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PERFORMANCE ANALYSIS OF BANDWIDTH BASED HANDOFF ALGORITHM FOR 4G HETEROGENEOUS WIRELESS NETWORKS BASED ON WDHOP

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ABSTRACT

The integration of diverse wireless technologies is the emerging trend in providing ubiquitous access to the high data rate wireless network. Currently, in 4G networks, new mobile devices aim to provide the user with great flexibility and connectivity for network access but also generate the challenging problems of mobility support among different networks. Users expect to continue their connections without any disruption when they move from one network to another by the process handoff. In this paper, bandwidth based handoff algorithm for multiple heterogeneous wireless networks are developed. The wrong decision handoff probability is major problem in 4G wireless networks. Wrong decision handoff probability is calculated based on proposed bandwidth based handoff algorithm and the performance of the proposed algorithm is estimated.

Keyword: RSS, bandwidth, handoff, 4G, WDHOP.

1. INTRODUCTION

In the present day scenario, mobility management is the one of the major challenge in wireless communication networks for providing global access among the users. Handoff is the continuation of an active call when the mobile is moving from one Base Station (BS) to another [1].Gudmundson M. *et al.* [2] explained handoff is the most important phenomena while dealing with the mobility of the users. Handoff makes it possible for a user to move between diverse networks or cells while having seamless connection. Tripathi N. D., *et al.* [3], presented handoffs such as hard handoff and soft handoff, handoff strategies. Traditional handoff algorithms are based on received signal strength (RSS) [4] - [5]. RSS based handoff algorithms are simple and ineffective due to "ping-pong effect". To eliminate this, the RSS with hysteresis method is used [6].

In 2G GSM, follows hard handoff which is a "break –before- make" approach. In hard handoff, first MS breaks the connection with the serving BS and then it makes the connection with the target BS [7]. GSM systems have limited system capacity. To improve the system capacity, in CDMA cellular systems the soft handoff ("make - before- break) is used [8]. In CDMA when the mobile is moving from one cell to another, it first makes the connection with the target cell and then it breaks the old connection [9]. This process appears in 2G and 3G cellular systems like CDMA, UMTS and Wideband CDMA etc. In 4G, the integration of various wireless networks is called heterogeneous wireless networks or "Next Generation Heterogeneous Wireless Networks". The vertical handoff is performed in these networks for Ex. Handoff between cellular network (GSM/CDMA/UMTS) and a Wireless LAN (WLAN) [10]. To achieve seamless mobility among heterogeneous networks, conventional RSS based handoff decision algorithms are not suitable due to different physical technology adopted by different networks [11]. Xiaohuan Yan, *et al*. [12], explained particularly, for the vertical handoff across heterogeneous networks.

In the literature, RSS based handoff algorithms are proposed [1]-[9]. But, RSS only indicates the availability of a network and can't give more details of a network such as available bandwidth which is most useful for 4G applications [13]. So, bandwidth is considered for developing handoff algorithms in 4G cellular networks. Bandwidth based handoff algorithms are suitable for improving the quality of service of 4G. Proper design of efficient handoff algorithms is a cost – effective way of enhancing the capacity and for reducing the switching load of the network while maintaining the quality of service. Bandwidth based handoff algorithm for two heterogeneous networks and its wrong decision handoff probability analysis is available in the literature [14]. So, in this paper, bandwidth based handoff algorithm for three heterogeneous networks is developed and the performance of proposed algorithm is estimated by calculating wrong decision handoff probabilities (WDHOP) analysis which is combination of unnecessary and missing handoff probabilities. In section II, explains the relationship between handoff algorithms and wrong decision handoff probability. Section III gives the details for bandwidth based handoff algorithms for three heterogeneous networks. Section IV gives the WDHOP analysis for three heterogeneous wireless Networks. Section V explains the results and discussion and the last section conclusions of the paper.

2. RELATIONSHIP BETWEEN HANDOFF ALGORITHMS AND WRONG DECISION HANDOFF PROBABILITY

The heterogeneous wireless networks that are available are denoted by ni, i=1, 2,.. N, N is the maximum number of available networks. W_i and w_i is the maximum bandwidth and available bandwidth of network i. Usually upper layer applications are more sensitive on QoS

parameters such as bandwidth, delay etc. The available bandwidth is used here as the criteria to determine network's quality. Mobile node's requirement on available bandwidth is denoted by r, which reflects the node's sensibility on available bandwidth. Higher 'r' means that the node wants higher network quality. In this paper, the explicit expression of the relation between handoff algorithms and Wrong Decision Handoff Probability (WDHOP) is proposed.

Wrong decision handoff probability (WDHOP): WDHOP is the combination of Unnecessary Handoff Probability (UHOP) and Missing Handoff Probability (MHOP).

a) Unnecessary handoff probability (UHOP)

If Mobile Node (MN) is in niand mobile node decides to move to njat time t_1, but $w_i \geq r$, and $w_j < r$ at time t_2, $t_2 > t_1$. This kind of events are termed as Unnecessary Handoff Probability ($Y_{nj|ni}$)

b) Missing handoff probability (MHOP)

If Mobile node is in niand mobile node decides to stay in network niat t_1, but $w_j \geq r$, and $w_i < r$ att$_2$, $t_2 > t_1$. This kind of events is termed as Missing Handoff probability (Θ_{ni}) [14].

Therefore, for N no. of networks the WDHOP is defined as,

$$WDHOP = \sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} \Pr\{Y_{nj/ni}\} + \sum_{i=1}^{N} \Pr\{\Theta_{ni}\} \quad (1)$$

Unnecessary Handoffs refers to the events that a mobile node decides to move to the other network, but the new network cannot satisfy its bandwidth requirement in next time period while the previous network can meet the requirement. Missing Handoffs refers to the events that a mobile node decides to stay at its present network, but this network cannot satisfy its bandwidth requirement while the other network can satisfy. Unnecessary Handoff is considered for handoff performance evaluation criterion; a mobile node will be bias to not doing handoff at all, which is not reasonable if other network provides better service. On the other hand, if only Missing Handoff is taken into consideration, too many handovers may occur and will introduce high network load. These two parameters are jointly generating wrong decisions. Therefore, in this paper, wrong decision handoff probability which is the combination of MHOP and WHOP is considered as performance evaluation criteria.

Handoff probability (HOP): The probability of Mobile Node (MN) to moves out of its current network.

Handoff probability of handoff algorithm reflects the handoff occurrence of a MN. For handoff algorithms with similar WDHOP, less handoff probability replicates less network load introduced by handoffs.

Consider, P_{ni}, i=1, 2...N denotes the probability of mobile node staying at network ni. The handoff probability of MN is defined as,

$$HOP = \sum_{i=1}^{N} \sum_{\substack{j=1 \\ j \neq i}}^{N} P_{ni} P_{nj/ni} \quad (2)$$

WDHOP mainly depends on the decision time intervals D, D=t2 - t1 denote the time when the MN makes a decision to move or to stay as t, and the time to decide if the decision is correct or wrong is t+D. For each network and MN, D is predefined.

The following events are necessary for defining the WDHOP.

$M_{nj/ni}(t)$: MN decides to move from network *ni*to network *nj*at time *t*;

$S_{ni}(t)$: MN is at network *ni*and decides to stay at present network at time t;

$\Psi_{ni,nj}(r,t)$: Available bandwidth of network *ni*is greater than or equal to *r* and available bandwidth of network *nj*is less than *r* at time *t*.

$P_{nj/ni} = \Pr\{M_{nj/ni}(t)\}$ is the probability that a MN moves from network *ni*to *nj*at *t*.

$P_{ni/ni} = \Pr\{S_{ni}(t)\}$ is the probability that a MN is in *ni*and still in *ni*at time *t*.

The probability of unnecessary handoff $\Pr(Y_{nj/ni})$ and the probability of missing handoff $\Pr\{\Theta_{ni}\}$ also depend on the parameter which denotes the duration of the time t when MN makes handoff decision to the time t+D to check if the decision is correct or wrong.

The UHOP when MN tend to move from network i to j is defined as,

$$\Pr\{Y_{nj/ni}\} = P_{ni} P_{nj/ni} \times \Pr\{\Psi_{ni,nj}(r, t+D) / M_{nj/ni}(t)\} \quad (3)$$

The MHOP when the MN is staying at network ni is,

$$\Pr\{\Theta_{ni}\} = P_{ni}(1 - P_{nj/ni}) \times \Pr\{\Psi_{nj,ni}(r, t+D) / S_{ni}(t)\} \quad (4)$$

Substituting Eq. (3) and Eq. (4) in Eq. (1),

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$$WDHOP = \sum_{i=1}^{N}\sum_{\substack{j=1\\ j\neq i}}^{N} P_{ni}P_{nj/ni} \times \Pr\{\Psi_{ni,nj}(r,t+D)/M_{nj/ni}(t)\} + \sum_{i=1}^{N} P_{ni}(1-P_{nj/ni}) \times \Pr\{\Psi_{nj,ni}(r,t+D)/S_{ni}(t)\} \quad (5)$$

WDHOP mainly depends on the probability of a MN staying at each network, handoff decision algorithm i.e., how MN decides whether to handoff or not in the decision interval D.

3. BANDWIDTH BASED HANDOFF PROBABILITY ANALYSIS FOR THREE WIRELESS HETEROGENEOUS NETWORKS

Wireless heterogeneous networks are considered as ni, i=1, 2….N. W_i and w_i are the maximum capacity and the available bandwidth of ith network, i=1, 2…N.

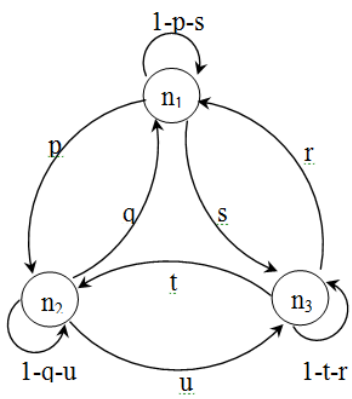

Figure-1. Three State Markov Model for handoff between three networks.

The three state Markov model is used to capture the process of MN switching between n1 to n2; n2 to n3; n3 to n1 and vice versa as shown in Figure-2.[15]. In this model, p, q, r, s, t, u are the probabilities of MN to move from n1 to n2, n2 to n1, n3 to n1, n1 to n3, n3 to n2, n2 to n3 and,(1-p-s), (1-q-u) and (1-t-r) are the probabilities of the MN to stay at n1, n2 and n3 respectively.
The probability of MN to stay at n1 is,

P_{n1}= (q +r) / (p + q + r + s + t +u)
= (Pn_1/n_2+Pn_1/n_3) /
(Pn_2/n_1+Pn_1/n_2+Pn_1/n_3+Pn_3/n_1+Pn_2/n_3+Pn_3/n_2) (6)

The probability of MN to stay at n2 is,

P_{n2}= (p +t) / (p +q + r +s + t +u) (7)
= (Pn_2/n_1+Pn_2/n_3) /
(Pn_2/n_1+Pn_1/n_2+Pn_1/n_3+Pn_3/n_1+Pn_2/n_3+Pn_3/n_2)

The probability of MN to stay at n3 is,
P_{n3}= (u +s) / (p +q + r + s +t +u) (8)
= (Pn_3/n_2+Pn_3/n_1)/
(Pn_2/n_1+Pn_1/n_2+Pn_1/n_3+Pn_3/n_1+Pn_2/n_3+Pn_3/n_2)

The traffic load (γ) of network i, where i=1,2 3 is modeled as an M/M/W_i process.The arrival rate of requests for channels follows a poission distribution with parameter λ_i ,i=1,2,3 and the service rate, at which the channel cleared, follows an exponential distribution with parameter μ_i. From queuing theory results, the following equation hold.

$$\mu_{i,k} = \begin{cases} k\mu_i & k \le W_i \\ 0 & otherwise \end{cases}$$

The Probability of channels to be occupied is defined as,

$$\prod_{i,k} = \prod_{i,0} \gamma_i^k / k! \quad ,0 < k \le W_i \quad (9)$$

Where, i =network number
k =the number of occupied channels
γ = traffic load (no.of connections to the particular network)
W_i =maximum bandwidth of the network
In this,

$$\prod_{i,0} = \frac{1}{\sum_{k=0}^{B_i} \frac{\gamma_i^k}{k!}}, i = 1,2 \quad (10)$$

w_i, is the available bandwidth of network *i*, *i* =1, 2. Then, the probability of available bandwidth of the network is,

$\Pr\{w_i = j\} = \Pi_{Wi-j}$, j = 0, · · ·,Wi, i = 1, 2., (11)

The probability of available bandwidth w_i, *i* = 1, 2 being greater than ris the number of request being less than W_i−ris,

$$\Pr(w_i \ge r) = \sum_{k=0}^{W_i - r} \prod_{i,k} \ , \ i = 1,2, P_{ni/nj}, j = 1,2, i \ne j \quad (12)$$

Eq. (11) depends on handover algorithm and for different handover initial algorithms, $P_{ni|nj}$can be calculated. With $P_{ni|nj}$ is known P_{n1} and P_{n2} and $P_{n3}$are calculated from Equation (6), Equation (7) and Equation. (8).

But $\Pr\{\Psi_{ni,nj}(r,t+D)/M_{nj/ni}(t)\}$,

$\Pr\{\Psi_{nj,ni}(r,t+D)/S_{ni}(t)\}$ need to be calculated before getting the expression of WDHOP which mainly depends on the bandwidth based handoff algorithm.

Bandwidth based handover probability algorithm

Step 1: Let network available bandwidth w_1, w_2, w_3 and threshold d_{th}.

Case 1: A mobile node is at n1.
If w_2-w_1> = d_{th}, the mobile node moves to n2
Else if w_3-w_1> = d_{th}, the mobile node moves to n3
Otherwise stays at n1.

Case 2: A mobile node is at n2.
If w_3-w_2> = d_{th}, the mobile node moves to n3
Else if w_1-w_2> = d_{th}, the mobile node moves to n1
Otherwise stays at n2.

Case 3: A mobile node is at n3.
If w_1-w_3> = d_{th}, the mobile node moves to n1
Else if w_2-w_3> = d_{th}, the mobile node moves to n2
Otherwise stays at n3.

Step 2: Finding the probabilities of MN to move from one network to another.

The probability of MN to move from nj to ni is,
$P_{ni/nj}$= P $\{w_i-w_j \geq d_{th}\}$ i=1, 2, 3, j=1,2, 3, i≠j

The probability of MN which is at n1 to stay at n1 itself is,

$$Pn_1/n_1 = 1-p-s = 1-Pn_2/n_1-Pn_3/n_1 \quad (13)$$

The probability of MN which is at n2 to stay at n2 itself is,

$$Pn_2/n_2 = 1-q-u = 1-Pn_3/n_2-Pn_1/n_2 \quad (14)$$

The probability of MN which is at n3 to stay at n3 itself is,

$$Pn_3/n_3 = 1-t-r = 1-Pn_2/n_3-Pn_1/n_3 \quad (15)$$

Step 3: Calculation of handoff probability of two wireless heterogeneous networks

From Equation (2), for three wireless heterogeneous networks

$$HOP = Pn_1\ (Pn_3/n_1+Pn_2/n_1) + Pn_2\ (Pn_3/n_2+Pn_1/n_2) + Pn_3\ (Pn_1/n_3+Pn_2/n_3) \quad (16)$$

Consider, w_1, w_2 and w_3 are independent, then

The probability of MN to move from n2 to n1 is given by,

$$Pn_1/n_2=\Pr\{w_1-w_2\geq d_{th}\} = \sum_{i=0}^{W_1}\sum_{\substack{j=0,\\ i-j\geq d_{th}}}^{W_2}\prod_{1,W_1-j,}\prod_{2,W_2-i} \quad (17)$$

The probability of MN to move from n1 to n2 is given by,

$$Pn_2/n_1 = \Pr\{w_2-w_1\geq d_{th}\} = \sum_{j=0}^{W_1}\sum_{\substack{i=0,\\ j-i\geq d_{th}}}^{W_2}\prod_{1,W_1-j,}\prod_{2,W_2-i} \quad (18)$$

The probability of MN to move from n3 to n2 is given by,

$$Pn_2/n_3=\Pr\{w_2-w_3\geq d_{th}\} = \sum_{i=0}^{W_2}\sum_{\substack{j=0,\\ i-j\geq d_{th}}}^{W_3}\prod_{2,W_2-j,}\prod_{3,W_3-i} \quad (19)$$

The probability of MN to move from n2 to n3 is given by,

$$Pn_3/n_2 = \Pr\{w_3-w_2\geq d_{th}\} = \sum_{j=0}^{W_2}\sum_{\substack{i=0,\\ j-i\geq d_{th}}}^{W_3}\prod_{2,W_2-j,}\prod_{3,W_3-i} \quad (20)$$

The probability of MN to move from n1 to n3 is given by,

$$Pn_3/n_1=\Pr\{w_3-w_1\geq d_{th}\} = \sum_{i=0}^{W_3}\sum_{\substack{j=0,\\ i-j\geq d_{th}}}^{W_1}\prod_{3,W_3-j,}\prod_{1,W_1-i} \quad (21)$$

The probability of MN to move from n3to n1 is given by,

$$Pn_1/n_3 = \Pr\{w_1-w_3\geq d_{th}\}=\sum_{j=0}^{W_3}\sum_{\substack{i=0,\\ j-i\geq d_{th}}}^{W_1}\prod_{3,W_3-j,}\prod_{1,W_1-i} \quad (22)$$

Substituting Equation (17) to Equation (22) in Equation (6), Equation (7) and Equation (8) the values of P_{n1}, P_{n2}, P_{n3} can be obtained. By substituting all these values in Equation (16) handoff probability can be obtained.

For equal bandwidth three wireless networks (W_1=W_2=W_3 =W) considering, the traffic load of the each network is also equal i.e. γ_1=γ_2=γ_3=γ and Pn_1/n_2 =Pn_2/n_1 =Pn_1/n_3 =Pn_3/n_1 =Pn_2/n_3 =Pn_3/n_2=P, then From Equation (16),

$$HOP = 2*Pn_1/n_2 \quad (23)$$

4. PERFORMANCE EVALUATION OF BANDWIDTH BASED HANDOFF ALGORITHM FOR THREE HETEROGENEOUS WIRELESS NETWORKS BASED ON WDHOP ANALYSIS

The performance of the specific bandwidth based handoff algorithm is estimated by calculating the WDHOP which is the combination of UHOP, MHOP.

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For two heterogeneous wireless networks, the unnecessary handoff probability (UHOP) is,

UHOP=Pr $\{Y_{nj/ni}\}$=Pr $\{Y_{n1/n2}\}$ +Pr $\{Y_{n2/n1}\}$,i, j=1,2. i ≠ j (24)

Using Eq. (3), the Eq. (24) can be written as,

UHOP=Pr $\{Y_{nj/ni}\}$

$$= P_{n1}P_{n2/n1} \times \Pr\{\Psi_{n1,n2}(r,t+D)/M_{n2/n1}(t)\} + P_{n2}P_{n1/n2} \times \Pr\{\Psi_{n2,n1}(r,t+D)/M_{n1/n2}(t) \quad (25)$$

The missing handoff probability (MHOP) is,

MHOP= Pr $\{\Theta_{ni}\}$ =Pr $\{\Theta_{n1}\}$ +Pr $\{\Theta_{n2}\}$ i, j=1, 2. i ≠ j(26)

Using Equation (4), the Equation (26) can be written as,

MHOP= Pr $\{\Theta_{ni}\}$

$$= P_{n1}(1-P_{n2/n1}) \times \Pr\{\Psi_{n2,n1}(r,t+D)/S_{n1}(t)\} + P_{n2}(1-P_{n1/n2}) \times \Pr\{\Psi_{n1,n2}(r,t+D)/S_{n2}(t)\} \quad (27)$$

The WDHOP is the combination of UHOP and MHOP. From Equation (1) the WDHOP for two wireless networks, N=2,

Using Equation (26) and Equation (27), the Equation (28) can be written as,

WDHOP=

WDHOP = Pr $\{Y_{n1/n2}\}$ +Pr $\{Y_{n2/n1}\}$ +Pr $\{\Theta_{n1}\}$ +Pr $\{\Theta_{n2}\}$ (28)

$$P_{n1}P_{n2/n1} \times \Pr\{\Psi_{n1,n2}(r,t+D)/M_{n2/n1}(t)\} + P_{n2}P_{n1/n2} \times \Pr\{\Psi_{n2,n1}(r,t+D)/M_{n1/n2}(t)\}$$
$$+ P_{n1}(1-P_{n2/n1}) \times \Pr\{\Psi_{n2,n1}(r,t+D)/S_{n1}(t)\} + P_{n2}(1-P_{n1/n2}) \times \Pr\{\Psi_{n1,n2}(r,t+D)/S_{n2}(t)\} \quad (29)$$

WDHOPdepends on the probability of a MN staying at each network, initial handoff algorithm and decision intervals. It is necessary to get Pr $\{\Psi_{n1,n2}(r, t+D)/M_{n2/n1}(t)\}$ and Pr $\{\Psi_{n2,n1}(r, t+D)/S_{n1}(t)\}$ to get expression for WDHOP. For simplicity of notation, time indication t and t+D are abbreviated in the following.

The conditional probability of the MN to move from network n1 to n2 when available bandwidth of network n1 is greater than or equal to r and available bandwidth of network 2 is less than r at time t +D is,

Pr $\{\Psi_{n1,n2}(r, t+D)/M_{n2/n1}(t)\}$ =

$$\sum_{j=d_{th}}^{W_2} \Pr\{w_1 \ge r/w_1 \le j-d_{th}\} \Pr\{w_2 = j\} \sum_{i=0}^{W_1} \Pr\{w_2 < r/w_2 \ge i+d_{th}\} \Pr\{w_1 = i\} \quad (30)$$

The conditional probability of the MN which is at network n1 and to stay at n1 at time t when available bandwidth of network n2 is greater than or equal to *r* and available bandwidth of network 1is less than *r* at time t+D is,

Pr $\{\Psi_{n2,n1}(r, t+D)/S_{n1}(t)\}$ =

$$\sum_{i=0}^{W_1} \Pr\{w_2 \ge r/w_2 \le i+d_{th}\} \Pr\{w_1 = i\} \sum_{j=d_{th}-1}^{W_2} \Pr\{w_1 < r/w_1 \ge j-d_{th}\} \Pr\{w_2 = j\} \quad (31)$$

Similarly, the conditional probability of the MN to move from network n2 to n1 when available bandwidth of network n2 is greater than or equal to r and available bandwidth of network1 is less than r at time t +D is,

Pr $\{\Psi_{n2,n1}(r, t+D)/M_{n1/n2}(t)\}$ =

$$\sum_{j=d_{th}}^{W_1} \Pr\{w_1 < r/w_1 \ge j-d_{th}+1\} \Pr\{w_1 = j\} \sum_{i=0}^{W_2} \Pr\{w_2 \ge r/w_2 \le i+d_{th}-1\} \Pr\{w_2 = i\} \quad (32)$$

The conditional probability of the MN which is at n2 and to stay at n2 at time t when available bandwidth of network n1 is greater than or equal to *r* and available bandwidth of network 2is less than *r* at time t+D is,

Pr $\{\Psi_{n1,n2}(r, t+D)/S_{n2}(t)\}$ =

$$\sum_{j=d_{th}-1}^{W_1} \Pr\{w_2 < r/w_2 \ge j-d_{th}+1\} \Pr\{w_1 = j\} \quad \sum_{i=0}^{W_2} \Pr\{w_1 \ge r/w_1 \le i+d_{th}-1\} \Pr\{w_2 = i\} \quad (33)$$

Let q be the variable and

$$f_1(r,q) = \Pr\{w_1 \ge r \;\; at \;\; t+D/w_1 \le q \;\; at \;\; t\},$$

$$g_1(r,q) = \Pr\{w_2 < r \;\; at \;\; t+D/w_2 \ge q \;\; at \;\; t\},$$

$$f_2(r,q) = \Pr\{w_1 < r \;\; at \;\; t+D/w_1 > q \;\; at \;\; t\},$$

$$g_2(r,q) = \Pr\{w_2 \ge r \;\; at \;\; t+D/w_2 < q \;\; at \;\; t\}$$

By using above notations, Equation (30), Equation (31), Equation (32), Eq. (33) can be written as,

Pr $\{\Psi_{n1,n2}(r, t+D)/M_{n2/n1}(t)\}$ =

$$\sum_{j=d_{th}}^{W_2} f_1(r, j-d_{th}) \Pr\{w_2 = j\} \sum_{i=0}^{W_1} g_1(r, i+d_{th}) \Pr\{w_1 = i\} \quad (34)$$

Pr $\{\Psi_{n2,n1}(r, t+D)/S_{n1}(t)\}$=

$$\sum_{i=0}^{W_1} g_2(r, i+d_{th}) \Pr\{w_1 = i\} \sum_{j=d_{th}-1}^{W_2} f_2(r, j-d_{th}) \Pr\{w_2 = j\} \quad (35)$$

Similarly, Pr $\{\Psi_{n2,n1}(r, t+D)/M_{n1/n2}(t)\}$=

$$\sum_{j=d_{th}}^{W_1} f_2(r, j-d_{th}+1)\Pr\{w_1=j\}\sum_{i=0}^{W_2} g_2(r, i+d_{th}-1)\Pr\{w_2=i\} \quad (36)$$

Pr $\{\Psi_{n1,n2}(r, t+D)/S_{n2}(t)\}=$

$$\sum_{j=d_{th}-1}^{W_1} g_1(r, j-d_{th}+1)\Pr\{w_1=j\}\sum_{i=0}^{W_2} f_1(r, i+d_{th}-1)\Pr\{w_2=i\} \quad (37)$$

Let l_i be the number of requests that leave network i during time interval D, and a_i be the number of requests that can be admitted to network i during time interval D, i=1, 2. Based on the queuing networks result, the leaving process of each server of M/M/N process is Poisson distribution with parameter λ/N, where λ is arrival rate of M/M/N system. When network i, i=1, 2 has k available bandwidth, the occupied bandwidth is W_i-k, then the leaving rate of the network will be $L_i = \lambda_i \times (W_i-k)/W_i$, i = 1, 2 .The probability of difference between the no. of requests that are admitted and the number of requests that leave the network i is ($a_i - l_i$) which is less than are equal to the difference between the no. of occupied channels and the no. of requests during the decision time interval D is given as,

$$\xi_i(k, r, D) = \Pr\{a_i - l_i \le k - r \text{ during } D\} = \sum_{m=0}^{W_i-k}\frac{(L_i D)^m}{m!}e^{-L_i D}\sum_{s=0}^{m+k-r}\frac{(\lambda_i D)^s}{s!}e^{-\lambda_i D} \quad (38)$$

The probability of difference between the no. of requests that are admitted and the number of requests that leave the network i is ($a_i - l_i$) which is greater than or equal to the difference between the no. of occupied channels and the no. of requests during the decision time interval D is given as,

$$\psi_i(k, r, D) = \Pr\{a_i - l_i > k - r \text{ during } D\}$$

$$= \sum_{m=0}^{W_i-k}\frac{(L_i D)^m}{m!}e^{-L_i D}\left[1 - \sum_{s=0}^{m+k-r}\frac{(\lambda_i D)^s}{s!}e^{-\lambda_i D}\right] \quad (39)$$

The general formulae are for obtaining $f_1(r,q)$, $g_1(r,q)$, $f_2(r,q)$, $g_2(r,q)$ are given as,

$$f_1(r,q) = \sum_{k=0}^{q}\Pi_{1,W_{1-k}}\xi_1(k,r,D) \quad (40)$$

$$g_1(r, q) = \sum_{k=q}^{W_2}\Pi_{2,W_{2-k}}\psi_2(k, r, D) \quad (41)$$

$$f_2(r, q) = \sum_{k=q+1}^{W_1}\Pi_{1,W_{1-k}}\psi_1(k, r, D) \quad (42)$$

$$g_2(r, q) = \sum_{k=0}^{q-1}\Pi_{2,W_{2-k}}\xi_2(k, r, D) \quad (43)$$

In the above equations, $\xi_i(k,r,D)$, $\psi_i(k,r,D)$ (i=1,2) values can be obtained using Eq. (38) and Eq. (39). Three wireless heterogeneous networks, WDHOP =

$$\begin{aligned}
&P_{n1}P_{n2/n1}\times\Pr\{\Psi_{n1,n2}(r,t+D)/M_{n2/n1}(t)\} + P_{n2}P_{n1/n2}\times\Pr\{\Psi_{n2,n1}(r,t+D)/M_{n1/n2}(t) + \\
&P_{n2}P_{n3/n2}\times\Pr\{\Psi_{n2,n3}(r,t+D)/M_{n2/n1}(t)\} + P_{n3}P_{n2/n3}\times\Pr\{\Psi_{n3,n2}(r,t+D)/M_{n1/n2}(t) + \\
&P_{n3}P_{n1/n3}\times\Pr\{\Psi_{n3,n1}(r,t+D)/M_{n1/n3}(t)\} + P_{n1}P_{n3/n1}\times\Pr\{\Psi_{n1,n3}(r,t+D)/M_{n3/n1}(t) + \\
&P_{n1}(1-P_{n2/n1})\times\Pr\{\Psi_{n2,n1}(r,t+D)/S_{n1}(t)\} + P_{n2}(1-P_{n1/n2})\times\Pr\{\Psi_{n1,n2}(r,t+D)/S_{n2}(t)\} \\
&+ P_{n2}(1-P_{n3/n2})\times\Pr\{\Psi_{n3,n2}(r,t+D)/S_{n2}(t)\} + P_{n3}(1-P_{n2/n3})\times\Pr\{\Psi_{n2,n3}(r,t+D)/S_{n3}(t)\} \\
&+ P_{n1}(1-P_{n1/n3})\times\Pr\{\Psi_{n1,n3}(r,t+D)/S_{n3}(t)\} + P_{n1}(1-P_{n3/n1})\times\Pr\{\Psi_{n3,n1}(r,t+D)/S_{n1}(t)\}
\end{aligned} \quad (44)$$

5. RESULTS AND DATA PROCESSING

The mathematical model for analysing the bandwidth based handoff algorithm has been developed for multiple 4G wireless networks. WDHOP is the performance metric used to measure the exactness of a handoff algorithm which can be applied uniformly for a homogeneous and a heterogeneous wireless networks. Figure-2 and Figure-3 give the details of the implementation of the proposed work in detail.

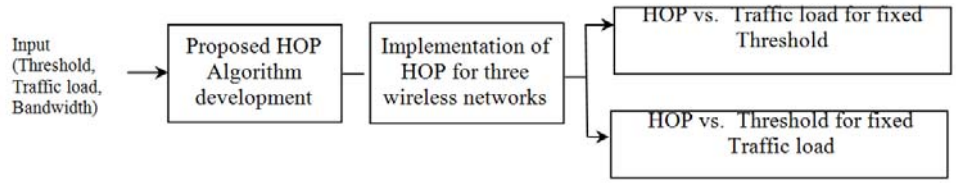

Figure-2. Implementation of the proposed bandwidth based handoff algorithm for three wireless networks.

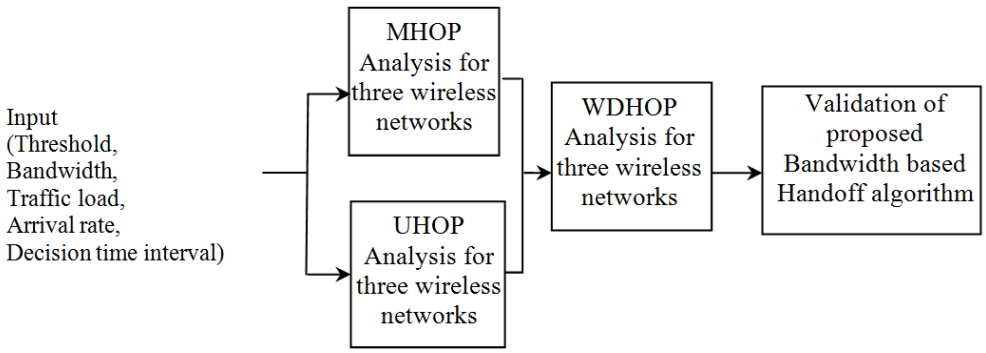

Figure-3. Validation and performance analysis of three wireless networks.

A. HOP analysis in three wireless networks

HOP analysis due to diverse traffic load configurations

Figure-4 illustrates the results obtained due to HOP analysis for multiple networks (three) for different threshold (d_{th}) values. In this configuration, for equal bandwidth (W_i =11 Mbps) and fixed threshold value, the variations in the HOP is observed very less with respect to the increase in the traffic load. It is also examined that as the threshold increases, HOP reduces with respect to traffic load. The resultant values are presented in Table-1.

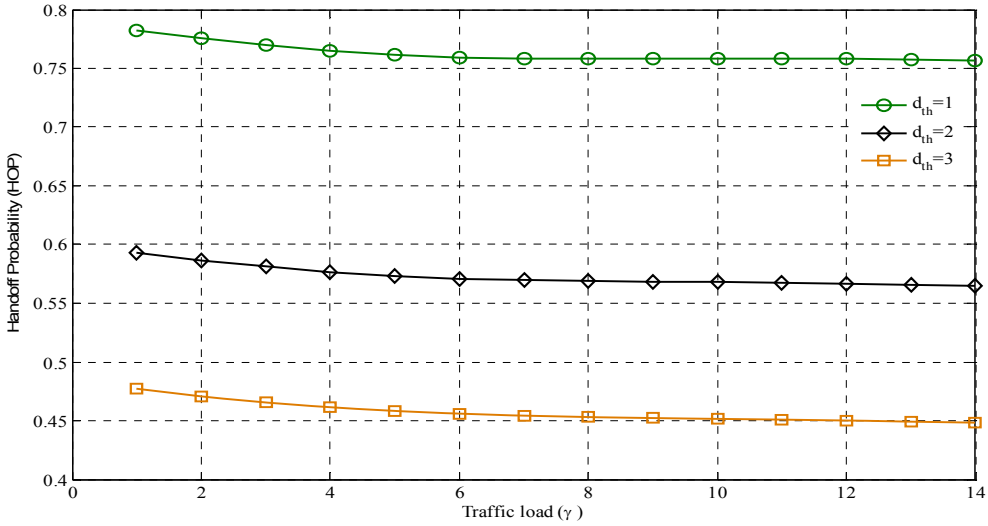

Figure-4. Traffic load (γ) vs. HOP for diverse thresholds for three equal bandwidth networks.

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Table-1. Handoff probability (Hop) Fordifferent traffic loads and at diversethresholds for three wireless networks.

S. No.	$P_{n1}=P_{n2}=P_{n3}$	Traffic load (γ)	Handoff Probability (HOP) at d_{th} =1	Handoff Probability (HOP) at d_{th}=2	Handoff Probability (HOP) at d_{th} =3
1	1/3	1	0.78202545	0.59269846	0.47687358
2		2	0.77574962	0.58665286	0.47092310
3		3	0.77009418	0.58129642	0.46576819
4		4	0.76526310	0.57674035	0.46143558
5		5	0.76163014	0.57321774	0.45804889
6		6	0.75941465	0.57084628	0.45565064
7		7	0.75844276	0.56946499	0.45408576
8		8	0.75825747	0.56872170	0.45306920
9		9	0.75837810	0.56825917	0.45232182
10		10	0.75846062	0.56782513	0.45164785
11		11	0.75832155	0.56728482	0.45094106
12		12	0.75789610	0.56658866	0.45015933
13		13	0.75718826	0.56573583	0.44929715
14		14	0.75623433	0.56474823	0.44836621
Mean			0.7627	0.5729	0.4570
Standard deviation			0.0079	0.0085	0.0087

Table-1 represents the HOP variations with respect to increase in the traffic load for equal bandwidth (11Mbps) three wireless networks. HOP decreases marginally with respect to traffic load. As the threshold (d_{th}) increases from 1 to 3, the mean value of HOP is reduces from 0.7627 to 0.4570 and standard deviation is increases very less from 0.0079 to 0.0087.

Handoff probability analysis due to various threshold values

Figure-5 demonstrates the results obtained due to HOP analysis for three network configuration for different traffic load (γ). It is examined that, the HOP decreases with increase in the threshold values. It is also identified that at a fixed threshold, the variations in the HOP with the traffic load are very less amount.

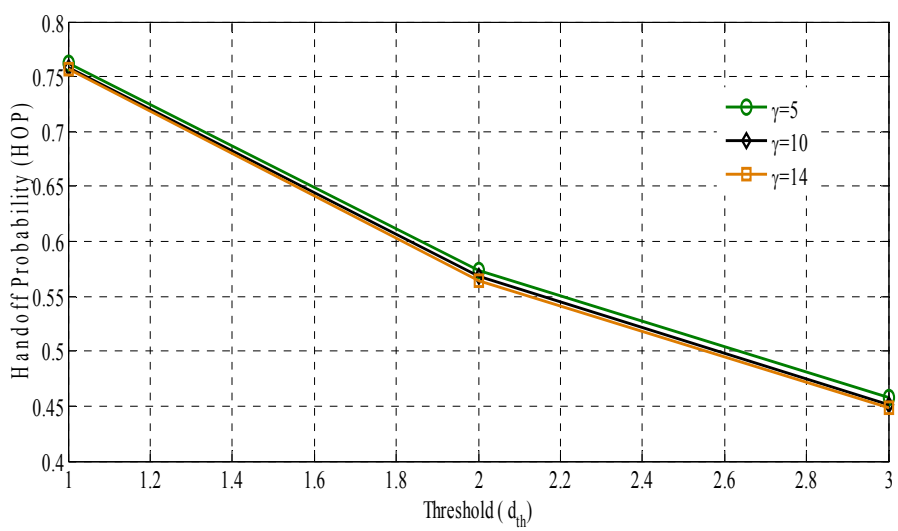

Figure-5. Threshold (d_{th}) vs. Handoff probability (HOP) for different traffic loads for three wireless networks.

B. Wrong decision handoff probability (WDHOP) analysis for three wireless networks

UHOP analysis due to various threshold values

Figure-6 demonstrates the results obtained due to UHOP analysis for three wireless network configurationsfor different threshold (d_{th}) values. In this analysis, with fixed threshold value, the variations in the UHOP increases with respect to the increase in the traffic load. It is also examined that as the threshold increases UHOP reduces with respect to traffic load.

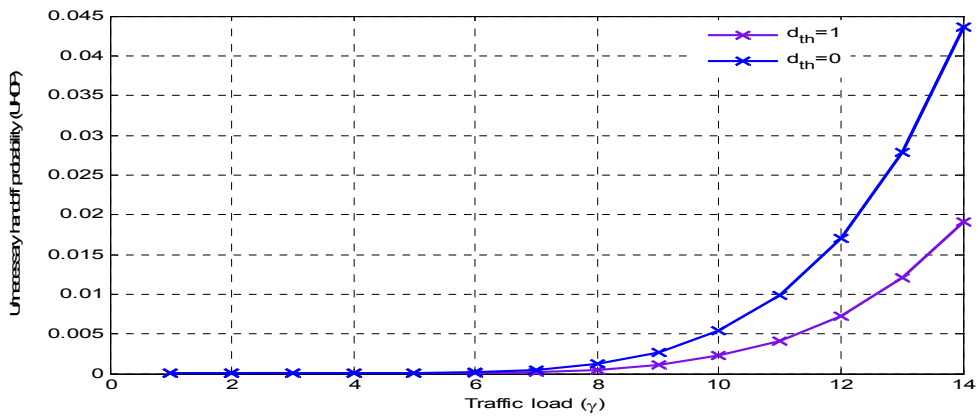

Figure-6. Traffic load (γ) vs. Unnecessary handoff probability (UHOP) at dth=0, 1.

MHOP analysis due to various threshold configurations

Figure-7 shows the results obtained due to the MHOP analysis for different threshold (d_{th}) values. It is studied that in a three with fixed threshold value, the variations in the MHOP increases with respect to the increase in the traffic load. It has also been identified that as the threshold increases MHOP reduces with respect to traffic load.

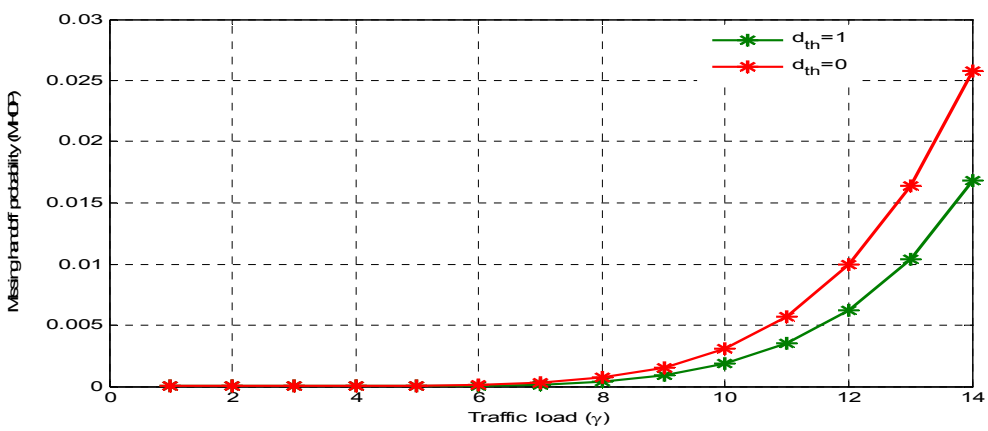

Figure-7. Traffic load (γ) vs. Missing handoff probability (MHOP) at d_{th}=0, 1.

WDHOP analysis due to various threshold configurations

Figure-8 shows the results obtained due to WDHOP analysis for for different threshold (d_{th}) values. The different threshold values used in the analysis are, d_{th} =0 and d_{th}=1. It is examined that for equal bandwidth (W_i=11 Mbps) three wireless network configuration with fixed threshold value, the variations in the WDHOP is increases with respect to the increase in the traffic load. It is also noted that as the threshold increases WDHOP reduces with respect to traffic load. The resultant values are presented in Table-2.

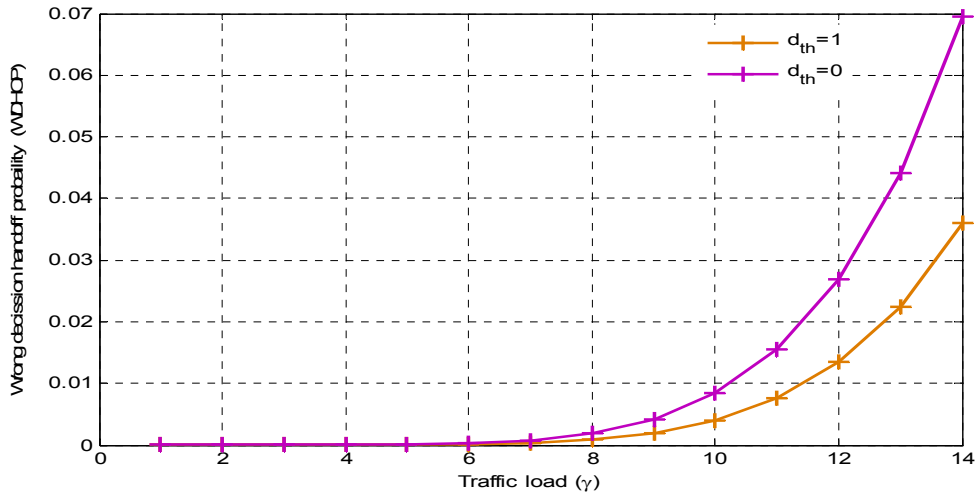

Figure-8. Traffic load (γ) vs. Wrong decision handoff probability(WDHOP) at dth=0, 1.

Table-2. Wrong decision handoff probability (WDHOP) for different traffic loads and at various thresholds for three wireless networks.

S. No.	$P_{n1}=P_{n2}=P_{n3}$	Traffic Load (γ)	Wrong decision handoff probability at d_{th} = 0	Wrong decision handoff probability at d_{th} = 1
1	1/3	1	0.00000000	0.00000000
2		2	0.00000017	0.00000007
3		3	0.00000245	0.00000101
4		4	0.00001689	0.00000723
5		5	0.00007727	0.00003405
6		6	0.00026960	0.00012156
7		7	0.00077339	0.00035561
8		8	0.00191068	0.00089429
9		9	0.00419578	0.00199730
10		10	0.00838056	0.00405626
11		11	0.01549297	0.00762448
12		12	0.02686845	0.01344597
13		13	0.04417495	0.02248331
14		14	0.06943223	0.03594440

Table-2 represents the WDHOP variations with respect to increase in the traffic load for equal bandwidth (11Mbps) three wireless networks. It is observed that WDHOP increases with respect to traffic load. For example, when threshold (d_{th}) is 0 and at traffic load 1 WDHOP is observed to be zero. At traffic load 2 the WDHOP observed is 0.00000017; and at traffic load 14, WDHOP is observed is 0.06943223. It is also noted that as the threshold increases to 1, WDHOP decreases. For example, at traffic load 3, the WDHOP is 0.00000007; and at traffic load 14, WDHOP is 0.03594440

6. CONCLUSIONS

In this paper, mathematical analysis for bandwidth based handoff probability and wrong decision handoff probability are presented for the multiple wireless networks (three wireless networks). In three networks, as traffic load increases, the HOP does not vary much with fixed threshold. The WDHOP is the combination of MHOP and UHOP. As threhold increases MHOP and UHOP decreases for a fixed traffic load. MHOP and UHOP are increases as traffic load increases.For a fixed traffic load 14, threshold 0, WDHOP 0.06943223 and when threshold 1, the WDHOP 0.03594440. The performance of the three wireless networks has increased with the minimum WDHOPs based on bandwidth based

handoff algorithm and also WDHOP analysis improves the QoS. This proposed algorithm is applicable for 5G Wireless Networks with minimum wrong decision handoffs.

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