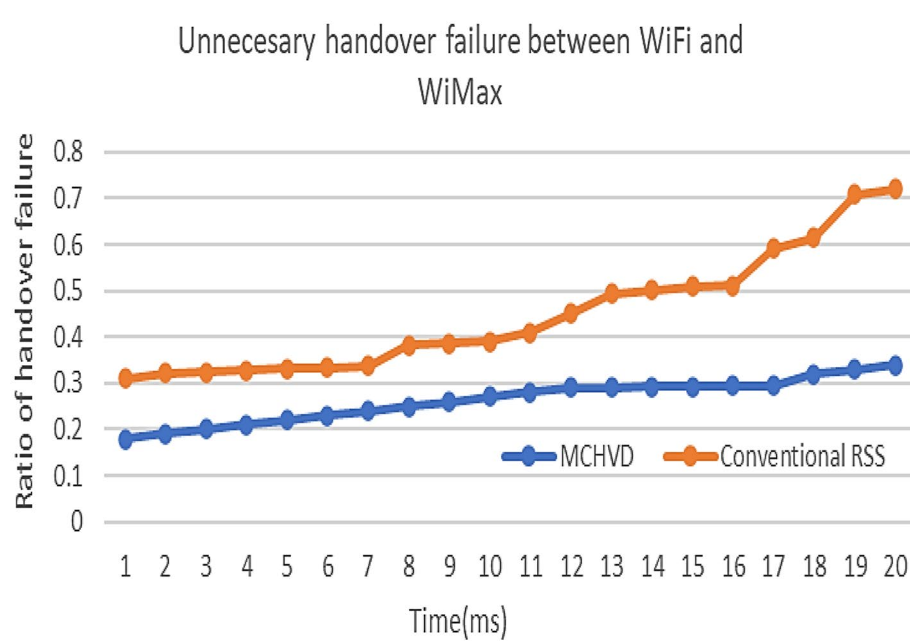

Fig. 2 Unnecessary handover failure between WiFi and WiMax describing the ratio of handover failure and time variance in both MCHVD and conventional RSS

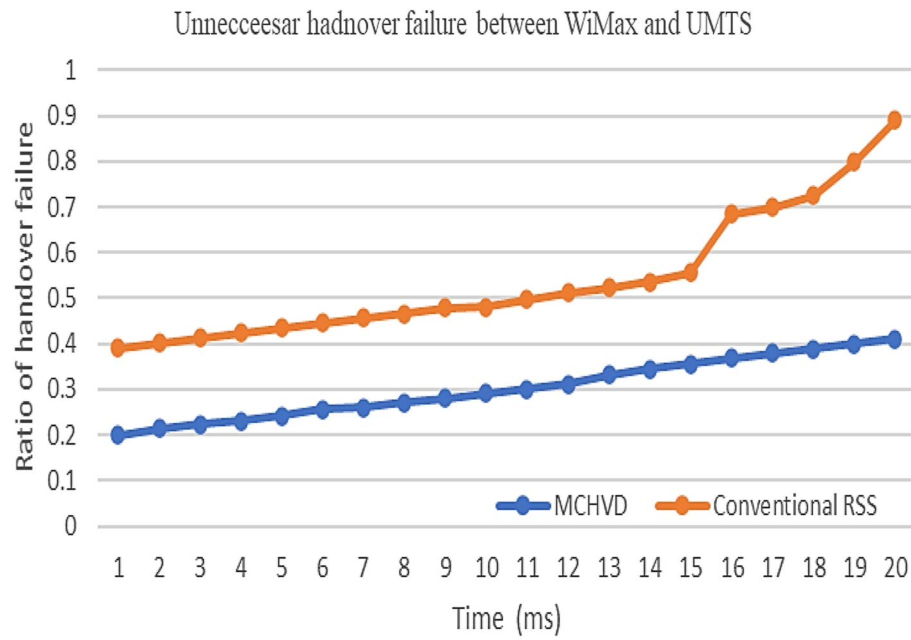

Fig. 3 The ratio of unnecessary handover failure between WiMax and UMTS. It describes the Quality of Service (QoS) and time variance in both MCHVD and conventional RSS scheme

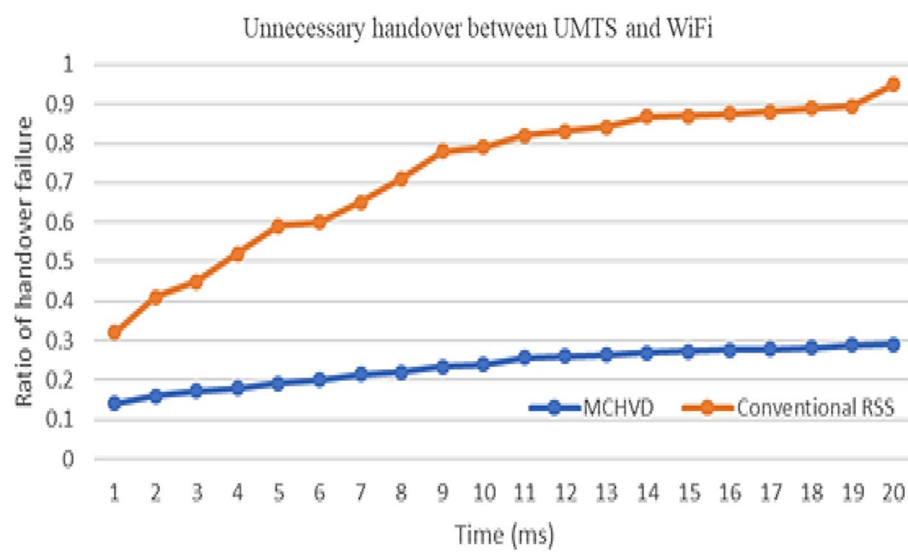

Fig. 4 Unnecessary handover failure between WiFi and UMTS

However, some limitations of the work include the consideration of factors such as available bandwidth, received signal strength (RSS), access cost, dwell time, security, and speed while deciding to perform vertical handover. It is important to carefully evaluate the benefits and drawbacks of vertical handover before considering these factors.

4.2 Novelty of the proposed approach

- It acts as a statistically significant probabilistic approach ($p < 0.05$) that does not exceed handover failures above the threshold limit.
- The comparison of the MCHVD approach with an existing RSS scheme reveals that the proposed approach is superior as it keeps the probabilities of handover failure much closer to the designed values, resulting in the avoidance of handover failures and improved resource utilization.

5 Conclusion and future scope

A Novel Multi-Criteria Vertical Handover Decision (MCHVD) approach is used to reduce resource constraints

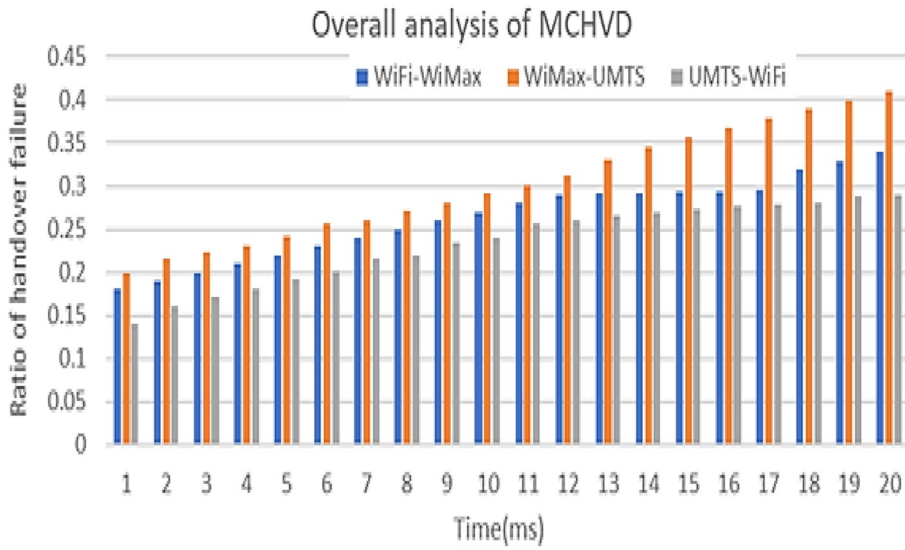

Fig. 5 Overall analysis for MCHVD results in unnecessary handover failure between WiFi-WiMax (UHF 1), WiMax-UMTS (UHF 2), and UMTS-WiFi (UHF 3)

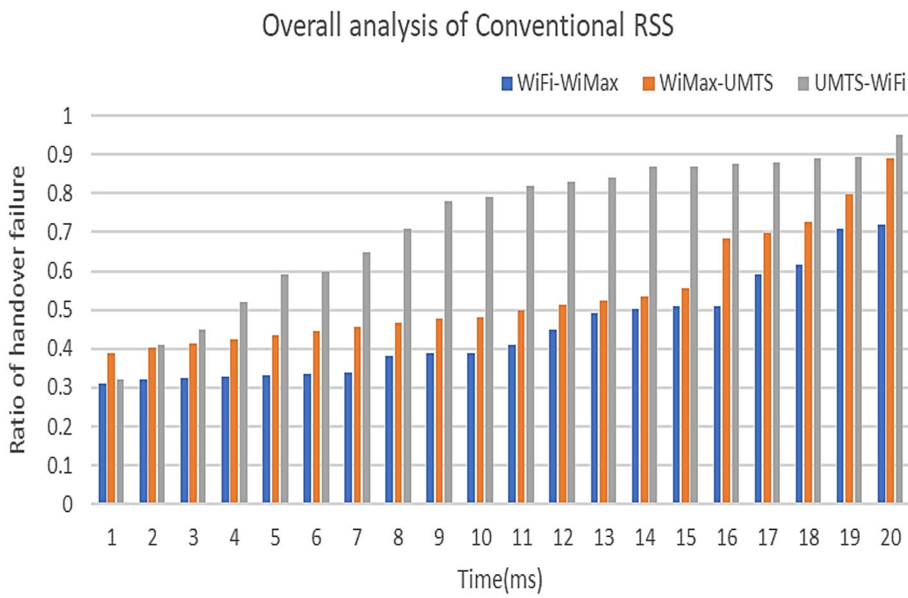

Fig. 6 Overall analysis for conventional RSS results in unnecessary handover failure between WiFi-WiMax, WiMax-UMTS, and UMTS-WiFi.

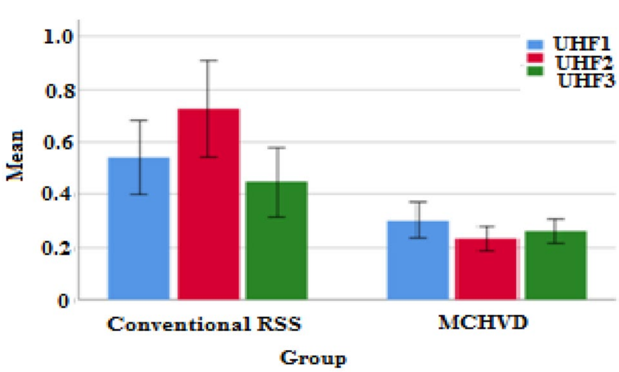

Fig. 7 Mean difference between Conventional RSS and MCHVD approach with 95% confidence interval and error bars +/-1 SD.

and unnecessary handover failures by estimating the probability of handover failure among wireless networks including WiFi-WiMax (UHF 1), WiMax-UMTS (UHF 2), and UMTS-WiFi (UHF 3). An independent sample T- test is also done, which reveals that the probability of handover failure (p) is 0.01 ($p < 0.05$), which is found to be statistically significant in the MCHVD approach when compared with the conventional RSS scheme. The results show that the handover failure rate for MCHVD is significantly lower than that for conventional RSS-based methods with respect to 20 iterations.

As a future scope, the work can be extended to analyze more handover factors linked to different simulation environments. It may also involve application of test to feel real time scenarios.

Declarations

Conflict of interest There are no conflicts of interests associated with this study.

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