Traffic Sensitive based Load Balanced Vertical Handoff Decision Algorithm

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Abstract— **Mobility nature of the mobile nodes has the most obvious problem, call drop. A handoff methodology should ensure drop rate reduction for the proper functioning of the network. Call drop may occur mainly because of the loss of signal strength when the mobile node moves away from the coverage of the base station and bandwidth starvation because of the congestion. Congestion can be handled by reducing the load by call drop or balancing the load by distributing to the nearby channel where the bandwidth is sufficient. Even if the call drop is reduced by changing the ongoing call from current channel to the next available channel, when the QoS requirement of the current traffic is not satisfied by the target channel because of the bandwidth starvation, again the ongoing call needs to be changed into another channel, which is frequent switching between the base stations (ping-pong effect), is also important to reduce to avoid the unnecessary wastage of resources. This paper concentrates on successful handoff decision; reduce unnecessary handoff and proper utilization of resources by implementing load balancing.**

Keywords-Congestion Indicator, Load Balancing, QoS, Handoff, MCDM, ACO, TSLBVHO

I. Introduction

Unimaginable development in the field of wireless network and mobile communication technology offers various advanced features and services for communication. People use the technology in their day to day life for personal communication, business communication and military communication, etc. To magnetize more and more number of users to make use of those features successfully, seamless and continuous connection should be provided at anytime and anywhere with best Quality of Service. Recent advancement in the mobile communication technology supports the Mobile Stations (MSs) to have multiple interfaces and to access the different types of cellular networks like Global System for Mobile Communication (GSM), General Packet Radio Services (GPRS), Code Division Multiple Access (CDMA), Bluetooth based Personal Area Network (PAN), IEEE 802.11 (WiFi), IEEE 802.16 (WiMAX), Vehicular Ad-hoc Networks (VANET), and Satellite networks. Each network has been developed for specific purposes with different features. Integration of these various networks leads to the development of Heterogeneous Wireless Networks, which has different access technologies, overlapping and coverage, and network architecture, protocols for transport, routing and mobility management.

Mobile Communication system consists of mobiles devices, base station and a switching center. Each mobile communicate via base stations. Radio frequency spectrums are used to do communication between the mobile devices. Because of the limited spectrum frequency only limited numbers of calls could be accommodated. Hence, the available spectrum should be utilized in an efficient manner via channel reusability. Once a call is in progress, the switching center adjusts the transmitted power and changes the signal of the mobile device and base station to maintain call quality as the mobile device moves in and out of the range of a given base station.

Further, maintaining the Quality of Service is also one of the most important requirements of the mobile communication in heterogeneous networks. Appropriate signal selection proves to be the major issue in handoff due to the availability of a large number of signals requesting for the same signal. The inappropriate allocation might either make the allocation unnecessary, due to the unavailability of the requested quality, or might lead to starvation of other signals, if the allocation is over qualified for the request. The handoff decision making algorithms that are proposed in this research should be able to satisfy all the requirements during signal selection.

While switching from one to another network, it is essential to maintain load balancing among various attachment points. Load balancing is a prime matter of concern to make use of available resources efficiently among single networks as well as different technologies in heterogeneous wireless networks. Therefore, handoff is one of the most important tasks in order to maintain the continuity during a call in progress. And its failure will cause an increase in the call dropping rate and also call blocking rate. The importance of dynamic resource utilization among heterogeneous wireless networks is on the increase day by day. Moreover, it is observed that various methods are used to reduce the ping-pong handoff, which unnecessarily occurs between different services with a rapid back-and forth frequency when there is an inefficient or insufficient resource allocation. Ping-pong handoffs are notorious for increasing the signaling load, and so various approaches are proposed to avoid these handoffs. Some of the successful approaches include dwelling timer method, hysteresis margin method, methods applying the average rectangular window on RSS values, and application of the least square line (LSL) on RSS values. Based upon this information, a position based vertical handoff algorithm is proposed [1]. Thus, load balancing between wireless networks is of prime importance. For the purpose of proper resource utilization, and extension of system capacity, as well as for providing the clients with improved quality service, load balancing is a significant step [2]. In various researches [7-11], it is indicated that load balancing is a needful step for improvising overall system performance, avoiding network congestion and increasing its capacity to provide best quality of service and accommodate more call request. This paper provides introduction about basic heterogeneous network and the need for handoff and load balancing. Section II discuss about related work exists on handoff and load balancing techniques. Section III depicts the problem statement and Section IV explains about the TSLBVHO algorithm. Section V provides the performance analysis of TSLBVHO and Section VI concludes the work.

II. Related work

Several research works have been proposed for vertical handoff decision and for best signal selection among heterogeneous networks. Some of them are discussed here. Traffic sensitive vertical handoff algorithm [22] considers different types of traffic with QoS and selects the best channel among the various network technologies. QoS aware traffic sensitive handoff reduction algorithm [23] deals to reduce handoff decision time, number of handoffs and maintains the quality using Artificial Neural Networks (ANN). Statistical Analysis was proposed in [24] to find the quality of the various networks (WiFi, WiMAX, WCDMA) by applying multi-criteria decision making (MCDM) to select appropriate channel to handoff with best QoS. Ant Colony Optimization (ACO) based MCDM [25] was proposed by considering the pheromone concentration τ and the evaporation rate ρ for efficient signal selection. Enhanced handoff with hybrid parallelized ant colony search [26] deals with variants of ACO and proves that hybrid parallelized approach reduces the handoff decision time and selects best quality signal. All of these algorithms doesn't consider congestion and load balancing as a prime factor for network selection.

Some of the following works is highlighted due to their significant impact in the research direction by considering load distribution. A load control algorithm has been presented in [3]. Which periodically adjust the threshold among neighbouring networks according to the load condition, though it does not indicate hoe the clients are to be assigned in heterogeneous networks? Previously, a lot of algorithms have been used for performing vertical handoff. M-OPTF algorithm considers the parameters like RSS, load, velocity of the mobile node, to scrutinize the performance of vertical handoff algorithm[4].M-OPTF algorithm concentrates on distribution of the load equally among all the attachment points. To fully exploit the capacity of the wireless channel, and to overcome ping-pong effect, an efficient power estimation method is required [5,6]. The ping-pong effect occurs if factors for VHO decision are changing rapidly and an MT performs the handoff as soon as it detects a more suitable BS. Because of heterogeneity, PHY and MAC layer of different IHWN are different, so a unified approach must be taken into consideration for collection of specific measures from different networks. As a result, more sophisticated VHO algorithm is required to extend the throughput of multilayer network and to increase efficiency of resource management for next generation of HWNs. Utilizing an accurate joint velocity and ARP estimation algorithms, a novel VHO algorithm is proposed which can effectively be used for load balancing and internetwork ping-pong effect reduction in HWNs in [12]. In a homogenous environment, the ping-pong effect is a phenomenon that rapidly repeats HHOs between two BSs and can be mitigated by means of dwell timer (DT) or hysteresis margin [13]. In a heterogeneous environment, the ping-pong effect occurs if factors for the VHO decision are changing rapidly and an MT performs handoff as soon as the MT detects the better BS [14]. Early works on VHO considered multitier homogeneous networks and used the RSS as the main factor of the hand-off decision-making process [15]. However, the VHO needs to be triggered considering a few more factors [16]. In [17], a VHO algorithm is proposed based on a assumption that a data call is kept in the higher bandwidth network as long as possible and voice calls are vertically handed over as soon as possible to avoid handoff delay. In [18], a network selection strategy that only considers mobile users' power consumption is introduced. To maximize the battery life, the mobile user selects the uplink or downlink that has the lowest power consumption from all of the available networks. In [19], a policy-enabled network selection strategy is proposed, which combines several factors such as bandwidth provision, price, and power consumption. By setting different weights over different factors based on the user's preference, a mobile user can connect to the most desired network.

III. Problem statement

Network load is to be considered during effective handoff. It is important to balance the network load to avoid deterioration in quality of services. Variations in the traffic loads among cells will reduce the traffic-carrying capacity. To provide a high quality communication service for mobile subscribers and to enhance a high traffic-carrying capacity when there are variations in traffic, network load must be paid attention. A model is developed that analyzes the case in which a vehicle is kept at different positions of a highway, and the network ranking optimizes the "best" network in multiple constraint environments [15]. This evaluation technique requires knowledge of vehicular speed, RSS, type of application (bandwidth requirements), network traffic load, usage cost of service and initial delay for connection establishment. The proposed methodology avoids unnecessary handovers and hence encounters "ping-pong effect".

In the previous work Congestion Based Vertical Handoff Decision Using TSCBVHO Algorithm [20], it is mentioned that, as the mobile nodes initiate more applications, the network may have limited resources that would not allow it to provide the same quality of services. If signal strength of the next channel is strong enough, more numbers of ongoing calls switched over towards the same channel. Hence more resources are utilized and bandwidth starvation arise which leads to congestion. In order to reduce the congestion on the network, an effective congestion control algorithms is required. To reduce the congestion, fix the threshold value to reduce the numbers of handoff triggered to the same channel.

But reducing the number of handoffs to the same channel by fixing the threshold value may not suitable when there is more number of handoff requests. Number Mobile Node (MN) users are increasing each and every minute rapidly. Hence, all the users must be provided with best quality communication without call drop. When the MN users are increased automatically more number of handoff requests might be triggered. Even though, some of the handoff requests are unnecessary but most of the request should be handed off to the next available channel. But preventing the handoff to the same channel might reduce the congestion but leads to call drop. Therefore, this paper concentrates to monitor the congested network and distributes the load to the nearby channel based the traffic requirement and available bandwidth to make that channel as a congestion free in order to maintain the channel as below threshold level. So that the more number of handoff request can be successfully handled to avoid call drop, at the same time QoS is maintained and resources are utilized in a better way to reduce ping-pong effect.

IV. Tslbvho algorithm

Traffic Sensitive based Load Balanced Vertical Handoff Decision Algorithm (TSLBVHO):

Whenever handoff is required, first of all link layer is triggered by a mobile node. All the information such as RSS, velocity of mobile nodes and battery power is exchanged between link layer and Media Independent Handover Function (MIHF). MIHF is a protocol stack which is present in access point, base station as well as MNs. In order to exchange information between different networks such as traffic load, handoff call dropping rate, network capacity and so on, MIHF acts as a medium of communication [2]. In this proposed work, handoff decision is made based on several factors such as, speed of the mobile node, direction, traffic type and its quality requirement, available bandwidth and network congestion. If the network is monitored as congested immediately the load has been distributed to the nearby channel based on the available bandwidth. Thus the algorithm has three phases like Handoff Decision Making Module, Congestion Indicator Module and Load Distribution Module. First two phases were given in [20].

Table 1 Traffic classes and their QOS requirements

Traffic	BER	Delay	Jitter	Bandwidth
Conversational	Need not be Low	Should be Low	Should be Low	Need not be high
Streaming	Need not be Low	Should be Low or medium	Should be Low	Should be high
Interactive	Should be Low	Should be Low or medium	Need not be Low	Should be high
Background	Should be Low	Need not be Low	Need not be Low	Should be medium at least

i) Handoff Decision Making Module:

Handoff Decision can be made by considering the Received Signal Strength (RSS), speed of the mobile node, direction, QoS requirement of the traffic, etc.

Assumptions [20]:

i. Received Signal Strength (RSS) is given by [25]

$$10 \log 10\ r = 10 \log 10\ PTX + 10 \log 10\ C - 10 \log 10\ (d\ \tilde{}d)\beta + \eta \quad (1)$$

where C, ˜d, β, and η, respectively, denote a constant value depending on the antenna characteristics and the average channel attention, a reference distance for the antenna far-field, the path loss exponent, and a variation depending on the channel fading[6].

The received signals from the base stations are affected by two major factors [27]: path loss and shadow fading.

$$L_{dB} = PL + 10n \log(d) + S \quad (2)$$

where PL is the constant power loss, *n* is the path loss exponent with values between 2 to 4, *d* represents the distance between the MT and WLAN's AP and *S*, represents shadow fading which is modeled as Gaussian with mean $\mu = 0$ and standard deviation σ with values between 6 and 12 dB depending on the environment

Path loss [21] indicates the decline in the power of the wave during transmission from the sender to the receiver. In general, the path loss depends on the properties of the environment, the topography of the earth and the propagation medium, and the distance between the sender, the receiver, and the height of the BS/AP. The propagation or path loss from the sender antenna to the receiver antenna is computed using the equation: PL = 10 log [Pt / Pr] Where PL is the path loss in decibels (db), Pt is the transmitted power in watts, and Pr is the received power in watts.

By removing the logarithm of both sides in Equation (1), it is possible to obtain the RSS in milliwatt as follows.

r = nαd−β (2) where we define α and n as PTXC ˜d β and 10η/10, respectively.

For RSSI signal between -50db and -100db, quality ~= 2* (db + 100) RSSI ~= (percentage / 2) - 100 For example: High quality: 90% ~= -55db, Medium quality: 50% ~= -75db,

Low quality: 30% ~= -85db, Unusable quality: 8% ~= -96db

ii. Time to Drop (TD) can be determined by considering mobile node speed, direction using,

TD = Dx / Sx

Dx = √ (X2–X1)2 + (Y2–Y1) (3)

Where Dx is the distance to be covered for the call to drop from the network currently being used and Sx is the speed in which the user is travelling. X1, Y1and X2, Y2 are the co-ordinates occupied by the mobile node and the antenna respectively.

iii. Network Congestion (NetCon) is calculated by the network

iv. Network Congestion Threshold (NetConTh) is calculated based on required bandwidth of current types of traffic (voice, streaming, interactive etc)

Handover rate (Pn) [28]: reducing the number of handovers is usually preferred as frequent handovers would cause wastage of network resources. Pn can be calculated as shown below.

$$P_n = \frac{\text{Number of Handoff Requests}}{\text{Total Number of Users}} \quad (4)$$

Handover failure rate (Pf) [28]: a handover failure occurs when the handover is initiated but the target network does not have sufficient resources to complete it, or when the mobile terminal moves out of the coverage of the target network before the process is analyzed. Pf can be calculated as shown in equation.

$$P_f = \frac{\text{Number of Unsuccessful Handoff Requests}}{\text{Total Number of Handoff Requests}} \quad (5)$$

ii) Congestion Indicator Module (CIM) [20]:

In TSCBVHO algorithm [20], when the network congestion is beyond the threshold value, the ongoing call is maintained in the same network itself. But if the handoff request triggered because of QoS requirement, forcing handoff request call on the same network might degrade the QoS. Hence, if there is a possibility to distribute the load of the target network to the neighbouring channel. Now the CIM signals the Load Monitoring Module (LMM).

iii) Load Monitoring Module and Load Balancing Module:

Load Monitoring Module (LMM), scans the neighbouring channel continuously and calculates the unused bandwidth (BW) of the channel. LMM stores those channel details in the database for the future use and waits for a while to check, is there any load balancing request from the CIM. If yes, it triggers the Load Balancing Module (LBM).

LBM receives required bandwidth information about the congested channel from CIM. Distribute the traffic from the congested channel to the nearby channel based on the availability of the bandwidth. For example, some type of traffic may require only minimum bandwidth like conversational and some may need high bandwidth like interactive. If the network is having more conversational traffic it can be distributed to the nearby channel, which can accommodate minimum bandwidth traffic. By distributing some conversational traffic, the current network might have cumulated bandwidth, which is sufficient for interactive. Likewise, network should be monitored and light weight traffic can be offloaded in order to avail the high bandwidth for the handoff calls. If the available bandwidth is sufficient after load distribution then the handoff call is assigned to the channel. Otherwise it will be blocked.

TSLBVHO Algorithm:

Load Monitoring Module:

Step 1: Start LMM

Step 2: Scan the neighbouring channel

Step 3: Calculate the unused bandwidth

Step 4: Store those channel detail in a database

Step 5: Wait for while to check, is there load balancing request from CIM?

Step 6: If yes, call the LBM else continue step 2.

Load Balancing Module:

Step 7: Receives required bandwidth detail from CIM

Step 8: Distribute the traffic to the nearby channel based on the available bandwidth

Step 9: Make the congested channel free from congestion

Step 10: Calculate the currently available bandwidth of the channel

Step 11: If BW is sufficient, handoff call is assigned

else drop the call.

TSLBVHO Flow Chart:

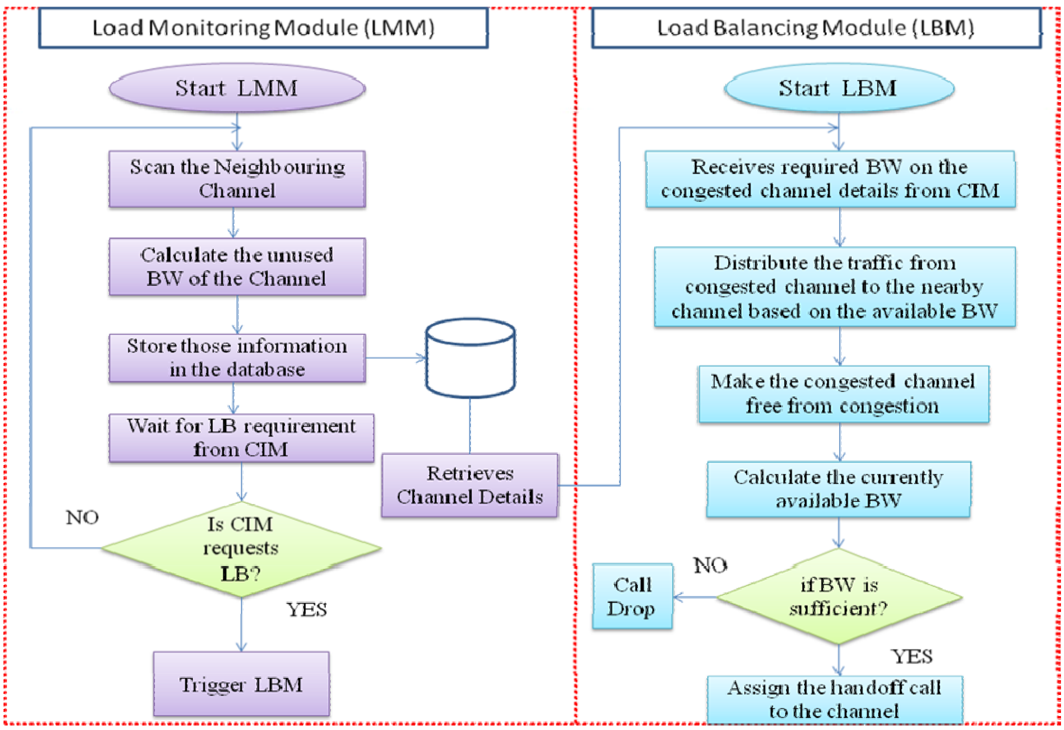

Fig. 1 Flowchart for TSLBVHO with LMM and LBM

V. Performance analysis

TSLBVHO algorithm is proposed to reduce handoff failure rate and better utilization of resources during handoff. Before that, the handoff decision making module decides whether the handoff is necessary by considering RSS, speed, direction, path loss factor of the mobile node and the QoS requirement of the traffic. Once it is decided that the handoff is needed then the congestion indicator module (CIM) monitors the best network channel to execute the handoff request and selects the channel which best suits for the current QoS requirement of the traffic using MCDM and ACO. It also indicates about the congested channel by applying network congestion threshold, in which the handoff should not be done. Once the CIM signals about the congested channel, LBM is triggered to offload the congested traffic to the nearby channel with the support of LMM. LMM scans the channel and stores those channels's unused bandwidth information in the database. LBM uses the information stored in the database and offloads the traffic to the best suited network channel. Hence, the number of QoS required handoff is executed successfully.

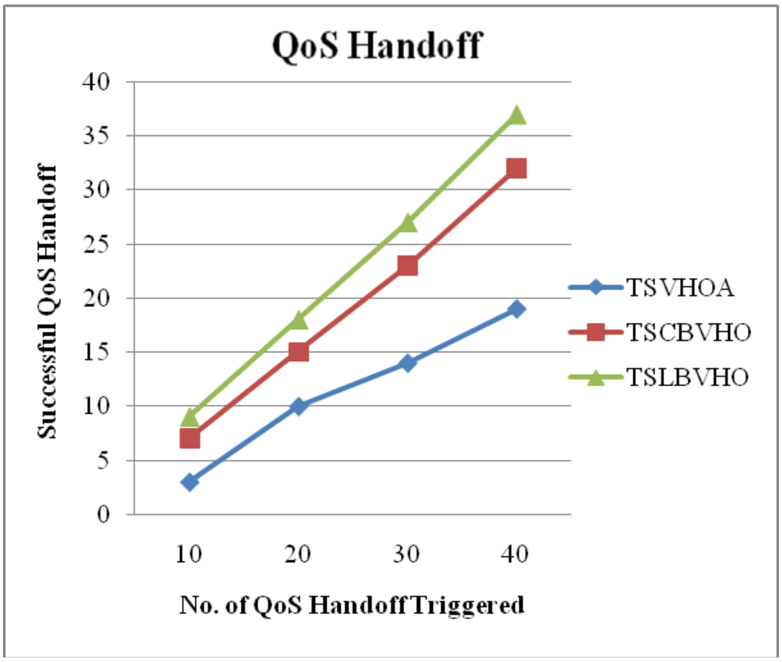

Fig.2 Comparison of Successful QoS Handoff

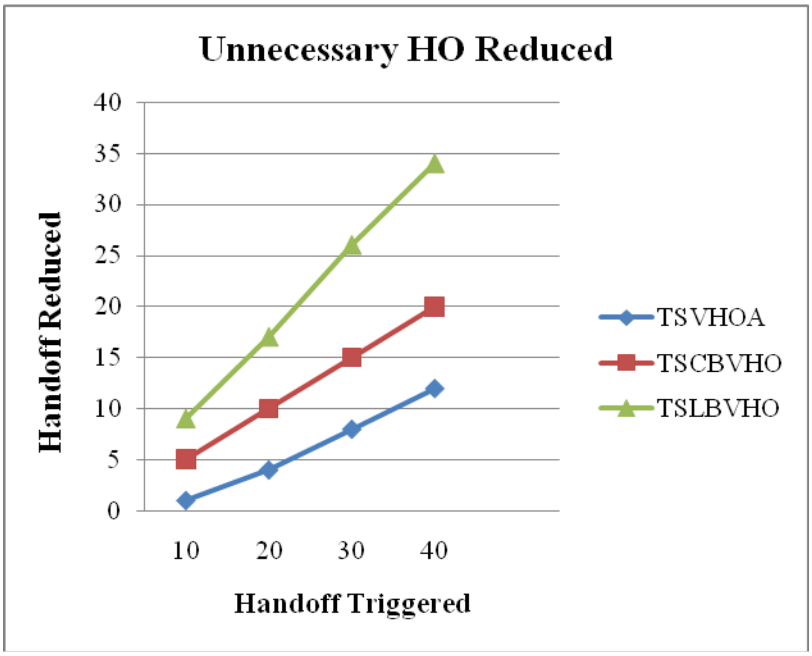

Fig.3 Comparison of Unnecessary Handoff Reduction

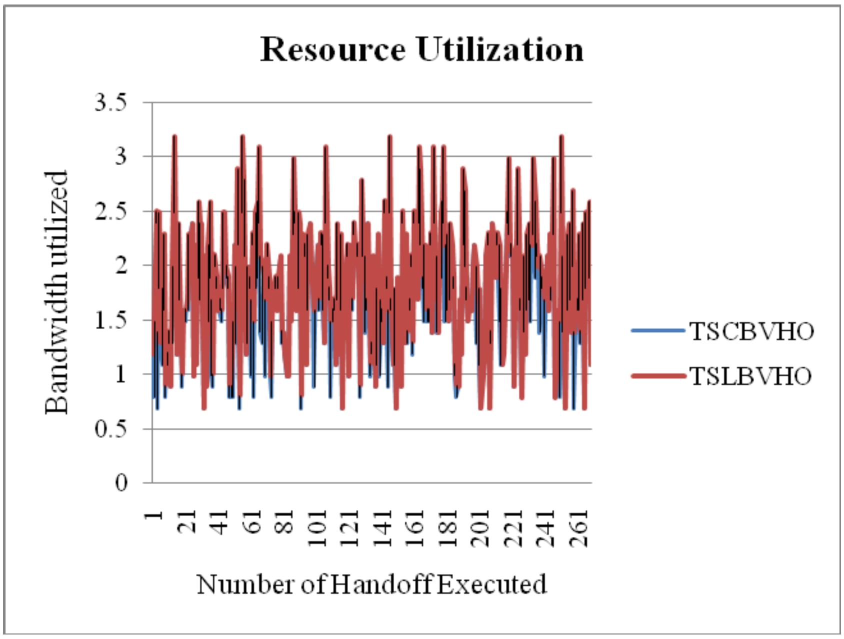

Fig.4 Network Resource Utilization

Fig. 2 depicts the comparison of TSVHOA, TSCBVHO and TSLBVHO with respect to number of QoS handoff triggered and successfully executed. All the three algorithms execute the handoff with 46%, 77% and 91% respectively. Fig.3 shows the comparison of TSVHOA, TSCBVHO and TSLBVHO with respect to Unnecessary Handoff Reduction with 20%, 50% and 86% respectively. Fig.4 shows the resources utilization by comparing the TSCBVHO algorithm and TSLBVHO algorithm. TSLBVHO shows the better utilization the resources than the TSCBVHO algorithm.

VI. Conclusion

The proposed algorithm effectively executes the handoff request by applying load balancing technique. Handoff rate is 78% and handoff failure rate is 22%. Almost 91% of handoff is successfully done over the best channel with sufficient bandwidth. Hence 86% of unnecessary handoff or frequent handoff request is reduced. Network channel bandwidth is utilized efficiently because of the load balancing technique

VII. References

[1] Position Based Vertical Handoff Decision Algorithm, shodhganga.inflibnet.ac.in/bitstream/10603/49427/8/08_chapter%203.pdf.
[2] D. Sumathi1*, T. Velmurugan2, S. Nandakumar2 and S. Renugadevi, Dynamic Weight Assignment based Vertical Handoff Algorithm for Load Optimization, Indian Journal of Science and Technology, Vol 9(37), DOI: 10.17485/ijst/2016/v9i37/102119, October 2016.
[3] Adaptive load balancing between multiple cell layers. http://ieeexplore.ieee.org/document/1040504/.
[4] Velmurugan T, Khara S, Basavaraj B. Modified handoff algorithm for providing optimization in heterogeneous wireless networks. Evolving Systems. 2015 Sep; 6(3):199–208.
[5] M Ylianttila, M Pande, J Makela, P Mahonen, Optimization scheme for mobile users performing vertical handoffs between IEEE 802.11 and GPRS/ EDGE networks, in IEEE Global Telecommunication Conference, San Antonio,TX, (December 2001)
[6] R Hsieh, ZG Zhou, A Senevirante, S-MIP: A seamless handoff architecture for mobile IP, in IEEE International Conference on Computer Communication San Francisco, CA, (April 2003)
[7] Load shared integrated networks. http://ieeexplore.ieee.org/document/1350189/. Date Accessed: 22/04/2003.
[8] Nandakumar S, Khara S. Modeling and Performance Analysis of an Improved Data Channel Assignment (DCA) Scheme for 3G/WLAN Mixed Cells. International Journal of Wireless Information Networks. 2015 Mar; 22(1):10–28.
[9] Song W, Zhuang W, Cheng Y. Load balancing for cellular/WLAN integrated networks. IEEE Network. 2007 Jan-Feb; 21(1):27–33.
[10] Jin L, Zhang H, Yang L, Zhu H. A Novel Adaptive Load Balancing Algorithm in Heterogenous Wireless Networks. Journal of Information and Computational Science. 2014 May; 1548–7741.
[11] Zhang Y, Zhang K, Chi C, Ji Y, Feng Z, Zhang P. An adaptive threshold load balancing scheme for the end-to-end reconfigurable system. Wireless Personal Communications. 2008 Jul; 46(1):47–65.
[12] Pourmina and MirMotahhary: Load balancingalgorithm by vertical handover for integrated heterogeneous wireless networks. EURASIP Journal on Wireless Communications and Networking 2012 2012:14. doi:10.1186/1687-1499-2012-14
[13] WF El-Sadek, MN Mikhail, Universal mobility with global identity (UMGI) architecture. IEEE International Conference on Wireless Networks and Information Systems, WNIS 09 Los Alamitos389–394.
[14] N Zhang, J Holtzman, Analysis of handoff algorithms using both absolute and relative measurements. in 44th IEEE Vehicular Technology Conference 82–86 (September 1994)
[15] GP Pollini, Trends in handover design. IEEE Commun Mag. 34(3), 82–90 (1996). doi:10.1109/35.486807
[16] N Mirmotahhary, Y Mafinejad, F Atbaei, A Kouzani, An adaptive policy-based vertical handoff algorithm for heterogeneous wireless networks, in IEEE 8th International Conference on Computer and Information Technology, Sidney, pp. 188–193 (July 2008)
[17] Q Zhang, C Guo, Z Guo, W Zhu, Efficient mobility management for vertical handoff between WWAN and WLAN. IEEE Commun Mag. 41(11), 102–108 (2003). doi:10.1109/MCOM.2003.1244929
[18] N Nam, N Choi, Y Seok, Y Choi, WISE: energy-efficient interface selection on vertical handoff between 3G networks and WLANs. IEEE Int Symp Pers Indoor Mobile Radio Commun 692–698 (July 2004)

[19] H Wang, R Katz, J Giese, Policy-enabled handoffs across heterogeneous wireless networks. in IEEE Workshop on Mobile Computing Systems and Applications 51–60 (1999)

[20] A. Bhuvaneswari, Congestion Based Vertical Handoff Decision Using TSCBVHO Algorithm, International Journal of Modern Communication Technologies & Research (IJMCTR) ISSN: 2321-0850, Volume-4, Issue-11, November 2016.

[21] Wail Mardini and Musab Q. Al-Ghadi, Ismail M. Ababneh, Distance-Based Scheme for Vertical Handoff in Heterogeneous Wireless Networks, JOURNAL OF EMERGING TECHNOLOGIES IN WEB INTELLIGENCE, VOL. 4, NO. 1, FEBRUARY 2012.

[22] Bhuvaneswari. A, E. George Dharma Prakash Raj, "A Cross Layer Based Vertical Handoff Decision Making Framework" – International Journal of Computer Applications, USA Volume 50– No.19, July 2012.

[23] Bhuvaneswari A, E. George Dharma Prakash Raj,"QoS aware Handoff Reduction Algorithm using TSVHORA" in the Fifth International Conference on Advances in Recent Technologies in Communication Computing, ARTCom 2013, Bangalore, India.

[24] Bhuvaneswari. A, E. George Dharma Prakash Raj, "Statistical Analysis to improve accuracy in Traffic Sensitive Vertical Handoff Reduction Algorithm TSVHO(R)A", International Journal of Computer Science & Network Solutions, Iran, Vol.2,No.3, March 2014, pages 108-118.

[25] Bhuvaneswari. A, E. George Dharma Prakash Raj, "ACO-ESSVHOA – Ant Colony Optimization based Multi Criteria Decision Making for Efficient Signal Selection in Mobile Vertical handoff", International Journal of Advanced Studies in Computers, Science & Engineering, USA, Vol.3, Issue 4, April 2014.

[26] Bhuvaneswari. A, E. George Dharma Prakash Raj, "Enhanced Vertical Handoff Using Hybrid Parallelized ACS – 3 Opt Local Search" , International Journal of Computer Science and Mobile Applications, Vol.2 Issue. 10, October- 2014, pg. 12-21 ISSN: 2321-8363.

[27] Gamal Abdel Fadeel Mohamed Khalaf˙, Hesham Zarief Badr, A comprehensive approach to vertical handoff in heterogeneous wireless networks Journal of King Saud University - Computer and Information Sciences, Volume 25, Issue 2, July 2013, Pages 197–205.

[28] Mohammed M. Alkhawlani, Multi-Criteria Vertical Handover for Heterogonous Networks, International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 2, April 2011 DOI : 10.5121/ijwmn.2011.3213 149.