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Fuzzy Based Multipath Routing over Wireless Mesh Networks for Video Transmission

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ABSTRACT

Wireless mesh networks (WMNs) are expected to be widely deployed owing to their ability to provide ubiquity, convenience, cost-efficiency, and ease for both service providers and end-users. Newly, in IEEE 802.11s standard we introduces the fuzzy based mesh routing protocol (FMRP) that is inspired by a combination of on-demand and tree-based pro-active routing algorithms. It argues that the unimetric path selection algorithm within the standard isn't reliable. This paper introduces and examines a novel multimetric wireless mesh path selection algorithm using fuzzy decision making under realistic wireless channel conditions. The projected path selection algorithm is designed to enhance the performance of both re-active and pro-active routing protocols of FMRP for not solely single-channel however additionally multichannel WMNs. The reported results show the superior performance of the proposed path selection algorithm in terms of delay, throughput and packet delivery ratio while not increasing overhead significantly. Though some fuzzy-based routing algorithms are defined in literature newly, to the best of the knowledge, this paper is that the first one to introduce and examine the use of fuzzy logic in the path selection of single- and multi-channel wireless local area network-based WMNs under realistic wireless channel conditions.

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INTRODUCTION

Overview:

Nowadays, mobile communications, particularly wireless technologies, plays great role in human lives. Advance inventions in hardware and software technologies lead to capable wireless mobile equipment. Wireless networking is classified into two main approaches [Schiller, 2003], namely, Infrastructure networks and Infrastructure-less networks. The convergence of this two approaches results in wireless mesh networks (WMNs) that guarantees larger flexibility, increased reliability, and improved performance. However, there are still several challenges in designing of wireless mesh networks (WMNs).

Video communications in WMN are typically Internet oriented and therefore the traffic is either from end user to Internet gateway (IGW) or vice versa [Nandiraju *et al*. - 2007]. In most WMNs deployed nowadays, the routing protocol focuses on finding a single best possible route from the source to the destination. Consequently, certain links might be heavily loaded whereas many others are significantly underutilized. Such a phenomenon could be a breach of traffic engineering principle and will deteriorate the overall performance of the network.

Overview of Proposed System:

In this paper, it investigates the delivery of multiple description (MD) videos over WMN. MD video is an important coding technique of error resilience and control for multimedia applications and has been recognized as an ideal candidate for video streaming in multi-hop wireless networks [Wang *et al*. - 2005, Kompella, 2007]. This video coding technique is drastically different from traditional layered video coding, wherever video reconstruction hinges upon successful delivery of the base layer.

After the video is MD coded, the multipath routing scheme constructs multiple paths from the source to the destination and video traffic is then delivered with every path carrying one sub stream. It investigates the multiservice environment in this paper, where video traffic can coexist with other forms of traffic in WMN.Fig.1 shows an example of wireless mesh network. [Ian *et al*. - 2005].To cut back the delay of video traffic, this work starts with the investigation on IEEE 802.11 MAC layer, from that it further develop an enhanced version of Guaranteed-Rate (GR) packet scheduling algorithm, particularly virtual reserved rate GR (VRR-GR), to provide video traffic high preference in multiservice

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environment.In this paper, a novel multimetric wireless mesh path selection algorithm using fuzzy decision making is introduced for both re-active and pro-active routing protocols while not modifying the control frames defined in IEEE 802.11s WMN. Usually, fuzzy expert systems and fuzzy decision making techniques offer a technique for handling uncertain values. They're utilized in several wide ranging fields, like linear and nonlinear control, pattern recognition, financial systems, and data analysis. Here fuzzy decision making is used for finding the path selection to transmit video frames. The contributions of this paper is describing a novel intelligent wireless mesh path selection algorithm using fuzzy decision making for both re-active and pro-active routing and to evaluate its performance by means that of extensive simulations.***Related Work:***

Recently, the IEEE 802.11s defined a novel hybrid routing protocol (i.e., HWMP), that applies AODV and tree-based routing protocols as re-active and pro-active routing protocols, correspondingly [Bahr , 2007]. Fig.2 shows an example of IEEE 802.11s WMN architecture, wherever a mesh access point (MAP) could be a special kind of MP equipped with the extra capability of an AP to provide service to STAs

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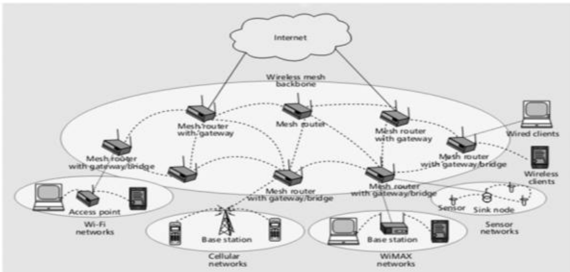

Fig.1: Infrastructure/Backbone WMNs.

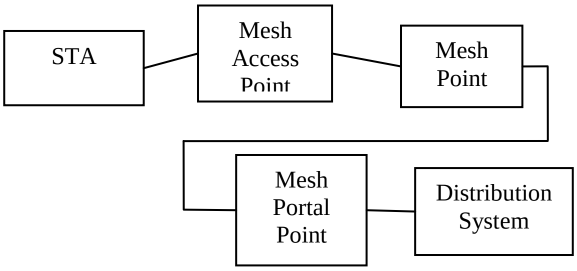

Fig. 2: IEEE 802.11s wireless mesh network architecture.

In addition, it considers ETX and congestion control for pro-active routing protocol. It'sworthyto say that the proposed path selection algorithm may be used for both single- and multi-channel WMNs.

Wireless Mesh Networks:

The IEEE standard 802.11s introduces an optional contention-less access mechanism, known as mesh deterministic access (MDA), to provide end-to-endQoS(Quality of Service) for delay sensitive traffic [Hiertz *et al*. 2008]. In IEEE 802.11s, the proxy MP is defined as the last WMN node connected to the non-mesh WLANs [Bahr, 2007]. As shown in Fig.3, the frames contain both proxied transmitter and receiver, correspondingly. To indicate that the request is sent or destined to a non-mesh node, an address extension (AE) bit ought to be set that islocated in the flags field. The other flag bits are for portal role, broadcast/unicast, and pro-active PREQ.

Video Communications Over Wireless Mesh Network:

A WMN consists of two kinds of nodes: mesh routers and mesh clients. The mesh routers form an infrastructure of mesh backbone for mesh clients. It can observe from Fig.3 that, a WMN can access the Internet through a gateway mesh router or IGW that is connected to the IP core network with physical wires.

To solve traffic congestion problem, it proposes to use multipath routing in WMN. The goal of this scheme is to distribute video traffic uniformly across the network, also as survive the video transmission on some error-prone wireless links.

3. 1.1 Multipath Routing for Multiple Description Coded Video Transmisssion in Mesh Network:

General structure:

Fig. 3 demonstrates the proposed multipath routing framework for MD coded video communications over WMN. In the framework, it assumes that the source node in the Internet splits the video into *K*substreams using MD coding. Above design depends on two key problems, i.e., MD coding and multipath routing.To beat this difficulty, it investigates next on how to reduce the video delivery delay in WMNs.

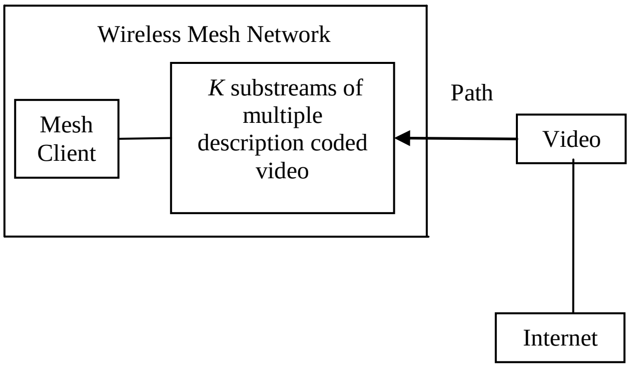

Fig. 3: Multipath routing framework for MD coded video communications over WMN.

3.1.2 Reducing The Delay Of Video Traffic In Wmn:

The packet delay in WMN is mainly caused by MAC layer latency and packet scheduling latency. It propose a new approach of virtual reserved rate GR (VRR-GR) to offer video applications preference throughout packet scheduling process in multiservice environment.

Fundamentals of Guaranteed-Rate Packet Scheduling Algorithms:

To meet the QoS requirements of multimedia services, a number of packet scheduling algorithms are proposed in the literature [Zhang, 1929], [Zhang and Keshav, 1991],[Parekh, 1992],[Golestani – 1994], [Zheng and Shin,1994].Guaranteed-Rate (GR) scheduling algorithms guarantee a delay bound to a packet based on its expected arrival time.

Consider a general case where flow is switched by network node. To provide guaranteed performance, network node allocates flow a reserved rate (in bits/second) as requested by the source of flow. Network node is termed a GR network node if it complies with the service discipline of work-conserving and non-preemptive and uses the Guaranteed-Rate clock value of a packet as scheduling priority. In other words, when GR network node switches a new packet, the packet in queue with the smallest Guaranteed-Rate clock value is chosen for service.

VRR-GR Packet Scheduling Algorithm:

1) Structural Design:

The proposed study focuses on a typical multiservice environment, i.e., video communications over WMN with other potential services. Significantly, it considers that the services might have various QoS requirements, and therefore the WMN must support four scheduling categories corresponding to the access categories (ACs) defined in EDCA: audio, video, best effort data, and background traffic.

To accommodate the diversity of multiservice environment, it emphasizes the differentiating capability throughout packet scheduling process in this paper. Fig. 4 demonstrates the architecture of extended GR packet scheduling architecture. It shows that four categories of services are scheduled together in the four priority queues, where the Guaranteed-Rate clock value of a packet is used as scheduling priority.

Let the total capacity of the network node, allocated to different service levels can then be delineatedand the sub-capacity allocated to audio, video, best effort data, and background traffic, correspondingly. For audio and video, every connection is viewed as a flow and guaranteed with a fixed bandwidth. For best effort data, and background traffic, the fixed bandwidth is allocated to all the connections as a whole; therefore, each connection can only share a part of it, which can vary from time to time.

2) Enhanced GR Scheduling Algorithm:

It develop a virtual reserved rate GR (VRR-GR) scheduling algorithm to determine the Guaranteed-Rate clock value of every flow in the priority queue of Fig. 4.

The target of the suggested VRR-GR algorithm is to combine multiple service stages into one packet scheduling model.Prioritizing video service by deducing the Guaranteed-Rate clock value from virtual reserved rate instead of actual reserved rate is the responsibleness of the VRR-GR, in this model.The bandwidth which a flow ultimately acquires was determined by the actual sub-capacity, while the induced delay throughout packet scheduling is determined by the virtual sub-capacity.The extra reserved rate which VRR-GR permits to a flow during packet scheduling is explained by the virtual offset-capacity, by employing conventional GR as a denotation. Fig.4 shows the architecture of extended GR packet scheduling.

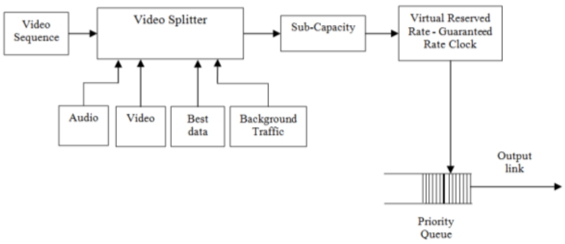

Fig. 4: The architecture of Extended GR Packet Scheduling.

In VRR-GR, virtual offset-capacities, serve as priority indicators in VRR-GR algorithm. Greater virtual offset-capacity means that additional scheduling priority. It might take positive or negative values. In practice, it typically configure the parameters, so that video service can borrow some packet scheduling resource from best effort data and background traffic.

As for best effort data or background traffic, it considers all the connections in that service category as one flow. In this paper, virtual offset-capacity is set to 0, which implies that the background traffic packets are scheduled only when the network node is idle. However, above phenomenon shall not be viewed as a performance compromise in WMNs, since best effort and background traffic haven't any strict requirements on the delay bound. As shown in Fig. 4, it assume that the packets are shaped and policed before entering the WMN, so that the subsequent admission control rule is guaranteed.

Fuzzy System:

This section, it presents a brief summary of fuzzy set theory, fuzzy control systems and fuzzy decision making.

4.1 Fuzzy set theory:

Fuzzy set theory was first conferred as a way of representing and manipulating data that wasn't precise [Zadeh, 1965].Afterwards from fuzzy set theory, fuzzy logic was built to cause with uncertain and confusing data and to present knowledge in an operationally strong pattern. A fuzzy set A in a non-empty set Xcan be specified by its membership function consistent with the fuzzy set definition and it is delineated as in below

$$\mu_A(x): X \to [0,1]. \qquad (1)$$

The completed non-membership degree and the completed membership degree were referred by means of 0 and 1, correspondingly, in Eq. (1), whereas the values between 0 and 1 indicate the intermediate membership degrees of element x in the fuzzy set A.

4.2 Fuzzy control system:

A fuzzy control system involves the collection and encoding of human knowledge concerning prediction and classification, with applying the predefined rules for a given set of inputs [Silerand Buckley, 2005]. The process modules of fuzzy control systems were given below:

(a)*Fuzzification* method requires determining the membership degrees of a linguistic variable

Octets:	1	1	1	1	1	4	6	4	0/6	4	4	1	1	6	4
	EID	Length	Flags	Hop-count	TTL	PREQ ID	S. MAC	S. Seq.#	Path Set	Lifetime	Metric	D. Count *N*	Per D. Flags #1	D. MAC	D. Seq.#

Fig. 5: Frame format of (a) Path request (PREQ) synonymous to a specified input value, known as crisp value, by utilizing membership functions.

(b)*Rule Base* part, additionally referred to as knowledge base, comprises the sets of rules (IF-THEN) employed for deducing in a fuzzy system.

(c)*Inference* part delineates two internal formulas: minimum inferencing and product inferencing. The inference part uses the rule base and also the two aforesaid general inference formulas to determine the truth values.

(d)*Defuzzification* is the method of computing a scalar (crisp) value from the inference fuzzy set output. Defuzzification combines the fuzzy set into a single value. Usually, two dissimilar systems were employed for defuzzification: maximum and centroid.

Octets:	1	1	1	1	1	6	4	0/6	4	4	6	4
	EID	Length	Flags	Hop-count	TTL	D. MAC	D. Seq.#	Path Set	Lifetime	Metric	M.S. MAC	M.S. Seq.#

Fig. 5: Frame format of (b) Path reply (PREP).

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The following Eq. (2) is used to calculate the centroid value [Mamdani - 1974]

$$\bar{X}(centroid) = \frac{\int_b^a x\mu(x)dx}{\int_b^a \mu(x)dx}, \qquad (2)$$

Where $\mu(x)$refers the membership degree of element *x* and *[a,b]*stands for the interval of the aggregated membership function.

4.3 Fuzzy decision making:

Both fuzzy set theory and fuzzy control system are used by fuzzy decision making, which is a fascinating method, to determine for complex multimetric schemes.The standard multi-attributive decision making (MADM) procedure will be shown in matrix form in this process.The best output of fuzzy decision making can be x_{ot}, wherever $X = \{x_i | i = 1, \cdots, m\}$ refers a finite set of decision alternatives and $G = \{g_j | j = 1, \cdots, n\}$ represents a finite set of targets, consistent with the common MADM framework.Let notice that x_{ot}contains the highest degree of desirability with reference to all applicable goals g_j.

Octets:	1	1	1	1	1	6	4	4
	EID	Length	Flags	Hop-count	TTL	Path Set	Root MP Seq.#	Metric

Fig. 5: Frame format of (c) Root announcement (RANN).

The common MADM framework infuzzy decision making schemes, can be finished within the two consecutive steps like, aggregation of the opinions with reference to all goals and per decision alternative and rank ordering of the decision alternatives consistent with the aggregated opinions. Yager's model [Zimmermann, 2001],[Yager, 1978], was one of the fascinating fuzzy decision making scheme, in which the goals were delineated by fuzzy sets that were weighted consistent with their significance.

5. *Novel Multimetricwireless Mesh Path Selection Algorithm:*

This section propose new multimetric wireless mesh path selection algorithm utilizing fuzzy decision making for both re-active and pro-active routing protocols is delineated.

5.1 Re-active routing protocol:

Formerly the destination MP gets the PREQ in the path selection algorithm, the distance to source MP is computed through the time to live (TTL) field in the obtained PREQ packet (refer Fig. 5(a)).

For the period of time ω_t (presented in sec), the destination MP remains and collects the other PREQ packets from its other neighbors and ω_t is given as,

$$\omega_t = \delta_{TTL} - \Delta_{dist} \qquad (3)$$

The intermediate MPs employ this computation to take a selection among forwarding or casting out PREQ packets is interesting to notice.If $\omega_t \leq 0$ (that is, $\Delta_{dist} \geq \delta_{TTL}$), then every intermediate MP casts out the PREQ specifically. The total overhead within the network is decremented by this attribute, apparently.

Later awaiting for ω_t, the destination MP chooses a desirable path through fuzzy decision making and employing the metrics that are given below:

Delay:

This parameter refers the distance between source MP and destination $MP(\Delta_{dist})$ through dissimilar feasible paths. As presented in Fig. 6, the membership procedure suggested for delay is employed by the destination MP for determining the membership degree of every path. $M\Delta_{dist}$ indicates the maximum Δ_{dist} of all paths in this membership procedure, that is, $M\Delta_{dist} = \max\{\Delta_{dist}(i), \ \forall i \in P\}$, where P represents the set of obtainable paths between source MP and destination MP. Presume $M\Delta_{dist} = 1s$ as an example, whereas the destination obtained 3 paths to

Source (that is to say, P = 3) that were $\Delta_{dist}(1) = 0.2$, $\Delta_{dist}(2) = 0.5$, and $\Delta_{dist}(3) = 1$.The degrees such as, Delay(1) = ''Small'', Delay(2) = ''Average'' and Delay(3) = ''Large'' were fuzzified through the suggested membership function.

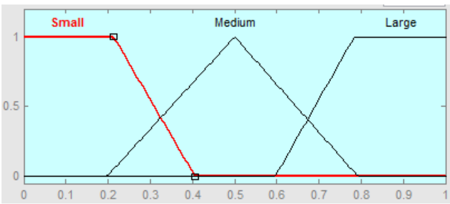

Fig. 6: Membership function for delay of the path.

Hop count:

The membership function of Hop count demonstrated in Fig.7 is suggested for hop count of the path when the maximum hop-count value is employed through the destination MP for determining the membership degree of the paths.MH refers the maximal hop-count value of all paths, $MH = \max\{H(i), \ \forall i \in P\}$, in this membership function.

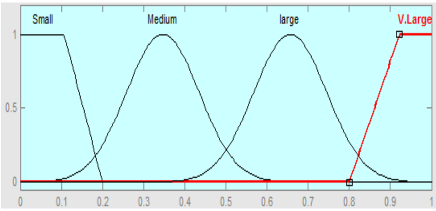

Fig. 7: Membership function for hop count of the path.

Signal strength:

It evaluates the quality of the signal between destination MP and also its in-path neighbor. Through the received signal strength indication (RSSI) in the WLAN physical (PHY) layer, the signal strength can be calculated [Kaemarungsi, 2006].As demonstrated in Fig.8, it's next mapped out to the membership degree using the membership function for the signal strength of every path.

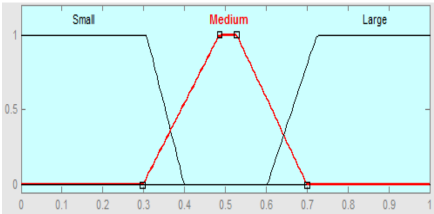

Fig. 8: Membership function for congestion control of the path.

Congestion control:

This parameter refers the quality of path in terms of congestion by considering the number of congestion control messages obtained from the in-path MPs[Wang and Lim, 2008]. As pointed in Fig.9 the

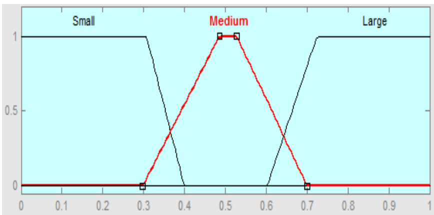

Fig. 8: Membership function for congestion control of the path.

Destination MP applies the membership function for determining the membership degree of every path in terms of congestion control in suggested system. MC_n indicates the maximal number of congestion control packets obtained from in-path MPs of all paths, $MC_n = \max\{C_n(i), \ \forall i \in P\}$, in this membership function.

Radio metric cost:

This parameter will be identical to the default RM-AODV that utilizes the metric field of PREQ frame format to designate the quality of a path.The membership function suggested for the path's radio metric cost is presented in Fig.9.MC_arefers the maximum airtime cost of all paths, $MC_a = \max\{C_a(i), \ \forall i \in P\}$, in this membership function.

The above-named parameters and delineated formulas are used by the inference part to choose a path with the highest quality. Solely two instances of formulas delineated within the rule base part of fuzzy decision making are presented, for example:

1. IF (Delay = ''Large'') AND (Hop Count = ''V.Large'') AND (Congestion Control = ''Large'') THEN Path Quality = ''Low''
2. IF (Delay = ''Small'') AND (Hop Count = ''Very few'') AND (Congestion Control = ''Small'') THEN Path Quality = ''High''

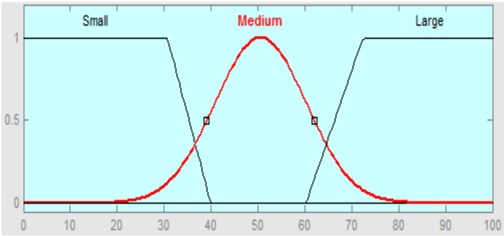

Fig. 9: Membership function for quality of the path.

The centroid method is regarded to compute the best scalar (crisp) output values owing to its fairness capablenesses in the defuzzification operation. Along with the centroid method, the membership function that demonstrated in Fig.8was accustomed to defuzzificate the path quality membership degree. Presume three dissimilar paths, Path Quality(1) = ‘‘Low’’, Path Quality(2) = ‘‘Medium’’, Path Quality(3) = ‘‘High’’, that were established and measured (i.e., P = 3) for example. The optimal path quality for every of these paths, Path Quality(1) = 20%, Path Quality(2) = 50%, Path Quality(3) = 80% were defuzzified, using the suggested membership function and also the centroid method.[Navid, 2011]

The operational block diagram of the suggested path selection algorithm is depicted in Fig.10.The destination MP unicasts a PREP packet to the source MP after choosing the desirable path and the receptions of PREQ packets from its neighbors are preserved. For verifying its neighbors’ join connectivity through HELLO messages, the MP will be effective. The intermediate MP unicasts a path terminate (PT) packet to the destination MP when there’s a disjointed connection on the path that taken place by the time the intermediate MP forwarded the PREQ packet till it obtains the PREP. With the reverse data specified to the destination MP and a flag to clarify its type, the PT frame format is identical to that of the PREP packet. Using the aforesaid fuzzy decision making strategy, formerly obtaining the PT packet, the destination MP finds the PREQ left timeout and if it’s even relevant the MP chooses other substitute path from the entered PREQs. Till obtaining data from the source MP or $\delta_{TTL} < \Delta_{dist}$, the destination MP remains obtaining of PREQ packets. The path selection operation ends instantly by the destination MP, in this event.

The lifetime parameter refers the expiration time of every path. The lifetime field will be decided from the obtained PREP frame in the MP’s routing table(refer Fig. 5(b)).The lifetime of a demanded path is computed by the destination MP and then replicates it within the PREP’s lifetime field[Perkins *et al*., 2003]. Also by changing traffic, the lifetime field of the source MP, destination MP and in-path MPs were restructured. The lifetime values of the path entries should be updated by the in-path intermediate MPs that broadcast PREP as given below

$$LT_i = \max\left(exLT_i, \left(T_{cur} + P_{to}\right)\right) \quad (4)$$

Where $LT_i$and $exLT_i$ represent the new lifetime and existing lifetime of MP_i, T_{cur} signify the current time andP_{to} refers the active path timeout, called active route timeout in AODV, in the WMN.Notice that the source node determines the consecutive hop of the path from the proxied receiver MAC address of PREP (refer Fig. 5(b)).

5.2 Load balancing techniques:

In WMNs, load balancing is an essential subject (particularly for MPPs) and may be executed utilizing the subsequent techniques like, centralized load balancing method and distributed load balancing methods.

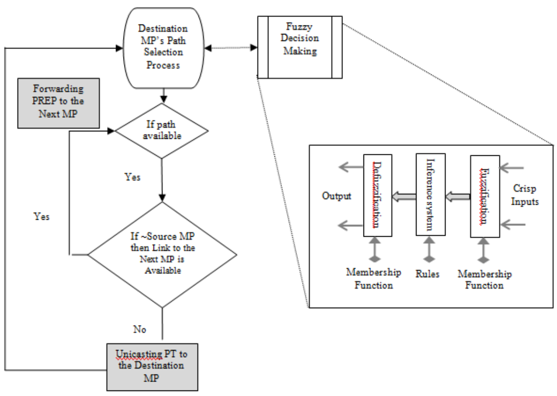

Fig. 10: Functional block diagram of the proposed path selection algorithm for re-active routing protocol.

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In Fig.10, the path selection algorithm, it take into account the path-based load balancing scheme for the peer-to-peer transmissions between MPs, wherever the loads of in-path MPs are taken into account to select a reliable path. In the path selection process, different alternative paths are compared in terms of number of congestion control messages received from their in-path MPs. Using the delineated congestion control membership function shown in Fig.8, a destination MP finds the membership degree of every path in terms of congestion control. Therefore, every MP's fuzzy decision making module finds a suitable path by considering congestion control and also the other aforesaid parameters.

Furthermore, it designs an integrated path-based and MPP-based load balancing scheme for the proactive tree-based routing. The fuzzy decision making module of the path selection algorithm takes the number of hops, ETX, and loads of MPPs into consideration for choosing an appropriate pro-active path. More specifically, every congested MPP multicasts a congestion control packet to its neighbor MPs and multihop connected MPs that are already registered within the MPP's routing table. A source MP that needs to establish a path to the DS applies the received congestion control packets from different MPPs and in-path MPs in its selection process, whereby a less congested path is taken into account as an additional suitable path.

It additionally introduce an online load balancing technique, wherever every MP ranks all connected MPPs in its routing table based on the specifications of every MPP (e.g., traffic load). In this approach, like the primary path selection process, not solely congestion control howeveradditionally the aforesaid parameters are employed in the selection of a suitable path that eliminates the route flapping as a result of unimetric path selection schemes, like MPP's queue status proposed in [Zhao *et al.*, 2005].

5.3 Multi-channel wireless mesh networks:

To resolve congestion and increase the capacity of wireless links, the multi-channel technology is defined for and presently is deployed in WMNs. In the proposed intelligent wireless mesh path selection algorithm, the source MP, destination MP, and intermediate MPs ought to use re-active/proactive PREQ and RANN packets to report the status of their channel with the highest quality. Therefore, a path with the highest channel quality is chosen through a fuzzy decision making process. It's vital to note that in this algorithm, all channels are thought of and a channel with the best conditions (based on proposed criteria) is chosen by every MPs (i.e., source, destination, and intermediate MPs). Clearly, it's possible that a path using different channel is chosen.

6. *Experimental Result And Discussion:*

Under practical wireless channel circumstances, the reliableness of the suggested path selection algorithm is expanded in this section. Three dissimilar terrain types were urged for the performance valuation of wireless networks such as, Type A delineates urban environment with maximal path loss, Type B defines suburban environment with moderate path loss and Type C depicts rural environment with minimal path loss, along with [Erceg *et al*. - 2003].The path loss (PL) for a specified distance between a pair of linked nodes within a range d of each other can be presented furthermore as follows

$$PL = A + 10\,\chi \log_{10}\left(d/d_0\right) + s\,. \qquad (5)$$

In Eq. 5, $A = 20\log_{10}(4\pi d_0/\lambda)$ where λ and d_0 denote the wavelength (given in meter) and reference distance between two connected nodes with $d > d_0 = 1$ meter, correspondingly [Navid *et al.*, 2011]. Further, χ denotes the path loss exponent, *s* (given in dB) denotes the shadow fading whose value depends on the terrain type.

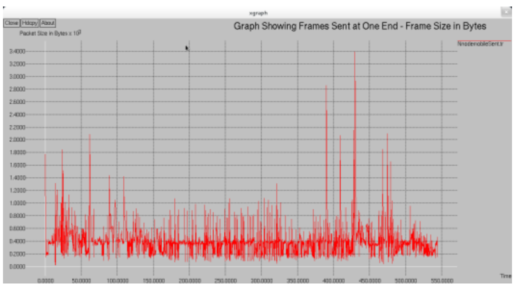

Fig.11: Transmission system with total number of frames sent.

In fig.11, performance graph shows the transmission system with total number of frames sent at one end based on time and the frames size is given in bytes.

The proposed path selection algorithm takes the path loss into account and selects a reliable path by using the signal strength and radio metric parameters in the re-active routing protocol.

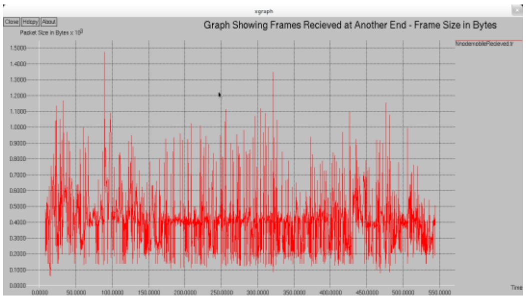

Fig. 12: Receiver system with total number of received frames.

The graph in fig.12 shows the performance of receiver system that has total number of received frames based on time, where the packet size is given in frames.

Furthermore, different values for bit error rate (BER) of wireless channel may be considered, whereas in conjunction with them the path selection algorithm uses the radio metric and ETX parameters in the re-active and pro-active path selection protocols, correspondingly. The above figures represent the overall performance of the system in terms of total packet delivered and the packet received.

The performance graph in fig.13 shows the comparison of routing throughput for existing multipath scheduling and proposed fuzzy mesh routing protocol system based on time. And it shows higher throughput for FMRP when increase in time.

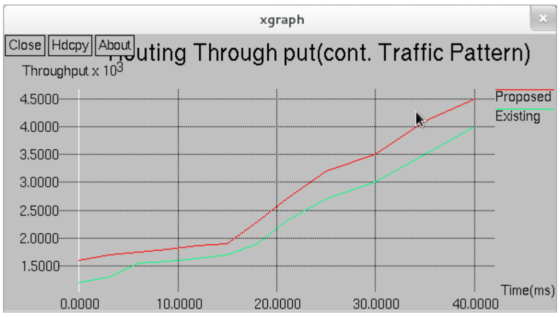

Fig. 13: Throughput of FMRP while comparing with multipath scheduling.

Table 1 Comparison table of Routing Throughput.

Sl. No.	Time(ms)	Existing	Proposed
1	0	1200	1600
2	3	1300	1700
3	6	1550	1750
4	9	1590	1800
5	12	1630	1870
6	15	1700	1900
7	18	1900	2300
8	21	2305	2705
9	25	2708	3208
10	30	3000	3500
11	35	3504	4104
12	40	4000	4500

The performance graph in fig.14 shows the comparison of routing end-to-end delay in continuous traffic pattern for multipath scheduling and FMRP system based on time, here the proposed FMRP system has low end-to-end delay while increase in time when compared with other existing protocols.

The performance graph in fig.15 represents routing Packet Delivery Ratio(PDR) for existing multipath scheduling and proposed FMRP based on time The PDR for the proposed system is linearly increasing when time increases compared to the existing protocols. The ETX metric defined in Eq.2 denotes the quality and stability of every link in different realistic wireless conditions. Whereas the channel condition in urban area with a larger path loss has a larger ETX with a lower stability, the rural area with a smaller path loss has a smaller ETX with a more stability.

Consistent with the definition of ETX parameter, it applies the successful forward delivery ratio and successful reverse delivery ratio to select the path with the highest packet delivery ratio.

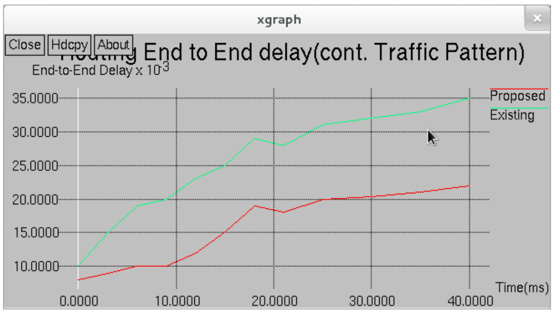

Fig. 14: End to End delay of FMRP while comparing with multipath scheduling.

Table 2 Comparison table of Routing End to End delay.

Sl.No.	Time(ms)	Existing	Proposed
1	0	0.01	0.008
2	3	0.015	0.009
3	6	0.019	0.010
4	9	0.020	0.010
5	12	0.023	0.012
6	15	0.025	0.015
7	18	0.029	0.019
8	21	0.028	0.018
9	25	0.031	0.020
10	30	0.032	0.029
11	35	0.033	0.021
12	40	0.035	0.022

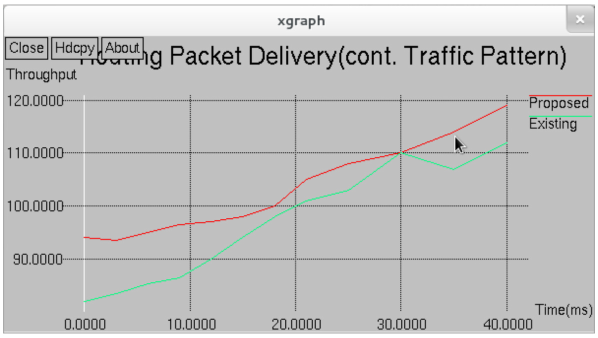

Fig. 15: packet delivery of FMRP with multipath scheduling.

Table 3: Comparison table of Routing Packet Delivery.

Sl. No.	Time(ms)	Existing	Proposed
1	0	82	94
2	3	83.5	93.5
3	6	85.3	95
4	9	86.5	96.5
5	12	90	97
6	15	94	98
7	18	98	100
8	21	101	105
9	25	103	108
10	30	110	110
11	35	107	114
12	40	112	119

The performance graph in fig.16 represents the comparison for existing multipath scheduling and proposed FMRP based on time. The control packets for multipath system with fuzzy routing protocol is less when compared with other routing protocols and it shows better results.

7. *Conclusion:*

This paper projects that the existing unimetric path selection algorithm within the standard isn't reliable. In this system, a novel multimetric wireless mesh path selection algorithm using fuzzy decision making for video transmission under realistic wireless channel conditions are examined. The projected path selection algorithm is designed to enhance the performance of both re-active and pro-active routing protocols of FMRP for not solely single-channel however additionally multichannel WMNs. The reported results shows the superior performance of the proposed path selection algorithm in terms of delay and packet delivery ratio while not increasing overhead significantly.

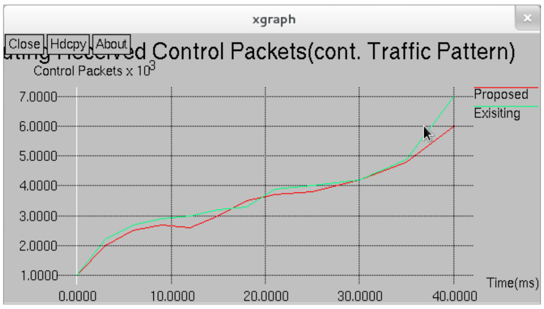

Fig. 16: control packets of FMRP while comparing with multipath scheduling.

Table 4: Comparison table of Routing Received Control Packets.

Sl. No.	Time(ms)	Existing	Proposed
1	0	1000	1000
2	3	2200	2000
3	6	2700	2500
4	9	2900	2700
5	12	3000	2600
6	15	3200	3000
7	18	3300	3500
8	21	3905	3705
9	25	4008	3808
10	30	4200	4200
11	35	4904	4804
12	40	7000	6000

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