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An Efficient Multipath Routing Protocol with Replication for On-demand Video Streaming in MANETs

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Abstract – Mobile Ad hoc Networks (MANETs) are becoming more essential to wireless communications due to growing popularity of mobile devices. On-demand video streaming over wireless networks is an increasingly important and attractive service to the mobile users. However, MANETs do not seem to effectively support multimedia applications and especially video transmission due to certain limitations like rapidly changing connectivity, network partitions, high error rates, collisions, limited bandwidth and power constraints. In this paper, we proposed and implemented EMRP_R (an Efficient Multipath Routing Protocol with Replication) based on the forecasting of parameters of nodes or routes that effect the performance for on-demand video streaming in MANETs. The main objective of the proposed work is to provide a smooth on-demand video streaming with minimum packet loss. Simulation was carried out in NS2 and the results obtained show that the proposed approach will improve the quality of on-demand video streaming when compared to the other existing approaches.

Keywords – *MANETs; Multimedia Applications, On-Demand Video Streaming, Multipath Routing, Replication.*

1. Introduction

1.1. Streaming in MANETs

Networks in which nodes are moving and communicating with each other via wireless medium with no infrastructure are said to be Mobile Ad-Hoc Networks (MANETs). These networks can be formed on fly with no prior establishment of any type of network supporting devices. The nodes in the network can be any type of mobile devices/wireless devices that can support LAN configurations. The nodes can move at ease and communicate with each other without any dedicated routers. Each node is capable of acting as router for the traffic, source or destination depending on the requirement. The nodes cooperate themselves to cope up with the mobility of the nodes and configures themselves from time to time. This makes them very useful in situations like disaster recovery, establishment of networks temporarily or in emergency situations in which there is no pre-established infrastructure or lack of it. But the downside of these networks is their mobility due to which there is continuous change in network topology, interference in wireless access media, intermittent connectivity, frequent changes in routing path, limited energy and resources of the mobile nodes etc. These constraints make them challenging to use in real time applications like sensor networks, video streaming etc.

Video streaming is one of the promising areas which is gaining more popularity in recent decade due to the invention of powerful and smart mobile devices. The advancements in the internet technology also make them to use for online applications that support video streaming. Accessing and routing of video streams in MANETs is a big challenging task as these networks are dynamic in nature due to the mobility of the nodes, frequent routing path changes which may occur for a variety of reasons. The mobility of the nodes is the biggest challenge to handle in case of video streaming in MANETs, which accounts for the large data packet loss. The packet loss may be due to node failures or interference in the wireless medium. To summarize, the mobility of the nodes, dynamic topology, node failures, link failures between the nodes etc. make the video streaming in MANETs a big challenge [1, 2].

Video transmissions generally fall into two categories. One is downloading the entire video and then playing the video, which is not preferred by most of the users as the downloading of a video takes more time due to its large size in general. The other category is playing the video while the downloading is in progress, which commonly referred as on demand video streaming [3, 4]. Normally the playing of the video starts as soon as the sufficient number of frames are available to play the video. To continue the playing of the videos without any interruption, it should be ensured that there is a continuous feeding of the frames (streaming of the remaining frames) in a fixed time without fail. This makes the streaming most challenging task in networks like MANETs which are highly dynamic in nature [5, 6].

1.2 Role of Routing in MANETs for Video Streaming

Routing is the major concept that affects the transmission of packets from source to destination. MANETs employ a different kind of routing protocols when compared to those of wired networks due to their special characteristics. The conventional routing protocols for MANETs normally establish a single path between the source and destination with route establishment, maintenance and repair in case of failures. Single routing introduces delay in packet delivery in case of route failure, as it takes time to either repair the route or establish a new route. This causes the delay in delivering packets and makes it unsuitable for video streaming, in which the delay is not tolerated. A better solution is to establish multiple paths between source and destination and lead to the reduced probability of packet loss bursts. This may also indirectly reduce congestion in the network by balancing the load among multiple routes. For video streaming to work better, the multiple paths should be selected such that they match to the requirements of video transmission. The characteristics such as stability of the path, load distribution in the intermediate nodes, the energy levels of the participating nodes in the routes strongly affect the effectiveness of the routes selected. The multipath routing provides the advantages like load balancing, speed recovery from failures, more available bandwidth and are preferred to the single routes [7]:

This suggests us to use a good multipath routing algorithm for video streaming in MANETs. Many research works are going on this topic. Till now, there are no guidelines to fix the optimum number of routes for streaming. This is due to the reason that this factor always depends on the network configuration(s) under consideration such as the number of nodes, speed and movements of the nodes, frequency of topology change, stability of the nodes, energy of the nodes and many more.

In this paper, we proposed and implemented a dynamic multipath routing technique with replication for on-demand video streaming in MANETs. The main objective of the proposed work is to provide a smooth on-demand video streaming with minimum packet loss.

2. Literature Survey

A few researches have been done in this area. In this section we review some of the previous works done on video streaming in MANETs.

NDMP-AODV [8] is node disjoint multipath routing protocol that establishes multiple paths between source and destination. It takes the help of conventional AODV protocol to find the routes. The data transmission begins immediately as soon as the first route is formed. Then protocol proceeds to find a backup route concurrently. When the primary route fails to deliver the packets, the secondary route is selected immediately to transfer the packets. Meanwhile the source finds a new route to the destination. The protocol also requires that the intermediate nodes should also store multiple paths to the destination to avoid paths with common nodes or links. It is shown by simulation that the protocol provides better performance over conventional single path routing methods in terms of route availability, control overhead, average end to end delay and packet delivery ratio.

As the data is transmitted immediately after the first route is detected and do not wait for the new route discovery in case of a route failure, NDMP-AODV provides low end to end delay. The authors suggest improvements in the route selection process to match to the user or application requirements. This protocol is well suited to the applications like on demand video streaming, real time systems which need high data transmissions and less end to end delay.

The ESAR (Energy Saving Ad hoc Routing) [9] algorithm concentrates on energy saving routing path. The source initially sends a route request. The RREQs are filled with the energy levels by the intermediate nodes. The destination waits for certain amount of time to receive multiple RREQs, instead of immediately sending the RREPs. The algorithm then constructs a path which has high energy and thus may sustain for a longer time. The transmission continues till any node in the path reaches to a threshold value, which indicates the instability of the route in near future. As soon as the threshold value is reached, the algorithm selects another route and continues the transmission. The algorithm also maintains back up paths for better results. The algorithm continues unless all paths to destination are exhausted in terms of their energy.

In [10], a multipath routing algorithm is proposed which considers the best energy level route. The link failures due to the nodes mobility are also handled. As multiple paths are available, the average end to end delay is reduced and provides the better video streaming. The source uses alternate paths in case of the transmitting route failure. The algorithm lacks of a best energy management and also security concerns.

In [11], the authors have proposed a multipath routing specific to MPEG-2 videos. They concluded that the optimal number of paths for streaming MPEG-2 video is three. The three paths are used to stream the three different frames, namely I, P and B frames. Based on the priority of the packets, the routes are selected. This ensures that the video can be played during streaming without any disturbance.

Jiazi YI et al[12] have proposed a protocol to improve the delivery of H.264/SVC video streams in MANETs. The protocol considers to improve the Quality of Experience (QoE) measurements like PSNR and the protected data with higher priority over the packet loss networks. The underlying protocol used is MP-OLSR (Multipath Optimized Link State Routing) [12]. The MP-OLSR is used with Unequal Error Protection (UEP) scheme to achieve this. They have also developed a framework for H.264/SVC video transmission.

The traditional dynamic source routing has been modified to multiple paths by Monica et al. [13, 14]. The Multipath Multimedia Dynamic Source Routing, MMDSR, uses the Probe Messages to establish the routes. This protocol is used to meet the QoS requirements for video streaming in MANETs. Initially the DSR is used to find multiple paths. The protocol then tries to grade the routes found by using the probe message packets. The source sends a Probe Message (PM) packet, to the destination in each of the routes. The destination, after receiving the first PM packet, starts a timer. It keeps on receiving the PM packets from multiple routes until the timer expires. It discards the remaining PM packets received after this time, since they are received through paths which are having higher delays due to many reasons. The destination then generates a Probe Message Reply, PMR, packet for each of the PM packets received by each route. The destination fills the PMR with QoS parameters calculated by the destination from the samples available in each of the PM packets, which are filled by the nodes in each path. Now the paths are graded by the source and the video packets are sent through three best paths to the destination as per the priority of the packets.

Another such protocol which finds the multiple routes and labels the routes with different qualities is AODV with multiple alternative paths (AODV-MAP) proposed by Vaidya et al. [15]. The highest priority packets of the video such as base layer are sent through a path labeled as primary path and the other layers are sent through the paths labeled as node disjoint path and fail safe path.
Another protocol that improves the video streaming in MANETs is proposed by George Adam et al. [16] which makes use of the MAC layer information and feeds it to the transport layer protocol, TCP Friendly Rate Control (TFRC) and the network layer. In this design, the reason for packet is expected beforehand by sensing the Signal to Noise Ratio (SNR) from MAC layer. Based on this, the reason for packet loss is estimated by using a threshold value. If the packet loss is due to congestion, the TFRC acts, else the networking layer searches for alternate route and continues the streaming in the alternate path. Simulations show that the protocol performs better compared to the TFRC protocol alone.

3. Multipath Routing with Replication

Unlike the other protocols discussed so far, our proposed protocol uses the replication concept along with the multiple routes from source to destination to compensate for the packet losses due to various reasons.

Initially to find the route, the protocol uses two types of control messages: i) Route Request Messages (RREQ) and ii) Route Reply Messages (RREP). The source node starts the route discovery by flooding the RREQ messages into the network. Every intermediate node that is receiving the RREQ forwards the message to its neighbors only once by avoiding any duplicate broadcasting of the RREQ. The duplicate RREQ messages are prevented from broadcasting to the neighbors by maintaining a table, namely RReqRecd Table. AnRReqRecd table is maintained in each intermediate node to check the duplication of RREQs that are transmitted by it to its neighbors. RReqRecd table stores two values of each RREQ in the corresponding record: i) Source IP address and ii) Flooding ID of RREQ (*f_id*). Upon receiving RREQ, every intermediate node checks it with the available entries and discards the RREQ if it is a duplicate; otherwise it forwards the RREQ and updates the Seen Table.

In our approach, we allow destination alone to send the replies to the received requests (RREQs) by using RREPs. No intermediate node can send the reply to the source node even though it has an active route to the destination. This is incorporated into the routing discovery phase to make the multiple routes to be node disjoint and enable the destination to calculate route efficiency. The destination node, upon receiving the first RREQ message, sends the RREP message to the source by attaching a broadcast ID (b_id) to it. Then the destination waits for at least two duplicate RREQ messages to be received from the same source, in given threshold time. The destination node reply to at least two RREQ messages. The maximum number can be decided by the application and user requirements. The threshold by which the destination waits for duplicate RREQ may be decided by the nature of the network configuration.

When the destination sends the RREPs, each node in the path including the destination node adds its *node efficiency NE(n) value*. After all the RREP's are received by the source node, for every RREP received by the source node, it adds its *node efficiency NE(n) value* and calculates the *route efficiency (RE) value for each route*, which is the measure of the efficiency of the route.

3.1 Route Efficiency Estimation, Selection and Video Transmission

In order to find more efficient routes for video transmission in MANETs, we find efficient routes by using a new value called*route efficiency (RE) value*, which is a measure of the efficiency of the route.

The *route efficiency RE(p)* of a route is equal to the lowest *node efficiency value NE(n)* of the node in a path and is greater than a threshold value ω. *RE(p)* is given in Eq(1):

$$RE(p) = MIN\ (NE(SourceNode),...NE(IntermediateNode), ...NE\ (DestinationNode)) \quad (1)$$

where $RE(p) > \omega$, the selecting value for route efficiency.

3.1.1 Node Efficiency Estimation

In the proposed approach, the estimation of the node efficiency *NE(n)*, of a node *n*, is considered to be based on three different parameters e.g. Energy Forecast*(EF),* Stability Forecast*(SF)*and Traffic Load Forecast*(TLF)*. The proposed simple linear equation for node efficiency *NE(n)*of a node *n* is given in Eq.(2).

$$NE(n)= a*EF(n) + b*MF(n) + c*TLF(n) \quad (2)$$

where *a, b, c,* are weighing factors for the corresponding parameters. All three parameters, with values ranging from 0 to 1, are chosen so that $a + b + c = 1$. These values are kept flexible so that they can be changed as per the network scenario.

In the computation of *NE(n)* above, *EF*is the forecasting of energy level of node. When energy of each intermediate node is empty, it is impossible to communicate and link break occur. *MF*is the mobility forecasting of node that indicates the stability of a node.*MN* implies node stability and hence the stability of route. *TLF*is traffic load forecasting of a node. Less the traffic load, more the successful delivery of packets.

a. Energy Forecasting of a node

In energy estimation, the Energy Level *EL* of a node *n* depends on the available energy *EA* of a node*n* which depends on total initial energy and consumed energy [17]. Available energy of node *n* is given in Eq. (3).

$$EA(n)= TE(n) – EC(n) \quad (3)$$

TE(n) is the *total initial energy* of node *n* and *EC(n)* is the *consumed energy* of node *n.* The energy consumed *EC(n)* depends on transmitting (*E_transmit*) and receiving (*E_received*) one packet is given in Eq. (4).

$$EC(n) = E\_transmit\ (n) + E\_received\ (n) \quad (4)$$

In our model, we use the available energy of a node EA(n) to forecast the node capacity to sustain in future for routing. This is done by using the weighted move average method. If E_{t-2}, E_{t-1}, and $E_t$are the consumed energy in the last three time periods, then the energy for the next time period is forecasted by using the Eq. (5).

$$EForecast_n= 0.2*E_{t-2} + 0.3* E_{t-2} + 0.5*E_{t-1} \quad (5)$$

The $EForecast_n$ is normalized to a value of 1, as given in Eq. (6).

$$EF\ (n) = 1 \text{ if } EForecast_n / RTT >= 6$$
$$= 6 / (EForecast_n / RTT) \quad \text{otherwise} \quad (6)$$

where RTT is the RoundTripTime of the route for which node n is acting as intermediate node (including destination).

b. Node Mobility Factor Deciding Model

In a dynamic network such as MANET, the mobility of nodes cannot be ignored. It has a vital role in maintaining a stable route. Thus, we consider mobility or average displacement of node to be the vital parameter so that better efficient route stability can be achieved. In our proposed approach we adopt the policy given in [19], where a node with lower average displacement has a higher chance of being an intermediate node. The weights assigned to the nodes are reciprocal to their respective displacements. i.e. a node with lower average displacement is assigned a higher weight and the node with higher value is assigned a lower weight. Basically, we consider the mobility of a node by taking the average of the distances covered by mobile node in a given time slot.

We forecast the node n's moving average using the weighted moving average, as given below.

The mobility forecast of a node n, *MForecast (n)*, iscomputed by using the Eq. (7).

$$MForecast(n) = 0.2 * D_{t-2} (n) + 0.3 * D_{t-1} (n) + 0.5 * D_t (n) \quad (7)$$

D_t *(n)* is the distance covered by node *n* in time slot *t*, from position P_{t-1}(x, y) to P_t(x, y),which is calculated using Euclidian Distance formula as given in Eq. (8).

$$D_t(n) = \sqrt{(x(n)_t - x(n)_{t-1})^2 + (y(n)_t - y(n)_{t-1})^2} \quad (8)$$

The MForecast (n) value is now used to calculate the chance of the node moving away from the route or near neighbors in next 6 time units using Eq. (9).

MF (n) = 1 if TR (n) / MForecast (n) >= 6
= 6 / (TR (n) / MForecst (n)) otherwise. (9)

where TR(n) is the transmission range of the node n.

c. Traffic Load Forecast

Traffic Load Forecast for a node is defined as the normalized value of traffic load that is estimated by using the weighted moving average over the past three normalized traffic load values in the past three time slots or periods. Usually the one time slot is chosen to be the RTT value. The traffic load forecasting of a node n is given by the Eq. (10).

$$TLF(n) = 0.2 *NTL_{t-2}(n) + 0.3 *NTL_{t-1}(n) + 0.5 *NTL_t (n) \quad (11)$$

where $NTL_t(n)$ is the normalized traffic load of node n at time slot t and is computed by Eq. (12).

NTL_t (n) = 1 if the (routing) queue of the node was full at any moment in the time period t
= MQL / CQ (12)

Where MQL is the maximum occupied queue length in the last three time slots and CQ is capacity of the queue.

d. The Routing Process

In the present work, we have assumed that in the network, each mobile node sends messages to any other node with a uniform rate.The proposed scheme estimates the *RE(p)* of each route formed. After finding the *RE(p)* for each path, the path with minimum *RE(p)* is selected as a primary path and the path with next minimum value is selected as the secondary path.

After the primary and the secondary paths are discovered, the source node starts transferring actual video data packets to destination through the primary route and the redundant copy of the video data packets through the secondary path to the one-hop neighbor of the destination node and periodically checks the efficiency of both the primary and the secondary routes. All the other node-disjoint routes that are discovered will be stored in the routing table as back up for route maintenance process. After storing the primary route and a specified number of secondary routes in the routing table (the number routes that are to be stored or cached can be chosen depending on the network characteristics), all the other routes (if any) are discarded. During the transmission if any of the primary or secondary routes efficiency falls under the given threshold (a route's *RE(p)* value less than a predefined threshold value) at some instance of time and/or a link/route breakage is detected along the route, the source node then initiates a maintenance process in order to continue smooth video transmission.

3.2 Route Maintenance Process

To recover from the route failure either from link breakage and falling less than the threshold the Source node initiates a maintenance scheme. In this scheme, the Source node periodically calculates the *RE*s of all the routes from source to destination. If primary route fails; destination node sends request to all its one-hope neighbors for the missed video packet. The one-hope neighbor which stored the missed redundant segment responds to the request and sends it to the destination and the secondary route which included this neighbor is extended up to destination and this route becomes the primary path. Mean while Source S finds another secondary route to transmit redundant video segments. Source continues its transmission by this new primary route and redundant segments through another new secondary route. If the secondary route falls under the threshold or breaks, S routes the redundant packets through another route and considers it as the new secondary route.

The overall conceptual algorithm of the proposed approach is as follows.

1. Node D **REQUEST** a video transmission from S.
2. The requested Video Clip which is at node S is divided into SEGMENTs.

3. Source S **FIND**s**N**ode **D**isjoint **M**ultiple **R**outes to D using AODV-Multipath algorithm.
4. One route which is having the high rank (based on three parameters i.e. residual energy of the nodes, stability of the nodes and traffic load of the nodes in the route) is **SELECT**ed as the **Primary route** and the route with next low rank is selected as **Secondary route**.
5. Source S **START**s **TRANSMIT**tingfirst segment to D through the primary route and redundant segment through the secondary route up to the one hope neighbor of D.
6. This process continues until the primary route or the secondary fails or the rank of primary or the secondary routes falls under a given threshold. (S periodically **MONITOR**s the strength of the primary route and secondary routes).
7. If primary route fails; node D **GET**s the **D**ropped **S**egment from its one hope neighbor which stored the redundant segment by making a request.
8. Mean while S now makes the secondary route as the primary route and finds another secondary route.
9. S continues its transmission by this new primary route and redundant segments through another new secondary route.
10. If the secondary route falls under the threshold or it breaks S routes the redundant packets through another route and considers it as the new secondary route.
11. If the one hop-neighbor which is storing the redundant segments is moving far from its location, then it relocates its redundant segments in to another node which is nearer, stable and having high residual energy and updates the route.

4. Simulation and Performance Evaluation

In this section, we illustrate the feasibility and effectiveness of the proposed video streaming approach in the NS-2 simulator and compare it with NDMO-AODV and Cross-layer design with TFRC approaches based on various performance metrics like packet delivery ration (PDR) and quality of video etc.

The detailed simulation parameters are listed in Table 1.

TABLE 1. Simulation parameters

Parameter	**Values**
Simulator	NS2
Simulation time	700sec
Simulation area	1200x1200 sq.meter
Number of nodes	50
Transport protocol	UDP
Routing protocols	PROPOSED, NDMP-AODV, AODV
Mobility model	Random way-point
Pause Time	0 to 250 sec
Video	One segment of the India's Biggest Motion Picture Baahubali
Video Codification	H.264SVC
Number of Primary Routes	01
Number of Secondary Routes	01

Figures 1a and 1bshows the packet delivery ratio (PDR) of the proposed approach compared with NDMO-AODV and Cross-layer design with TFRC approaches. The PDR (Number of video packets delivered) obtained with the proposed approach is high when compared to existing methods. The PDR is better than the other approaches because of using multiple paths to send the data from source to destination.

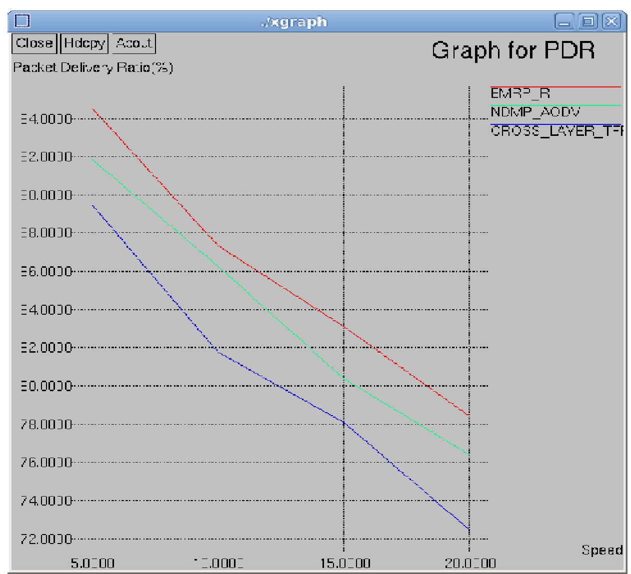

Fig. 1a. Packet Delivery Ratio

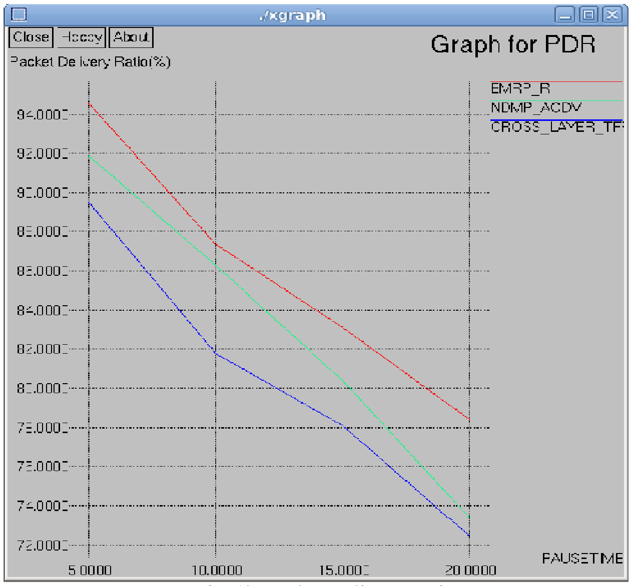

Fig. 1b. Packet Delivery Ratio

In Figures 2a and 2b the average delay is displayed for the three simulated scenarios. Since the proposed approach maintains replicas at the nearest neighbor of the receiver, delay will be minimized at the receiver side.

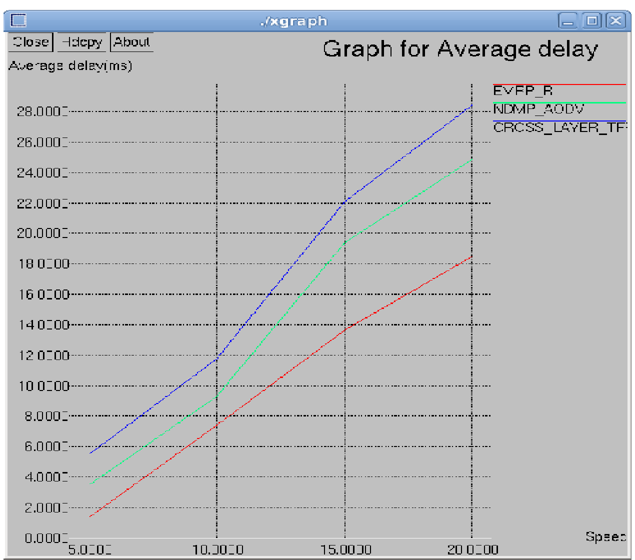

Fig. 2a. Average Delay

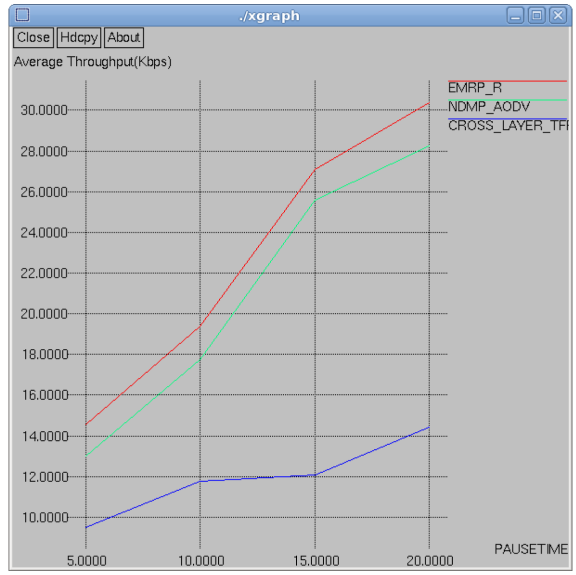

Fig. 2b. Average Delay

In figure 3a and 3b the average throughput is displayed for the three simulated scenarios. Since the proposed approach maintains a replica of the packets,throughput i.e., the rate of successful message delivery is high.

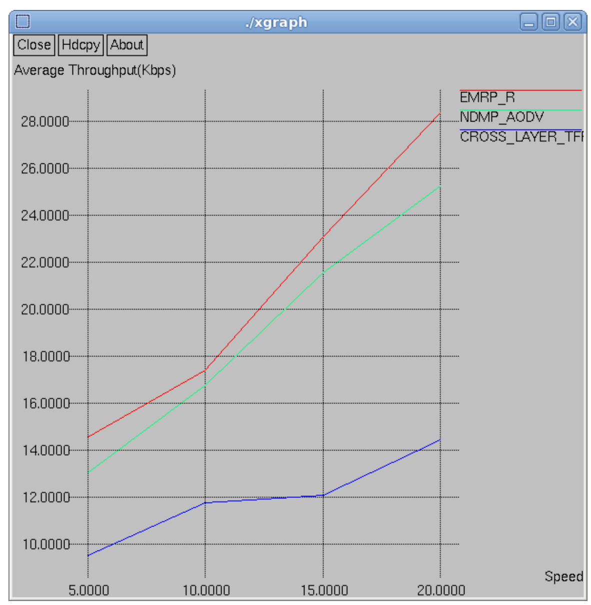

Fig. 3a. Average Throughput

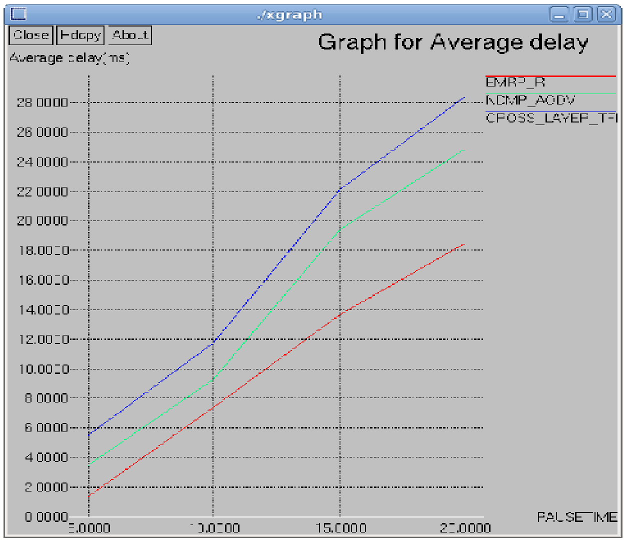

Fig. 3b. Average Throughput

In figure 4a and 4b the average PSNR is displayed for the three simulated scenarios. We can observe that the use of multiple paths leads to the improvement of average PSNR. This means that the proposed method greatly reduces the video frame losses, and thus allows for a better video display quality at the receiver side.

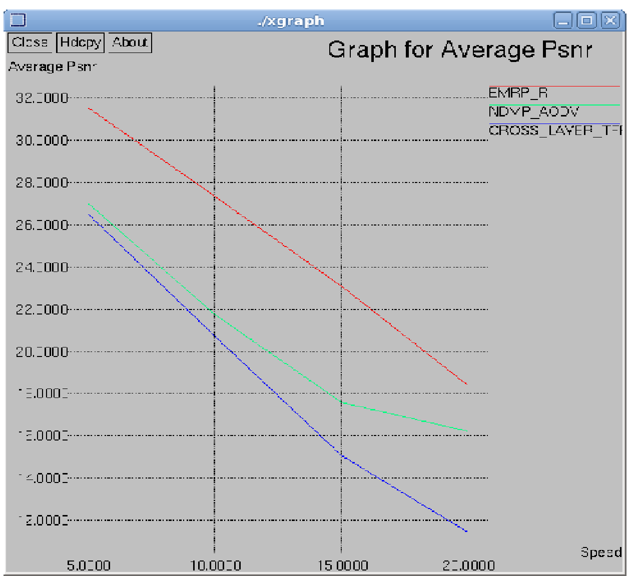

Fig. 4a. Average PSNR

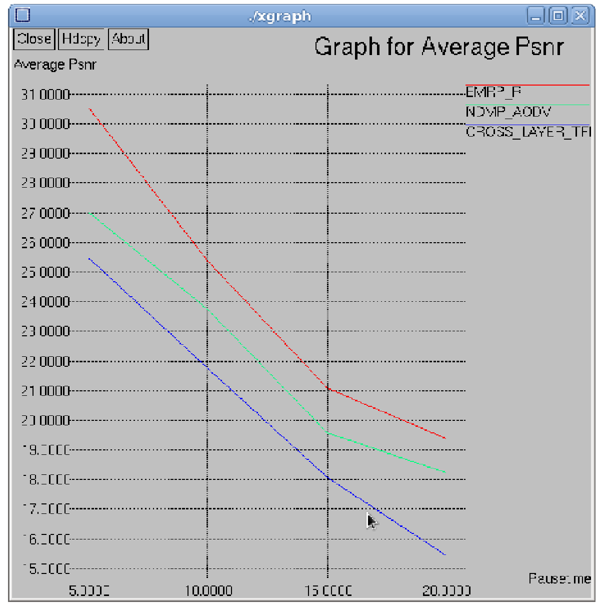

Fig. 4b. Average PSNR

5. Conclusion

In this paper, we proposed a dynamic node disjoint multipath routing with replication scheme for on-demand video streaming inMANETs based on AODV protocol. The proposed approach takes three vital parameters, namely node's residual energy, stability and traffic load, into account for constructing node disjoint multipath routes. This approach uses a primary and a secondary route to deliver video data packets, so that it avoids packet losses which are caused by using only one route. Due to multiple routes available in routing video data, video data is always made available for the receiver node even though one of the routes is broken. The replication scheme is used to store the replica of the packets at the one hop neighbor to the destination in the secondary route. Simulation results show that the proposed approach is able to provide high packet delivery ratio and good video quality by keeping packets available all the time to the receiver. The approach may be extended to improve the availability of the video data packets more even in the situation where the nodes storing the replicas are moved away from the receiver.

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