A Water Flow Algorithm Based Link Optimization in Common-Hop for Congestion Control in Wireless Mesh Networks

M.Sowmiya, R. Nedunchelian

Abstract: ***One of the famous and popular networks is Wireless Mesh Networks (WMN), in which any node can communicate with any other node. Nodes in the WMN are called as mesh nodes, including multi-radios changed to non-overlapping channels for improving their capacities. Since mesh connection, data transmission between any two nodes is confused with selecting a link and bandwidth among pair of nodes dynamically. In the mesh network, any single node becomes a common-hop, can have multiple links from various sources nodes. When a greater number of data packet arrives into the common-hop, understanding and forwarding them is a critical issue and congestion occurs. In mesh network, obtaining a potential bandwidth route is also a critical task. The common-hop meets difficult in selecting a next hop based on the potential bandwidth, and forward the appropriate data packet. Due to the variations in packet arrival, common-hop meets congestion, flooding and jamming. To avoid this kind of problems in mesh network, this paper proposed Water Flow Algorithm (WFA) for optimizing the link and avoid congestion in mesh networks. The data packet flow from the source nodes is forward in the optimized links eliminates congestion. The proposed WFA optimization is simulated in MATLAB software and the results are compared with the existing algorithms for performance evaluation.***

Keywords: Wireless Mesh Networks, Congestion Control, Bandwidth Calculation, Link Optimization, Water Flow Optimization Algorithm.

I. INTRODUCTION

A collection of radio nodes is connected and organized in mesh topology is called as wireless networks. Wireless Mesh Networks (WMN) comprises of various wireless Adhoc networks [**1-2**]. Number of mesh nodes/clients, routers and gateways are interconnected through wireless communication medium. Cell phones, wireless devices, laptops and etc., are referred as mesh nodes. All the devices communicate with one another and with internet through routers and to gateways [**3**]. It is not necessary that WMN is connected with the internet.

A WMN consists of mesh gateways (MGs), mesh routers (MRs), mesh clients (MCs) and set of wireless links between them. An MC is considered as user device as in most cases, an end-point of a flow of traffic through the network.

MRs Forms a group of wireless backbone and provides better service to MCs.MG performance at the point at which WMN connected to a wired infrastructure and generally to the internet. When a network request originates from MC would be transferred through its linked MR onto the wireless backbone, where it takes one or more hops to reach MG before reaching the internet. This architecture is illustrated in Figure-1.

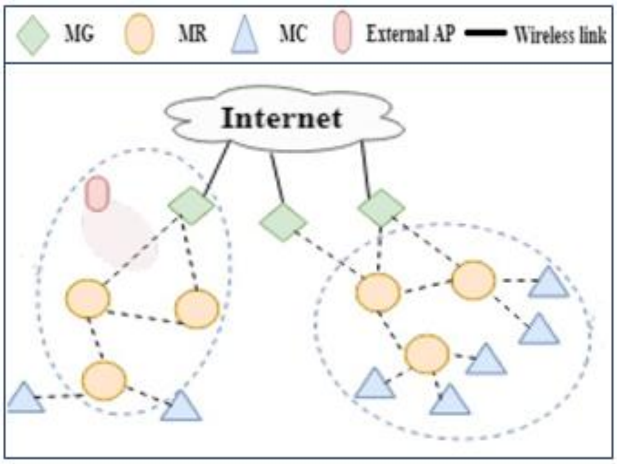

Fig. 1 A Sample Scenario of Wireless Mesh Networks

The entire coverage area of the single network is referred as mesh cloud. Any independent nodes can access to mesh cloud. Due to the radio communication, the MN creates redundancy and it is reliable. Each node is bind with multiple radios, to improve efficiency of the entire WMN in terms of capacities [**4**]. Any node in WMN can communicate with any other node in the network directly or through intermediate nodes in the route. WMN follows the IEEE 802.11, 802.15 and 802.16 standards [**5**]. In recent years IEEE 802.11(Wi-Fi) has become universal where everyone expecting connection anywhere, whether it may be at home, office, restaurants or plane. As due to their low coverage and low QoS guarantees (quality of service) single access point (AP) has failed to meet increasing broadband service requirements, resulting it appeals for a multi AP networks called Wireless Mesh Networks (WMNs).

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When congestion occurs in network it will affect the queuing delay, packet loss rate throughout the network when traffic occurs heavy when sending messages, the network response time slows down. To predict and avoid traffic flow and any kind of congestion algorithm should be designed to monitor.

The use of traffic engineering technique changes the routes and prevents congestion; it is one of the preventive types. The main objective in monitoring algorithm is minimization of the control messages.

Various earlier research works have been focused on solving congestion control problems in wireless mesh networks. For example, author in [**6**] proposed an interior point method to solve large-scale network congestion and author in [**7**] presented a detailed survey on interior point methods for common networks. Some of the authors discussed and proposed state-of-the-art methods based on dynamic tree data structure [**8**], Fibonacci heaps method [**9**], self-programming [**10]**, learning and reasoning [**11**], and Extended Threaded Index (XTI) method [**12**] for congestion control in various networks.

II. MOTIVATION OF RESEARCH WORK

In this research, two main contributions are introduced, where it can be divided into multiple sub contributions. Comparing to new user's traffic, handoff users have more priority when the user is moving. The first contribution in this theory is presentation of new admission and routing algorithm, the algorithm proposed in the research examines finding completely disjoint path from old path for the user handoff traffic, this makes the end user to find the handoff process does not go smoothly and the user can notice the reduction of QOS while moving. Algorithm makes smoother handoff users by proposing multihoming and maximum joint paths to the handoff user's traffic. For the new user's traffic algorithm in the research can accept/reject the call based on resource network, it also tries new user's traffic by triggering multihoming in highly jammed network, which makes availability more for acceptance of new traffic and utilize the resource in better way. This has been modelled mathematically using MDP, and the sub optimal solution is found using value iteration method.

Another contribution is the recommendation of newly congestion and routing algorithm, which is a flexible algorithm that can adjust the transmission rate based on predicted congestion link status. The prediction condition allows us to route our packets in convenient way. To maximize the transmission rate, new route is used in sub-optimal order. By defining the user satisfaction as a part of Heaviside and sigmoid function a new mathematical model is used to increase the user satisfaction for the better Quality of Experience (QOE). Our proposed algorithm for mobility management exceed other algorithms in this research in terms of blocking possibility for the new and handoff user's traffic, number of hard handoffs, handoff delay and packet loss. The other recommended algorithm for congestion control is also compared with other algorithm in the research and shows better achievement in terms of delay, packet loss and throughput.

Existing Methods for Congestion Monitoring

The network traffic flow is analysed using various network monitoring tools like sniffer. The monitored data is carried out into segments to analyse the highest volume of traffic. During network monitoring session, various problems obtained in the network like network bottlenecks, protocol settings, connection among the network nodes, priority assignment, and scheduling to avoid congestion. Various methods have been proposed for congestion control in wireless network and some of them such as, Leaky Bucket [**12**] algorithm, channel allocation [13], Bayesian learning [**14**] and K-means clustering [**15**] method, some of them are described below. Not only conventional methods, machine learning approaches is also used for improving the network traffic control in WMN [**16-19**]. Author in [**20**] presented a machine learning approaches for handling congestion in wireless networks and proved machine learning algorithms are better in congestion control.

Channel Allocation

The channel allocation problem deals with allocating channels to the wireless links among MRs in a WMN such that interference effects are minimized and channel utilization is maximized. For example, consider the scenario given in Figure-2, four non-overlapping channels 36, 40, 44 and 48 (in the 5 GHz band) should be assigned among the given links to avoid the possibility of,

1). intra-flow interference (between links of the same flow) and

2). inter-flow interference (between links of adjacent flows). It is clear that only the last assignment satisfies both requirements (other links with the same channel are too far apart to interfere).

A fair share of ML related WMN channel allocation approaches in the literature employ LA based strategies. Most of these are distributed in nature, with each of the MRs acting as a learning automaton. To this end, Leith and Clifford [**10**] proposed a self-managed LA based algorithm that does not require any communication between MRs. Each automaton maintains and updates a vector $\psi\psi$, which contains a probability corresponding to each channel that reflects its history of interference.

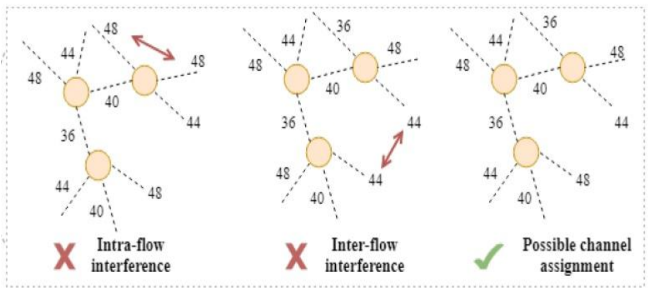

Fig. 2 Channel Allocation

If the current channel quality is above a certain threshold, the MR will continue to operate in it; otherwise, a channel is selected randomly based on the current value of $\psi\psi$. They also theoretically proved that the convergence of their algorithm is guaranteed, provided that the channel assignment was feasible.

Bayesian learning

Bayesian learning tries to calculate the posterior probability distribution of the target features of a testing object conditioned on its input features and the entire training data set.

For example, if an object could be a wireless channel, and its features could be measurement data on its signal, noise and inter references levels measured at a radio operating on that channel at a particular MR. Bayesian learning is well suited for occasions where there is a limited number of data points and when outliers need to be handled well. Examples include Maximum Likelihood Estimation (MLE) and Maximum A Posteriori Estimation (MAP). In the practical application of Bayesian models, Gibbs sampling provides a convenient way to approximate posterior distributions. Authors of [**10**] proposed a self-organized method for automatic channel assignment in IEEE 802.11 WLANs with the aim of minimizing the total interference received by all MRs, using a Gibbs sampler. For this, they define an energy function on each node where the energy depends on the channel assignment to that node. This is utilized in an iterative procedure where the network converges to a collection of states with minimum global energy—the optimal channel assignment.

K-means clustering

K-means clustering groups [**15**] a set of unlabelled data consisting of nn observations into a group of kk clusters based on the similarity of a set of features that are provided. Each cluster has a centroid, which can be used as it's label and is usually defined as the mean of the data points within that cluster. The most common algorithm for clustering uses an iterative refinement technique. While k-means clustering has been applied on several classification and decision-making tasks related to WMNs in the literature, we want to highlight one potential application of this technique related to channel assignment. Several algorithms using rule-based procedures cluster nodes to several groups with the purpose of treating channel allocation in a divide and conquer fashion. A typical approach would assign the same channel to radios within the same cluster and would present a methodology to assign channels to radios on the boundary between clusters to achieve inter-cluster connectivity. We note that k-means based clustering could be used to intelligently cluster the set of MRs for this purpose. Most such approaches also require a cluster head to function; k-means clustering is naturally suited for this as the cluster centroids output by it could be used for this purpose (or some variation of it).

Network Deployment

Network deployment typically deals with placing the MGs and MRs at locations which are optimal to achieve maximal network performance. Even though many other optimization problems like routing and channel assignment assume a predefined placement of these nodes, the performance of their ultimate outcome is dependent upon the initial physical arrangement of nodes. MGs are extremely important in a network where most traffic is destined towards the Internet, like in a home network. More gateway nodes are beneficial as it would result in shorter paths on average for most MCs. However, this is unrealistic in most real-life deployments where the number of different wired connections to the Internet is extremely limited.

So, the problem is the compromise of figuring out the minimum number of gateway nodes and the ideal location for them to be placed. The placement of MRs is critical as it determines network coverage. It is equally important in channel assignment—in some occasions, the locations could be in such a way that no channel assignment is likely to improve performance beyond a satisfactory level. For example, the MRs could be located in areas of high interference caused by neighbouring external APs; relocation of MRs is essential in such cases. Metaheuristic techniques like Simulated Annealing (SA), Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) have virtually become the de facto standard for intelligently solving MR and MG placement problems in WMNs.

Since these techniques fall more under the umbrella of Artificial Intelligence rather than ML, we will not discuss them in detail. However, it must be noted that RL techniques like Q-learning and LA may still be worth exploring in this regard. A recent attempt has been made successfully at solving the MR placement problem where the idea of balancing the front haul and backhaul throughput of an MR was employed as a strategy. Semi-supervised support vector machines (S3VMs), which are a variation of support vector machines that support unlabelled data, were used to identify throughput regions, while an exploration and exploitation strategy like RL was used as the learning strategy.

Common Scenario of Congestion Creation

This paper aimed to control the dynamic congestion created in wireless networks. During the data transmission, any one or two of the nodes become a common node as behave as a intermediate node can collect and forward the data packets sent by more than one node. An example scenario is illustrated in Figure-3. The two nodes are represented as source and destination node and the red color node is the common node where the congestion occurred.

It is assumed that the average size of the data packets transmitted in the network from one node to another node is 512kb/s. It means, each node is capable of transmitting 512kb/s at any time in the network which provides better quality of service in the network. In Figure-3, it is noticed that, there are 4 number of nodes send data packets to the common node just for forwarding to destination.

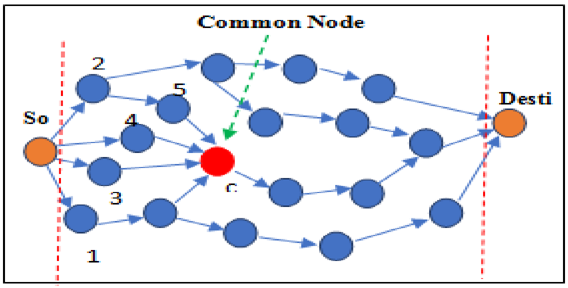

Fig. 3 Common Node Congestion

Since the capacity of the common node cannot increase from 512kb/s into 4 x 512kb/s, the data packets congested, some of the packets will be dropped out and some of the packets will be jammed. It is not sure that the data packets and the data transmission rate are fixed. In order to find out the congestion creation in the wireless network and network traffic is controlled by Water Flow Optimization Algorithm (WFOA).

Water Flow Optimization Algorithm

Water flow optimization algorithm is one of the naturally inspired algorithms used to optimize network parameters and control the congestion. In this paper, the congestion-controlled network traffic is cleared by WFO algorithm. WFO algorithm is designed as an object-oriented method. Nodes capacity $\mathbf{N_{cp}}$, data packet size $\mathbf{d_{ps}}$, data transmission rate $\mathbf{dtr}$and the dynamic saturations regarding data transmission rate $\mathbf{sdtr}$and data packet size $\mathbf{sd_{ps}}$are the set of parameters used for analysing the network traffic. To increase the efficiency, the WFA repeats the process of water processes (moving, merging, precipitation) from source node, until reach the destination point. It is assumed that the water flow starts from source node '**S**' and reach the destination '**D**'. WFO algorithm has set of unique behaviour like water flow is controlled by gravitational force and governed by energy conservation law and the flow with higher momentum which generates more streams water flow and sub-flows. Some of the lower flows are merged into higher flows, more flows are merged into single water flow when all the flows are aimed to reach the same destination. Object design of the proposed WFO algorithm documents the problem from the beginning to final stage.To understand the WFO algorithm, it is figuratively represented in Figure-4.

There are two functions such as, constructing the traffic model and optimizing the traffic flow are designed based on the WFO functionalities and various parameters are used for deciding the traffic in accordance to the dynamic properties of the network traffic flow. Including the network parameters, velocity, delay, and density are the first level parameters with the sub-parameters in the second and third level of the traffic model which can decide about the traffic and it control the congestion. The model is constructed in accordance to solve the objective function to plan and control the network traffic. Network traffic and decision making are the two main classes used in the object-oriented design. Network traffic class considered and manipulates the parameters such as, $\mathbf{N_{cp}}$,$\mathbf{d_{ps}}$, $\mathbf{dtr}$, $\mathbf{sdtr}$, and$\mathbf{sd_{ps}}$, but the optimization class considers and manipulates the parameters such as velocity, density, delay and saturation etc. The decision class is mainly used for optimizing the traffic model.

To solve the congestion problem, the WFO algorithm is designed. Initially, **N** number of flows/main-flows **F** are initialized as **1** and the sub-flows are **SF**. The term flow in WFO algorithm represents the traffic flow (data transmission rate) in network. Each $\mathbf{SF_i}$ is identified by the velocity $\mathbf{V_i}$ is calculated as:

$$\mathbf{n_i = min\left\{max\left\{1, int\left(\frac{W_iV_i}{T}\right)\right\}, \bar{n}\right\}} \qquad (1)$$

Where, $\mathbf{W_iV_i}$ is the momentum of the $\mathbf{i^{th}}$ main flow, **T** is the base momentum, and $\mathbf{\bar{n}}$ used to represent maximum limit of the sub-flows obtained by splitting the main flows.

Traffic Flow $\mathbf{n_i}$ is divided into $\mathbf{SF_i}$, the mass of each $\mathbf{SF_i}$ ($\mathbf{W_{ik}}$) is recalculated using the following equation as:

$$\mathbf{W_{ik}} = \left(\frac{\mathbf{n_i+1-k}}{\sum_{\mathbf{r=1}}^{\mathbf{n_i}}\mathbf{r}}\right) \times \mathbf{W_i} \qquad (2)$$

Where, **k=1** to $\mathbf{n_i}$. Similarly, the velocity of the $\mathbf{SF_i}$ is divided from flow **i**, where the energy conservation ($\mathbf{\mu_{ik}}$) is calculated using the following equation as:

$$\mathbf{\mu_{ik}} = \begin{cases} \sqrt{\mathbf{V_i^2 + 2g\delta_{ik}}}, & \mathbf{if\ V_i^2 + 2g\delta_{ik}} > 0 \\ \mathbf{0} & \mathbf{otherwise} \end{cases} \qquad (3)$$

Where, **g** represents the gravitational acceleration and $\mathbf{\delta_{ik}}$ says the dynamic behaviour of the drop flow from the $\mathbf{i^{th}}$ traffic flow to their sub-flow **k**, and it is calculated using the following equation as:

$$\mathbf{\delta_{ik}} = \begin{cases} \mathbf{f(X_i) - f(U_{ik})}, & \mathbf{for\ minimization} \\ \mathbf{f(U_{ik}) - f(X_i)}, & \mathbf{for\ maximization} \end{cases} \qquad (4)$$

Finally, the velocity of the traffic flow in the route is measured and calculated by merging behaviour and merging the traffic flow as:

$$\mathbf{V} = \frac{\mathbf{(W_i\mu_i)+(W_j\mu_j)}}{\mathbf{W_i+W_j}} \qquad (5)$$

To obtain the best solution there are two different operations such as evaporation and precipitation are carried out. These operations change the parameters associated with the traffic flow. Let the network **G** is considered as a directed graph have **N** number of nodes and **M** connections, where each connection connects two nodes in the network. For each connection $(\mathbf{i},\mathbf{j}) \in \mathbf{A}$the cost $\mathbf{C_{ij}}$ spend for transmitting the data from node **i** to node **j**. The flow $\mathbf{x_{ij}}$should within the range from $\mathbf{l_{ij}}$ to $\mathbf{u_{ij}}$. The cost depending on the flow of the data in a route where lesser cost represents the lesser flow. Hence the objective function is given as minimizing the cost based on the flow in the route. The optimization processes obtain the objective function value OFV is calculated using the following equation as:

$$\text{OFV} = \sum_{(\mathbf{i},\mathbf{j})\in\mathbf{A}} \mathbf{C_{ij}x_{ij}} \qquad (6)$$

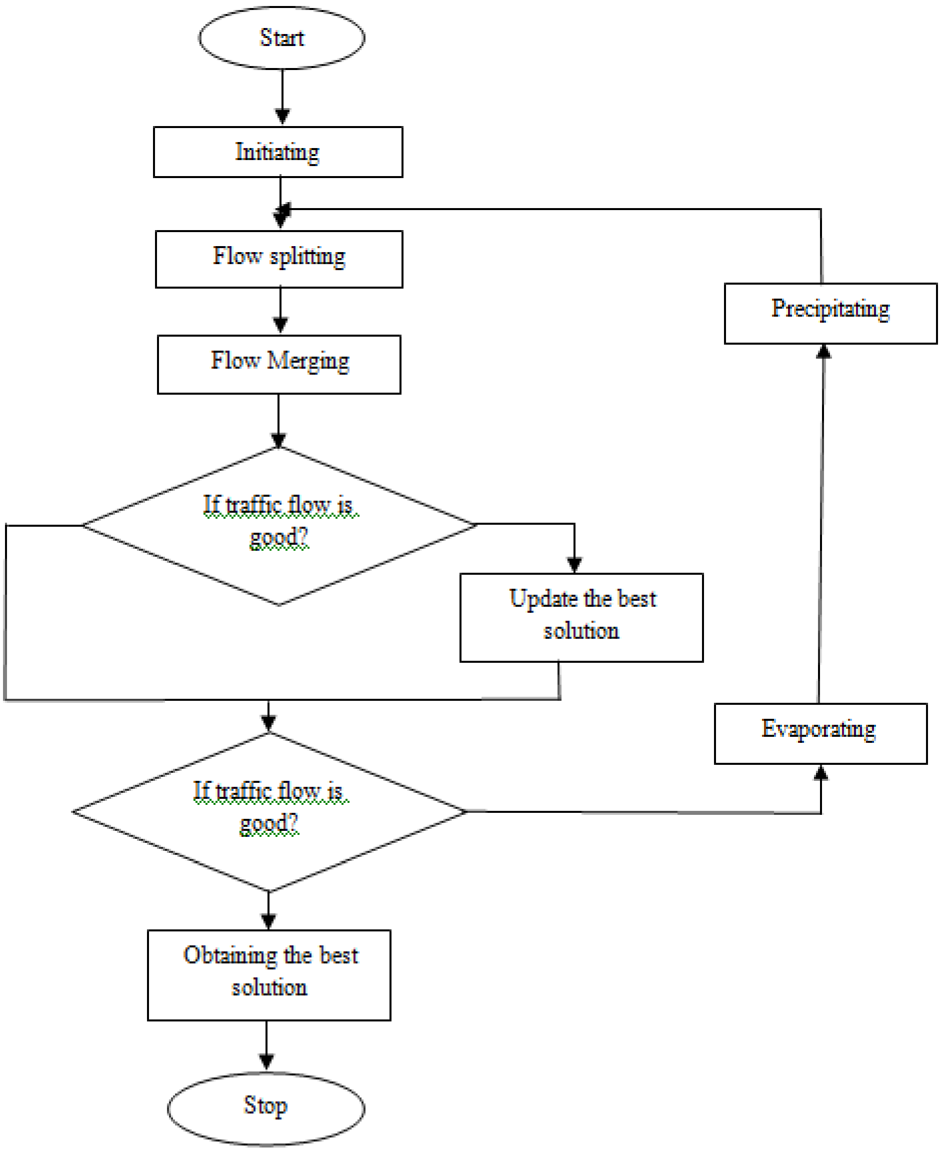

Fig. 4 Dataflow Diagram for WFO Algorithm Based Network Traffic Controlling

Where $\mathbf{C_{ij}}$ represents the cost taken for traffic flow from source node to destination node, and $\mathbf{x_{ij}}$ under certain constraints as:

$$\sum_{k(i,k)\in A} x_{ik} - \sum_{j(j,i)\in A} x_{ji} = b_i, \forall i \in N \qquad (7)$$

$$l_{ij} \leq x_{ij} \leq u_{ij}, \forall (i,j) \in A \qquad (8)$$

In the above constraint, given in the equation (7) is called as the flow conservations under the range of value given in equation (8) is called as the capacity of the flow. The objective function is scanned from earlier research works [**21-22**]. This process is repeated for R number of times iteratively to obtain the best solution. The best solution is managed traffic flow in shortest path with less cost.

Simulation Settings

The simulation is carried out in Network Simulation Software-2.34 [17] and the results are verified. To get the approximate accurate results, the simulation scenario is executed a greater number of times by changing the parameter values. The scenario is wireless mesh network, with source and destination nodes. Each intermediate node is treated as mesh clients as well as mesh routers based on the data transmission scenario. All the nodes in the network is places within the area of 1800 x 1800 meters. The nodes placed according to the layout given in Figure-2. All the nodes are reliably connected with one another and statically placed in the network. Due to the availability of the routing nodes status (like busy) the routing nodes can be changed automatically and connection established. The data transmission is carried out using CBR traffic model and various performance values are calculated.

The above proposed WFO algorithm is programmed in TCL programming language under Network Simulator -2 software and the results are verified. To simulate the proposed approach certain network parameters are assigned to describe the network scenario. The parameters and the assigned values are given in Table-1. The parameter and the values of the parameter determines the behaviour of the network and the quality of service. The quality of service can also be assured by various performance metrics such as, delay, throughput, energy, packet loss and packet delivery ratio obtained in the network. In this paper, the congestion measured and eliminated based on the capacity of the common node and calls the WFO algorithm to spilt and merge the data packets to control the traffic flow. By controlling the traffic flow, the network behaviour is improved by concentrating on the QoS parameters. In order to evaluate the performance, the number of nodes, data packet size, simulation time and the data transmission model.

Initially the entire data is converted into packets are transferred from source node to destination node through different nodes placed in the different paths. First source node transfers the data packets into node-1, node-2, node-3, node-4 and node-5. Then node 1, node-3, node-4 and node-5 transfer the data packets into node-cc. When all the data packets reach node-cc, the number of packets in the node-cc is high where the capacity of node-cc cannot be able to manage. It will create congestion of data packets. It makes packet loss, overloading of packets and various issues in data transmission.

Table. 1 Simulation Parameters used in NS-2 for Experimenting Congestion Control

Parameters	**Values**
Simulation Tool	NS-2.34
Traffic Model	TCP, TCP/IP, CBR
Simulation Area	1500 x 1500
Simulation Time (at each round)	15 sec
Number of Rounds	10
Number of Nodes deployed in the Network	50, 100, 150, 200, 250, 300, 350, 400, 450, 500.
Transmission Range	250m
Node Speed	5 to 25ms
Packet Size	256, 512 bytes
Data Transmission Rate	0.016Mbps to 1Mbps

During the congestion the water flow optimization algorithm applies merging and dividing process and transmit the packets sequentially. Hence WFO algorithm is activated/enabled at node-cc, divide the data packets entering into node-cc based on the sender node. It is well known that each node transmits their packets into other node with sender-id. The number of packets from one sender have a sequence id and sender id, represents the set of packets are sent by one sender. Based on the sender and the sequence WFO divide the data packets into separate groups and allocate other possible router nodes for transmission else it sends the packets using round-robin method. The data packets sent by node-1, node-3, node-4 and node-5 are separated and merged together in four queues and transmitted though node-cc or other nodes. Even though round-robin consume more time, this paper aimed to avoid congestion in the mesh network. If it is assumed the same scenario cloud applications, the uploading and downloading time is increased whereas the data will be downloaded or uploaded perfectly.

III. RESULTS AND DISCUSSION

Initially packet delivery ratio is calculated and the obtained result is given Figure-5. PDR is calculated for various Data Transmission Rate (DTR) like 5ms to 25ms, but the obtained PDR for 25ms DTR is calculated and given in Figure-5. The PDR obtained using WFO is compared with the existing approach presented in [24]. Packet delivery ratio is the number of packets received by the destination node. PDR is high for less DTR, whereas if DTR increases then PDR will be reduced due to various issues like congestion, node like stability and reliability of routing. From Figure-5, it is identified that comparing with existing approach the proposed WFO approach obtained high amount of PDR. PDR is calculated by changing the speed, simulation time and packet size. DTR is measured in Mega bytes per second, and it is changed from 5Mbps to 25Mbps and PDR is calculated and compared.

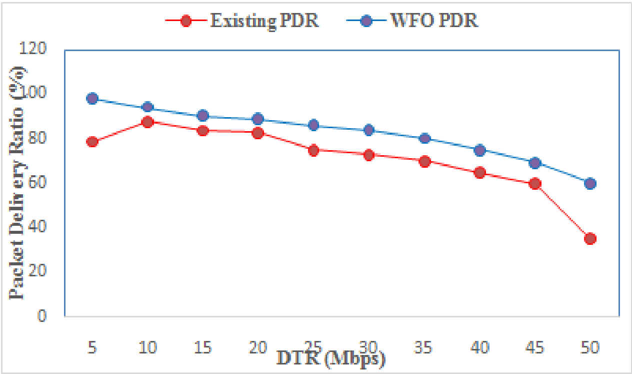

Fig. 5 Data Transmission Rate versus Packet Delivery Ratio

Other parameter which can decide the performance parameter such as Routing Overhead (RO) is calculated from the simulation and the result is verified. RO occurs because of routing and data packets sharing the same network bandwidth. Those packets are and routing in the network is called as overhead and routing overhead respectively. Routing overhead can decide about the DTR, PDR and improved routing.

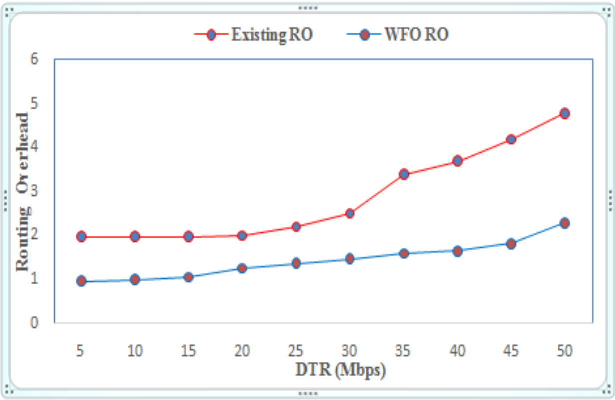

Fig. 6 Data Transmission Rate versus Packet Delivery Ratio

Routing overhead occurs when congestion occurs. If the RO increases then PDR and throughput decreases. Also, RO increases when DTR increases in the network. If the network size is small then RO occurs frequently but not in large scale networks. RO is calculated in the simulation of WFO, compared with the existing approach and given in Figure-6. From figure-6, it is identified that the proposed WFO algorithm outperforms by obtaining lesser RO for increased DTR comparing with existing approach. But RO is increased for increased DTR and it is calculated.

Another concern which affects the quality of service of the network is packet drop. Packet drops happen when packet flow is more than the queue size, due to congestion, traffic jam and routing/packet overhead. In this paper it is assumed that the due to DTR variation, packet drop occurs. Based on the DTR changed from 5Mbps to 25Mbps, the packet drops (PD) is calculated and given in Figure-7. The PD obtained using WFO is compared with existing approach and given in the same figure. Based on the comparison and the obtained results, it comes to know that WFO obtained very less PD which increases the quality of service parameters.

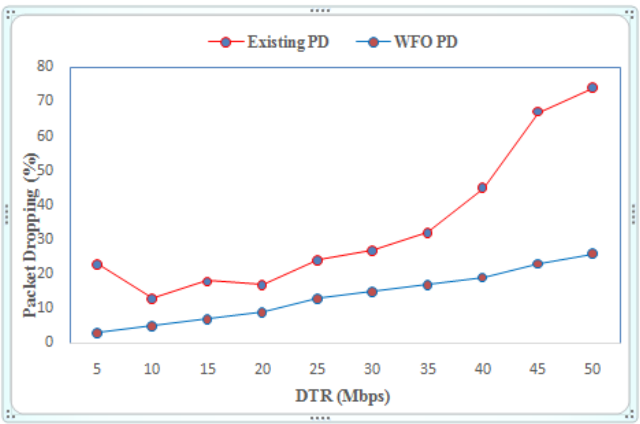

Fig. 7 Data Transmission Rate versus Packet Delivery Ratio

Fig. 8 DTR versus average round-trip time

To evaluate the performance of the proposed WFO approach, the performance in terms of round-trip time is calculated for the varying DTR and compare with the existing Congestion Control Channel Assignment (CCCA) protocol [25] and given in Figure-8. To provide a perfect comparison, the number nodes used in the WMN is 30 in both CCCA and in WFO approaches. The basic standard used in the routing procedure is IEEE 802.11a and b in the network, since it uses 5GHz and 2.4GHz. In order to verify the RTT, the DTR is changed from 5Mbps to 25 Mbps. Figure-8, it shows that the proposed WFO consumed lesser RTT comparing with the CCCA.

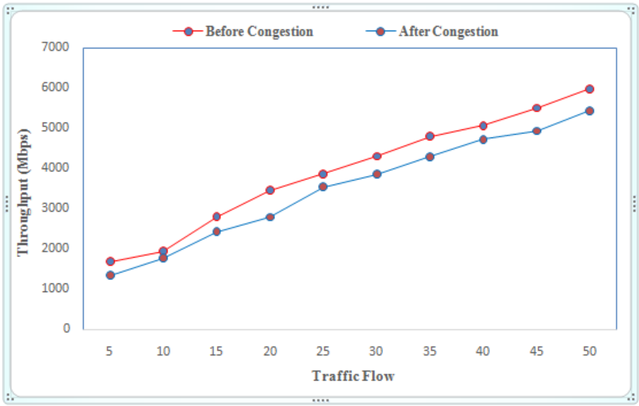

Fig. 9 Traffic Flow Versus Throughput

The performance of the proposed WFO algorithm is computed in terms of throughput before and after congestion and the obtained results is given in Figure-9. The throughput is increased when the traffic flow increases. From the figure, it is identified that throughput before congestion is increased than after congestion. The congestion is controlled and adjusted by applying WFO algorithm is applied in the network.

From the above discussion, it is clear identified that the proposed WFO algorithm outperforms than the existing methods given in [24, 25]. By dividing and merging the packets reaching node-cc the congestion is eliminated.

IV. CONCLUSION

The main objective of this paper is to control the congestion and improve the traffic flow in Wireless mesh networks. To understand the statement of the problems a detailed literature survey is carried out and the WFO algorithm is used for controlling the congestion. To verify the performance of the WFO algorithm, it is experimented and simulated in NS2 software and the results are obtained. Also, the results of the proposed approach are calculated and compared with the existing approaches and find that WFO outperforms than the other existing algorithms. WFO provides better throughput, less RO, PD, RTT and improved PDR and proved through simulation. Hence it is concluded that WFO algorithm is more suitable and it can correct and control the congestion in WMN.

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