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Minimum Cost, Minimum Interference and Minimum Load (M^3) Gateway Deployment Algorithm for Multi-radio Multi-channel Wireless Mesh Networks

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Abstract

In Multi-radio Multi-channel (MRMC) Wireless Mesh Networks (WMNs), the existing work on load balancing consider single radio single channel which may cause overloading and channel quality will be more. Also, the gateway should be chosen with minimum path cost. This paper proposes to develop a Minimum Cost, Minimum Interference and Minimum Load Gateway Deployment Algorithm (M^3GDA) for MRMC WMNs. In this algorithm, the set of mesh routers (MRs) within a D-hop neighbourhood are clustered. The gateway node is selected based on Gravitation Search Algorithm (GSA). The path from each mesh router to gateway node is constructed by assigning an interference free channel (from the list available channels) to each pair of mesh routers towards the GW. The upload or download of data from or to IAP by mesh client is performed based n the average load of the cluster. Experimental results have shown that M^3GDA minimizes the path cost and network load.

1. INTRODUCTION

Wireless mesh networking is a novel pattern for future generation wireless networks. WMNs comprise of mesh clients (MCs) and mesh routers (MRs), where the MRs form a wireless backbone with the wired network to offer Internet connectivity to the MCS. This impression can be utilised for diverse wireless access skills like IEEE 802.11 based wireless local area network (WLAN). WMNs Prospective application can be utilised in home networks, enterprise networks, public networks, and intellectual transport system networks like vehicular ad-hoc networks. [1].

WMNs will significantly aid the customers to be access data from anywhere at anytime. Furthermore, the entry/bridge functionalities in MRs allow the addition of WMNs with several prevailing wireless networks. Based on the operation mode of the nodes, WMNs can be categorized into three: Substructure backbone, user backbone and hybrid. [2].

A WMN with high performance should satisfy the following characteristics: low cost, easy network connectivity, communication with high quality such as: High bandwidth, minimum jitter, latency, and error rate, as well as load balancing. A WMN which satisfies all the characteristics mentioned above with minimum energy consumption and minimum CO2 volume produced by the ICT(Information and Communication Technology), is named Green Wireless Mesh Networks. According to the previous statements, energy consumption has become a major factor that characterizes ICT, industries, and communication performance of Wireless Mesh Networks. [3].

WMN is made by a group of MCs and MRs which perform connectivity in the backbone via Internet Mesh Gateway (IMG). Load balancing (LB) is the method of poising the load over diverse links and sources to evade jamming at a MCs, MRs and gateways. In WMN, a Internet Gateway (IGW) performs as the dominant point of connectivity. The data in WMN is transmitted to and from the IGW. Due to the enormous intensification in the traffic and also because of the partial link ability, the entry is probably a possible bottleneck. Hence LB has turned out to be a significant concern in WMN. [4].

As discoursed above, entry disposition is a real-world and significant issue, and ought to be well addressed. Numerous investigation efforts have been done to place entries deliberately in WMNs. These methods goal to curtail the number of entries with numerous network factors considered, like traffic demand, network output, node dimension, link bandwidth and path length. Inappropriately, some of them consider LB and interference reduction. Traffic combination create entries turn out to be the bottlenecks of WMNs. Inequity of entry load will cause hefty jamming of limited entries, and intensely effect the network output. Intrusion is essential to wireless networks, because of the transmission nature of wireless medium. In WMNs, if entries are positioned thickly, extreme intrusion amongst them will considerably disturb network act. [5].

Entry nodes are a vitalmodule of WMNs. In numeroususes of WMNs many traffic will be focussed to/from entries. Therefore, traffic accumulationhappens in the routescausing anentrythat can causejamming. One significantconcern is the approach employed to associate nodes with a specificentry. [6].

GSA relies on the law of gravity where the means are taken into consideration as matters and their act is measured by their masses. All these matters entice one another by the gravitational force. This force leads to universal association of the entire matter towards the matters with heftier masses. Therefore, the masses collaborateby means of a straight form of communication via gravitational force. The hefty masses, which agree to good resolutions, transfer more gradually than lighter ones. This promises the utilization step of the procedure. In GSA, every mass (agent) has four stipulations: position, inertial mass, active gravitational mass and passive gravitational mass. The location of the mass agrees to a resolution of the issue. Its gravitational and inertial masses are resoluteby means of a fitness function. To say, every single mass offers a resolution, and the procedure is traversed by appropriately regulating the gravitational and inertia masses [12][13].

1.1 Problem Identification and Objectives

The existing works on load balancing [5][6][8][9] mostly considers single radio single channel only , where the chances of overloading and bad channel quality are more. The works [4], [7] and [10,11] concentrates on multi-radio multi-channel (MRMC) WMNs.

The main issues involved in gateway load balancing are : (i) minimizing the path length (iii) detecting overload of gateways (iii) balancing the load of gateway nodes (iii) minimizing the path interference [4][5]. Hence the gateways have to be selected, considering these issues.

Though the proposed work of [4] addresses all these issues, it considers only the multicast scenario. Similarly, the work [5] addresses all these issues. But it needs to build various spanning trees routed towards each gateway which may become complex when the number of nodes is high. The work [6] reduces both path cost and gateway overload but didn't consider the interference occurring from the links. In [7], interference free path with minimum hop and minimum load difference is selected. But it did not present methods for gateway deployment and overload detection. The work in [8] depends on the concept of unlocked sinks to build the paths. But this assumption is impractical when the traffic is high. Though the work [10] selects interference free paths, it does not provide any solution for gateway load balancing and reducing the path cost. In order to solve the issues of these existing solutions, the following objectives have to be met:

- Assign interference free channels to links in MRMC WMN
- Choose gateways with minimum path cost to the mesh router
- Detect the balance the overloaded traffic of selected gateways
- The gateway selection and path construction should incur minimum overhead and delay

2. RELATED WORKS

Kruti.N.Kapadia et al [2] have suggested EAOMDV-LB for MR-WMN. The etiquette computes numerous paths by means of suggested airtime congestion aware (ACA) metric and does LB by calculating queue usage of a node. Furthermore, the effectual LB method upholds data broadcast on idealtrack by distracting traffic the whole mode via jammed zone. WMNs have, of late increased a lot of admiration because of their fast disposition, immediate communication abilities and help for several kinds of use. For these uses, network jamming is the foremost cause for lower output and extended delay.

Mijahed Nasser Aljober et al [4] have suggested a PMRGLB algorithm goals to attain four purposes, i.e. reducing the aggregaterate of the network, lessening path length, lessening GW LB, and curtailing path intrusion.

Xiaojun Wang et al [7] have offered a LBR procedure for MRMC WMNs. The purpose of this procedure is to lessen interference and poise network load amongst links. Initially, the network sample is offered. Depending on this sample, a link allocation procedure is suggested to allot all links to channels which goals to reduce interference extent of networks. Once the links are allotted to channels, a route-selection procedure is suggested to choose a track from source to terminus to poise network load.

Juan J. Galvez et al [8] have suggested an adaptive online LB etiquette for multi GW WMNs which, depending on the existing network circumstances, poises load amidentries. Traffic is stable at the flow level and, as a consequence, the total output, average flow output and fairness of flows progresses. The suggested system is extremely receptive, thanks to rapid GW selection and the fact that present traffic situations are sustained up-to-date always deprived of any overhead.

Avinash Chandra Mishra et al [9] have suggested a system for LB which utilises the idea of numerous GWs and pool it with the idea of numerous queues at each entry. Ordering of the actual data packets reaching at each entry queue is made and therefore QoS is attained together with LB. The suggested result also encounters the necessity of QoS and successfully poises load on entries and is apt for actual situations.

3. PROPOSED SOLUTION

3.1 Overview

A Minimum Cost, Minimum Interference and Minimum Load (M^3) Gateway Deployment algorithm for MRMC WMNs is developed. In this algorithm, the set of MRs within a D-hop neighbourhood are clustered. Then based on GSA, a gateway (GW) is selected based on the following constraints:

- The distance between the Internet Access Point (IAP) and the GW is minimum
- The distance between each MR and the GW is minimum
- The average cluster load (which is based on the loads of each MR in the cluster) should not exceed the maximum capacity of GW.

A fitness function will be derived in terms of these 3 metrics and the GSA algorithm will be executed on each cluster until the GW with maximum fitness function is selected. If no such GW can be selected maximizing the fitness function, then the MRs are clustered again by suitably adjusting the value D-hop.

After GW selection, the path from each MR to GW is constructed by assigning an interference free channel (from the list available channels) to each pair of mesh routers (MR_i, MR_j) towards the GW. This is done by estimating the intra-flow and inter-flow interferences among the MRs.

When a mesh client needs to upload/ download data from/to the IAP, the average load of its corresponding cluster is checked. If it is found to be overloaded, then the GSA based GW selection process will be invoked again.

3.2 System Model

We take into consideration WMN which contains MRs connected to MCs. These nodes form a wireless multi-hop network. The set of MRs within a D-hop neighbourhood are clustered and gateway node is selected based on the Gravitation Search Algorithm (GSA). It is detailed in the below sections

3.3 Estimation of Cluster Load

Load (L(i)) denotes the traffic mass of the MR which is the summation of traffic queue of MR and the traffic queue of all its adjacent.

$$L(i) = \sum_{\forall j \in N(i)} l_i \tag{1}$$

where N(i) is the neighbourhood of the MR

l_i is the size of the traffic queue

L_i is the aggregate of traffic queue of each neighbours of MR i

$$AL = \sum_{\forall j \in MR(i)} L(i)_i \tag{2}$$

3.4 Cluster Formation

The cluster formation is done as per the following steps:

1. Every single MR_i transmit the HELLO message to its neighbors ($Neigh_i$).

$MR_i \rightarrow Neigh_i$: Hello

The node distance is assessed regarding number of hops

2. Depending on the HELLO Message, every single MR_i sustains the neighbors list (L_{neigh}).
3. If ND is minimum

   Then

MR_i announces itself as CH.

$MN_i \rightarrow L_{neigh}$: CL_REQ

End if

Hence the MR with least distance is declared as cluster head (CH), since it is said to be more stable

4. On receiving the CL_REQ, the nodes in L_{Neigh} directs join retort message to MR_i to join the group.

$MR_i \leftarrow$ Lneigh: J_REP

5. Next to the groupcreation, the server (S_i) saves the particulars of the whole CH's and their members and transmission group data packet (C_IN) to the whole CH's.

$S_i * \rightarrow$ CHs: C_IN

The C_IN comprises the group heads ID and its location. CH's saves the C_IN in its group table.

Fig 1 validates the group formation system. It comprises 3 groups C_1, C_2 and C_3. MR_2, MR_{11}, and MR_{17} are selected as group heads CH_1, CH_2, and CH_3 as they have least distance value. Here, MR_1, MR_8 and MR_{20} are selected as gateway nodes.

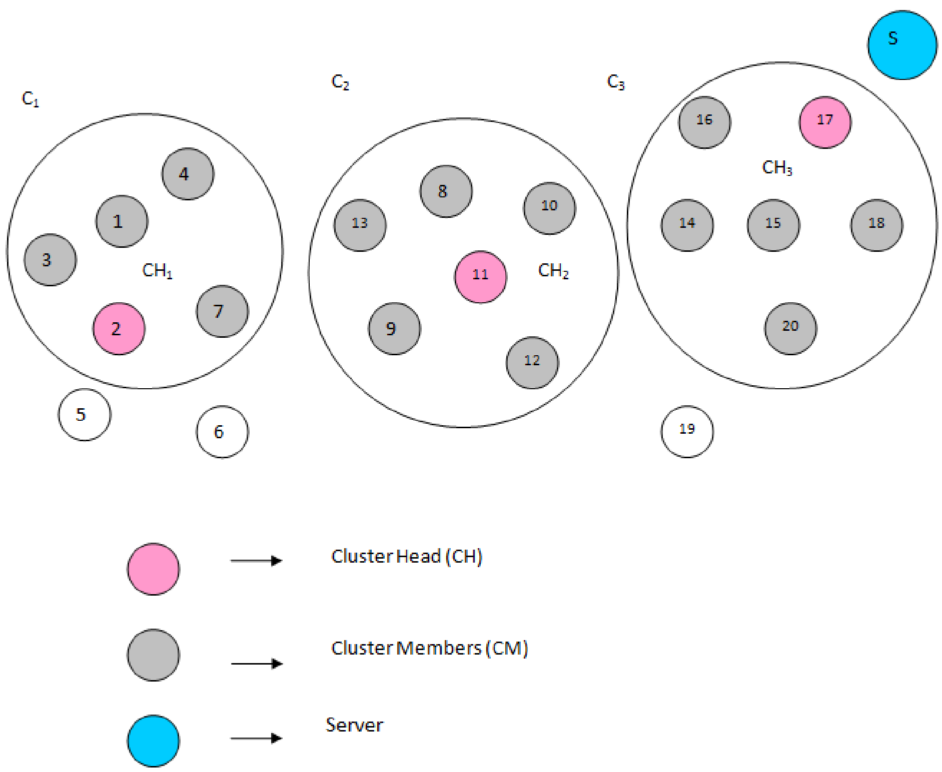

Figure 1: Wireless mesh network.

3.4.1 Gateway Node Selection

Based on Gravitation Search Algorithm (GSA), a GW is selected based on the following constraints:

- The distance between the Internet Access Point (IAP) and the GW is minimum (D_1)
- The distance between each MR and the GW is minimum (D_2)
- The average cluster load (which is based on the loads of each MR in the cluster) should not exceed the maximum capacity of GW. (AL)

Let W_i be the ith agents (masses)

$$\text{i.e., } W_i = \lfloor P_{i,1}(t), P_{i,2(t)}, \ldots, P_{i,z}(t) \rfloor \quad (3)$$

where$P_{i,d}(t)$ = position of the ith MRs in the zth dimensions

$$p_{i,d}(t) = (x_{i,d(t)}, y_{i,d}(t))\ 1 \le i \le N_p,\ 1 \le z \le Z \quad (4)$$

1) The force on the ith mass from the jth mass at time t is defined as follows:

$$F_{ij}^{z} = Z(t)\ \frac{G_{pagi}(t) \times G_{acgj}(t)}{D_{ij}(t) + \rho} \times (p_i^z(t) - p_j^z(t) \quad (5)$$

Where G_{acgj} is active gravitational agent related with jth agent at time t.

$G_{pagi}(t)$ is passive gravitational agent related with ith agent at time t.

Z(t) is gravitational constant

ρ = small constant

$D_{ij}(t)$ = Euclidean distance within agents i and j

$$Z(t) = Z_0 \times \exp(-\tau \times \delta_{cur} / \delta_{\max}) \quad (6)$$

Where Z_0 and τ are initial and descending coefficient respectively

δ_{curr} and $\delta_{\max}$ are current and maximum number of iterations

2) The total force on agent for each iteration is evaluated as follows:

$$F_i^z = \sum_{j \in H_{BEST,J \neq I}} \psi_j F_{ij}^z(t) \quad (7)$$

Where H_{best} = set of V agents with optimal fitness values and largest weights

ψ_j is random number in the range [0,1]

3) By using the fitness, the inertial mass of each agent is derived as:

$$M_i(t) = \frac{\Omega_i(t) - worst(t)}{best(t) - worst(t)} \quad (8)$$

$$M_{ini}(t) = \frac{M_i(t)}{\sum_{j=1}^{N} m_j(t)} \quad (9)$$

where $\Omega_i(t)$ is the fitness value of ith agent at time t

4) The fitness function is formed using the parameters D_1, D_2 and AL.

$$\Omega_i(t) = D_1 \times u_1 + D_2 \times u_2 + D_3 \times u_3 \quad (10)$$

where u1, u2, u3 are constants

5) The MR_i with best fitness function are selected as gateway nodes (GW_i).

The values best(t) and worst(t) is defined as follows:

$$best(t) = \max_{j \in \{1,\ldots,N\}} \Omega_{j(t)} \quad (11)$$

$$worst(t) = \min_{j \in \{1,\ldots,N\}} \Omega_{j(t)} \quad (12)$$

6) Acceleration of ith agent at time t is given by

$$ACC_i^z(t) = \frac{\Omega_i^z(t)}{M_i^t} \quad (13)$$

7) Velocity and position of agent is defined as follows:

$$\lambda_i^z(t+1) = \psi_i \times \lambda_i^z + ACC_i^Z(T) \quad (14)$$

$$\mu_i^z(t+1) = \mu_i^z + \lambda_i^z(t+1) \quad (15)$$

8. If no such GW is found maximizing the fitness function, then the MRs are clustered again by suitably adjusting the value D-hop. (as explained in section 3.3)

3.5 Path Construction

After GW selection, the path from each MR to GW is constructed by assigning an interference free channel (from the list available channels) to each pair of mesh routers (MR_i, MR_j) towards the GW. This is done by estimating the intra-flow and inter-flow interferences among the MRs.

The equal bandwidth of the simulated link under analytical intra-flow interference is

$$BWintra_{ij} = \frac{BW_i \times BW_j}{BW_i + BW_j} \quad (16)$$

where, BW_i and BW_j are the bandwidths of links i and j correspondingly.

When two adjacent links that join the various flows cannot be dynamic concurrently when working on the same channel, it is called as inter-flow interference.

$$BW_{Inter,i} = (1 - T_i) \times DR \times IRi \quad (17)$$

where T_i = channel busy time (utilization of channel used by link i)

DR = normal link data rate

IR = interference ratio

$$T_i = (TT_i - IT_i)/TT_i \quad (18)$$

TT_i = entire monitoring time

IT_i = idle time

$$IR = SINR_i / SNR_i \quad (19)$$

The corresponding bandwidth of the simulated link under several interferences can be described as

$$BW_{ij} = \frac{BW_{Interi} \times BW_{Interj}}{BW_{Interi} + BW_{Interj}} \quad (20)$$

If interference occurs amid links of two hops, then

The initial link of the path which initiates from the base does not have preceding link. Therefore its corresponding bandwidth can be assessed by means ofEquation (16).

For the present link u and preceding link v, its corresponding bandwidth can be assessed as given below:

$$BW_l = \begin{cases} BW_{inter,v} & C(u) \neq C(v) \\ \frac{BW_{interu} \times BW_{Interv}}{BW_{Interu} + BW_{Interv}}, & C(u) = C(v) \end{cases} \quad (21)$$

If u and v are joined to diverse interfaces on the similar MR, they will not disturb one another and can transfer concurrently.

For the 3rd link of the path (r) and links next to it, may impede with its preceding link v and link v's preceding link u; the corresponding link bandwidth k can be described as

$$\begin{cases} BW_{inter,r} & C(r) \neq C(u), C(r) \neq C(v) \\ \frac{BW_{interu} \times BW_{Interr}}{BW_{Interu} + BW_{Interr}}, & C(r) \neq C(u), C(r) = C(v) \\ \frac{BW_{interv} \times BW_{Interr}}{BW_{Interv} + BW_{Interr}}, & C(r) = C(u), C(r) \neq C(v) \\ \frac{BW_{uv} \times BW_{Interr}}{BW_{uv} + BW_{Interr}}, & C(r) = C(u), C(r) = C(v) \end{cases} \quad (22)$$

Based on the bandwidth, the routing metric for path m is defined as:

$$E(m) = \sum_{r \in m} AL \times \frac{L}{BW_r}$$

where AL = average load of link r

L = packet size

When a mesh client needs to upload/ download data from/to the IAP, the average load of its corresponding cluster is checked. If it is found to be overloaded, then the GSA based GW selection process will be invoked again.

The algorithm is presented as follows

Algorithm

The set of mesh routers (MRs) within a D-hop neighbourhood are clustered.

1. GW node is selected based on the D_1, D_3 and AL using GSA technique
2. If GW is not found even after maximizing the fitness function in GSA technique, then the MRs are clustered again by suitably adjusting the value D-hop.
3. After GW selection, the path from each MR to GW is constructed by estimating the intra-flow and inter-flow interferences among the MRs.
4. When a mesh client needs to upload/ download data from/to the IAP, the average load of its corresponding cluster is checked.
5. If it is found to be overloaded, then the GSA based GW selection process will be invoked again.

4. EXPERIMENTAL RESULTS

4.1 Experimental Parameters

The proposed Minimum Cost, Minimum Interference and Minimum Load (M^3) Gateway Deployment Algorithm (M3GDA) protocol is implemented in NS2 and compared with the metric based on uniform description of interference and load (MIL) [10] scheme and LBR [7] .

The experimental settings are shown in Table 1

Table 1: Experimental settings

Number of nodes	53
Size of the topology	1300 X 1300
MAC Protocol	802.11
Traffic type	Constant Bit Rate
Traffic Rate	50,100,150,200 and 250Kb
Propagation type	Two Ray Ground

4.2 Results and Discussion

The traffic rate is varied from 50 to 250Kb.

Scen-1

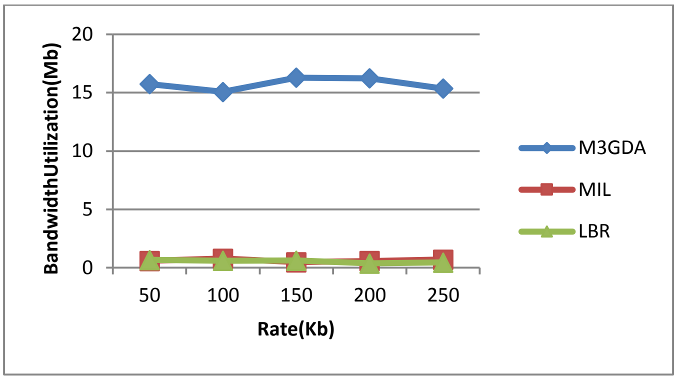

Figure 2 . Bandwidth utilization for traffic rates

Figure 2 shows the bandwidth utilization measured for M3GDA,LBR and MIL for different rates. The utilization of M3GDA varies from 15.5 to 15.3 , the utilization of MIL varies from 0.58 to 0.70 and the utilization of LBR varies from 0.66 to 0.45. So the bandwidth utilization of M3GDA is 96% of higher than MIL and 97% of higher than LBR.

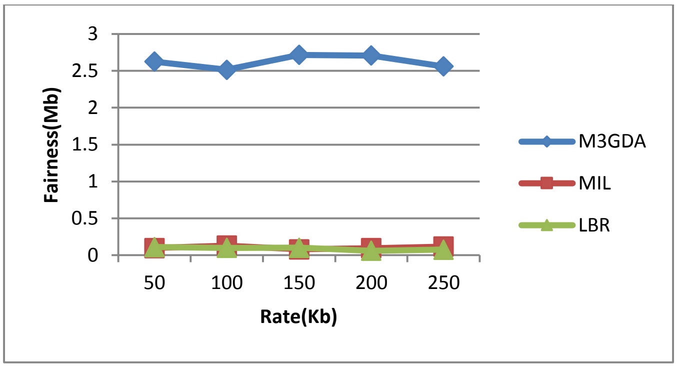

Figure 3. Fairness for traffic rates

Figure 3 presents the fairness measured for M3GDA,LBR and MIL for different rates. The fairness of M3GDA varies from 2.6 to 2.5Mb, the fairness of MIL varies from 0.09 to 0.11Mb and the fairness of LBR varies from 0.11 to 0.07Mb. So the fairness of M3GDA is 96% of higher than MIL and 97% of higher than LBR.

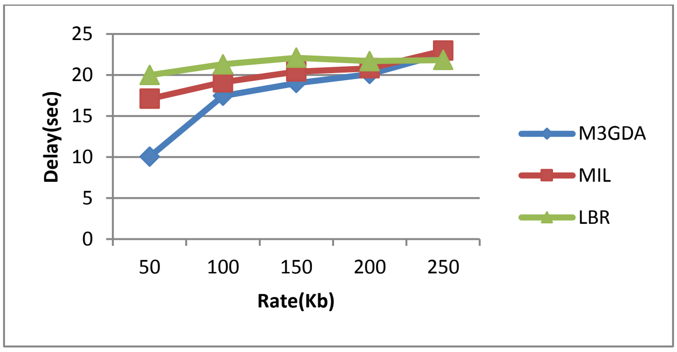

Figure 4. Delay for traffic rates

Figure 4 presents the delay measured for M3GDA,LBR and MIL for different rates. The delay of M3GDA varies from 10.0 to 22.6 sec, the delay of MIL varies from 17.1 to 22.9 sec and the delay of LBR varies from 20.0 to 21.8 sec. So, the delay of M3GDA is 12% of lesser than MIL and 17% of lesser than LBR.

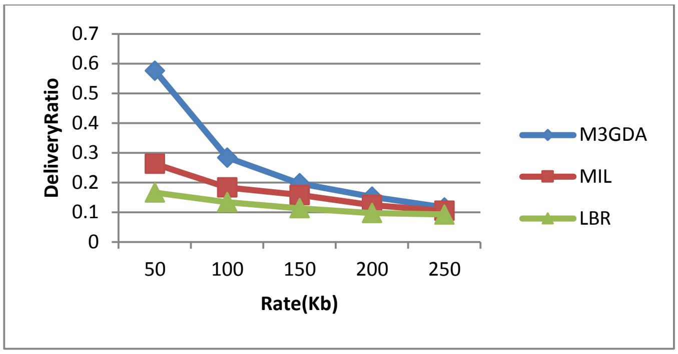

Figure 5. Packet Delivery Ratio (PDR) for traffic rates

Figure 5 presents the PDR for M3GDA,LBR and MIL for different rates. The PDR of M3GDA varies from 0.57 to 0.11 , the PDR of MIL varies from 0.26 to 0.10 and the PDR of LBR varies from 0.16 to 0.09. So the PDR of M3GDA is 28% higher than MIL and 44% of higher than LBR.

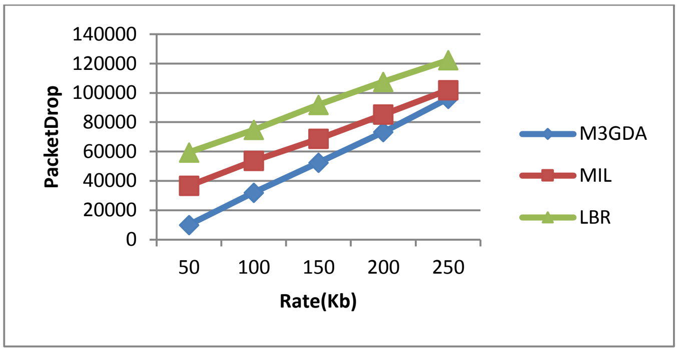

Figure 6. Packet Drop for traffic rates

Figure 6 presents the packet drop for M3GDA,LBR and MIL for different rates. The packet drop of M3GDA varies from 9993 to 96024 , the packet drop of MIL varies from 36702 to 101884 and the packet drop of LBR varies from 59411 to 122271. Hence the packet drop of M3GDA is 31% lesser than MIL and 47% lesser than LBR.

Scen-2

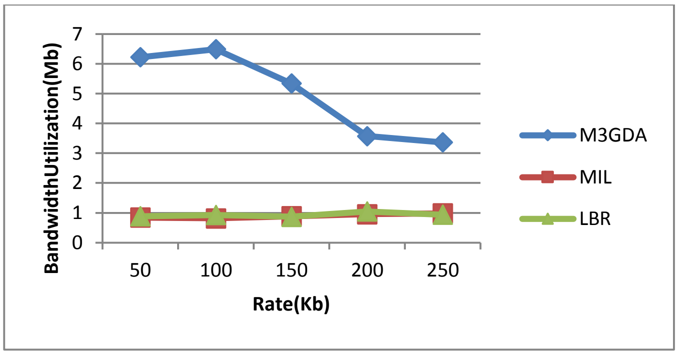

Figure 7. Bandwidth Utilization for traffic rates

Figure 7 presents the bandwidth utilization measured for M3GDA,LBR and MIL. The bandwidth utilization of M3GDA varies from 6.2 to 3.3Mb, the bandwidth utilization of MIL varies from 0.84 to 0.98Mb and the bandwidth utilization of LBR varies from 0.88 to 0.93Mb. So the bandwidth utilization of M3GDA is 80% of higher than MIL and 80% of higher than LBR.

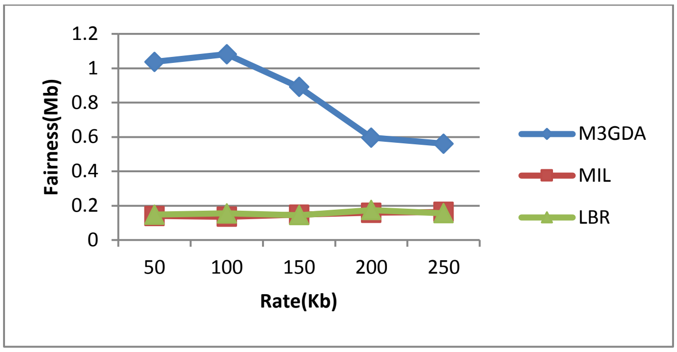

Figure 8. Fairness for traffic rates

Figure 8 depicts the fairness measured for M3GDA,LBR and MIL schemes. The fairness of M3GDA varies from 1.0 to 0.5Mb, the fairness of MIL varies from 0.14 to 0.16Mb and the fairness of LBR varies from 0.14 to 0.15Mb. So the fairness of M3GDA is 80% higher than MIL and 80% of higher than LBR.

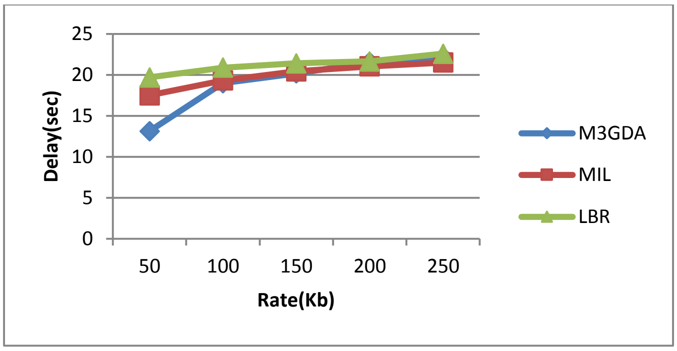

Figure 9. Delay for traffic rates

Figure 9 depicts the delay for M3GDA and MIL schemes. The delay of M3GDA varies from 13.1 to 22.1sec, the delay of MIL varies from 17.4 to 21.4 sec and the delay of LBR varies from 19.6 to 22.5 sec. So the delay of M3GDA is 4% lesser than MIL and 10% of lesser than LBR

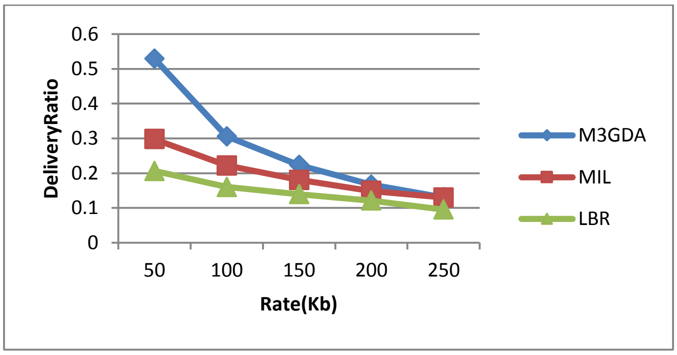

Figure 10. Packet Delivery Ratio (PDR) for traffic rates

Figure 10 presents the PDR for M3GDA,LBR and MIL schemes. The PDR of M3GDA varies from 0.52 to 0.13 , the PDR of MIL varies from 0.29 to 0.13 and the PDR of LBR varies from 0.20 to 0.09. So the PDR of M3GDA is 20% higher than MIL and 40% of higher than LBR.

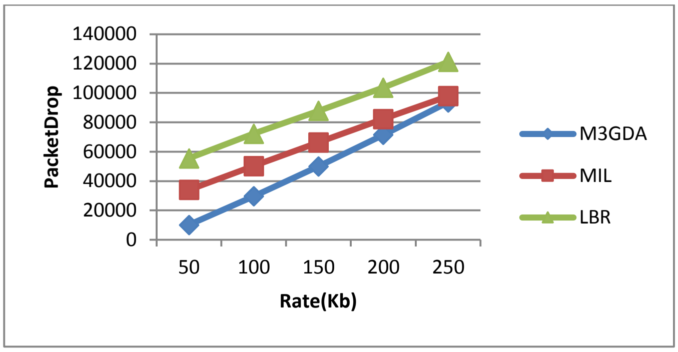

Figure 11: Packet Drop for traffic rates

Figure 11 depicts the packet drop for M3GDA,LBR and MIL schemes. The packet drop of M3GDA varies from 10119 to 93599, the packet drop of MIL varies from 34018 to 97798 and the packet drop of LBR varies from 55407 to 121193. So the packet drop of M3GDA is 31% lesser than MIL and 48% lesser than LBR.

5. CONCLUSION

M^{3}GD algorithm for MRMC WMNs is proposed in this paper. In this algorithm, the set of mesh routers (MRs) within a D-hop neighbourhood are clustered. The gateway node is selected based on Gravitation Search Algorithm (GSA). The path from each mesh router to gateway node is constructed by assigning an interference free channel (from the list available channels) to each pair of mesh routers towards the GW. The upload or download of data from or to IAP by mesh client is performed based n the average load of the cluster. Experimental results have shown that M^{3}GDA minimizes the delay and packet drop, compared to LBR and MIL schemes.

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