International Journal of Engineering Trends and Technology Volume 68 Issue 11, 63-71, November 2020
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V68I11P208

Inter-Gateway Handoff Management Using Ant Colony Optimization (ACO) for Wireless Mesh Networks

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Abstract - *(Wireless Mesh Network (WMN) is emerging network which is being widely used to handle most of the wireless internet access available in today's world. WMN is a self sustaining network made up of numerous mesh routers which are deployed and are static in nature and the mobile clients/ mobile stations which are highly mobile nodes. The gateway is responsible for connecting the mobile stations with the internet. When the mobile station move from one network to the other, the handoff process needs to be carried out to maintain the connectivity of the mobile station with the internet network. The handoff process is usually degraded due to several factors like signalling packet transmission delay, channel contention, etc. In this paper, it is proposed to develop a Inter-Gateway Handoff Management Using Ant Colony Optimization (IGHMACO) for Wireless Mesh Networks. In this technique, the Ant agents are used to estimate utility function based on which the next access point is determined. The contention in channel is reduced by splitting the channel and the signalling packet transmission delay is reduced by storing the handoff history. In this way, the handoff process is performed effectively, in turn ensuring efficient network operation.*

Keywords — *Wireless meshnetwork (WMN), Gateway (GW), Access points(APs), Mesh Router(MR).*

I. INTRODUCTION

Wireless mesh networks (WMNs) is being considered as a critical wireless technology since it is utilized in supporting almost all the wireless internet access of the present day. In WMN, the backbone network is made up of numerous wireless mesh routers (MR) which are static in nature. In WMN, the data traffic flows from MN to internet and vice versa through the mesh routers. Few specific MR are considered as Gateway (GW) mesh router since it is linked to the internet through wired links. Gateway mesh router functions as Internet entry point to the remaining MR in the group. Few MRs are referred as wireless Access Points (APs) as it is responsible for permitting the wireless mesh backbone entries into the mobile nodes in the Gateway scheduling based beam forming network (GAS) [1]. Wireless mesh networks (WMN) is basically a self arranging and self sustaining network. The setup configuration expense of WMN is relatively very lesser, and hence is recognized and preferred for multiple applications like public safety disaster recovery applications, etc. WMN basically consists of two kinds of nodes referred as mesh clients and mesh routers and WMN is also considered as multi hop multi radio communication network. The functions and specifications of the mesh clients and mesh router are different from one another. Some of the mesh clients like phone, PDA, laptops, etc have power limitation criteria and hence function as minute radio transmitters that function similar to wireless routers as well as utilize IEEE 802.11a, b and g standard to link with one another. A wireless network can be created by the mesh clients in a mesh topology without the requirement of any mesh router and can also be linked with wireless mesh router via Ethernet cards or Network Interface Cards (NICs) from intra domain handoff management scheme for wireless mesh network (IMEX) [2].

WMN are used in various applications like IoT [15]. The WMN is made of numerous static access points (APs) which offer very reliable packet transmission during data forwarding process between mobile stations. Due to the static infrastructure of the AP, the WMN is capable of aiding many services along with effective usage of the available network resources and enhancing the network operation based on Ant colony based optimization based scheduling algorithm (ACO)[11] for vertical handover. WMN find its application mostly in fields where the users are fixed in nature or involve minimum movement such as in campus, offices, etc. Lately, research is being carried out by many organizations in order to deploy the WMN application in transportation vehicles in the roads which is basically highly mobile. Thus, in order to offer good Quality of Service (QoS) to the network users as well as to use the available network resources effectively handoff and the mobility management becomes critical in WMN based on channel time allocations and handoff management(CA-HO) [3].

The scheduled networks with different mechanisms are combined with selection of combination of networks using combined channel transmissions (CCT) and separate channel transmission(SGT)[13].

A. Handoff Management in WMN

In WMN, the two kind of nodes i.e., mesh router (MR) and mesh client (MC) are different from one another. The mesh router is mostly a fixed node with very less mobility. The mesh client is a very mobile node. In every WMN, there exists at least one gateway which is actually a specialized mesh router that is linked to the internet. The wireless mesh backbone is created by the set of mesh routers and it is responsible for the transmission of the packet traffic. The wireless mesh backbone offers last mile broadband internet access to the mobile client. Since the mobile client have increased mobility, for appropriate functioning of the WMN, it is important to perform mobility management. Location management as well as handoff management are the two important phases of mobility management [4].

When the network layer handoff process is being carried out, the network layer signalling packets must be transferred between the mobile client and the internet through multi-hop wireless mesh backbone. The mobile client's mobility is considered as transparent to applications when the network layer signalling packet end to end delay is very small. But, the throughput may reduce in the presence of the multi-hop wireless links in the mesh backbone network because of the channel access delay through multi-hop links. This can lead to longer Inter-Gateway handoff delay in the multi-hop WMNs [6].In this scheme(IGHMACO) of approach handoffs are analyzed between different number of users at one instance and the other isby varying speed between Mobile Stationsfordifferent number of Gateways , how the handoffs are analyzed between the Access points(APs).To enhance the parameters such as Delay, Data rate, Fairness Index and Throughput an approach called IGHMACO is modelled.

II. RELATED WORKS

Haopeng Li et al., [1] have given about physical locations of moving objects which make the possibility of providing the continuous connection to wireless mesh network (WMN). Here multi-hop signal communication is eradicated due to degrade of service, so they have used seamless communication handoff with Gateway scheduling (GAS) based beam formingscheme for handoff support but it is constrained to only single radio communication channels. It is extended to multi radio and multi channel communication signaling schemes.

Fawaz a. Khasawneh1 et al., [2] have developed a self configured and error free network access with less cost effective basis. Wireless mesh network(WMN) consists of mesh client (MC)and mesh router (MR). Every client are equipped with different mesh routers. The mesh router has the nature of less mobility during wireless signal propagation. From the delay layer, network layer and application layer different delays are verified. The method which was used in the protocol is session initiation protocol (SIP). By analyzing the new optimum path channel utilization can be modeled and improved.

Lei Qin et al., [3] have presentedwireless mesh network(WMN) with number of Access Points(APs) and Mobile Stations (MSs) with proper service fairness between the various Mobile Stations (MSs)located in various geographical areas. Coverage areas of Access Points (APs) and Mobile Stations (MSs) are dependent. The performance of load balancing is achieved through fair quality of service (QoS)[14]. When the large number stations are located near one

Access Point which are not in coverage area of other Access Points(APs) have been modeled to improve fair throughput. Each Access Point path is calculated with the average utility information. The throughput which is achieved can be improved[16].

Yinan Li et al., [4] have designed an routing protocol for location management and signal propagation. The consideration parameter in this is routing based location update and notes update. When data packets are receiving the gateway of mesh client(MC) to obtain location information from the data packets. The wireless mesh network uses this information to update the location database.

When the data packets are not in up-to-date location informationcannot be continuously updated. The location management has to be done efficiently which is a slow moving process and its speed can be enhanced

Weiyi Zhao et al., [5] have presented an efficient solution for large scale wireless internet access. Handoff management has been extensively studied with wireless signaling schemes. The implementation is based on multi-cast control overhead to maintain the status of the signal for saving the bandwidth. From X-cast based catching IMEX architecture proves a low control overhead for querying multiple address and reduced packet loss. According to this procedure cross layer hand off procedure is prepared for wireless mesh network(WMN). When the XGRs are configured to connect different groups delay is not properly modeled and this factor can be reduced further.

Haopeng Li et al., [6] haveensured a signal path for reducing long handoff delay by multi-hop wireless links.Here wireless mesh network is a part of static mesh routers and mobile mesh clients. The combination of mesh routers form an gateway. The Inter-Gateway is divided into link layer handoff and network layer handoff. The signal is choosen according to the best received signal strength.Based on channel splitting techniquethe handoff signalling packetsare obtained by a new IP address for the mesh client (MC)to find a new route to the gateway. Here fair throughput occurrence is not properly ensured.

Haopeng Li et al., [7] have given an emerged cost effective solution for providing effective way of finding a route for wireless signal propagation .The handoff signalling packets are delivered through split channel control .The speed of

propagation is not optimum and
It can be modelled further.

Bo Rong et al., [8] havedesigned a wireless mesh network(WMN) for supporting mobile users moving around the network without any interruption .They have developed an efficient handoff techniques for different computational methods. It provides seamless handoff mechanism and reduced handoff in the wireless networks. In the mesh routing and client topology it provides proactive scan scheme .Its speed of performance can be enhanced.

Awadallah M. Ahmed et al., [9] have designed model for serving critical applications such as surveillance and rescue systems. They Provided solution for gateway replacement problem in a particular desired loacation.It works through external interfacing to interconnect the internal Access Points(APs) called Internet Gateways.The connection of Internet Gateways and Mesh routers(MRs) can be modeled more efficiently.

Ferdawss Douma et al., [10] have presentedan approach to improve routing mechanism in wireless signal propagation using media independent handover (MIH) variable functions. Here majorly vertical handover in wireless networks between Wi-Fi and Wi-Max technologies. The source of movement of handoff if efficiently enhanced.

Fariha Nosheen et al., [11] have proposed a scheduling algorithm for based on ACO technique. Imad El Fachtali et al [12] have proposed a QoS aware verticalhandoff mechanism based on ACO.

Srikanth D et al., [13] have designed channel splitting scheme to enhance both link layer and network layer handoff. The separate channel transmission and combined channel transmission is developed to improve the handoff performance without any measured delay. This can be modeled for better fair throughput in the signal propagation.

From the above observations it is found that some of the deficiencies are as follows.

i) Capable of performing single-Hophandoff only.
ii) Channel utilization is notmaximum used
iii) Handoff signal delay is more.
ii) Throughput is not properly ensured.
V) Good fairness is achieved.

In order to overcome these limitations an algorithm is proposed called Inter-Gateway Handoff Management Using Ant Colony Optimization (IGHMACO).

III. PROPOSED WORK

A. Inter-Gateway Handoff Management Using Ant Colony Optimization (IGHMACO)

In this paper, it is proposed a new handoff management technique for WMN using IGHMACOin order to meet the main objectives of the handoff management while selecting a new AP or gateway.

- Fair throughput is ensured
- Channel resource utilization is maximized.
- Handoff signaling delay is reduced
- Data loss due to mobility are prevented

In this technique, the IMeX architecture [5] is assumed. To reduce the signaling delay, data packets and handoff signaling packets are communicatedindividuallythrough their channels [6]. The Inter-Gateway AP is selected by means of a utility function.

IGHMACO technique is utilized for selecting the handoff network. Here, Ant agents deployed at AP estimates the utility of corresponding AP and exchanges the details of each AP [2] and stores them in a table. Whenever, a MS decide to do inter gateway handoff it collects the details from the Ant agents of other APs and selects the AP which maximizes the utility. The handoff history is recorded by Ant agent to reduce the signalling delay and reduce buffer size at mobile station.Thus the proposed technique satisfies all the objectives.

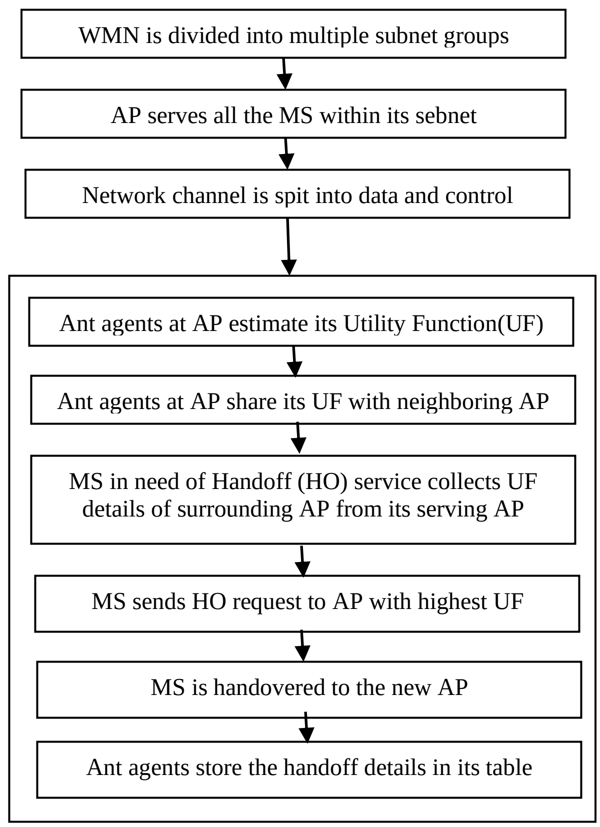

Fig. 1: Flow chart of IGHMACO scheme

B. IMeX architecture with split channel for packet transmission

The IMeX architecture is considered in the proposed technique[2]. This network consists of several subnets; each consisting of many Access Points (AP) and mobile stations. The X-cast based Group Router are deployed between subnets and functions as a bridge between different subnets during the handoff process [5]. A Inter-Gateway AP is dedicated to each subnet to link the subnet with the internet.

The network channel is split into two: data channel and control channel [6] in order to avoid the contention for channel access between the data packets and signalling packets. This reduces the signalling delay significantly. This process is described in algorithm 1.

Algorithm 1

Notations	**Meaning**
AP	Access Point
GAP	Inter-Gateway Access Point
XGR	X-cast based Group Router
IP	Internet Protocol
MS	Mobile Station

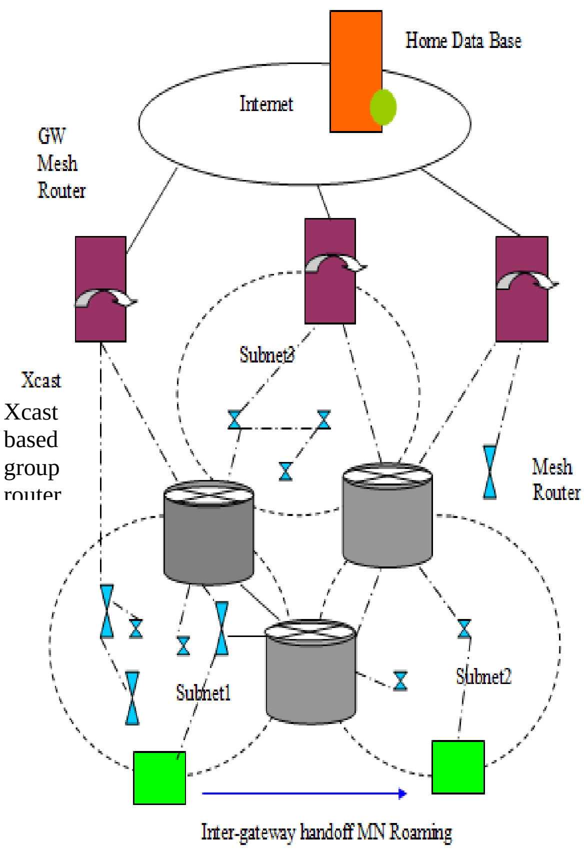

Fig. 2: IMeX architecture with three gateways

1. The WMN is divided into several subnets.
2. Each subnet consists of several AP interconnected with each other
and a GAP with a specific IP address prefix [5].
3. The IP address prefix of each subnet varies from one subnet to
another.
4. XGRs are deployed at the border of two or more subnets such that
it is belongs to all the involving subnets.
5. XGR are equipped with many IP addresses, each IP address
addressing a different subnet present within the network.
6. XGR connects different subnets by acting as a bridge between the
corresponding subnets facilitating information [8]. Exchange during Inter-Gateway handoff.
7. The XGR are also linked to the nearby XGRs and GAP along with
the AP.
8. The GAP serving a subnet, connects the internet with the subnet
nodes with or without the aid of XGR.
9. In the network, the base channel is split into two as data channel for transferring the data packets and controlchannel for transferring the control signal packets[4].
10.The control channel will be used by the MS during handoff to
send signalling packets to the AP/GAP [6].
11.Then the data channel is used for the transmission of the data
packets without contending with the signalling packets between
the internet and the MS through the AP and GAP[1].

Thus the network architecture is developed such that the hierarchy from mobile station, AP, XGR, Inter-Gateway AP to Internet is maintained so as to ensure appropriate network operation [9].

C. IGHM-ACO

IGHMACO applies ACO which is an agent based optimization algorithm. It copies the normal behaviours of ants and derive algorithms for learning and testing. It is mainly applied in problem solving skills. In ACO, a Forward Ant agent (FA) determines the pheromone track to the source node and a Backward Ant agent (BA) determines the pheromone track to the destination node [11].This pheromone track information will assist in searching for the future ants.

The basic functions of ACO algorithm can be described as follows:

In each step of the algorithm, the ants select the visiting nodes based on the pheromone trails [8]. The ants deposit the pheromone trail depending on the outcome of a fitness function [12].

The probability of FA visiting each node N_i is based on the following decision rule (shown in Eq.1).

$$P_r(N_i, S) = \begin{cases} \dfrac{a(N_i,S)^{\zeta}}{\sum_{N \epsilon N_R}[a(N_i,S)]^{\zeta}} & ,\text{if } r \notin RT(N_i) \\ 0 \;, & \text{otherwise.} \end{cases} \quad (1)$$

Where $a(N_i, S)$ represent pheromone value

N_R represents the receiver node. RT (N_i) represents set of nodes N_i in a network, ζ and σ are the parameters that control the relative weight of the pheromone and heuristic value respectively.
The AP ,i represents gateway i and i=1,2,3….N .
The AP ,j represents gateway j and j=1,2,3….N.

1) ACO for Inter-Gateway Handoff Management

TheAnt colony optimization (ACO) technique is utilized for selecting the handoff network. The ant agents estimate the utility function based on the frame throughput and weighted average of every mobile station [3]. This estimated utility function value is used by the mobile station to select the next access point during hand off. This process is described in algorithm 2.

Algorithm 2

Notations	Meaning
AP	Access Point
T_{fr}	frame throughput
W_{avg}	weighted average rate
$UF_{avg,i}$	:average utility function of AP, i
I	set of all AP
i	Access Point of i^{th} gateway
t	frame
$A_{im}(t)$	set of binary variable
$T_{im}(t)$	amount of time that AP,i transmits to MS, m during frame
$R_{im}(t)$	instantaneous transmission rate when AP, i transmits to MS, m
β	parameter for throughput weight balance in past and recent frame
N_i	set of neighbouring APs of AP, i
$\|N_i\|$	number of neighbouring APs of AP, i
$\|M_j\|$	total number of MS associated with AP, j
m	Mobile Station
j	Access Point of j^{th} gateway
MS	Mobile Station
AP_{high}	new AP
TS	Time stamp value

1. The forward ant (FA) agents are deployed at every MS of each AP in the network.
2. The ant agents at the AP estimate the frame throughput, value according to equation (2)

$$T_{fr} = \sum_{i=1}^{N} A_{im}(t).T_{im}.R_{im}(t)\ ,\ (i\epsilon I) \quad (2)$$

3. The forward ant (FA) agent maintains the details of each MS along with a time stamp value TS, as shown in table 1.
4. Then the ant agents estimate the weighted average of each MS at the AP according to equation (2) given below:

$$W_{avg}(t) = (1-\beta)w_{avg}(t-1) + T_{fr}(t-1) \quad (3)$$

5. Next based on the estimated T_{fr} and W_{avg} values, the $UF_{avg,i}$ at AP is estimated according to equation (3) shown below

$$UF_{avg}{}_{,i,j} = \frac{1}{|N_i|}\sum_{i=1}^{N}\left[\frac{1}{|M_j|}.\sum_{j=1}^{N}\frac{T_{fr}(m)}{W_{avg}(m)}\right], j\epsilon N\ , m\epsilon M_j \quad (4)$$

6. After the estimation of $UF_{avg,i}$ value at the AP, the backward ant agents (BA) collect the information from each neighbouring AP towards the starting one.
7. In this way,the ant agents collects the $UF_{avg,i}$ information of all the Surrounding APs and record it in their table as shown in table 1.
8. When a MS needs to perform Inter-Gateway handoff, it requests the $UF_{avg,i}$ information of the surrounding AP with its current AP through the control channel in table 2[10].
9. The ant agents provide the $UF_{avg,i}$ information and other related details of the surrounding AP to the MS through the control channel.
10.On receiving the $UF_{avg,i}$ information, the MS selects the AP with highest $UF_{avg,i}$ value, AP_{high}as its next AP for performing handoff.
11.The MS sends HO_Req to AP_{high}through its current serving AP,and then GAP through the data channel.
12.On receiving the HO_Req, the AP_{high}responds by sending HO_Resp through the data channel if it finds MS to be a trustworthy node.
13.When MS receives HO_ Resp from AP_{high}, it gets handovered to its new subnet.
14.After the handoff of MS to the new AP[4], the ant agents updates the handoff details in its Handoff History Table.
15.In this way, the details of all operations at every AP is recorded by the itself and surrounding APs.
16.Next time, if any details of the previous handoff operations are required, then this information can be easily retrieved from the Handoff History Table.

Table 1. Table to store each Forward agent.

MS id	$UF_{avg,i}$	AP_i	TS

Table 2. Table to store each Backward agent.

AP id	T_{fr}	W_{avg}	TS

Thus, handoff is performed based on the utility function at the AP[12]. Higher utility value ensures higher handoff success rate. The use of the Handoff History Table at the AP eliminates the use of the data caching mechanism at each MS. In this way, the channel probing delay and storage buffer of each MS is minimized to a greatest extent.

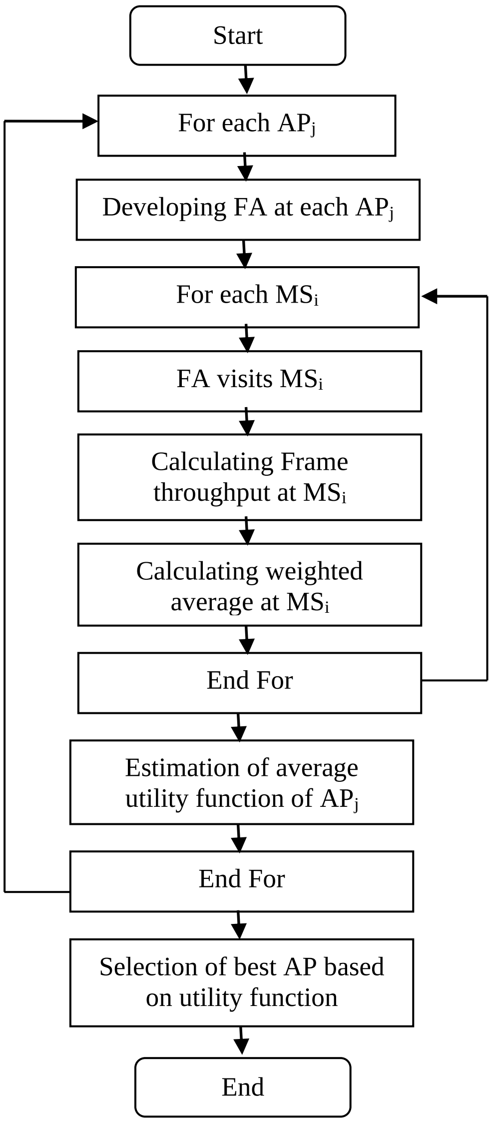

Fig. 3: Flow chart of calculating utility function in IGHMACO

IV. SIMULATION RESULTS

The proposed IGHMACO technique is simulated in NS2 with different Access points(APs) in the gateway.

Figure 4 shows thetopology used in the simulation. It shows that 4 gateways are connected to AP. The simulation parameters are listed in Table 3.

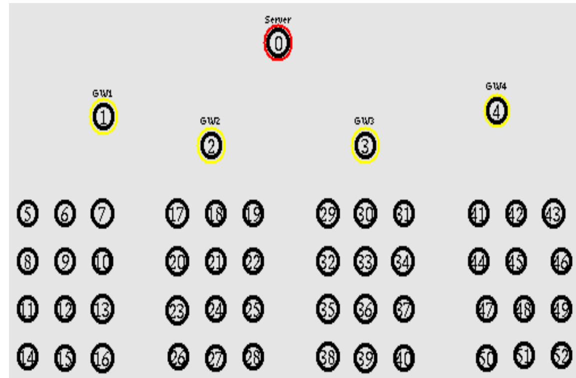

Fig. 4. Simulation Topology.

Table 3. Simulation parameters

Parameter	Value
Number of Nodes	53
Area size	1300 X 1300m
Traffic Type	CBR and Exponential
Flows	1,2,3,4,5 and 6
Propagation model	Two Ray Ground
Antenna model	Omni directional Antenna
Initial Energy	7.0 Joules
Transmission Power	0.5 watts
Receiving Power	0.3 watts
Speed	10,20,30,40 and 50m/s

A. Performance Metrics

The Proposed IGHMACO technique is compared with CA-HO [3], IMeX [5] and CCT [13] techniques. The performance metrics Delay, Datarate, Fairness Index and Throughput are measured.

B. Results & Analysis

The results are observed by varying number of handoff users as 1to 6 and by increasing speed of Mobile Stations(m/s) between users.The numbers which are considered from 1 to 6 indicate number of users(From 1 to 6,1 indicate one user ,2 indicate 2 users and so on)performing handoffs among them with a Data rate of 2Mbps.Between the number of users by increasing the Speed between the Mobile Stations(m/s) of 10 m/s to 50 m/sfor whichthe handoffs are observed . For each method it is observed among CCT,CA-HO,IMEX and IGHMACO then it is shown that this proposed method which is IGHMACO performed better than other methods shown in Fig. 5 to 12.

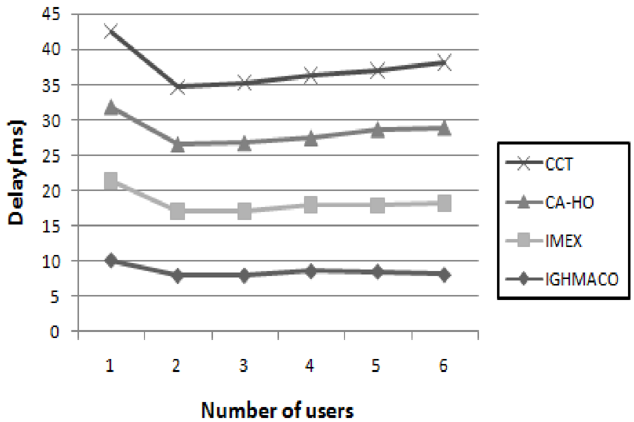

Fig.5: Different data networks.Number of usersVersusDelay (ms).

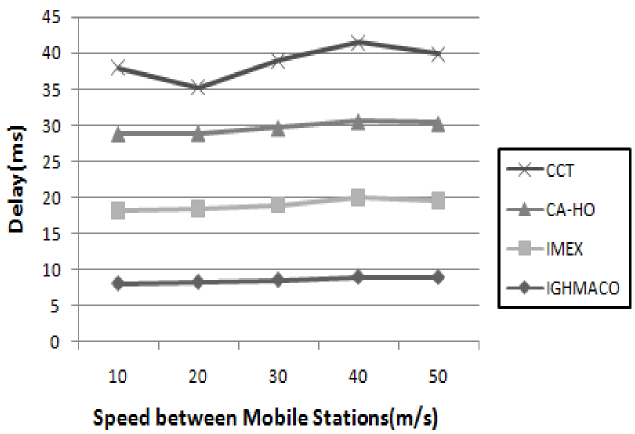

Fig .6: Different data networks.Speed between Mobile Stations (m/s)VersusDelay(ms).

Fig 5 shows the performance of number of users 1 to 6 and delay(ms) response .The number of users are present in the network are in static mode with a data rate of 2Mbps .when the different data networks are accessed among the users like CCT , IMEX and CA-HOthe IGHMACO has the less delay path .This reduction delay is due to accessing the Access Points(APs) from the forward and backward Ant agents and we get clear short path for the signal to travel.

Fig 6 Shows the performance between varying speed between number of Mobile Stations of 10m/s to 50m/s and corresponding delay is observed accordingly .There is reduction of delay for IGHMACO compared to other methods CCT,IMEX and CA-HO.

When the speed of Mobile Stations increases continuous handoff signal is required for the Gateway to continue the network communication .This can achieved by knowing the path of short distance travelled Ant agents signal from the handoff history table.

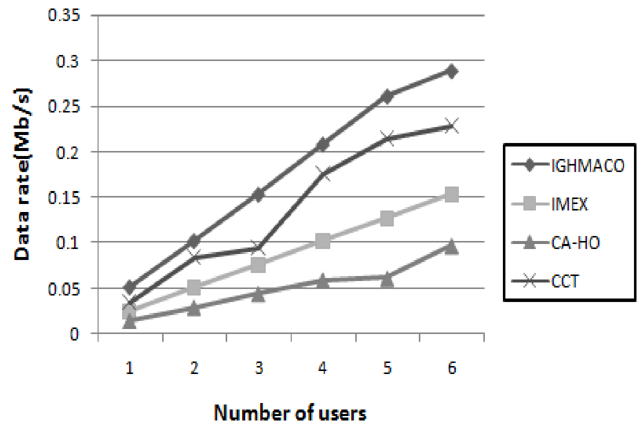

Fig.7: Different data networks .Number of usersVersusData rate(Mb/s).

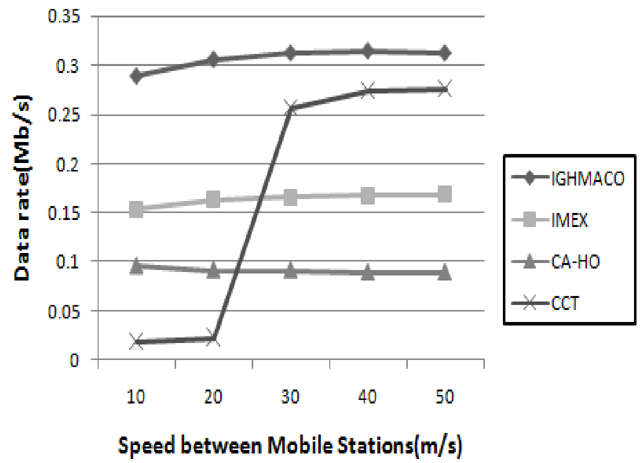

Fig.8: Different data networks. Speed between Mobile Stations(m/s)versusData rate(Mb/s).

Fig 7 shows that optimum data rate with number of users between different data networks, the data rate between number of users having 2Mbps data carrying capacity between different schemes haslower in CCT ,IMEX and CA-HO.IGHMACO performs better from the other methods.When the number of users are static position the data rate is high in IGHMACO compared to other methods.Due to all the Access Points(APs) serves all the mobile stations with in the subnet.Each Ant agent will show high priority handoff process request.

Fig 8 shows the maximum increase of data rate from varying speed between different Mobile Stations.This is achieved by grouping different routers on the Inter-Gateway .When the speed of mobile station are increasing continuously handoff request is processed from high priority Ant agent signal which is calculated from utility function.IGHMACO has high performance compared from CCT,IMEX and CA-HO.

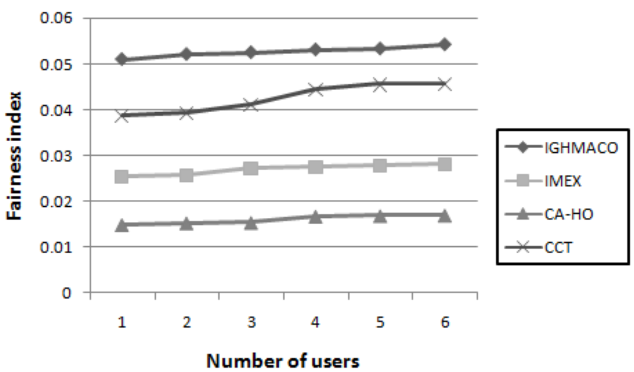

Fig.9: Different data networks .Number of users Versus Fairness Index.

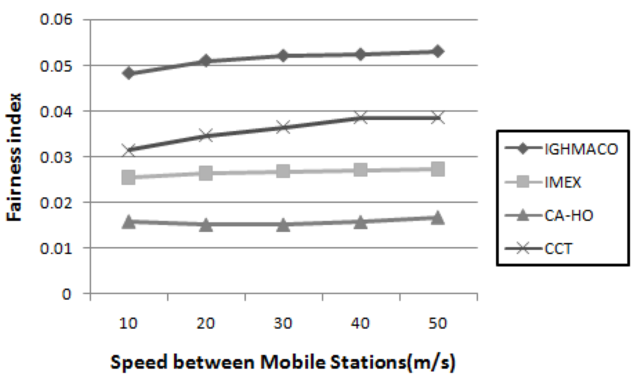

Fig.10: Different data networks .Speedbetween Mobile Stations(m/s) VersusFairness Index.

Fig 9 shows the good fairness index between number of users by IGHMACO compared with CCT , IMEX and CA-HO. The fairness index indicates the good voice quality and strong network connection.This is achieved by forward Ant agents and backward Ant agentsmoving signal information of nearest Access Points(APs) with high strength signals.

Fig 10 shows the performance of fairness index has been increased. when the speed between differentMobile Stations has been increased to 10m/s to 50m/s,IGHMACO shows the better performance compared to CCT, CA-HO,IMEX methods.This is achieved by calculating the handoff signal from the nearest Access Points (APs) which are given by Ant agents.

Fig 11 shows the increased throughput between the number of users by IGHMACO compared to CCT, IMEX, CA-HO. This is achieved from the detail information on Access Points(APs) which are very near to Gateways is calculated based on Ant agent signal strength for high utility function value.

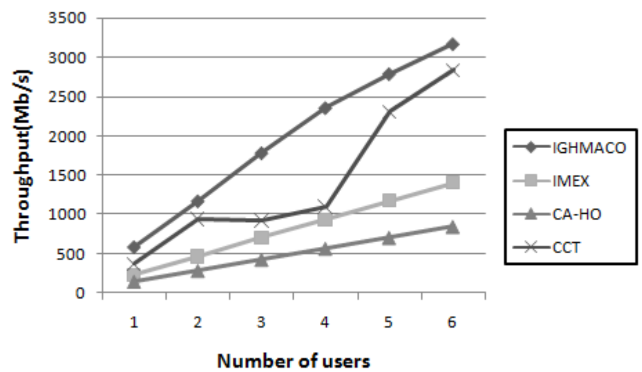

Fig.11: Different data networks .Number of usersVersus Throughput(Mb/s).

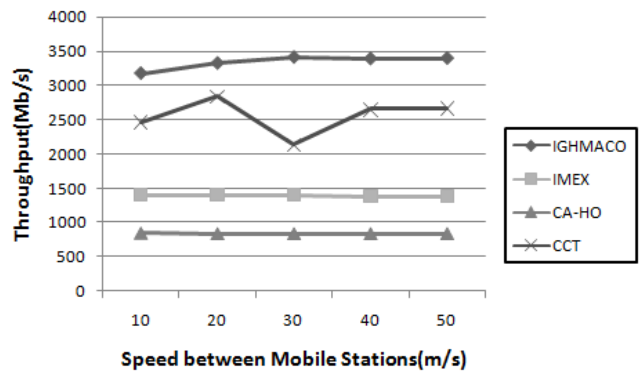

Fig.12: Different data networks.Speed between Mobile Stations(m/s) VersusThroughput(Mb/s).

From the Fig12 shows the increased throughput values when the speed of mobile stations are changing from 10 m/s to 50m/s by IGHMACO compared to other methodssuch as CCT,IMEX and CA-HO.This is achieved by properly estimating the ant agents signal path and locating the nearest Access Points(APs) with greater utility functionin the subnet.

V. CONCLUSION

In this paper, it is introduced that IGHMACO based architectural design with special Gateways and mesh routers and observed a significant reduction of handoff delay levels. Also it has been verified efficient channel utilization with minimum packet loss and hence fair throughput is ensured .The efficient handoff signal is obtained by calculating the utility function which indicates the high valued signal.

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