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An Optimal Multipath Routing Protocol for Video Transmission in Wireless Mesh Networks

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Abstract: In recent years, wireless networks are part of our everyday life. Wireless Mesh Networks (WMNs) are considered as a potential solution for offering low-cost access to broadband services. It is dynamically self-organized and self-configured. In WMN, traffic between mesh nodes and the internet is routed over the mesh gateways. Even though there are a lot of researches have been carried out in the routing, still it becomes a significant issue in WMN. By considering routing as a factor, this study establishes and examines an optimal wireless mesh path selection algorithm for video transmission through multiple paths using fuzzy under wireless channel conditions. The proposed path selection algorithm is intended to improve the performance of both pro-active and re-active routing protocols for the transmission of video frames in single and multichannel wireless mesh networks. The simulation results shows that the performance of the proposed Optimal Multipath Routing Protocol (OMRP) for video transmission gives better results while considering delay, throughput, congestion control and higher percentage of packet delivery ratiowhen compared with other path selection algorithms.

Key words: Mesh network, multipath routing, fuzzy path selection, video communication, significant

INTRODUCTION

Among the various technologies, wireless mesh networks plays as an emerging technology for wireless networks recently by Schiller (2003). Although, there are plenty of researches carried out in multipath routing, there are still a number ofchallenges in Wireless Mesh Networks (WMNs) and how to prolong routing for video communication effectively is one of the most considerable issues.

Multimedia communications in wireless mesh networks are internet oriented and therefore, it is predictable that continuous data in huge amounts such as multimedia streams to be transmit through wireless network with strict timing necessities and support good user perceived feature as mentioned by Odabasi and Zim (2010) and Nandiraju *et al*. (2007).

In the existing works of routing, they focus mainly on finding a best single route in which certain links are heavily loaded whereas many other routes from source to destination in the network are unused from the source to the destination. In order to reduce the overhead of single path and to get the better performance of the network by reducing the delay we focus on multipath routing in WMN. The traffic is to be scattered uniformly across the network and the video frames can be reached in time without delay.

Wireless mesh networks: In multimedia environment, Wireless mesh network plays a vital role in wireless technologies andinvolves two kinds of nodes such as mesh router and mesh clients are included by Zhang *et al.* (2008). In order to provide an end-to-end QoS (Quality of Service) for delay sensitive trafic, the IEEE standard 802.11s initiate an optional contention-less admittance mechanism, it is called as Mesh Deterministic Access (MDA) as by Mao *et al.* (2003).

In recent times, IEEE 802.11s defineda novel hybrid routing protocol (HWMP), which applies Adhoc On Demand Distance Vector (AODV) which is mostly used for end to end video transmission between fixed or mobile nodes which can be referred as mesh points and tree-based routing is applied to provide mesh points with access to the wired distributed system through the fixed gateway nodes called mesh portal points like by Bhar (2007). The main advantage of this protocol is that it responds quickly to the topology changes and is loop free by avoiding the count to infinity problem by Flauzac *et al.* (2009).

Figure 1 shows the IEEE 802.11s WMN architecture, in which a Mesh Access Point (MAP) could be a special kind of node called Mesh Point (MP) equipped with the extra capability of an access point to provide service to STAs which is discussed by Ghazisaidi *et al.* (2012).

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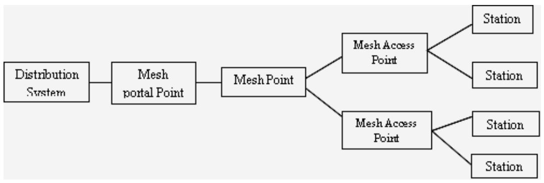

Fig. 1: IEEE 802.11s wireless mesh network architecture

Routing in wireless mesh networks Routing is termed as the process of determining the end-to-end path between a source and the destination by Waharte *et al*. (2006). The routing protocols can be categorized into two types namely topology based routing protocols and position based routing protocols. The paths will be selected based on the topological informationsuch as links in topology based routing and further, it is classified into three types namely reactive, proactive and hybrid routing protocols by Bedi *et al*. (2012).

Reactive routing protocols generate the route and routing tables only on demand basis. It reduces the control traffic overhead and is preferred for high mobility networks. Some of the reactive routing protocols such as AODV and DSR which are mainly designed for MANET can also be applicable to the Mesh networks due to the similarity in data transmission by Mohan and Kasiviswanath (2011).

In proactive routing protocols each node knows the route to every other nodeat all the time in the network. Here, there is no latency but the control overhead will be increased by theregular maintenance of unused routes in the routing table. The route discovery delay is also minimized at the cost of exchanging data periodically which consumes network bandwidth. Some of the proactive routing protocols include OLSR, DSDV and TBRPF as cited by Mohan and Kasiviswanath (2011).

The reactive routing is used for less used paths and more distant nodes whereas proactive routing is used for often used path and nearer nodes. The advantages of both reactive and proactive routing protocolsare combined in hybrid routing referred by Schiller (2003). If WMN is segmented into clusters, multiple algorithms can be used such that proactive is used within each cluster and reactive algorithm is used between the clusters.

Overview and justification for the proposed system: This study mainly focus on two things multipath selection for video frames and enhanced VRR-GR algorithm for scheduling the lost packet. The multiservice environmentin WMN is video traffic can coexist with other forms of traffic. In order to diminish the delay of video traffic, this research starts with the investigation on IEEE 802.11 MAC layer and also an enhanced version of virtual Reserved Rate GR packet scheduling algorithm named Enhanced Virtual Reserved Rate GR (EVRR-GR) was developed for providingvideo traffic high preference noted by Rong *et al*. (2010).

The existing works are mostly based on traffic balancing, queue aware routing suggested by Billy Pinheiro *et al*. (2012) and multi constraint routing for data transmission. In general, fuzzy expert systems and fuzzy decision making offer a technique for handling uncertain values. They are utilized in several fields like financial systems, linear and nonlinear control and pattern recognition. This study consider the delivery of video frames over WMN using fuzzy based path selection for providing better performance of video communication with respect to throughput, delay, congestion controland packet delivery ratio.

Now a day, when a WMN is utilized for surveillance video streaming, it is becoming a huge task to deliver the video without quality degradation where the packet loss and delay may be the major concern for the video quality. The necessary broad bandwidth required for the video traffic and use of wireless medium in a multi-hop environment are the most challenging issues.

Multiple description video is the one of the most important coding technique of error resilience and control for multimedia applications and has been identified as a suitable solution for video streaming in multi-hop wireless networks referred from Kompella *et al*. (2007) and Wang *et al*. (2005). In this research, multiple ‘n’ sub streams are generated from the input video and transmitted to the selected path. The multiple paths were selected based on the fuzzy decision making from the source to the destination and video traffic is then deliver with each path carrying one substream each. The ‘n’ sub streams (video, audio and data) were received in the destination separately through the selected paths and are combined to rebuild the original video.

The quality of the video can be achieved by the number of received sub streams. If any packet loss occurs during the transmission, the EVRR-GR algorithm is used for scheduling the priority for the lost packets. In WMN, the video coding method is completely different from traditional layered coding; wherethe reconstruction of the video depends upon successful delivery of the base layer.

Our contributions of this study are to propose anoptimal path selection algorithm for video transmission using fuzzy in WMNfor both re-active and pro-active routing protocols and to evaluate its performance by means that of extensive simulations. Moreover for solving the traffic congestion problem, this research proposes to use multipath routing in WMN and the goal of this

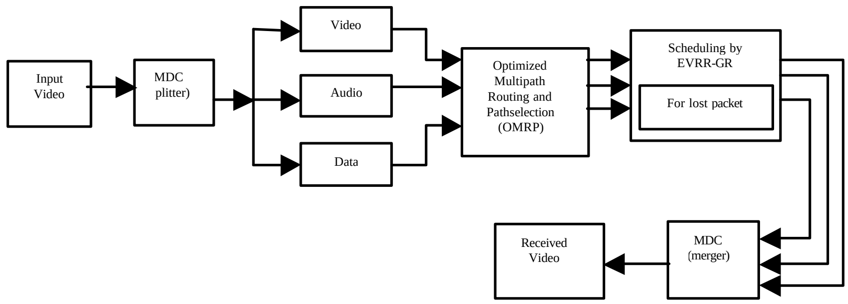

Fig. 2: Block diagram of optimized multipath routing with enhanced VRR-GR

method is to dispense video traffic uniformly across the network by using the selected path to avoid delay and also to receive the video frames on some error-prone wireless links. Figure 2 shows the overall view of our proposed Optimal Multipath Routing Protocol (OMRP)for video transmission.

Although, a few fuzzy-based routing algorithms are defined in the literature, justified that to the best of author's knowledge, this study 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 for video transmission under realistic wireless channel conditions.

MATERIALS AND METHODS

Multiple description coding: In our proposed framework for video communications over WMN, it is assumed that the source node in the Internet splits the video into 'n' sub streams using MD coding. The design depends mainly on two problems such as MD coding and multipath routing. For multimedia application, Multiple description video is an important coding technique as by Rong *et al.* (2010). Multipath routing offers a great performance in the overall network by allowing better sharing of the obtainable network resources.

One way to generate multiple sub streams is to use a standard video codec and split the resulting bitstream into several substreams. Here, round robin method is used for sending the frames throughout the path. In order to avoid the dependency amongsub streams the frames sent on one path must be predictively coded with respect to frames on similar path. This technique is called Video Redundancy Coding (VRC) founded by Mao *et al.* (2003). It requires higher bit ratesare the major problem in VRC. Although, this method prevents the loss in one path from the affected frame, in other path error propagation still exists within the frames in same path. Layered coding method is another way of generating multiple streams. A layered coder encodes the video into several layers such as Base Layer (BL) and Enhancement Layer (EL). The crucial part of the video frames isincluded in the base layer which guarantees a basic display quality and the enhancement layer improves the video quality. The video frames cannot be rebuilt satisfactorily without the BL. In general, EL packets may be dropped at a congested node to protect BL packets and FEC or ARQ protects the BL packets suggested by Khansari *et al.* (1996).

In order to generate multiple equally important substreams we go for Multiple description coding in our proposed research where each stream will give a low but good quality. A high quality reconstruction can be decoded from all the received bit streams together while a lower but acceptable quality reconstruction is achievable even if only one stream is received. The correlation among the sub stream makes, it possible to partially recover the lost information carried from other correctly received sub streams given by Rong *et al.* (2010). As all the descriptions are equally significant, the transport layer does not need to protect one stream over another. Multiple equivalent substreams are generated from ainput video in MD coding and from that the video, audio and data are splitted separately from each sub stream.

Optimized multipath routing and path selection

Need for multipath routing: In most of the Wireless Mesh networks, the main concentration of the routing protocol is to search a single best possible route from source nodeto destination node. By this single path, certain links are heavily loaded and many other links are unused. In order to solve this problem, multipath routing is proposed in WMN to distribute the traffic evenly across the network concept from Rong *et al.* (2010). The main objective of multipath routing is to allow the use of several good paths to destination rather than identifying just only the best single path. This should be attained without imposing excessive control overhead in sustaining such path. It is used for severalfunctions such as bandwidth aggregation, reducing end to end delay, enhancing fault tolerance, load balancing and so onas by Bedi *et al*. (2012).

After the multiple descriptions of the video frames, multiple paths from the source to destination is identified using fuzzy path selection and the video traffic is then delivered by carrying one sub stream through each path. Earlier in the literatures of multipath routing, the main concentration is on finding fully disjoint paths. But, maximally disjoint paths were identified because fully disjoint paths are not available in the network at all times founded by Rong *et al*. (2010) and Lee and Gerla (2001). In our research, in order to attain better traffic engineering performance, we go for the paths with fewer numbers of hops, i.e. least joints. Here, a numerous paths were identified by applying the above procedure andthe best three out of all were identified using fuzzy concepts.

Optimal multipath routing protocol: The proposed path selection algorithm is designed to improve the performance of both reactive and proactive routing protocols of Hybrid Wireless Mesh Protocol (HWMP) not only for single channel but also for multichannel wireless mesh network. A hybrid wireless mesh protocol is defined by IEEE802.11s which is inspired by a combination of AODV routing for Medium Access Control (MAC) address based path selection and tree based proactive routing from Bhar (2009) and Nandiraju *et al*. (2007).

In our optimal multipath selection algorithm for video transmission, once the destination node is fixed the source node will find all the available paths to the destination. These available paths and the membership functions were taken as input to the fuzzification system. The fuzzy rules were framed using the membership functions. Depending on the rules and the fuzzifier output the inference engine works. After defuzzification the best paths with less number of hops were received. Figure 3 shows the block diagram of the proposed optimal path selection algorithm for the best path selection.

From Fig. 3, it is observed that the source node finds the destination node and then it will find all the possible routes to the destination. After that by using optimal path selection algorithm, the best paths will be selected. These paths are checked for availability and if the first best path is free, it will be assigned for transmitting video frames. Next, the second best free path will be assigned for transmitting the audio frames and then the third best free path will be allotted for sending the data frames. For sending all ‘n’ sub streams the above process will be repeated. If any path fails or any node failure occurs a negative acknowledgement will be received and the frame is send through another path and the failed path will not be considered for further transmission. If no path availability occurs then it will send the Path Terminate (PT) message to the destination node.

Once, the PT packet is forwarded to the destination node, the source node selects another alternative path from the selected paths by means that of the aforementioned fuzzy decision making. This process keeps on until all the packets are reached to the destination from the source node. The main advantage of

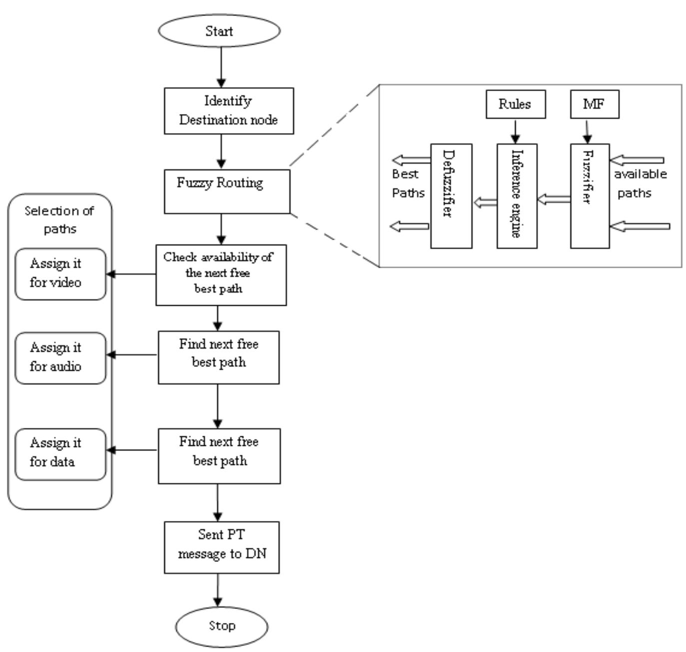

Fig. 3: An optimal multipath selection algorithm

using fuzzy in video transmission is, here the delay can be avoided because the paths are already identified using fuzzy and the frames are send one after the other through the elected paths.

Membership function: The proposed optimal path selection algorithm selects a reliable path by considering the delay, signal strength, hop count and congestion control parameters in the reactive routing protocol. The paths were identified based on fuzzy decision making and the packets were transmitted through those paths. The member ship function for the following parameters was computed as follows.

Delay: Delay can be defined as the time taken for a packet to transmit across the network from the source node to destination. Average end-to-end delay can be defined as:

Average end-to-end Delay =
(packet received time-packet send time)

This parameter represents the distance between source node and destination over different possible paths. The destination node uses the proposed membership function of delay and the membership degree of every path can be calculated as follows. The membership function for "small" is computed as Eq. 1:

$$\mu_{small}(x_i) = \begin{cases} 1 & \text{if} \quad x < a \\ -\dfrac{x+b}{b-a} & \text{if} \quad a < x < b \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

and for the "medium" delay it can be calculated as Eq. 2:

$$\mu_{medium}(x_i) = \begin{cases} 0 & \text{if} \quad x < a \\ -\dfrac{x-b}{c-a} & \text{if} \quad a \le x \le c \\ -\dfrac{x-e}{(e-c)} & \text{if} \quad c \le x \le e \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

And the " larger" delay is computed as Eq. 3:

$$\mu_{large}(x_i) = \begin{cases} 1 & \text{if} \quad x \ge e \\ -\dfrac{x-d}{a-f} & \text{if} \quad d < x < f \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Hop count: Hop count is a routing metric which calculates the distance between a source node and destination node on the number ofpoint-to-point links in a transmission path ie. the number ofrouters in the path.In this membership function, MH denotes the Maximum Hopcount value of all paths. The membership function for finding the hop count value of the path can be calculated as follows. The membership function for "very few" hop count can be evaluated as Eq. 4:

$$\mu_{very\,few}(x_i) = \begin{cases} 1 & \text{if} \quad x < a \\ -\dfrac{x+c}{c-a} & \text{if} \quad a < x < c \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

and if hop count is "few", it can be computed as Eq. 5:

$$\mu_{few}(x_i) = e^{\frac{(x+d)^2}{2b^2}} \tag{5}$$

If the hop count is "larger", then this can be evaluated as Eq. 6:

$$\mu_{large}(x_i) = e^{\frac{(x+f)^2}{2d^2}} \tag{6}$$

and for "very large" hop count the membership function can be Eq. 7:

$$\mu_{very\,large}(x_i) = \begin{cases} 1 & \text{if} \quad x > g \\ -\dfrac{x-e}{e-g} & \text{if} \quad g < x < e \\ 0 & \text{otherwise} \end{cases} \tag{7}$$

Congestion control: It refers the quality of the path in terms of congestion by counting the number of congestion control messages received from the in-path nodes defined by Wang and Lim (2008). In our proposed approach, the destination node uses the membership function for finding the membership degree of each path in terms of congestion control.

In this membership function, the maximum number of congestion control packets received from in-path nodes of all paths is taken. If the control packet received is less than fourfor the congestion control of the path, then it is fuzzified as "less" and the evaluation of membership value is:

$$\mu_{less}(x_i) = \begin{cases} 1 & \text{if} \quad x < a \\ -\dfrac{x+b}{b-a} & \text{if} \quad a < x < b \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

if the received control packet is between four and seven then it is fuzzified as ‘‘average’’ and it is computed as Eq. 9:

$$\mu_{average}(x_i) = \begin{cases} 0 & \text{if} \quad x < a \\ -\dfrac{x-a}{c-a} & \text{if} \quad a \le x \le c \\ 1 & \text{if} \quad c < x < d \\ -\dfrac{x-e}{(e-c)} & \text{if} \quad d \le x \le f \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

and if the control packet is more than seven it is fuzzified as “more” and it is evaluated as Eq. 10:

$$\mu_{more}(x_i) = \begin{cases} 1 & \text{if} \quad x > f \\ -\dfrac{x-e}{e-f} & \text{if} \quad f < x < e \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

Signal strength: This parameter measures the quality of the signal between the destination node and its in-path neighbor. The signal strength is calculated by means that of the Received Signal Strength Indication (RSSI) in the WLAN physical layer indicated by Kaemarungsi (2006). After that it is mapped to the membership degree of every path by means of the membership function for the signal strength and it is fuzzified as ‘‘low’’, ‘‘good’’, ”very good” and ‘‘excellent’’.

The membership function for the “low” signal strength can be computed as Eq. 11:

$$\mu_{low}(x_i) = \begin{cases} 1 & \text{if} \quad x < a \\ -\dfrac{x+c}{c-a} & \text{if} \quad a < x < c \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

and for the “good” signal strength it can be computed as Eq. 12:

$$\mu_{good}(x_i) = e^{\frac{(x+d)^2}{2b^2}} \tag{12}$$

if the signal strength is “very good” then it is evaluated as Eq. 13:

$$\mu_{very\,good}(x_i) = e^{\frac{(x+f)^2}{2d^2}} \tag{13}$$

And also for the “excellent” signal strength the membership function is calculated as Eq. 14:

$$\mu_{excellent}(x_i) = \begin{cases} 1 & \text{if} \quad x > g \\ -\dfrac{x-e}{e-g} & \text{if} \quad g < x < e \\ 0 & \text{otherwise} \end{cases} \tag{14}$$

Path quality: It is identified based on the parameters such as delay, number of hop count used, signal strength and congestion control. By using the above input parameters and the membership function the quality of the pathiscomputedas“low”, “medium” and ”high”.

Thus, three different qualities of the paths are recognized and evaluated. In this, the path quality is ‘‘Low’’, if the value is less than 40% and the membership function is computed as:

$$\mu_{low}(x_i) = \begin{cases} 1 & \text{if} \quad x < b \\ -\dfrac{x+d}{d-b} & \text{if} \quad b < x < d \\ 0 & \text{otherwise} \end{cases} \tag{15}$$

and if the value is less than 60% then the path quality is ‘‘Medium’’ and is evaluated as Eq. 16:

$$\mu_{medium}(x_i) = e\frac{(x+f)^2}{2c^2} \tag{16}$$

and ‘‘High’’ for the value >60% and the computed membership function is presented in Eq. 17:

$$\mu_{high}(x_i) = \begin{cases} 1 & \text{if} \quad x > g \\ -\dfrac{x-e}{e-g} & \text{if} \quad e < x < g \\ 0 & \text{otherwise} \end{cases} \tag{17}$$

With the proposed membership function and by the centroid technique the optimal path qualities for every identified path are defuzzifed.

Fuzzy inference system: The process of creating the mapping from a given input to an output using fuzzy logic is called fuzzy inference system. This mapping then gives a foundation from which decisions can be made. The method of fuzzy inference system includes all of the pieces that are described in the earlier sections such as membership functions, operators and if-then rules.

Using the above mentioned membership function the inference engine can be designed. Based on this more

Table 1: Rules for the rule base module of fuzzy decision making

Delay	Hop count	Congestion control	Signal strength	Quality of the path
Small	Very few	Less	Excellent	High
Small	Few	Less	Excellent	High
Small	Large	Less	Very Good	High
Small	Few	Average	Very Good	High
Medium	Very few	Average	Good	Medium
Medium	Few	Average	Good	Medium
Medium	Large	Average	Good	Medium
Medium	Large	Less	Very Good	Medium
Large	Very large	More	Low	Low
Large	Large	Average	Good	Low
Large	Very large	More	Excellent	Low
Large	Few	Average	Good	Low

than 140 rules can be framed. The samples of 12 rules are listed in Table 1. By using this Table 1, the quality of the path is identified for sending data packets.

Enhanced VRR-GR packet scheduling algorithm: Guaranteed Rate (GR) scheduling algorithm is defined by Hiertz *et al*. (2008) as the ones that allocate a given reserved rate to a flow of packets. In GR scheduling algorithm based on its expected arrival timea delay bound is guaranteed to a packet as by Rong *et al*. (2010). The guaranteed rate clock value of a packet is used as scheduling priorityin GR network node where as the traditional GR scheduling algorithm dealsmainly on reserved rate service. The extended version of guaranteed rate packet scheduling algorithm called Virtual Reserved Rate (VRR-GR) is used defined by Rong *et al*. (2010).

The development of VRRGR scheduling algorithm is to determine the guaranteed rate clock value of each flow in the priority queue. The key difference between VRR-GR and conventional GR is that the former uses virtual reserved rate in terms of real reserved rate for calculating the guaranteed rate clock value. The key objective of VRRGR algorithm is to combine multiple service levels into one packet scheduling framework. In this regard, VRRGR has the responsibility to prioritize video service by deriving guaranteed rate clock value from virtual reserved rate rather than real reserved rate. VRRGR provides good delay performance when compared with Traditional GR. VRRGR is developed forproviding high preference to video traffic during packet scheduling process.

In order to improve the overall capacity, to overcome the packet delay,and also to schedule the packet correctlyan Enhanced Version of Virtual Reserved Rate GR (EVRR-GR) scheduling algorithm is developed to determine the Guaranteed-Rate clock assessment of each flow in the priority queue. In VRRGR packet scheduling, four categories of services are scheduled together in the four priority queues wherever the Guaranteed-Rate clock value of a packet is used as scheduling priority. But only three categories of services which include video, audio and data are considered in our research.

The proposed EVRR-GR algorithm aims schedule the priority over lost packets. During packet transmission, if any one path fails are any node failure occurs a negative acknowledgement was received and the frame is send through another path and the failed path will not be considered for further transmission. The source node will select the next pathafter receiving the negative acknowledgement that is the best shortest path in the list using fuzzification is to be used for forwarding the packet. Here after the path selection and to set the priority for the data packet, ie. which packet is to be transmitted first from the Queue EVRR-GR algorithm is used.

In this framework, EVRR-GR has the responsibility to prioritize video service by deriving the guaranteed-rate clock value from virtual reserved rate. Real sub-capacity decides the bandwidth that a flow finally obtains where as the induced delay is decided by virtual sub-capacity.

Merger: In the receiver side all the framessuch as video, audio and data are received through the identified paths and merged together as a single frame (video) in MDC (Merger). The received frames were arrangedbased on the sequence number and played accordingly one after the other.

RESULTS AND DISCUSSION

Experimental setup: We have implemented our simulation using NS-2 simulator. This network simulation is modeled by using 50 mobile nodes placed at random locations in an area of 800×800 m. The simulation time is 400 sec. The node movement is random in nature and the mobility speed is set as 5-10 m^{-1}sec. The transmission speed is 128 kbps and the transmission range for all nodes is 50 m. The simulation parameters are summarized in Table 2.

Experimental result and analysis: In this study, the simulation results of our proposedapproach is evaluated by implementing the path selection algorithm using fuzzy for video transmission. In our simulation, we have considered the optimal path selection algorithm and the performance metrics include through put end-to-end delay from source node to destination node. Also, the control packets and packet delivery ratio have been analyzed for the received packet when compared to simple multipath routing with VRR GR and unipath routing with conventional GR. The performance graphs for the proposed multipath routing protocol with fuzzy is simulated and analyzed based on two criteria. Varying the speed of nodes and varying the number of nodes in the network.

Table 2: Simulation parameters

Parameters	Particulars
Simulator	Network simulator-2.35
Routing protocol	AODV-OMRP
Number of nodes	50
Simulation time	400 sec
Simulation area	800 x 800m
Mobility	Random movement
Mobility speed	5-10 $m^{-1}s$
Transmission rate	128 Kbps
Transmission range	50 m

Criteria I: varying the speed of nodes: In this criteria, the performance graphs of the proposed multipath routing protocol with fuzzy is measured for the performance metrics under consideration by increasing the speed of the nodes from 0 to 50 $m^{-1}s$. Figure 4. delineates the performance of various parameters of multipath routing using OMRP.

Throughput: Network throughput is one of the most important parameter to evaluate the performance ofrouting in wireless mesh networks. The percentage utilization of the network capacity is termed as throughput. The throughput is computed based on number of bits transmitted per second. Throughput is the measurement of number of packets passing through the network in a unit of time. In order to provide better performance, the system throughput must be high.

Figure 4a, it is observed that, the packet transmission of the proposed multipath routing using FMRP protocol provides higher throughput with the increase in speed. In this, more number of packets can be transmitted with less time and delay is also low while increasing the speed of the node. Thus, the proposed protocol gives better results when compared with othersingle path using conventional GR, multiple paths routing by sVRR-GR protocols.

End-to-end delay: End-to end delay is the average end-to-end delay of the received packets during the simulation period. Delay can be occurred due to path discovery, packet overloading, etc. Delay can be defined as the ratio between packet received times to the packet send time. In order to provide better performance of the network the end-to-end delay should be low.

From Fig. 4b, it is examined that the proposed multipath routing with fuzzy protocol exhibit lesser values of end to end delay when compared with other existing multipath routing protocol. Due to the increase in speed several paths can be identified in proposed FMRP and if one link fails it will not affect the network rather it has the possibility for choosing another link without any delay. Thus, the proposed FMRP protocol has very low end-to-end delay when speed increases.

Packet delivery ratio: Packet Delivery Ratio (PDR) is the total amount of packet delivered successfully at the destination. PDR is defined as the ratio between total numbers of packet received successfully to the total number of packets send by the source node. It is expected that,the packet delivery ratio should be high to get the better performance of the network. The proposed algorithm applies the successful forward delivery ratio and successful reverse delivery ratio to select the path with the highest packet delivery ratio.

From Fig. 4c, it is analyzed that the packet delivery ratio for the proposed FMRP protocol is 99% while increasing the speed of the node. But for other multipath protocolsas the speed increases, it is closer to only 90%. The simulation results show that, the proposed system with fuzzy has high packet delivery ratio compared with other single path and multiple path routing protocols.

Control packets: In the proposed research in addition to the data packets the control packet are also considered, ie. number of control packets send per unit time. To get the better performance of the network the control packets should be much lower than the data packets.

From the Fig. 4d, it is examined that, the amount of control packets send in addition to the data packets are low while increasing the nodespeed. As the delay is low and the path discovery process is faster, only less number of control packets is needed for FMRP when compared with other existing multipath routing protocolsand thus it gives better results.

Criteria II: varying the number of nodes: In this criteria the performance graphs of the proposed multipath routing protocol with fuzzy is measured for four metrics which consist of end-to-end delay, throughput, packet delivery ratio and control packets by increasing the number of the nodes from 0-120 nodes. The following graphs show the performance comparison while varying the nodes.

Throughput: In Fig. 5a, simulation results of throughput versus number of nodes are plotted. In general when the number of node increases, the throughput should be high.

From Fig. 5a, it is observed that, the throughput for the proposed multipath routing with fuzzy is high while the number of nodes are increased from 0-125. In the proposed protocol, there is the availability of more paths with less number of hops due to the larger number of nodes and hence having the possibility of selecting the best paths without congestion. By this, the throughput is increased while increasing the number of nodes when compared with single path and multipath using VRR-GR protocols.

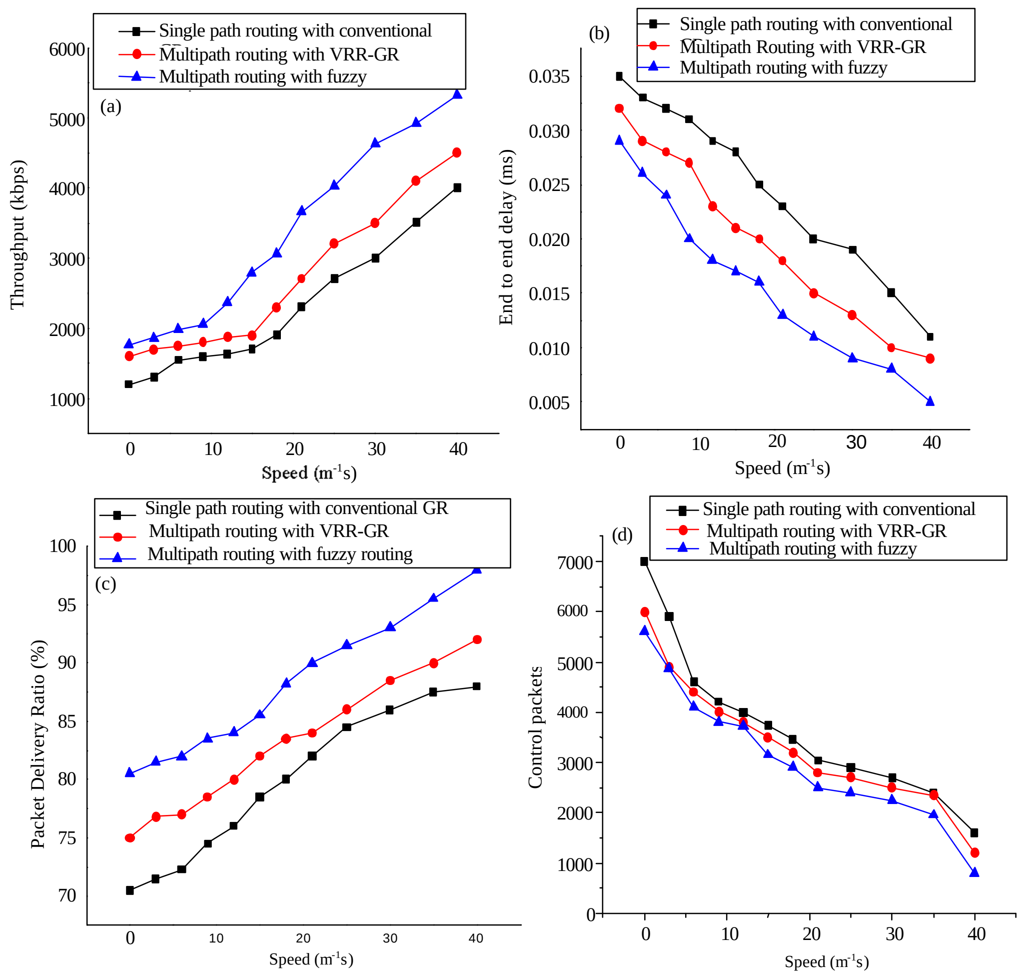

Fig. 4: Multipath routing using OMRP for various parameters by varying the speed of nodes; a) throughput; b) end to end delay; c) packet delivery ratio; d) control packets

End-to-end delay: The simulation results of end-to-end delay versus number of nodes are plotted in Fig. 5b. From the review, it is expected that the delay should be low while increasing the number of nodes for the better performance of the network.

From Fig. 5b, it is analyzed that, the end to end delay is low for our proposed FMRP protocol while comparing with other single path and multipath protocols when increasing the number of nodes. By increasing the number of nodes there is the availability of more paths using fuzzy for better transmission. There is no need for the packet to wait in a queue. Also if one link or node failure occurs, there is the possibility for selecting another link or node respectively without any delay.

Packet delivery ratio: In Fig. 5c, simulation results of packet delivery ratio versus number of nodes are plotted. To obtain the better performance, the packet delivery ratio should be high.

Based on the above results the packet delivery ratio of the proposed FMRP protocol is higher than other existing single path and multipath routing protocols. When increasing the number of nodes from 10-120, the packet delivery ratio also increases to 99%. But, the packet delivery ratio for the existing multipath protocol provides average ratio of 94%. Due to the larger number of paths, better packet transmission without delay and congestion, faster route discovery process, the packet delivery ratio is high in our proposed protocol. Thus FMRP gives better results when compared with other protocols.

Control packets: In general while increasing the number of nodes the control packets should be low. From Fig. 5d it is noted that when increasing the number of nodes the number of control packet sent is very low compared with other existing protocols. Owing to the large number of

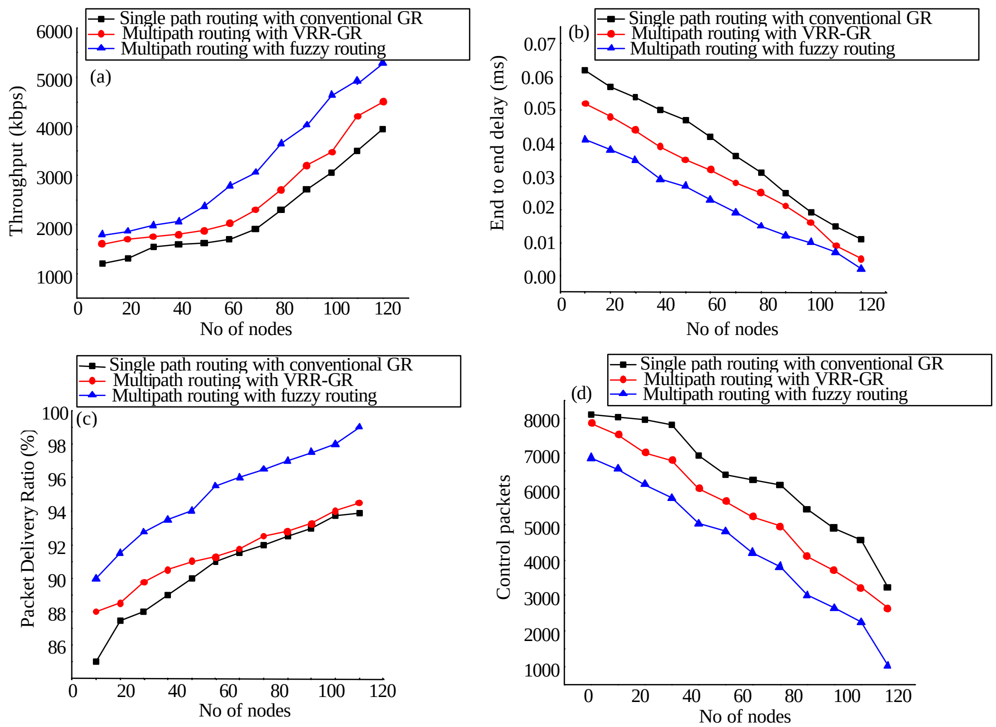

Fig. 5: Multipath routing using OMRP for various parameters by varying the number of nodes; a) throughput; b) end to end delay; c) packet delivery ratio; d) control packets

nodes there is the availability of larger path and hence packet drop and delay is avoided. Hence, there is no need of packet retransmission and only less number of control packets is essential for sending only the original packets. The packet transmission is also faster and thus our proposed protocol provides better results with other single path and multipath routing protocols.

CONCLUSION

In wireless network, selection of the best single path algorithm within the mesh standard is notconsistent. In this study, an optimal wireless mesh path selection algorithm for video transmission through multiple paths using fuzzy for wireless mesh network areobserved. This work improves the performance of reactive and proactive Routing Protocols of OMRP for not exclusively for single-channel however additionallyfor multichannel WMNs. The reported results show the higher performance of packet delivery ratio in the proposed path selection algorithm when it is compared with other path selection algorithms. Also, it gives better results by providing less end to end delay, higher throughput and less control packets when compared with the multipath routing with existing conventional GR and other multipath routings protocols. In future, this research can be extended by varying the number of paths or links. Also, the security issues are not been considered in this research. To tackle such issues several mechanisms can be identified.

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