A novel framework for quality of service aware vertical handover process in heterogeneous wireless networks

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Abstract. The evolution of wireless communication technology and the growing number of mobile users with various applications together have formed a heterogeneous environment of wireless communication networks with real-time availability and high bandwidth preferences. Everyone in the world wants consistent mobility to connect seamlessly to the best available network anytime and anywhere. Therefore, an efficient and Quality of Service (QoS) aware Vertical Handover (VHO) techniques are needed when the mobile connections have to switch from one network to another network to provide effective mobility performance, seamless connectivity, and high availability of connections. Applying efficient VHO process in a heterogeneous wireless network is still a big topic of interest in research field. It has been observed that existing handover techniques are not much capable of providing user preference and QoS aware mobile communication and network selection process. This problem incorporates various unwanted factors such as communication delay, inconsistent mobility, security towards the communication process. This paper discusses various existing research works that have been carried out to improve the VHO process to boost overall communication performance and to raise QoS of wireless mobile communications in the heterogeneous networks.

Keywords: wireless communication, vertical handover, heterogeneous networks, quality of service.
1. Introduction
The importance of handover mechanism cannot be ignored in modern-days telecommunication system. The first importance of handover process is its extensibility of the network by ensuring that there should be no call drop when a mobile user (on call) is migrating from one network region to another. The second importance of the handover process is that it can divert the traffic from bottleneck region to idle region and thereby utilizes the channel capacity in more efficient way [1]. It is because of the reason that there are good possibilities of overlapping of signals of mobile users if they are present in massive number in one cell. Hence in such condition, handover process can transfer the communication to different cell and thereby make good utilization of the channel capacity of cell [2].

1.1. Classification of VHO techniques
VHO techniques has been classified into various based on the different factors [3-4].

1.1.1 Directional factor-based
Upward VHO: In this, the Mobile node (MN) switches from a lower radio network cell with higher bandwidth to a higher radio network cell with lower bandwidth. For example, network connectivity changes from Wi-Fi to Wi-Max. i.e. smaller to bigger coverage.
Downward VHO: In this, MNs switches from a higher radio network cell with lower bandwidth to a lower radio network cell with higher bandwidth. For example, network connectivity changes from Wi-Fi to Bluetooth networks. i.e. bigger to smaller coverage.

1.1.2. Process-based
Hard VHO: In this, MN disconnects from the current network before switching to the target network. i.e. break before make.
Soft VHO: In this, MN stays connected to the current network unless it is fully connected with the target network. i.e. make before break.

1.1.3. Parametric decision based
Imperative VHO: In this, Received Signal Strength (RSS) decides the VHO mechanism-based on the RSS value. When the value of RSS decreases from the cutoff value, then the initialization of VHO occurs.
Alternative VHO: In this, VHO is initialized after analyzing various network parameters such as bandwidth and network cost.

1.1.4. Control process-based
Mobile Control: In this, VHO is decided or controlled according to the MN.

2. Related work
In the recent past various researchers have offered different solutions to enhance the handover procedure with improved security and efficiency. The research work carried out by Zeng etal.[5]hasaddressedthesecurityrequirementforthehandoverprocedure.Theyintroduceda signature-based authentication protocol. The experiments are conducted on the smart phone and a personal computer. The study outcomes show that the presented approach meets various security requirements and also gets user revocation property. However, this approach does not reflect on the case study of Energy-Efficient VHO which is also essential for investigation. Research work towards energy efficient offers better realization of the cost-effective handover process, and one of similar research work has been presented by Foukas et al. [6] where the authors have studied cost-benefit trade-offs related to small range cooperation. The study designed a model based on the mathematical process and concept of small-array cooperation between mobile nodes for capturing the average energy cost per handover.

Some other research progress has been also made to boost the efficiency of VHO decision algorithms to overcome service interruption and network delay problem [7]. The work carried out by
Abdullah et al. [8] has, offered multiple criteria based on an improved VHO decision technique in the heterogeneous wireless network. The presented technique composed of three network technology Long Term Evolution (LTE), Wi-Max, and WLAN with three VHO algorithms such as equal, mobile, and network priority. However, the analytical result shows that the presented technique outperforms traditional VHO decision techniques in term of handover number of probability and the failure probability. However, the above discusses work does not focused on the consistent mobility for seamless service availability in heterogeneous wireless networks. To ensure the administration progression and QoS factor, an analytical study is conducted, in which various QoS parameters are investigated [9]. Also, considering multiple criteria in heterogeneous environment networks the presented study has reviewed various Techniques for Order Preference by Similarly to Ideal Solution (TOPSIS) based network selection handover decision algorithms. Bhatia and Kumar [10] has presented a novel approach depended on multi-attributes decision making for selecting efficient network from the best available network for various Wireless Body Area Networks (WBAN). The numerical results demonstrate that the introduced system performs very effectively for selecting best available network during conflicts between QoS requirements of different WBAN applications.

Another work carried out by Salwe and Naik [11] attempts to promote faultless communication among the heterogeneous wireless network by introducing a futuristic VHO technique. The authors have considered Bluetooth and Wi-Fi networks for transmitting the data on ISM radio bands. The proposed work uses image data in the form of a discrete image in their simulation to examine the performance of the proposed VHO mechanism and to observe the transmitting factor of data. To enhance the mobility feature for good connectivity in the heterogeneous wireless network through handover technique Mahardhika et al. [12] have introduced an upgraded version of VHO decision-making system based on multi-criteria metrics. The author has incorporated multiple matrices such as RSS, traffic type, mobile speed and the network occupancy with three network interfaces that are WLAN, WCDMA, and Wi-Max. Also, the authors have utilized three priority based VHO decision making algorithm named as a mobile priority, equal priority, and network priority. The Experimental performances were carried on the MATLAB simulation where the overall outcomes demonstrate the efficiency of each introduced algorithm, i.e., the equal-priority algorithm obtains handoff value nearly 47%. Therefore, the mobile-priority technique achieves an improvement of handoff value nearly 91% and balance index is found to be 0.09%. Moreover, the results of network-priority technique improve the handoff decision with nearby 85%, balance index up to 180.3% and also achieved 20.23% mean blocking probability rate. Therefore, it seems the proposed method is found to be better when compared to the similar existing system.

The study conducted by Rajule and Ambudkar [13] aims to provide an efficient solution to enhance end-to-end QoS of handoff functionality and to reduce the call-drop probability of wireless network in the heterogeneous environment. Markov Decision mechanism is considered for facilitating user's requirement according to their specification preferences. Also, the authors have assumed the heterogeneous system with various integrated networks such as GSM, UMTS, Wi-Fi, LTE and Wi-Max with considering delay factors as its primary factor during handoff to select the network. Various datasets are used in the simulation where the network selections are performed during audio and video call in both real and non-real-time where it is found that for voice call GSM, LTE and UMTS showing maximum returns and UMTS is selected with less delay rate. Similarly, for video call, UMTS is selected with higher bandwidth. The study results that the presented approach improves the QoS in respect of reduced delay and better connectivity and coverage. The work of Ali and Saquib [14] focuses on upgrading seamless connectivity and improving the quality of heterogeneous networks for real-time applications. The authors have constructed an advanced analytical framework to investigate the performance of VHO algorithms for analyzing packet-loss rate in the interoperable environments. Some block-wise patterns used to optimize the computational burden of the presented framework. The authors have also set some criteria for a call drop in respect of data-loss pattern. The Numerical tests are performed based on various parameters, and the experimental results are carried on Monte Carlo simulations and compared to know the varying rate of call drop probabilities, handoff thresholds and
efficiency of WLAN usage where it shows that data-loss pattern dependent algorithm performs better for real-time connections.

Many times, VHO mechanism are affected by the dynamic environmental changes, to solve the problem associated with environmental changes the study of Guo and Li [15] introduces adaptive method constructed on Hierarchy Process in order to provide better handoff decision making. The presented method allows handoff decision making process by adjusting the weight function of various parameters such as cost, energy utilization, RSS, security and signal delay interval. For the simulation purpose, authors have considered the heterogeneous environment of WLAN and UMTS network model. The performance parameter of the proposed algorithm is constructed by analyzing various cost function and after it is compared with the existing VHO algorithms. The outcomes of the study exhibit that the proposed method effectively optimizes the handover problem and reduces interval handover delay with reflecting user experience. In order to provide efficient QoS for good connectivity among the different technologies, it is very necessary to reduce the delay of the VH with on hand availability of choices of Mobile Terminals (MT). Imad et al. [16] have tried to achieve the significant QoS by presenting an ant colony based efficient VHO decision-making scheme. The prime objective of this study is to provide support to mobile terminals that it could able to maintain their archive database according to quality wise available network. The proposed scheme optimizes the cost metrics such as RSS, service cost, bandwidth, power utilization, etc. for making better decision making through VH algorithm. For the performance evaluation of presented scheme both numerical and simulation analysis is carried emphatically. The simulation of tests of experiments are carried on the MATLAB tool where it shows the proposed algorithm efficiently optimizes the cost matrices and meets the users QoS requirement, and it also enhances the overall performance functionality of network of network system by lowering the handoff missteps probability and discard unwanted handoff by 95%.

The practice of Kalpana Shanmugam [17] has offered Fuzzy logic-based Handoff management scheme for selecting a suitable candidate network. The advantage of the proposed solution is that it provides good switching functions with network selection when the network is subject to QoS degradation, channel unavailability, and weak RSS. The study outcome expressed that the introduced scheme focuses on promoting more resource utilization to ensure a higher success rate of connections and a lower rate of call blocking and dropping. The study of Tian et al. [18], [23] has used bio-heuristic based selection model for handover decisions for the heterogeneous network in dynamic surroundings. The prime objective of the introduced work is to ensure QoS handover solution for selecting the most suitable network that best satisfies the QoS as per specified user requirements. Through the experimental analysis, the outcome of suggested model illustrates better handoff adoption to the changing heterogeneous wireless environment and has gained better performance than the traditional schemes [24][25].

An energy efficient interface switching module for VHO is presented by Bastos et al. [19] in which they address the contribution of the IEEE 802.21 standards to optimize the cost of handoff between the dynamic network technologies such as Wi-Max, UMTS, and Wi-Fi[26]. The authors have performed the comparative analysis of the different network interfaces considering energy utilization and the mobility features of the MN. LTE networks provide higher data rates service have proven to be advantageous over the previous versions of GSM cellular technologies. However, due to uneven traffic distribution, the local network congestion and resource waste problems raised which usually degrades the performance and quality of LTE networks. To tackle the significant issue, the study of Gao et al. [20] have introduced a load balancing mechanism based on handoff optimization to minimize the impact of ping-pong effect and to provide flexible mobility and efficient resource utilization property. Also, most of the work consideration is put towards cell-edge user’s selection for the efficient handover [21]. From the tested result the proposed algorithm is found to be feasible and it improves network throughput with an increment of 20% [22].

2.1. Summary of above discussed research works towards VHO
This section illustrates the summary of the above carried literature survey in tabular form. This table briefs the details of existing efforts have been made to improve VHO process for consistent mobility and seamless connectivity. The performance evaluation of discussed techniques is based on various parameters; some essential parameters are as delay, latency, cost, quality, energy, packet loss, call drop probability, call block probability, computational cost and etc.

Table 1. Summary of existing research works

| Authors               | Problems Focused                         | Technique                                      | Performance Parameters                                      |
|-----------------------|------------------------------------------|-----------------------------------------------|-------------------------------------------------------------|
| Zeng etal.[5]         | Security                                 | Signature based authentication                | Anonymity, computational complexity, delay, authentication latency |
| Foukas etal[6]        | Energy utilization                       | Mathematical operation and small-array        | Link quality, energy, cost, availability of n/w resources         |
| Abdullah et al. [8]   | Service interruption and networkdelay    | Multiple criteria based an improved VHO decision technique | Probability of handoff failover and number of handoffs         |
| Bhatia and Kumar [10] | Network selection                        | Multi-attributes decision making VHO mechanism | Network selection ranking and data traffics                    |
| Salwe and Naik [11]   | Inconsistent communication               | RSS based switching mechanism                | Delay and time                                                |
| Mahardhika et al. [12]| Mobility                                 | Multi criteria metrics based VHO algorithm   | Balance index, Handoff Number and blocking probability average |
| Rajule and Ambudkar[13]| Qos and call-drop probability            | Markov decision mechanism                    | Delay, call drop probability                                 |
| Ali and Saquib[14]    | QoS and Connectivity                     | Analytical framework using block wise pattern | Delay, call drop probability, velocity                       |
| Guo and Li[15]        | Handoff decision                         | Adaptive method using weight function         | Cost, energy utilization, RSS, delay                          |
| Fachtali etal.[16]    | QoS                                      | Ant colony optimization                      | RSS, service cost, bandwidth, power utilization               |
| Sunisakunarak [17]    | Mobility, connectivity and QoS           | Neural network technique                     | Handoff overhead, call dropping and delay                     |
| Tian etal.[18]        | QoShandover                              | Bio-heuristic selection model                 | Bandwidth, delay and packet loss ratio                        |
| Bastos etal.[19]      | Cost                                     | Comparative analysis                         | Energy consumption                                           |
| Gao etal.[20]         | Ping-pong effect                         | Load balancing mechanism                     | Transmit resource scheduling, system bandwidth, fast fading   |
3. Proposed methodology

After reviewing various existing approaches in the literature review, it is found that there are various unsolved issues associated with the handover mechanism system especially in vertical handover system. It was found that existing issues towards seamless mobility was not totally addressed and they were only symptomatic. Researchers have used different forms of approaches and techniques towards ensuring there are reduced call drops during vertical handover system but they did that without considering heterogeneity among the networking and communication devices. Apart from this, it was also found that there are less emphasis to the faster processing and computation process, which is one of the essential performance parameter during vertical handover process. Apart from this, it was also found that there is quite a less memory management effectiveness in existing studies.

![Diagram](image)

**Figure 1.** Proposed methodology for novel framework of vertical handover process

The development of the proposed work emphasizes on offering a novel framework of vertical handover process in wireless heterogeneous network. As the proposed system targets to address all the identified problems associated with vertical handover, hence the design methodology adopts a standard
analytical approach in order to incorporate perfectness in modeling. In order to address the identified problem, the proposed methodology adopts modular implementation approach using sequential stages of implementation. Figure 3.1 highlights the blue-print of the proposed methodology implemented for proposed system. This paper discusses about stage 1 implementation and its results analysis. The brief discussion of the proposed methodology stage 1 is as follows:

3.1 Objectives of proposed methodology
The proposed methodology aims for developing a novel framework that assists in an efficient vertical handover mechanism to offer seamless communication. The term efficient will mean that proposed vertical handover mechanism should offer faster authentication, lightweight encryption, and efficient resource management with good QoS. In order to accomplish the above mentioned, the following objectives were set:

- To develop a novel framework for addressing the latency problem during authentication process in vertical handover mechanism.
- To present a unique modeling of resource identification for controlling a dynamic traffic management during vertical handover.
- To develop an optimization mechanism for further leveraging the seamless vertical handover mechanism to facilitate vertical handover.

3.2 Framework for minimizing latency during VHO
This is the first implementation phase of the proposed work where the problems associated with authentication delays over vertical handover are addressed. The complete process of reducing authentication latency takes place by three simple steps. These are i) Performing user authentication in home network ii) Setting up dedicated session between the network and user equipment iii) Carrying out vertical handover. This network model consists of correspondent node connected to various network terminals using internet as well as a novel platform. The heterogeneous network is formulated using UMTS, Wi-Fi, and Wi-Max. The prime intention of this phase implementation is solely to minimize delay for faster and effective vertical handover.

3.2.1 Algorithms implementation
The primary goal of the proposed system at stage 1 is to design a simple authentication vertical handover mechanism by considering three major components i.e. i) User node (µ), ii) Network (η), and iii) UNI-MOB (ϕ). Based on these components performance, have designing the three distinct algorithms such as i) Algorithm for user device authentication in home area network, ii) Algorithm for establishing communication session between user device and the network, and iii) Algorithm for successful vertical handover operation. The design and detail description about all three algorithms is as follows;

Algorithm for user device authentication in home area network
Input: µ, n, ϕ, α
Output: Successful authentication of u
Start
µ → regReq(n)
n → regMsg → ϕ
ϕ → (h(α)) → µ
End
From the implementation of this algorithm, system ensures the legitimacy of participating node in the handover process. The algorithmic steps of user device authentication process are given as follows;

Algorithm for establishing communication link between user’s node and network
Input: $l_1, l_2, l_3, t_1, t_2, t_3, t_4, Y_{th}$
Output: Successful or unsuccessful handover operation

Start
Init $l_1, l_2, l_3, t_1, t_2, t_3, t_4, Y_{th}$
Compute $l_4 = \sum_{i=1}^{2} l_i$
Compute $l_5 = 2l_4 + l_3$
Compute $Y = l_5 + \sum_{i=1}^{4} t_i$

If $Y < Y_{th}$
   Flag successful handover
Else
   Flag unsuccessful handover
End

End

Algorithm for successful vertical handover operation

Input: $\alpha$
Output: Communication link establishment

Start
For $n = 1 : n_{\max}$
\[ \mu : h(\alpha, t) = \alpha_1 \]
\[ \mu (\alpha_1) \xrightarrow{n} n \rightarrow (\alpha_1^n) \rightarrow \omega \]
\[ \omega(h(\alpha_1^n)) \rightarrow \alpha_2 \]
   If $\alpha_1 = \alpha_2$
   \[ \Omega(\alpha_2) \rightarrow n \]
   link($n, \mu$)
   Else Abort
End
End

4. Result analysis
The experimental analysis of the proposed system is carried out in JAVA environment by considering 500 no. of mobile nodes with 200m of transmission range with the speed of 1 to 10 meter per sec. All the network equipment’s are placed over the simulation area with 3min of communication link establishment time. The simulation results of the proposed system are compared with prior study of Gamalet.al with respect to data-loss, delay, handover failure, and effect of attack.

4.1. Comparative analysis of handover delay and transmission speed.

![Graph showing delay vs speed for different scenarios](image-url)
The above figure 2 represents the security performance with minimum delay as compared with existing work. From the above graph can notice that proposed system provides lightweight hashing operation as faster authentication has not negatively affected the proposed handover mechanism. Similarly, the increasing the speed range does not effect on the delay in a very large extent. The existing approach provided the predictive method with iterative process of distinct attributes to achieve good results in the selection suitable network. Additionally, the below table 2, provides numerical results which represents the effective performance in handover delay as compared to existing work.

| Technique                  | Handover Delay (msec) |
|----------------------------|-----------------------|
| Proposed Technique (With-Security) | 2.8 2.9 4 |
| Proposed Technique (Without-Security) | 3 3 4.5 |
| Gamal Work                 | 5 4.8 6 |

4.2. Comparison results of packet loss and speed

The simulation results of proposed VHO scheme, percentage of packet loss w.r.t speed (m/s) are analyzed. The figure 3, represents the comparative analysis among proposed vertical handover mechanism with existing with respect to packet loss vs. transmission speed (m/s). From the simulation results can says that, the proposed VHO algorithm provides a high security with minimum packet loss as comparing with existing system.

Figure 3. Comparative analysis between proposed methods w.r.t packet loss and speed (m/s)

Figure 3. Comparative Analysis between Proposed Methods w.r.t Packet Loss and Speed (m/s). The existing work is a predictive approach which is quit better in time consumption where the proposed mechanism reduces the variable values with two significant parameters i.e. time period and latency for that reason the simulation process takes very less computation time in faster
authentication with minimum packet loss. Also increases the mobility rate of the user device. The following table 3 shows the performance analysis of % of packet loss for distinct speed and from these numerical results can conclude that the proposed VHO algorithm provides higher security as compared to existing technique.

| Technique                          | % of Packet-loss |
|------------------------------------|------------------|
|                                    | 5                |
|                                    | 6                |
|                                    | 8                |
| Proposed technique (with-Security) | 5                |
|                                    | 8                |
|                                    | 15               |
| Proposed technique (without-Security) | 10               |
|                                    | 15               |
|                                    | 18               |
| Gamal work                         | 10               |
|                                    | 15               |
|                                    | 24               |

4.3. Comparative analysis of handover failure w.r.t speed

The graphical representation of handover failure rate is shown in the below figure 4.

![Figure 4](image-url)  
**Figure 4.** Percentage of handover failure with varying speed of mobile nodes (MS)

The proposed system evaluated the percentage of handover failure by different speed of network equipment’s. It highlights the inclusion of security rate in terms of decreasing rate of handover failure. As compared to Gamal work, the proposed system has 40% improvement in the reduction of handover failure also improves the performance accuracy up to 20% with respect to faster authentication. Even though, there is more availability in handover failure due to several factor occurrences for example increasing the rate of user mobility which effects on handover operation. But proposed system capable to reduce the percentage of handover failure with high rate of user mobility and shows the good results as compared to existing experiment. The numerical analysis of proposed system performance is giving in the below table 4.
Table 4. Performance analysis of percentage of handover failure w.r.t speed (m/sec)

| Technique                          | % of Handover Failure |
|------------------------------------|-----------------------|
|                                    | 5                     | 6                     | 9.5                    |
| Proposed technique (with-Security) | 3                     | 5                     | 8.5                    |
| Proposed technique (without-Security) | 5.5                  | 6.5                   | 12                    |
| Gamal work                         | 6.5                   | 10                    | 13                    |

5. Validation mechanism
As the proposed system implements an analytical modeling for offering better vertical handover performance, it is necessary that it should exhibit the standard characteristics to prove it. The study outcome of proposed system is evaluated with respect to delay, percentage of packet loss, percentage of handover failure rate, percentage of effect of attack, throughput, queue length, fairness index, processing time (encryption time, decryption time). All these performance parameters are used for assessing the vertical handover performance over heterogeneous networks. The effectiveness of the proposed system is checked by comparing the existing system with the proposed system with respect to the above mentioned performance parameters using different forms of test scenario.

6. Conclusion
This proposed mechanism improved the faster authentication with successful vertical handover operation where lightweight hashing operation is performed for security instead of complex cryptographic method. Another contribution of the proposed system contains an external agent (i.e. UNI-MOB) which handled the network resources associated with other forms of networks. Therefore, from the simulation study can conclude that proposed vertical handover mechanism provides higher accuracy in the reduction of data loss along with minimum latency by comparing with other predictive mechanisms.

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