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Study of multiple parameter algorithm for wrong decisions in vertical handovers in wireless heterogeneous networks

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ABSTRACT

One of the most important and challenging problems for seamless access of wireless and mobile services is mobility management, which will be regardless of the services and networks. Mobility management enables the Mobile (MT) to switch between networks for better resource management and is still a hot research topic. With so many handover algorithms available, how to evaluate and select the best algorithm becomes critical, thus making handover algorithms one of the essential components for the successful implementation of mobility. These algorithms need to be designed to provide the required Quality of Service (QoS) over a wide range of applications. This work is based on new criterion called Wrong Decision Probability (WDP) which is used to evaluate the performance of vertical handover algorithms and is based on signal strength (SS) and the available bandwidth (BW), which are combined together to obtain a better decision for handover. This paper proposes a new user centric algorithm for vertical handovers, which minimizes the wrong decisions during a handover process and maximize the user throughput by taking into account Bandwidth and Signal Strength of the network.

Introduction

The wireless industry has evolved rapidly, moving from the simple voice and text messaging to the next generation of services, devices and applications. Services, whether voice, data or multimedia at high reliable speeds have become the norm and users' expectations on these services are higher than ever before. While most new individual wireless technologies are capable of providing these services, the scarce and expensive frequency spectrum forces network operators to rely on heterogeneous wireless networks to satisfy the users' needs in different locations. Hence, the next generation wireless communications will likely rely on integrated networks consisting of multiple wireless technologies. With the rapid development of different wireless technologies and with the coexistence of these networks, the concept of vertical handovers was introduced and they tend to become a very important concept for the future wireless technologies, where an integration of these technologies offer Always Best Connected (ABC) advantage to the user [1]. ABC for a user, who wants to connect to a service, should be able to choose accesses and devices in a way that best suits his or her needs and to change when something better becomes available.

Handover is one of the most important techniques in wireless communication. It is a process where the user expects to continue the call without any disruption when he moves between networks. In such networks, efficient handover management is another primary area of concern for maintaining global mobility. While roaming, smooth handover is necessary for seamlessly maintaining the ongoing communication.

A homogeneous handover also called a horizontal handover is said to occur when the connection of the Mobile Terminal (MT) is transferred between two base stations using the same access technology for which signal strength is the commonmetric used to predict the continuity of connection by finding the best neighboring cell to associate to. Whereas a heterogeneous handover takes place between networks using different access technologies. In homogeneous networks, each MT is served by the signal with the strongest signal strength while the received signals from the others are treated as interference. In heterogeneous networks, such principles lead to sub-optimal performance. Hence in such systems, smarter resource co-ordination among base stations, better server selection strategy and more advanced techniques for efficient interference management can provide substantial gains in throughput and user experience.

Some of the parameters considered for handover are Bandwidth (BW), Signal Strength(SS), power level, user preference, network conditions, network connection time, Bit Error Rate(BER), Signal to Interference Ratio(SIR), distance, traffic, velocity, application types, cost etc. Though signal strength is the best parameter considered for triggering a handover in the case of horizontal handovers, this metric alone is not suitable and often not sufficient to trigger handover in case of vertical handovers as heterogeneous networks have different system characteristics, hence their performance cannot be simply compared using the signal strength of two networks. Parameters like Bandwidth, Signal strength, mobility, cost or a combination of these parameters can be considered for the efficient development of vertical handovers.

There is no single algorithm that offers low cost, high-speed, nearly universal coverage, and a high QoS, all at the same time that suits different needs of the user [2]. The algorithms can

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be broadly classified based on SS, BW, mobility, cost or also on a combination of some of these metrics. Also, the usage scenarios like handover delays, number of handovers, number of failed handovers due to incorrect decisions and the overall throughput of the call maintained over a typical mobility pattern can also be considered for the analysis of these handover algorithms.

Wrong decisions for handovers in wireless communication increases the computational load on the network, leads to increased call dropping and ping-pong effect thereby bringing in low network throughput. Hence the probability of the algorithm making a wrong decision for handover has to be minimized for which the effectiveness of the algorithm has to be determined. Most of the work done on vertical handovers consider the handover decision made by the algorithm as the right decision. An efficient algorithm should first check if the decision made by the algorithm for handover leads to a right decision. In this work, an effort has been made to develop an algorithm, in which a handover is performed only after determining if the handover does not lead to a wrong decision.

The effectiveness of the proposed algorithm is studied based on the analytical model developed. The triggering of the vertical handover process in this work is based on BW and Signal Strength and a combination of these two parameters. The number of Wrong decisions made during handover is measured using two performance metrics namely Unnecessary handover probability (UHP) and Missing Handover Probability (MHP). The paper is organized as follows: Section II presents the related work, Section III gives the analytical approach for calculating the WDP, simulation results are presented in Section IV. Finally conclusions and future work are presented in Section V.

Related work:

The growing demand for mobile broadband services is the catalyst for an ever-increasing variety of air interface technologies targeting local area to wide area connectivity. Mobile terminals have to accomplish vertical handovers among heterogeneous networks for the purpose of realizing seamless roaming and guaranteeing QoS. The handovers for heterogeneous networks should aim at overcoming the challenges of seamless network integration, efficient load management between networks, requiring no user intervention, saving battery life and selecting the lowest cost connection. Research activities carried out in heterogeneous handover context suggests the need for some modifications in the underlying network architectures. The most recognized among them is the Media Independent Handover (MIH) layer proposed by IEEE 802.21 working group [1]. Two standard drafts have been produced by the working group in 2005 and 2006, and many protocols and signaling have been proposed for the inter-network handover. In this work, the handover trigger mechanism, the effectiveness of the performance of the proposed algorithm and hence the reduction in wrong decisions for handover has been addressed. More research activity needs to be carried out for addressing the parameters that are best suited to be considered for reducing the wrong decisions in vertical handovers.

A survey of recent works on VHD algorithms is given in [3]. Various handover decision algorithms have been proposed in past few years. Traditional handover decision algorithms rely on SS and a handover is initiated when the SS is below a specific threshold. SS only indicates the usability of a network, and cannot give more details on a network such as the available bandwidth which is more meaningful for upper-layer applications. In [4], a decision to handover is taken by considering the performance of the entire system and is executed by selecting the best network based on the highest SS and lowest Variation of Received Signal Strength (VRSS). Though it ensures high system performance by reducing the unnecessary handovers, Bandwidth which is another critical parameter could have been considered for estimating the further reduction in unnecessary handovers. Nasser *et al*. have proposed a VHO scheme where the service quality of the networks are estimated and the network with the best quality is selected for handover. [6] proposes a generic vertical handover decision function (VHDF) by considering the different factors and metric qualities that give an indication of whether or not a handover is needed. The decision function assigns weights to different network parameters such as cost, quality of service, power requirements, personal preferences etc. In [7] a variable threshold which is obtained depending on the pilot strength received from the home base station is used for making a handover decision. The method proposed aims at reducing unnecessary idle handovers as the MT tracks the received signal with highest strength. [8] presents a Vertical handover decision (VHD) heuristic based on the WDP prediction. The WDP is calculated by combining the probability of unnecessary and missing handovers and the proposed algorithm shows an improvement in the performance of the handover algorithm by reducing the number of wrong decisions and improving the throughput. In this paper author considers Bandwidth as a handover metric for the evaluation of wrong decision probability which determines the performance of the proposed algorithm. Aghalya *et. al* [9] have proposed an efficient vertical handover decision (EVHD) algorithm to decide the best network interface and best moment to handover. An overall gain function has been utilized in this algorithm to make the right decision based on dynamic factors such as SS, Velocity and Position of the mobile terminal and the static factors like cost of each network. Most of the works have adopted the SS-based mechanism to determine handover thresholds, which causes a serious ping-pong effect that increases UHO [10]. Although integrating the SS-based mechanism with a hysteresis method reduces this, it suffers from high dropping and low utilization of the network resources. A better approach would be to integrate several parameters like BW, SS, mobility, power consumption etc in order to obtain better performance.WDP is a performance metric used to measure the accuracy of a handover algorithm which can be applied equally well for a homogeneous or a heterogeneous network. The probability of the algorithm making a wrong decision to handover has to be evaluated in order to determine the effectiveness of any algorithm. In this work, WDP has been used to measure the performance of a Bandwidth based, Signal Strength based and Bandwidth &Signal Strength based vertical handover algorithm. A conclusion has been drawn that making a handover decision considering the combination of Bandwidth and Signal Strength rather than Bandwidth alone reduces the probability of making wrong decisions thus enabling a better throughput.

Analytical approach:

Some of the performance metrics considered:

1.Handover Probability(HP): Handover Probability of the algorithm reflects the handover frequency of a MN. For handover algorithms with similar *WDP*, less Handover Probability reflects less network load introduced by handovers.

2.Unnecessary handover probability(UHP): Under a given input traffic condition, the probability of the mobile Terminal roaming into the other network for the condition that the observed parametric values are greater than current networks threshold but in the following *D* seconds they are not all greater than the network it was present initially making the handover performed an unnecessary one[11].

3.Missing handover probability (MHP): Under a given input traffic conditions, the probability of mobile Terminal not roaming into other network for the condition that the observed parametric values of the other network are smaller than the threshold value of the current network but in the following *D* seconds they are not all smaller than the network it was present initially. Hence on the assumption that the parametric values of the current network itself is sufficient to maintain a good quality link a handover to the other network with a better quality link has been missed[11].

4.Wrong Decision Probability (WDP): WDP is the sum of both MHP and UHP which indicates the accuracy of the handover algorithm. WDP=MHP+UHP. [8]

The probability of the algorithm making wrong decisions for handover has to be minimized for which the effectiveness of the algorithm has to be determined. For instance, to minimize the unnecessary handover, a MT tends to reduce handover times; while to reduce missing handovers, a MT tends to increase handover times. Considering only the minimization of unnecessary handover as a performance evaluation criterion is not reliable as a MT will be bias to not doing handover at all. In case only missing handover is considered as the criteria, then many handovers may occur which introduces high network load. This tradeoff between UHP and MHP could be solved by introducing WDP, where the two parameters are combined such that both have an impact on WDP. Optimal algorithms based on this parameter should be the algorithms not too conservative to trigger unnecessary handovers and not too sensitive to suffer handover flaps.

Multiple states Markov model is used to capture the process of MTs switching between different networks. In this work, three networks are considered which are represented by three state Markov model as shown in figure 1. This model is used to capture MT moving between different networks n_1, n_2 and n_3.

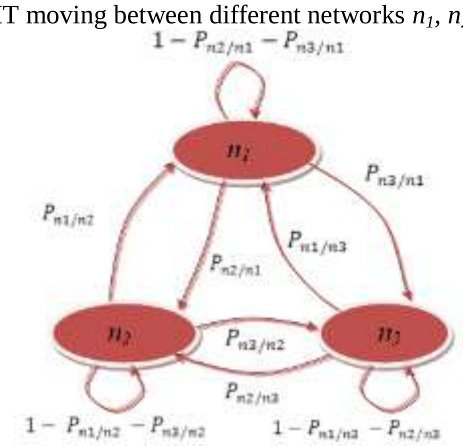

Figure 1: Three state Markov Model

In general Pn_j/Pn_i denotes the probability of mobile moving from network n_i to n_j; and Pn_i/n_i denotes the probability of mobile continuing to stay in n_i after a time interval *D*.

The probabilities that a MT stays at, n_1, n_2 and n_3 can be expressed as follows:

$$P_{n1} = \frac{P_{n1/n2} + P_{n1/n3}}{P_{n1/n2} + P_{n2/n1} + P_{n1/n3} + P_{n3/n1}} \quad (1)$$

$$P_{n2} = \frac{P_{n2/n1} + P_{n2/n3}}{P_{n1/n2} + P_{n2/n1} + P_{n2/n3} + P_{n3/n2}} \quad (2)\text{and}$$

$$P_{n3} = \frac{P_{n3/n1} + P_{n3/n2}}{P_{n1/n3} + P_{n3/n1} + P_{n2/n3} + P_{n3/n2}} \quad (3)$$

Handover probabilities for three network model is given by

$$HP = \frac{1}{3}\left\{ \begin{aligned} & P_{n1}\left(P_{n2/n1} + P_{n3/n1}\right) + P_{n2}\left(P_{n1/n2} + P_{n3/n2}\right) \\ & + P_{n3}\left(P_{n1/n3} + P_{n2/n3}\right) \end{aligned} \right\}$$

The three networks are represented by n_1, n_2 and n_3; and probabilities are defined as follows:

For a busy network with a large bandwidth, computing the probability of occupied bandwidth becomes computationally expensive. Hence the Sterling's approximation to compute the factorials of large numbers must be used, which is given by

$$n! = \sqrt{2\pi n}\left(\frac{n}{e}\right)^n$$

For an M/M/B process, the arrival rate of requests channels follows a Poisson's distribution with parameter λ_i and service rate given by

$$\Lambda_i = \lambda_i (B_i - k) / B_i$$

The WDP can be calculated [8] as

$$WDP = \sum_{i=1}^{N}\sum_{j=1}^{N} Pr\{\gamma_{nj/ni}\} + \sum_{i=1}^{N} Pr\{\theta_{ni}\}$$

where

$\gamma_{nj/ni}$ represents Unnecessary Handover when MT tends to move from network j to i,

θ_{ni} represents Missing Handover at network n_i and $i \neq j$.

The probability of occupied bandwidth is given by

$$\Pi_{i,k} = \frac{\rho_i^k}{k! \sum_{j=0}^{B_i} \frac{\rho_i^j}{j!}}$$

where ρ_i is the traffic load in channel *i*.

Bandwidth based algorithm:

In this algorithm, a mobile decides to move to another network when its available bandwidth in the new network is greater than by a threshold over the available bandwidth of current network. The value of the threshold can be zero or a positive integer. Following list of steps describe the algorithm designed in this work:

1. Assume that MT is in network n_1. If available bandwidth of network n_2 or n_3 is greater than n_1,it decides to move either to n_2 or n_3 depending on the threshold values of the networks.

2. Define the threshold value as *L* for each of the networks.

3.If the mobile is at n_1, then decision is made to switch over n_2 *when* $b2 - b1 \geq L$.

4. Else verify $b3 - b1 \geq L$ and switch over to n_3 *if* $b3 - b1 \geq L$ is true.

5.Else maintain the status quo.

Practically the available bandwidth of any network changes dynamically, and sometimes rapidly. For simulation purposes, the bandwidths of the networks are assumed to be static.

Hence,

$$P_{n2/n1} = P_r\,(b_2 - b_1 \geq L)$$
$$P_{n1/n2} = P_r\,(b_1 - b_2 \geq L)$$
$$P_{n3/n2} = P_r\,(b_3 - b_2 \geq L)$$
$$P_{n2/n3} = P_r\,(b_2 - b_3 \geq L)$$
$$P_{n3/n1} = P_r\,(b_3 - b_1 \geq L)$$
$$P_{n1/n3} = P_r\,(b_1 - b_3 \geq L)$$

where b_i is the available Bandwidth of the network for i=1, 2, 3, Pn_i/n_j is the probabilities of the networks for i=1,2,3 and for j= 1,2,3 and L is the predefined threshold value.

For BW based algorithm the decision making can be summarized in table 2 shown below. An entry of '1' means that the necessary condition is satisfied; else it is 0. For example, a 0 means that there is no bandwidth in the network represented by N_i while 1 means that there is a bandwidth available in the N_i so MT can be handed over to that network.

Bandwidth & SS Based Handover Algorithm:

In this algorithm, a MT decides to move to another network when its available bandwidth and signal strength in the new network is greater than by a threshold over the available bandwidth and signal strength of current network. However, the value of the threshold value can be zero or a positive integer. Following list of steps describe the algorithm:

1. Assume that MT is in network n_1,since available bandwidth and signal strength of network n_2 or n_3 is greater than n_1 , it decides to move either to n_2 or n_3 depending on the threshold values of the networks.
2. Define the threshold value as L for each of the networks.
3. If the mobile is at n_1, then decision is made to switch over to n_2 when $b2-b1 \geq L$ and $s2-s1 \geq 0$
4. Else verify $b3-b1 \geq L$ and $s3-s1 \geq 0$ and switch over to n_3 if $b3-b1 \geq L$ and $s3-s1 \geq 0$ is true.
5. Else maintain the status quo.

Practically the available bandwidth of any network changes dynamically, and sometimes rapidly but for simulation purpose the bandwidth is assumed to be static and the peak value of the signal strength over 500s is considered.

$$P_{n2/n1} = \Pr\{b2 - b1 \geq L\} \text{ and } \Pr\{s2 - s1 > 0\}$$
$$P_{n1/n2} = \Pr\{b1 - b2 \geq L\} \text{ and } \Pr\{s1 - s2 > 0\}$$
$$P_{n3/n2} = \Pr\{b3 - b2 \geq L\} \text{and } \Pr\{s3 - s2 > 0\}$$
$$P_{n2/n3} = \Pr\{b2 - b3 \geq L\} \text{ and } \Pr\{s2 - s3 > 0\}$$
$$P_{n3/n1} = \Pr\{b3 - b1 \geq L\} \text{ and } \Pr\{s3 - s1 > 0\}$$
$$P_{n1/n3} = \Pr\{b1 - b3 \geq L\} \text{ and } \Pr\{s1 - s3 > 0\}$$

where b_i is the available Bandwidth of the network for i=1, 2, 3, Pn_i/n_j is the probabilities of the networks for i=1,2,3 and for j= 1,2,3, L is the predefined threshold value, s_i is the signal strength of the network for i=1,2,3.

The peak of signal strength $s(t)$ is calculated as

$$s(t) = \rho(t) \bullet \cos(2.\pi.f_c.t + \theta(t))$$

Where ρ (t) is the amplitude of the signal which is taken to be equal to 1unit.

f_c is s the frequency of the signal, $\theta(t)$ is the phase of the signal, $\rho(t)$ and $\theta(t)$ are random variable whose values vary with time.

Probability of amplitude of signal strength is

$$\Pr(\rho) = \frac{\rho}{\sigma^2} e^{\frac{-\rho^2}{2\sigma^2}}$$

where, σ^2 represents the variance of ρ (t) which is the amplitude of received signal.

The amplitude of the received signal $\rho(t)$ is given by

$$\rho(t) = \sqrt{I^2(t) + Q^2(t)}$$

where $I(t)$ and $Q(t)$ are Inphase and Quadrature components.

For the above algorithm the decision making can be summarized as in table 3 shown below. An entry of '1' means that the required condition is satisfied; otherwise it is 0. For example, a 0 means that the link quality of the current network N_i in terms of bandwidth and signal strength is inferior, while 1 indicates that since the required conditions are satisfied, the MT stays back in its current network.

The parameters used in the simulation are as follows.

The site specific parameters are:

- Number of networks = 3.
- Number of Clusters in the system = 1

The parameters considered for bandwidth calculations:

- Initial traffic intensity = 1 user.
- Assumed number of channels per network = 21.
- Number of movements for each user from the current network =2
- Threshold , L is a parameter , default = 0

The parameters considered for signal strength calculations:

- Amplitude of the signal =1
- Signal variation is calculated over500 seconds
- probability of signal strength in candidate network being higher than in current network is 0.5

Simulation Results

The simulation is performed for both the algorithms considering 21 occupied channels. For BW and BW + SS based approach, the left side of plot of Y-axis and for SS approach, the right side of Y axis is considered. Reduction in wrong decisions for algorithm where both parameters are considered over the algorithm where only bandwidth or signal strength is considered is shown through the simulated results.

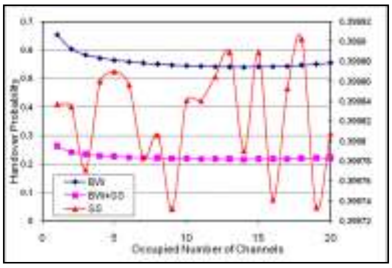

Fig.2: Handover Probability for N=3, occ. Ch.=21

The above figure shows the plot for Handover Probability for N=3 and occupied channels=21. The Handover Probability is calculated based on three approaches, namely, the bandwidth availability (BW),the signal strength(SS) and combination of both (BW + SS). For example in case of bandwidth availability, handover takes place from network 1 to network 2 only when b2 – b1 > L. Similarly, when only signal strength is considered as the parameter for handover, handover takes place only when probability of signal strength in candidate network is higher than in current network by 0.5.

It is seen that there is a random variation in the handover probabilities for the signal strength based approach as the signal strength at any point of time can vary abruptly due to various noise factors, whereas the handover probability distribution for BW and BW+ SS are not random, rather they show a steady state value which can be expected as all the channels get occupied.

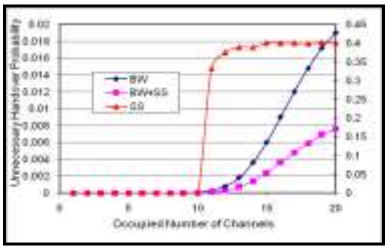

Fig. 3: Unnecessary Handover Probability

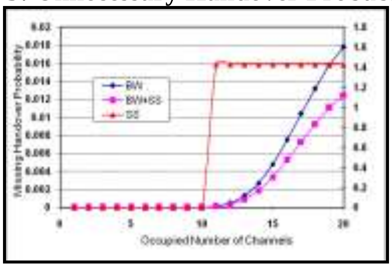

Fig.4: Missing Handover Probability

Figure 3 and Figure 4 shows Unnecessary and Mising Handover Probability for BW, SS and BW + SS based approach. Considering only BW or only SS suffers higher number of unnecessary and missing handovers compared to the BW+ SS based approach. If only signal strength is considered as the handoff parameter, almost 40% of the decisions are wrong even for low traffic load which can be attributed to the random variation of the received signal strength. The BW&SS based approach is the best since it has the least number of unnecessary handovers being performed or least probability of handovers being missed.

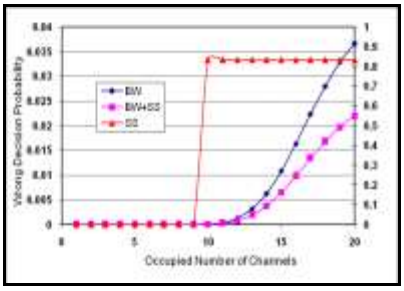

Figure 5: WDP Vs Occupied channel

Figure 5 demonstrates the reduction in wrong decisions when both Bandwidth and signal strength are considered for making a handoff decision. The BW&SS based approach outperforms the other two approaches since the approach based on only Bandwidth or only SS gives higher probability of wrong decisions, indicating that choosing only SS or BW as a parameter for performing handovers will not be a better option.

Conclusion:

In this work, the performance of a BW, SS and BW&SS based handover algorithms for wrong decisions were studied. The simulated results shows that considering both signal strength and network bandwidth is more advantageous to the network operator due to the reduction in the number of wrong decisions. Making handover decisions based on the predication method called *WDP* can provide better performance of the algorithm. As a future work, the mobility of the MT can also be incorporated to calculate the *WDP* which will further enable reduction of the wrong decisions for handover made by the MT thus ensuring a reduced computational load on the network and better spectrum utilization.

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Table 1: Description of Probabilities for three state Markov model used to capture process of MT moving between different networks

Probabilities	Definitions
$P_{n1/n2}$	The probability of MT moving from network n_2 to n_1
$P_{n2/n1}$	The probability of MT moving from network n_1 to n_2
$P_{n1/n3}$	The probability of MT moving from network n_3 to n_1
$P_{n3/n1}$	The probability of MT moving from network n_1 to n_3
$P_{n2/n3}$	The probability of MT moving from network n_3 to n_2
$P_{n3/n2}$	The probability of MT moving from network n_2 to n_3
$1 - P_{n2/n1} - P_{n3/n1}$	The probability of MT staying in the network n_1
$1 - P_{n1/n2} - P_{n3/n2}$	The probability of MT staying in the network n_2
$1 - P_{n1/n3} - P_{n2/n3}$	The probability of MT staying in the network n_3

Table 2: Decision Table for BW based algorithm

N1 BW1	N2 BW2	N3 BW3	Decision depends on the threshold value *L*
0	0	0	Stays in the current network
0	0	1	MN stays at N3
0	1	0	MN stays at N2
0	1	1	Compare BW2 with BW3 and move to network with greater Bandwidth
1	0	0	MN stays at N1
1	0	1	Compare BW1 with BW2 and move to network with greater Bandwidth
1	1	0	Compare BW1 with BW3 and move to network with greater Bandwidth
1	1	1	Stays at the current network

Table 3: Decision Table for Bandwidth & signal strength based algorithm.

N1 BW1*SS1	N2 BW2*SS2	N3 Bw3*SS3	Decision depends on the threshold value *L*
0	0	0	Stays in current network
0	0	1	MN stays at N3
0	1	0	MN stays at N2
0	1	1	Compare parameters of N2 with N3 and move to greater one
1	0	0	MN stays at N1
1	0	1	Compare parameters of N1 with N3 and move to greater one
1	1	0	Compare parameters of N1 with N2 and move to greater one
1	1	1	Stays at the current network