Network selection algorithm based on link quality parameters for heterogeneous wireless networks

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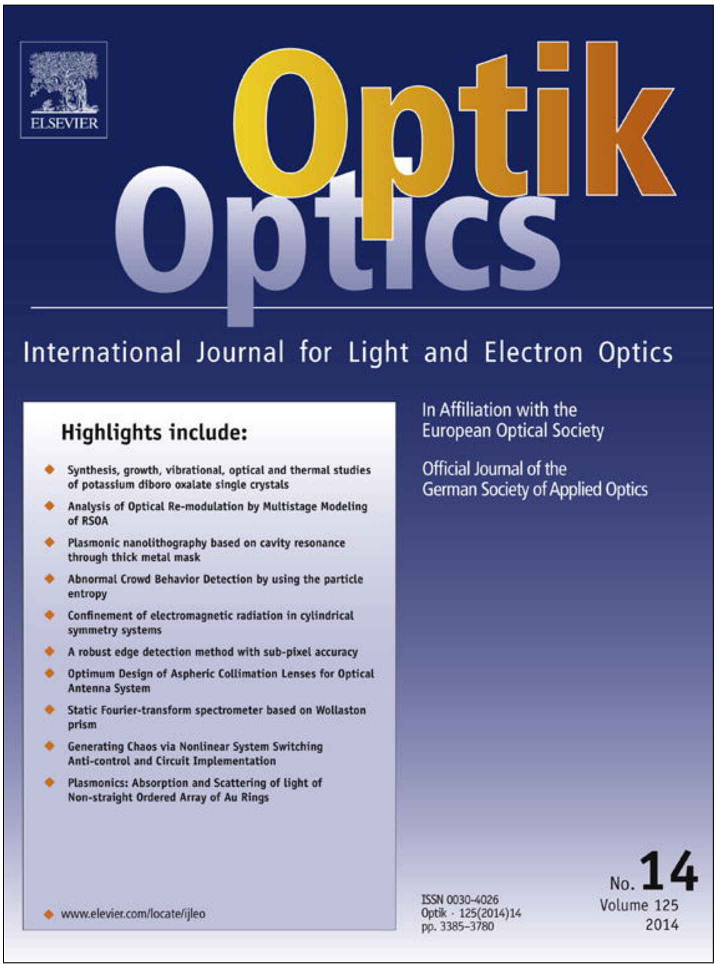
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ABSTRACT

Next generation wireless networks consist of heterogeneous access technologies. In order to provide global ubiquitous communication, it is required to provide a framework in which user can move across multiple access interfaces while maintaining its ongoing communication at perceived quality of service. Given the scenario of multiple access networks, it is further required to select the optimum network out of multiple candidate networks to meet the requirements of the ongoing session. The selection of optimum network in such heterogeneous environment is generally based on network conditions and user preference. In this paper, we propose an algorithm for network selection based on averaged received signal strength, outage probability and distance. The proposed algorithm comprises of two stages. Assuming that network conditions are dominant in network selection, in first stage, overlapping region is identified through distance estimation. Network selection algorithm based on averaged received signal strength plus outage is invoked in second stage to select the optimum network. Numerical results are obtained through a simulation model of two disparate networks – GSM and UMTS. It has been shown that the proposed algorithm offers 68% improved performance in terms of network selection rate.

1. Introduction

The expansion of wireless technologies is the outcome of the exponential growth and wide spread deployment of mobile devices, applications and services. In order to provide ubiquitous and seamless communication at global level, it is required to develop a framework in which a user can move in heterogeneous environment with ongoing communication availing required QoS [1]. To select the best suitable wireless network in heterogeneous environment is a key issue toward realizing ubiquitous connectivity. Presently 2G and 3G networks coexist to accomplish the requirements of service and different coverage targets. It is desired by the user to handle both the network uninterrupted in the ongoing service. This requires the selection of an optimal network. Network selection can be initialized by MS (mobile station) or can be based upon measurements of link quality by the network. Received signal strength (RSS) is one of the most widely used parameters for network selection. It is generally seen that serious ping-pong effect results from the selection based on thresholds of received signal strength (RSS). Low network throughput, long handoff delay, and high dropping probability are effects of the ping-pong effect. Outage probability is another important parameter for network selection in multimedia applications. It is determined based on receiver sensitivity or minimum acceptable signal strength. It is defined as the probability when the instantaneous received signal strength falls below a certain threshold. The location information of MS as provided by GPS (global positioning system) has inspired us in making the network selection decision in addition to link parameter measurements. In this paper, network selection in heterogeneous wireless environment is proposed on the basis of distance estimation and different link parameters (received signal strength (RSS), outage probability).

The organization of the paper is as follows: Section 2 describes the work done on network selection algorithms/methods. Section 3 presents the system model used for simulation of network selection in wireless heterogeneous environment. Section 4 states the proposed network selection algorithm and further describes the performance metrics used for network selection. Performance evaluation of proposed algorithm is discussed in Section 5. Finally, conclusions are drawn in Section 6.

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2. Related work

Number of research proposals have been reported in literature for network selection. In order to satisfy QoS requirements i.e. accommodate maximum number of calls, and reduce handoff occurrence frequency a preference value-based cell selection (PVCS) scheme was proposed [2]. However, it was only applicable to non real time services. Another useful access network selection algorithm was proposed which concatenate three methods viz. Multi attribute decision making (MADM) methods, the analytic hierarchy process (AHP) method and the total order preference by similarity to the ideal solution (TOPSIS) method [3]. But authors failed to take into consideration the important dynamic parameters such as RSS, signal to noise ratio (SNR) and resource availability. Utility based scheme was implemented in the urban areas for efficient network selection [4]. It considered number of factors which act as linchpin for multimedia communication. But it increased overhead and complexity for mobile station.

For multi-service heterogeneous wireless networks, a supple and scalable network selection was proposed in [5]. The best cell was assigned to a particular user through profile matching. In this scheme many parameters were required to be initialized on the basis of earlier activities. It created more burdens on MS in terms of database collection. Then a new theory, which entails improved access router discovery (IARD) based on network discovery, was anticipated. It consists of UMTS network and wireless local area network (WLAN) [6]. In this work, using a special weighted mean (WM) algorithm the selection of potential networks was performed. A context-aware network selection was suggested in which a modified weighted product method (WPM) based network selection was used for access. But it increased the computing process of network selection [7].

Information from different radio access technologies within a given time interval was obtained in [8], further it was used for multi criteria decision making between different available access networks. A decision tree approach in [9] was then anticipated to make use of various decisive factors to select network optimally. In [10] a handover scheme had been reported for the vertical handoff between UMTS and WLAN for guaranteeing the best QoS by selecting the most suitable network. It depends on data rate absolute signal strength and distance. Cognitive radio system with low cost and high spectrum efficiency was used in [11] for rapid transition from 2G to 3G.

While selecting a network, it is easy to have number of networks at same instance, but difficult to select the corresponding optimal network. So to identify the best algorithm or method among the above discussed network selection methods is a challenging issue. From the literature survey, it has been found that though there are numerous network selection mechanisms available, but these algorithms have certain drawbacks viz. overheads, complexity, time consumption, etc., which are of major concern. In this paper, the network selection algorithm based on distance, averaged RSS and outage probability has been proposed, which eliminates the drawbacks (signaling overhead) of conventional methods.

3. System model

A novel network selection algorithm has been proposed in this section. Heterogeneous environment may consist of n_i, $i = 1, 2, 3, \ldots, N$ different wireless networks. For sake of convenience, we have taken into the consideration GSM and UMTS cellular networks as shown in Fig. 1. Let's assume that a user is traveling at a constant speed in a straight line from the base station 'BS_g (2G)'to the base station 'BS_u (3G)'and considering the distance between the two base stations is 'D'. MS observes the received signal strength at regular distance intervals as

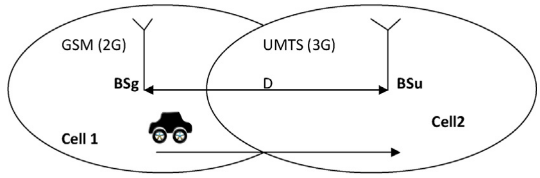

Fig. 1. Heterogeneous wireless network model.

$$d = kd_s \tag{1}$$

where k an integer with $k\,\varepsilon\,[0, D/d_s]$ and d_s is the sampling distance ($d_s = 1$ m) [12]. Both of the base stations are assumed to operate from the center of their respective cells.

Taking the supposition that mobile station lies in the coverage area of either GSM or UMTS. But due to mobility, it can move into the overlapping regions, i.e. simultaneously within the coverage area of both GSM (BS_g) and UMTS (BS_u). In order to overcome this dilemma of which network should be preferred in the overlapped region a network selection algorithm has been proposed.

In proposed algorithm first selection parameter is averaged RSS. RSS constitutes path loss attenuation with respect to distance, fast fading and shadow fading. The key component of received signal strength is path loss which can be evaluated by propagation path loss models [13,14]. The pilot signal strength received by MS from BS_g and BS_u respectively can be expressed in dBm as:

$$S_g(k) = K_1 - 10\gamma_g \cdot \log_{10}(kd_s) + \xi_g \tag{2}$$

$$S_u(k) = K_1 - 10\gamma_u \cdot \log_{10}(D - kd_s) + \xi_u \tag{3}$$

Here, the path loss parameter is K_1 and the path loss exponents for GSM and UMTS cell environments are γ_g and γ_u, respectively. Buildings, Hills, trees and foliage form an obstruction for the line of sight path between transmitter and receiver, causing *Shadowing*; hence transmitted signal is blocked due to severe attenuation. The relative positions of the transmitter and receiver with respect to the large encumbrance in the proliferation environment construct the amount of shadow fading. In above Eqs. (2) and (3), the shadow fading components are signified by ξ_g and ξ_u. The auto correction function of shadow fades [15] is notified as

$$E\{\xi(k)\xi(k+m)\} = \sigma_s^2 \alpha |m| \tag{4}$$

$$\alpha = \exp\left(\frac{-\nu T_m}{d_0}\right) \tag{5}$$

where σ_s is the standard deviation of shadow fading and m is an integer. The same value of standard deviation σ_s for both cells is assumed. d_0 is the correlation distance, T_m is the sampling time, and ν is velocity of the MS; hence $d_s = \nu T_m$. To reduce the multiple time network selection at the same time instance and to mitigate the outcome of shadow fading, the deliberate and standardized signal strength samples are averaged over a rectangular window before these could be used to select the network, which is given as follows [16]:

$$S_{ai}(k) = \frac{1}{N_w} \sum_{n=0}^{N-1} S_i(k-n) W_n \quad i = 1, 2 \tag{6}$$

where after grading and equating, the kth sample acknowledged is S_{ai} (k). The sample taken at the end of the $(k-n)$th interval is ascribed a weight denoted by W_n

$$N_w = \sum_{n=0}^{N-1} W_n \tag{7}$$

For a rectangular window, commensurate weight is given to all the precedent samples in the averaging window N_w therefore, $W_n = 1$ for all n. Fast fading is due to multipath cogitation of a transmitted wave by objects, such as houses, buildings other man-made contour, natural objects such as forests surrounding the MS. It is neglected for network selection commencement trigger due to its short correlation distance relative to that of shadow fading. Standard deviation of averaged shadowing samples can be obtained as [17],

$$\sigma^2 = \frac{\sigma_s^2}{N}\left[1 + 2 \times \sum_{n=1}^{N-1}\left(1 - \frac{n}{N}\right)\rho^n\right] \tag{8}$$

where σ_s and σ are the respective standard deviations of shadow fading before, and after taking average of signal strength measurements over N samples. The symbol 'ρ' denotes auto-correlation coefficient of the shadow fading.

Distance as another selection parameter is used to identify the overlapped region for network selection in heterogeneous environment to reduce burden on MS. In order to maintain low intricacy, we ascertain Gaussian statistics for distance measurement variables d_i ($i = 1, 2$). The apprehended distance of MS from BS_g and BS_u are enumerated as follows:

$$d_1(k) = kd_s + \chi_g, \tag{9}$$

$$d_2(k) = D - kd_s + \chi_w, \tag{10}$$

where χ_g and χ_w are compiled as zero mean independent wide sense stationary Gaussian random processes representing distance measurement errors with standard deviation σ_d. Average distance measurement error increases with σ_d. Assuming 50 m of maximum error tolerance, $\sigma_d = 50$ m is used in the replica for numerical data processing [18]. It reflects eminence of the measurement error at any sampling point. Relative distance of MS from the two BSs is defined as

$$X(k) = d_1(k) - d_2(k) \tag{11}$$

When the operator plans a system, the outage probability distributed in a cell is normally designed within the some limit for a certain traffic load (voice, data, video or multimedia, etc.). There are two possible cases in existing circuit switched cellular networks, first the outage level has reached the maximum acceptable value and second the outage level is below the maximum acceptable value [19]. So we consider another parameter for network selection algorithm that is outage probability. It is defined as the probability that the averaged received signal strength is less than a certain threshold. It is defined as

$$P_{out} = P[\Gamma < \Gamma_t] \tag{12}$$

Γ is received signal strength of wireless network present in heterogeneous environment and Γ_t is the threshold received signal strength. The threshold depends on the impact of wireless network types in heterogeneous environment [20].

For numerical ciphering, the main system specifications typically for proposed network selection algorithm based on averaged RSS, distance and outage probability have been chosen as shown in Table 1.

For exposition convenience, we consider the radius defined in Table 1 for both the cellular networks present in heterogeneous environment. Different path loss characteristics are chosen for each cellular network. Path loss exponent is lower in GSM cell, resulting in considerate aberration of signal strength with respect to distance as correlated to UMTS cell. RSS thresholds are the values of RSS available from BS_g and BS_u at cell boundary consequently due to deterministic path loss component only.

Table 1
System framework for simulation model.

S. no.	System parameters	Values
1.	Radius of GSM (R_g)	1000 m
2.	Radius of UMTS (R_u)	500 m
3.	Path loss exponent of GSM (γ_g)	3.0
4.	Path loss exponent of UMTS (γ_u)	3.4
5.	Standard deviation of shadow fading σ_s	8 dB
6.	Sampling distance (d_s)	1 m
7.	RSS threshold for GSM network outage	−88 dBm
8.	RSS threshold for UMTS network outage	−94 dBm

4. Proposed algorithm

The proposed algorithm identifies the best available wireless network while maintaining QoS for multimedia services in heterogeneous wireless environment. As discussed in earlier section, averaged RSS, distance and outage probability parameters are used to perform the network selection. If averaged RSS of any network is high and outage probability is less with respect to another network in overlapped region estimated by distance in heterogeneous environment, then that network is selected as the best suitable network.

$$\begin{aligned} \mathrm{NSF}_{(i)} = {} & F(S_{a(i)}(k) > S_{a(i+1)}(k))\,\mathrm{AND}\,F(S_{a(i)}(k) > S_{th}(k) \\ & \mathrm{AND}\,F(\mathrm{Pout}_{(i)}(k) < \mathrm{Pout}_{(i+1)}(k)) \\ & \mathrm{AND}\,F(\mathrm{Pout}_{(i)}(k) < \mathrm{Pout}_{th}(k))\,\mathrm{AND}\,F(d_{(i)}(k) > d_{th}(k)) \end{aligned} \tag{13}$$

where $S_{a(i)}$ denote the averaged RSS from access networks. S_{th} indicates the RSS threshold. $k = 1, 2, 3, \ldots, D$ is used to choose sample of averaged RSS and outage probability at various sampling distances. $\mathrm{Pout}_{(i)}$ denotes outage probability of wireless network in heterogeneous environment and Pout_{th} represents threshold outage probability value for multimedia services. $d_{(i)}$ defines distance of mobile user from its respective base station (BS), where d_{th} represents overlapped boundary threshold distance. $i = 1, 2, \ldots, N-1$ for wireless network present in heterogeneous environment as shown in Eq. (6). The function F (.) is an entity step function. The unit step function is an incoherent function whose value is zero for negative contentions and one for positive contentions. AND performs as logical and operation (i.e. multiply function). NSF (network selection function) yields null value if any of the condition in Eq. (13) is not satisfied. NSF_1 and NSF_2 denote 2G and 3G wireless network respectively in above defined heterogeneous wireless network environment.

The flow chart of the logic of network selection based on averaged RSS, distance and outage probability for selecting the network in composite context for multimedia assistance is represented in Fig. 2. In an overlaid network consisting of multiple access technologies, network selection can be made at any point of time and distance as per the requirements of the network conditions, quality of service requirements for the application and user preference. However, in the present work, we assume that network conditions (averaged RSS and outage probability) dominate the decision of network selection. In a dynamic radio propagation environment, network conditions vary with time and distance. In such scenario, we have defined an area of interest for making network selection around the coverage boundaries of the two networks. This area of interest has been limited by the distance vector as defined by Eq. (11).

Proposed network selection criterion is divided into two stages. In *first stage* overlapped area is identified and link parameters (RSS and outage probability) are calculated in *second stage*. The user has a prospect to account number of wireless networks together because

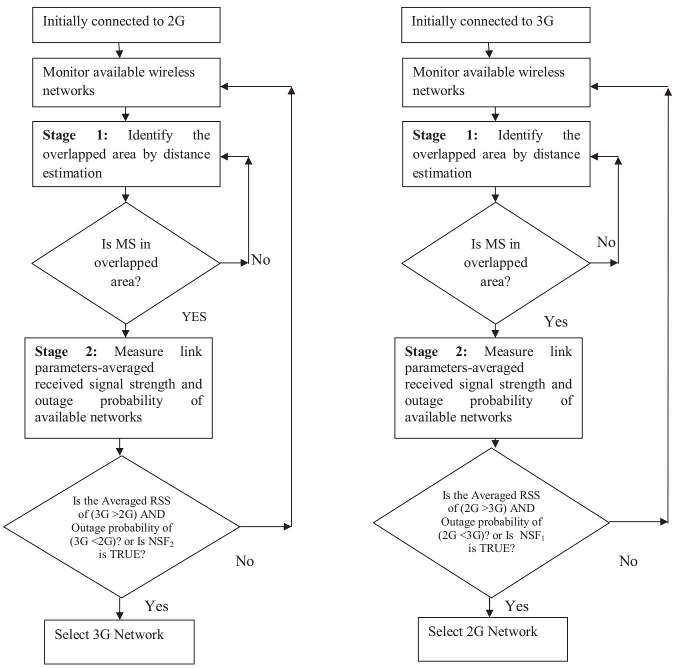

Fig. 2. Proposed algorithm for network selection in heterogeneous environment of 2G and 3G.

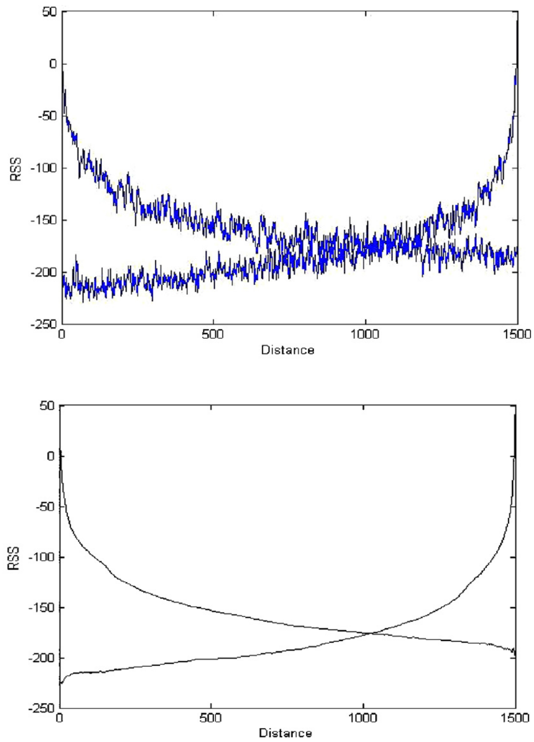

Fig. 3. (a) RSS (dBm) vs. distance (m). (b) Averaged RSS (dBm) vs. distance (m) in wireless heterogeneous environment of 2G and 3G.

of multimode mobile device [21]. In this paper, two interfaces of MS are considered which can access 2G and 3G networks. The excerpt of network also relies upon the application running at that instant. If the application was established on multimedia services then the primary concern is less outage probability as to reduce data loss in critical/secure usage like online banking transactions. Overall drafting of the network entrusts on user preferences, network conditions (more averaged RSS and less outage probability) and overlapped region.

Initially check the networks present in heterogeneous environment of multimode MS. It comprises tracking and observing radio link quality and conducive processing of link quality measurement.

Stage 1: The network selection commencement point in considered process is the amalgam of RSS and distance. RSS is initially used to discover the wireless network present. If the MS is having only single wireless network then it is automatically connected through it. But when the MS catches more than one wireless network at the same time then the problem of network selection comes into the picture for best QoS. Distance parameter is used to search the overlapped area to reduce overhead over the MS for network selection throughout the distance from the respective base station.

Stage 2: The proposed algorithm is employing combination of averaged signal strength and outage to perform a network selection between BS_g and BS_u in second stage. According to the proposed algorithm, first calculate the averaged RSS of both the networks present in heterogeneous environment. Then calculate the outage probability on the basis of averaged RSS and its threshold value. Here, averaged RSS and outage probability (link parameters) have been used as the metrics to select network in overlapped region. The network having greater averaged RSS and lesser outage probability is selected as the best network in the given heterogeneous environment under consideration as shown in Fig. 2.

5. Simulation results and discussion

The valuation of the network selection algorithm has been done as the MS moves with a constant velocity along a straight line trajectory between two BSs. Further for numerical computation, the typical values of system parameters falling in the range of practical interest have been taken as shown in Table 1. The received signal strength (which composes of path loss and shadowing) for both the wireless networks with respect to distance are shown in Fig. 3.

The randomness of shadow fading, results in change of the RSS and outage. This yields serious ping-pong effect when a mobile station moves around the overlay area of heterogeneous wireless networks. The ping-pong effect causes unnecessary network selection and brings some weakness including low network throughput, long handoff delay and high dropping probability. It is an undesirable condition so; smoothing is done through averaging window to eradicate this problem. The choice of averaging window size (N) is critical in the design of network selection algorithm for microcellular based networks. These networks require fast selections since timing is very critical issue due to fast signal level variation. Greatly smoothed version of signal strength may not detect the timely need of network selection and may lead to undesired network selection. Smaller N yields early network selections. Consequent to this, respective number of averaging samples in Eq. (7) are chosen as $N = 20$ for both GSM and UMTS cells to get the acceptable value of outage probability. Fig. 3(b) represents averaged RSS with respect to distance by using moving averaging filter concept.

Curtailment in RSS due to increase in distance in both the wireless networks can be observed in Fig. 3. Analytically, the network selection condition occurs when the protruding zone of wireless network comes into the entity. Network selection from BS_g to BS_u should be autogenously 100 m of the cell boundary in GSM cell. This setting connote that network selection may take place when MS is superlative than or equal to 900 m away from BS_g. Given R_g (radius of GSM cell) = 1000 m and R_u (radius of UMTS cell) = 500 m, this condition implores $d_0 \geq 900$ m and $d_1 < 600$ m as enumerated by Eqs. (9) and (10), which give the distance of MS from BS_g and BS_u consequently. Subsequently Eq. (11) gives $X \geq 300$ m for network selection from BS_g to BS_u. Similarly, to cause network selection from BS_u to BS_g is within 100 m of the cell boundary in UMTS cell.

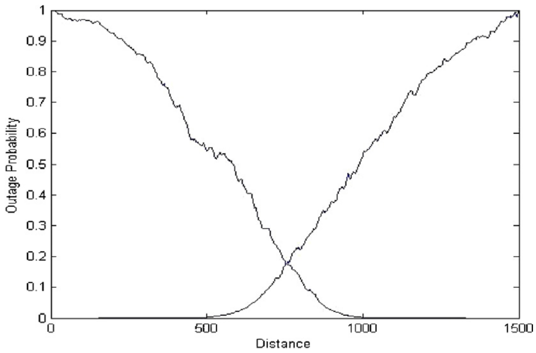

Fig. 4. Outage probability vs. distance (m) in wireless heterogeneous environment of 2G and 3G.

This context implies that network selection may take place when MS is greater than or equal to 400 m away from BS_u. This predicament requires $d_1 \geq 400$ m apart from BS_u. In turn, MS is less than or equal to 1100 m from BS_g and, therefore, contingent distance $X < 700$ m. These settings are based on the attainment that ±100 m is the overlapped region between two cells.

In conventional method, received signal strength is the only dominant parameter for network selection. Due to the conventional selection method multiple time network selection occurs. It irritates the user and also increases the overheads. So there is need to consider distance estimation for overlap region calculation and outage probability parameter in addition with the averaged RSS to make the final decision about the best network selection in heterogeneous environment.

Fig. 4 represents outage probability vs. distance graph in heterogeneous wireless environment. As the MS moves away from the base station the outage probability increases which varies from 0 to 1. The MS which receives greater averaged RSS and lesser outage to the MS is selected as the best network in wireless overlapped heterogeneous region. Network selection for multimedia services minimum required ≈0.2 outage probability value [22].

5.1. Performance evaluation of proposed algorithm

When MS moves from BS_g to BS_u and similarly, from BS_u to BS_g then evaluation is performed under proposed network selection algorithm as well as conventional method. Network selection rate and network selection delay have been used as the metrics to evaluate performance of the proposed network selection algorithm with respect to conventional method. Network selection rate is defined as the expected number of selections MS experiences while traversing a trajectory from one network to another. This performance measure represents switching load associated with the network selection process. Ideally, there should be one selection across the cell boundary. Network selection delay is marked by the position of first selection on the mobile trajectory [23].

Case 1: In this case assimilated RSS thresholds are chosen as $T_{gsm} = -88$ dBm and $T_{umts} = -94$ dBm. Network selection rate is enumerated for different values of T_{umts}, which is conglomerated from −106 to −74 dBm, while keeping $T_{gsm} = -88$ dBm. For exemplary method based on RSS only, the network selection rate = 6.299 is accomplished at $T_{umts} = -94$ dBm, while prospective algorithm based on distance, averaged RSS and outage probability abdicates network selection rate = 1.999. It is embellished from Fig. 5(a) that there is an indicative reduction in network selection rate under proposed algorithm. It is around 68% with respect to exemplary method. Due to this discernible improvement in network resource efficiency can be achieved by using the proposed algorithm.

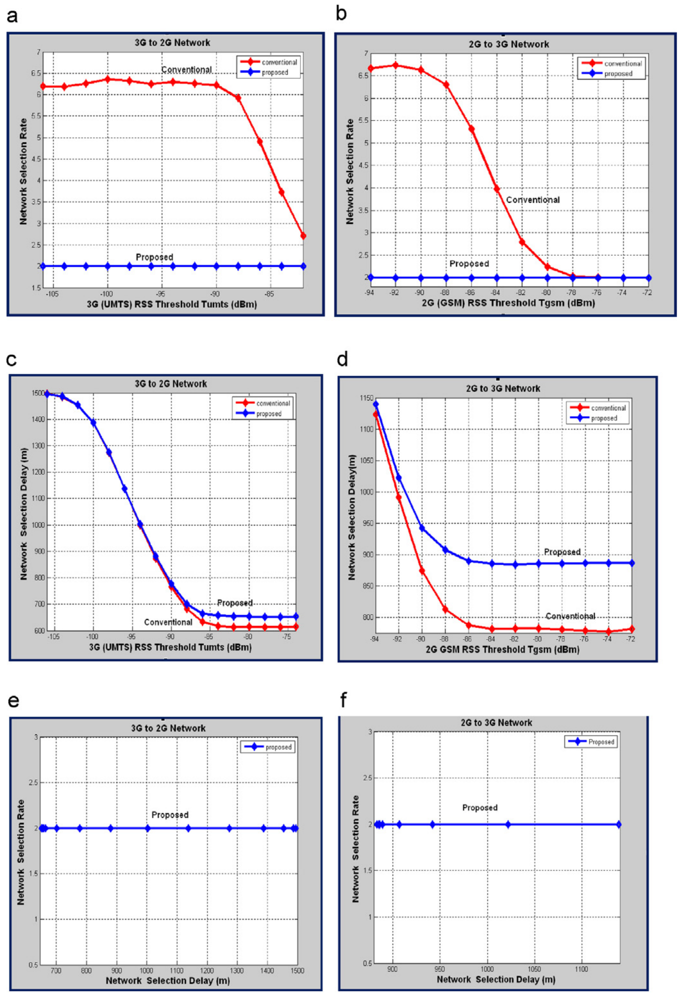

Fig. 5. (a) Network selection rate vs. threshold with fixed value of $T_{gsm} = -88$ dBm. (b) Network selection rate vs. threshold with fixed value of $T_{umts} = -94$ dBm. (c) Network selection delay vs. threshold with fixed value of $T_{umts} = -94$ dBm. (d) Network selection delay vs. threshold with fixed value of $T_{gsm} = -88$ dBm. (e) Trade off curves while moving from 3G to 2G network. (f) Trade curves while moving from 2G to 3G network.

Case 2: The concussion of RSS threshold setting of T_{umts} on network selection delay metric is credible by using Fig. 5(c). Greater value of T_{umts} will impediment the selection process and hence degrades the communication link quality from the serving BS_u. For smaller T_{umts}, early selection will be abetted. Proper value of T_{umts} setting should be chosen according to the link quality engrossments. Fig. 5(c) depicts the network selection delay with respect to UMTS RSS threshold. By predominant algorithm network selection can be conscripted within 615–1496 m and with proposed algorithm, network selection can be initiated within 653–1495 m by setting $T_{umts} = -74$ to −106 dBm. As such, under contingent algorithm, network selection can be conscripted at 1002 m by setting $T_{umts} = -94$ dBm as per selection conditions in overlapped area. Reducing network selection delay abridges call dropping probability and hence improved quality of service (QoS) as anticipated by the user.

Case 3: In this case network selection rate is enumerated for different values of T_{gsm}, which is varied from −94 to −72 dBm. It is observed that keeping $T_{umts} = -94$ dBm, network selection was computed for different perspective of signal strength threshold T_{gsm}. For conventional method, at the attributing value of $T_{gsm} = -88$ dBm the network selection rate = 6.301 is attained while on the other hand, proposed algorithm yields network selection rate = 2. As seen in Fig. 5(b), there is a significant reduction in network selection rate under proposed algorithm. It is evident from the above numerical results that proposed algorithm significantly improves 68% with respect to conventional method. It extemporaneously improves networks resource efficiency.

Case 4: In this case proper value of T_{gsm} setting is chosen acquiesce to the link quality preliminaries. Fig. 5(d) elucidates the network selection delay with respect to GSM RSS threshold. Under proposed algorithm, network selection can be erudited within 886–1139 m and by conventional algorithm network selection can be erudited within 781–1123 m by setting $T_{gsm} = -72$ to -94 dBm. In analogy, by conventional algorithm network selection can be take place at 991 m by setting T_{gsm} equal to -92 dBm whereas, network selection can be take place between 907 m and 1022 m by setting T_{gsm} from -88 dBm to -92 dBm in proposed algorithm. Due to abatement in link quality from BS_g T_{gsm} is equal to -88 dBm expedient.

The above results show the improved consummation of the proposed network selection algorithm for intersystem working. Reduction in network selection rate leads to less overhead of signaling and switching process on the cellular network. Indubitably, more resources are available to carry the traffic load, leading to less blocking and, therefore, improved QoS.

Case 5: Tradeoff as shown in Fig. 5(e) and (f) cogitated between network selection delay and network selection rate are used to optimize the network selection attainment. Following the requirements that network selection should be initiated at or around the cell boundary (1000 m away from BS_g), T_{umts} and T_{gsm} can be set in conformity with the discrete curves for the proposed algorithm.

6. Conclusion

In this paper, we propose a network selection algorithm based on distance and link parameters (averaged RSS and outage probability) of wireless networks employed on overlapped region of heterogeneous environment. The approach presented improves the network selection with less overhead and burden on MS with respect to conventional method (i.e. RSS only). It improves the performance 68% by using outage probability along with averaged RSS in overlapped area of heterogeneous environment of GSM and UMTS. Because of the overlapped region the overhead on MS reduced significantly and outperforms the conventional algorithm. It ameliorate the QoS by making radio and network resources accessible to multimedia users regardless of the network, it is originally concorded with. It accomplished the need of network selection decision which introspects after the application requisites and also keeps the connection dynamic during handover by engaging make-before-break approach i.e. adaptive soft handover method.

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