# A Survey on Handover Algorithms in Heterogeneous Wireless Network

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**Abstract.** The next generation of wireless network consists of many overlaying integrated networks which know as heterogenous network in which mobile node will be on mobility between/within these networks. During mobility of node, the ongoing call of mobile node should be transferred between/within these seamless networks. The transfer of mobile node between/within network can be done using handover algorithms. Most of the handover algorithms designed for heterogeneous wireless network are mainly based on parameters such as signal strength, SIR, distance, velocity, direction, and power consumption. For an effective handover, different approaches have been proposed. These approaches have their own advantages and disadvantages, and each of them performs better than the others under certain circumstances. The chapter classifies and discuss the different approaches for designing of vertical handoff mechanism.

**Keywords:** Handover · Signal · Base station (BS) · Mobile station (MS) · Receiving signal strength (RSS) · QoS

## 1 Introduction

One of the main objectives of handovers in a wireless network is to provide uninterrupted connectivity between users and the radio access network while they move across cell boundaries within/between network. Efficient handover algorithms should be designed to preserve capacity and enhance quality of service (QoS) of communication systems in a cost-effective manner [15]. There are researches working on developing efficient handover algorithms. For example, the occurrence of a handover can be attributed to several factors, which could be related to radio link quality, network management, and service options [19]. While radio link quality related handovers occur frequently and are most difficult to handle, network management and service option related handovers usually occur infrequently and are easy to handle [16]. There are different kind of algorithms to handle these handovers which are classified depending on different parameter as shown in Fig. 1 are discussed in this chapter. The chapter is organized as follows: Sect. 1 introduces handover algorithm, and Sect. 2 explains the process and phases involved in handover execution. Section 3 categorizes handover algorithm into six different categories and gives the overview of different handover algorithms. In Section 4, we have discussed benefits and drawbacks of different handover algorithms, and Sect. 5 is conclusion and future scope to work.


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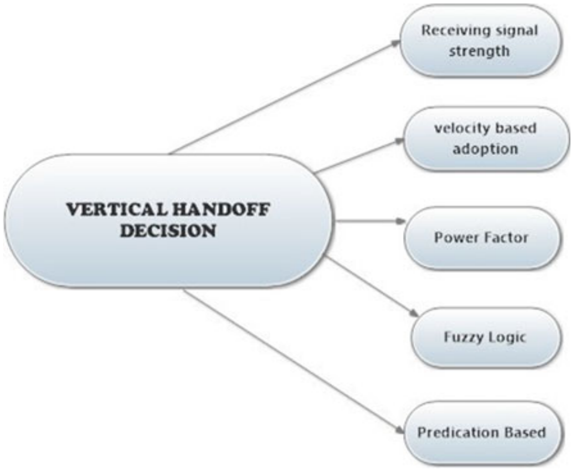


**Fig. 1.** Vertical handoff parameters

## 2 Execution of Vertical Handover Mechanism

To achieve seamless mobility for a mobile node during mobility between/within the network in heterogenous network, the handoff algorithm should be designed such that the handover process executes without any interruption of ongoing call of user. Handover executes in the three phases as shown in Fig. 2.

**Phase 1** **Network discovery**: The mobile node needs to discover new available network for providing service. If mobile node does not satisfy with existing connected network with parameter defined for QoS, then mobile node needs to search the new network available for services.

**Phase 2** **Handover decisions**: Depending on the parameters received in network discovery and required parameter defined in the handover algorithm, the decision of handover execution needs to be taken in this phase. Handover decision can be implemented on network side or at mobile node. If handover decision is executed at the network side considering all the parameter received during network discovery, then it is referred as network controlled vertical handover (NCVHO), and if decision of handover is taken at mobile node, it is called as mobile-controlled vertical handover (MCVHO).

**Phase 3** **Handover execution**: in Phase 3, the execution of phase 2 is done. In this phase, the handover execution of mobile node, i.e., the ongoing call of mobile node is transmitted to new network. Execution of handoff can be done in two method, soft handover and hard handover. In soft handover, the new link with the new network is established, and then, the earlier networks are terminated, i.e., connect and break, whereas in hard handoff, the existing link of network is terminated, and then new link is established, i.e., break before make.

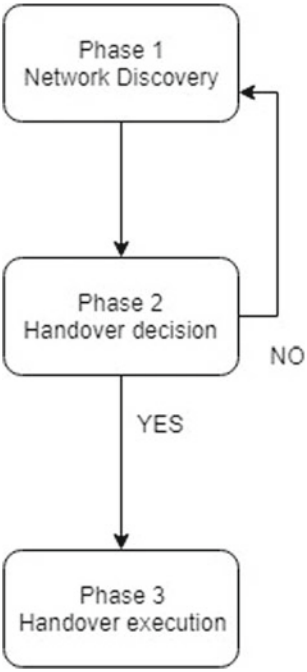


**Fig. 2.** Handover execution phases

## 3 Vertical Handover Algorithms

Handover algorithm in wireless network are classified depending on different parameter used by mobile node for execution of handover such as mobile node receiving signal strength [RSS], available quality of service (QoS), and velocity of mobile node, and depending on such parameter handover algorthims are classified as follows,

### 3.1 Signal Strength-Based Handover Algorithm

Signal strength-based algorithms are designed depending on receiving signal strength [RSS] of mobile node. According to the RSS criterion [1], an MS is connected with a BS from which it receives the highest signal strength. This algorithm allows the MS to be attached with the BS with the strongest signal. The disadvantage of this algorithm is that the signal strength may vary because of shadowing and propagation characteristics such as shadowing and refraction which can cause frequent handovers. Another disadvantage is that the MS may continue to stay connected to the current BS, until it receives good signal strength from other base stations even if it has crossed the designed cell boundaries. This will lead to difficulties in maintaining physically planned cell boundaries and load balance across the cells. The addition of hysteresis as an additional criterion will help to overcome these disadvantages. Although hysteresis helps in preventing frequent unnecessary handovers, it does not help in reducing call dropping as it introduces delay in necessary handover [2]. A balance between the number of handovers and delay in handover should be achieved by averaging signal strength and taking the appropriate hysteresis. By introducing hysteresis, if the RSS of any other BS exceeds the RSS of the current BS, then a handover is performed to the new BS. This can cause ping pong effect [2]. To avoid this, a handover margin is set. The North American personal communication systems (PACS) and personal communication service (PCS) standards combine hysteresis with dwell timer [3] to decrease total number of handovers. In the absolute signal strength algorithm, a handover is requested when the RSS drops below the threshold of 100 dBm for a noise limited system and 95 dBm for an interference limited system [5]. The handover threshold can be varied to achieve better performance. The handover threshold can also be determined dynamically by the mobile velocity and path loss slope. This will help completing a handover successfully and avoid unnecessary handover. However, this algorithm has several serious disadvantages. BS increases transmission power to cope with high interference. If the RSS is very high because of high interference, then a handover will not take place, although ideally, a handover is desirable to avoid interference. If the RSS is low, a handover will take place even if the voice quality is good, although ideally, a handover is not required. In such cases, the supervisory audio tone (SAT) information is used along with the RSS by some systems to avoid unnecessary handover [4]. Some of the findings reported in reference [6] with respect to this algorithm are (1) the probability of not finding a handover candidate channel decreases as the overlap region increases, (2) the probability of not finding a handover candidate increases as the handover threshold increases, (3) the probability of a late handover (handover occurred after the optimum time of handover) decreases as the handover threshold increases, (4) the probability of unnecessary handover, i.e., the ping pong effect, increases as the handover threshold increases, and the probability of unnecessary handover decreases as the hysteresis increases. In [17], author has derived a mathematical model for vertical handoff between WLAN and cellular network. The model takes the handover decision based on RSS in this model, and the handover decision was executed based on probability of handoff [21]. It is observed that handover failure probability increases when either velocity or handover signaling delay upsurges the fixed value of the RSS.

### 3.2 Velocity-Based Adaptive Handover Algorithms

Velocity-based adaptive handover algorithm helps in handling handover for users with different speeds. When users are moving at different speed, their handovers should also be performed in different time. A handover request from fast moving node must be processed quickly, and this can be done using a handover algorithm with short temporal averaging window. However, if the length of the average window is kept constant, optimal handover performance will be obtained only at a speed. Velocity-adaptive handover algorithm provides a good performance for an MS with different velocities by adjusting the effective length of the averaging window [5]. This algorithm can also serve as an alternative to the umbrella cell [5] approach for tackling high speed users if low network delay can be achieved. As the umbrella cell requires extra infrastructure, this alternative approach can lead to savings in terms of infrastructure cost. One of the velocity estimation techniques uses the level crossing rate (LCR) of which the threshold level should be set as the average value of the Rayleigh distribution of the RSS [6], requiring special equipment to detect the propagation-dependent average receiver power. Kawabata [6] proposes a method of velocity proportionality to the Doppler frequency. The velocity estimation technique exploits the method of diversity reception. If an MS is using selection diversity, this method requires no special equipment. The characteristics of a velocity-adaptive handover algorithm for microcellular systems are presented in reference [6]. Three methods for velocity estimation are analyzed: the LCR method, zero crossing rate method, and covariance approximation method. It is found that the spatial averaging distance that is required to sufficiently reduce the effects of fading depends on the environment. This algorithm can adapt the temporal averaging window (a window with a certain time length) used to take samples of RSS value. The window can be adapted either by keeping the sampling period of LCR constant and adjusting the number of samples per window or vice versa.

### 3.3 Minimum Power-Based Handover Algorithm

Power optimization in handover is important task, so while designing a handoff algorithm, power consumption need to be considered. In [18], the vertical handoff decision by management strongly affects the behavior of mobile terminal in terms of battery consumption, and the authors have compared the battery consumption of mobile node in WIFI and LTE which resulted LTE consumes less battery compared to WIFI; if mobile tries to be stay connected in LTE network, then mobile battery can be efficiently used for longer period [7]. Vertical handover scheme is to minimize the total power consumption required in serving a traffic flow, while guaranteeing a service rate of different access networks. Based on a Markov decision process (MDP), it uniquely captures the power consumption during the vertical handover execution as well as the transmission power and circuit power. In [8], author proposes an optimized vertical handoff algorithm based on Markov process in vehicle heterogeneous network. In this algorithm, it considers that the status transformation of available network will affect the quality of service (QoS) of vehicle terminal's communication service. Markov process is used to predict the transformation of wireless network's status after the decision via transition probability. In [22], the author proposes the scheme in which the performance was superior in the context of energy consumption, handover delay and time, throughput, and average stay time in a network.

### 3.4 Dynamic Programming-Based Handover Algorithm

A dynamic programming-based handover algorithm provides systematic solution to the handover problem. However, the efficiency of the handover algorithm depends on the model used. In [9], author investigates network selection and handoff decision with the goal of maximizing user QoS. An algorithm based on Q-learning is obtained that chooses the best network based not only on the current network state but also the potential future network and device states. The method does not require the knowledge of the statistics of the wireless environment but learns an optimum policy by utilizing the mobile device's experience. It is shown that the QoS results of the proposed dynamic handoff decision (DHD) algorithm come very close to the performance of an optimum oracle algorithm. Zhang et al. [10] proposes a vertical handoff decision algorithm based also on dynamic programming is presented, and the model considers the user's location and mobility information but assumes that there is no constraint on the user's total budget for each connection.

### 3.5 Prediction-Based Handover Algorithm

Prediction-based handover algorithm is proposed in chapter [11], for seamless mobility-based wireless networks. That is, scheme incorporates fuzzy logic with AP prediction process in order to lend cognitive capability to handover decision making. Selection metrics, including received signal streth, mobile node relative direction toward the access points in the vicinity, and access point load are collected and considered inputs of the fuzzy decision-making system in order to select the best preferable AP around WLANs. Adjustable weight vector concept for input metrics is proposed in order to cope with the continuous, unpredictable variation in their membership degrees. In [12], a prediction-based handover model is for multiclass traffic in wireless mobile networks by using software agents. The local and global handoff decisions are made by agent in mobile node based on speed of mobile node, i.e., for high speeds, global handoff is executed. The predictions are based upon the speed and moving direction of the mobile node. The scheme predicts location and provides necessary information for advance bandwidth (resource) reservation and optimal route establishment.

### 3.6 Fuzzy Handover Algorithm

Fuzzy logic-based algorithm is proposed in Ref. [13], and QoS-aware fuzzy rule-based vertical handoff mechanism makes a multi-criteria-based decision and is found to be effective for meeting the requirements of different applications in a heterogeneous networking environment. The QoS parameters considered are available bandwidth, end-to-end delay, jitter, and bit error rate. A new evaluation model is proposed using a non-birth–death Markov chain, in which the states correspond to the available networks. This algorithm uses fuzzy logic to make handover decision. The complexities involved in this handover criterion are tackled. The algorithm performs better than the traditional signal strength-based algorithm. It weighs different parameters according to the needs of the network. The algorithm is also capable of handling heavy fading. In [14], an adaptive fuzzy logic-based handoff decision algorithm is introduced for wireless heterogeneous networks. The parameters data rate, monetary cost, RSS, and mobile speed are considered as inputs of the proposed fuzzy-based system. According to these parameters, an output value, which varies between one and ten, is produced. This output describes the candidacy level of the available access points in the vicinity of smart terminal and is utilized in the access point selection algorithm [16]. This algorithm decides whether a handoff is necessary or not, by using the handoff resolution value. In [20], it is important to extend battery and save energy without abrupting the ongoing call or services, and even with reduced QoS, the author have designed a fuzzy rule to support an energy-efficient approach with less QoS.

## 4 Comparison of Handover Algorithms

As discussed in Sect. 2, handover algorithms can be designed by considering different parameters, and these handover algorithms have their own features and drawbacks as summarized in Table 1.

**Table 1.** Features and drawbacks of different handover algorithms

| Algorithm | Features | Drawbacks |
|---|---|---|
| Signal strength based | • Less handover failure<br>• Unnecessary handover is avoided<br>• Best suitable for location stable mobile nodes | • Extra handover delay<br>• The signal strength may vary because of shadowing and propagation which can results in frequent handovers |
| Velocity adaptive based | • Predication of handover can be done depending on velocity of mobile node<br>• More suitable for mobile node moving with high velocity or speed between/within cells | • More number of handover failure due to packet loss<br>• Extra overhead involved in calculating the velocity of mobile node<br>• Velocity may not be constant due which predication of handover may fail |
| Power consumption based | • Mobile stays for longer period in the network which consumes less power<br>• Battery life of mobile node will be increased | • High-speed networks like WLAN generally consumes more power, which may result into mobile node may never handover/get connected to high-speed network |
| Dynamic programming based | • Many parameters are considered and divided to take decision of handover<br>• Speed of handoff decision and reduced handover delay | • No general formation of dynamic program is available<br>• Increased complexity in designing of handover algorithm |
| Prediction-based handover | • Predication of handover was made on available history of mobile node<br>• Less handover delay and better packet delivery ratio | • Predication-based handover involves more complexity<br>• More signaling is involved for collection of parameters and predication |
| Fuzzy handover | • Algorithms are more customizable, reliable, and more accurate<br>• Consumes low power<br>• Easy transfer of ongoing call | • Low speed and increased handover delay<br>• For more accuracy, requires fuzzier grade which results in increase in complexity and rules |

## 5 Conclusion and Future Work

In this chapter, we have given an overview of vertical handover mechanism in heterogenous wireless network, and the focus and attention are given on existing handover algorithm proposed by different authors which we have broadly classified into six categories depending on the parameters and mechanism used in the handover execution algorithms. The features and drawbacks of each category of handover algorithms are discussed in detail. Depending on the drawback and benefit, a best algorithm with QoS can be designed for seamless transfer of ongoing call in the next generations heterogenous network.

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