Evaluation of Routing Protocols for Video Transmission over MANETs that use Multiple Interfaces and Multiple Channels per node

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***Abstract*—Mobile Ad hoc NETworks (MANETs) are becoming more essential to wireless communications due to growing popularity of mobile devices. Many researchers have committed effort to enhance the Multimedia (video) transmission over MANETs. Various algorithms and mechanisms concerning the optimization of multimedia transmission have been presented. In this work we evaluate the effect of using multiple interfaces and multiple channels per node in the performance of already existing MANET routing protocols during video transmission. The evaluation shows that all routing protocols benefit from using multiple interfaces and multiple channels per node, and the video transmission over MANETs is improved.**

Keywords: MANETs, Multiple interface, Multiple-channels, Video transmission, Emergency response

I. INTRODUCTION

Mobile Ad hoc NETworks (MANETs) are becoming more essential to wireless communications due to growing popularity of mobile devices. A node in a MANET could act as a router while having also the possibility of being the sender or receiver of information. Their ability to be self-configured and form a mobile mesh network using wireless links, makes them suitable for a number of cases for which other types of networks cannot fulfill the necessary requirements. MANETs offer the freedom to use mobile devices and move independently of the location of base stations (and outside their coverage) with the help of other network devices. The lack of predefined infrastructure makes them suitable in emergency situations. An important usage scenario of MANETs can be a disaster area or any kind of emergency, in which the fixed infrastructure has been destroyed or is very limited.

However, there are certain limitations when we consider MANETs for video transmission applications. First of all, in this dynamic topology routing becomes a very complicated task. The routing protocols that have been developed for MANETs are directly affecting data transmission, and the performance of the relevant applications. Each protocol has its own routing strategy that is used in order to discover a routing path between two ends. The performance varies, depending on network conditions like the density of nodes in a specific area, their speed and direction. It is obvious that the selection of the proper routing protocol for the specific network topology plays a critical role.

On the other hand, video transmission applications use UDP as the transport protocol for video packets. Although this is an obvious solution to avoid latency caused by the retransmission and congestion control mechanisms of TCP, it may cause two major problems. The first one has to do with possible bandwidth limitations in which uncontrolled video transmission without any congestion or flow control may lead to increased packet losses. The second issue relates to TCP-friendliness. Under some conditions, uncontrolled video transmission may lead to possible starvation of TCP-based applications running in the same network.

A large variety of research has been conducted regarding Multi-Interface Multi-Channel (MIMC) and multi-channel architectures. One of these include the design and implementation of a channel abstraction module [1] that provides the requisite kernel support and implements a hybrid multi-channel protocol using this module. The research results showed that interface switching can be supported with moderate overheads.

Another research work focuses on routing in MIMC, proposing an interface assignment strategy that keeps fixed one interface and switch the other interfaces in order to improve capacity with multi-channel networks in case of available interfaces are less than of available channels [2]. Also, in this work, a routing protocol is presented which selects high-

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throughput routes in MIMC and accounts the cost of switching interfaces. Moreover, it analyzes several factors contributing to routing and link-layer protocols for MIMC [3] which is implemented over existing IEEE 802.11 hardware.

In this paper, we evaluate the effect of using MIMC per node in the performance of already existing MANET routing protocols during video transmission. Section 2 presents the MANET routing protocols used during the evaluation. Section 3 provides some implementation details of MIMC in simulation environments. Section 4 presents the simulation based evaluation of MIMC effect on MANET routing protocols performance during video transmission. Finally, Section 5 concludes our paper and presents future work.

II. MANET ROUTING PROTOCOLS

In this section, we provide some details on the MANET routing protocol which we use during the evaluation of effect of multi-interfaces and multi-channels per node in the performance of MANET routing.

A. AODV

The Ad hoc On-Demand Distance Vector - AODV ([4]) routing protocol is intended for use by mobile nodes in an ad hoc network. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network. It uses destination sequence numbers to ensure loop freedom at all times (even in the face of anomalous delivery of routing control messages), avoiding problems (such as "counting to infinity") associated with classical distance vector protocols.

B. AOMDV

The protocol Ad hoc On-Demand Multipath Distance Vector (AOMDV) ([5]) is based on a multipath extension to a well-studied single path routing protocol AODV. The protocol guarantees loop freedom and disjointness of alternate paths. AOMDV shares several characteristics with AODV. It is based on the distance vector concept and uses hop-by-hop routing approach. Moreover, AOMDV also finds routes on demand using a route discovery procedure. The main difference lies in the number of routes found in each route discovery. In AOMDV, RREQ propagation from the source towards the destination establishes multiple reverse paths both at intermediate nodes as well as the destination. Multiple RREPs traverse these reverse paths back to form multiple forward paths to the destination at the source and intermediate nodes. Note that AOMDV also provides intermediate nodes with alternate paths, as they are found.

C. DSDV

Destination sequenced distance vector routing (DSDV) ([6]) is adapted from the conventional Routing Information Protocol (RIP) to ad hoc networks routing. It adds a new attribute, sequence number, to each route table entry of the conventional RIP. Using the newly added sequence number, the mobile nodes can distinguish stale route information from the new and thus prevent the formation of routing loops.

III. IMPLEMENTATION DETAILS

In the last years, research communities have proposed and implemented, in the network simulator ns2, various algorithms and mechanisms for the (simulated) transmission over ad-hoc networks. Many of these mechanisms have proved to be promising. As far as MIMC is concerned, TeNs [1] (The Enhanced Network Simulator), [7], and [8] are the most complete previous works for MIMC technology. An older project, MITF (which was discontinued, and is no longer available) was carried out at the University of Rio de Janeiro (see, [8]). This paper's approach follows the model of [8] to support MIMC technology in the simulations.

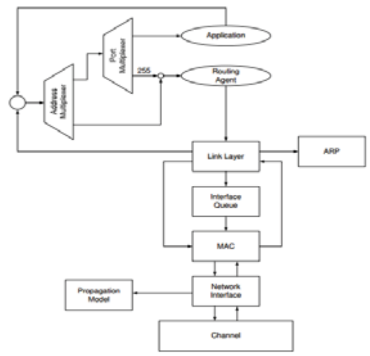

Figure 1. MobileNode Architecture without MIMC.

MIMC is a mechanism which permits one node to receive or send packets through multiple channels. Actually, one interface corresponds to one channel. As a result, the more channels we have, the more packets can be transported.

First of all, we should present and compare the MobileNode Architecture without and with MIMC. Figure 1 shows the MobileNode Architecture without MIMC. It consists of, below the Routing Agent, a chain of modules: Link-layer, ARP, Interface Queue, MAC and Network Interface which are connected to the same shared channel. Incoming packets arrive through the channel and go forward through the different modules. The Link Layer is connected to the Address Multiplexer which decides if packets are handled by the routing protocol or the application.

Figure 2 shows the MobileNode Architecture with MIMC. In this figure, we observe that the difference with the first figure is that incoming packets arrive through the corresponding channel. The Link Layer is connected to the same common point such as the initial MobileNode architecture but we should underline that the selection of the appropriate interface needs to be within the routing agent.

According to [8], there are four requirements we would like to fulfill. The first one is the number of channels in a particular scenario which should be modifiable. The second one is the variability of number of interfaces per node. The next one is each node within the same scenario that could connect to a different number of channels (of the ones that had been previously defined). The last one is Routing agents that may take advantage of the modified model, but legacy operation of

[1] http://www.cse.iitk.ac.in/users/braman/tens/

the simulator must be preserved, so as to ensure backwards compatibility.

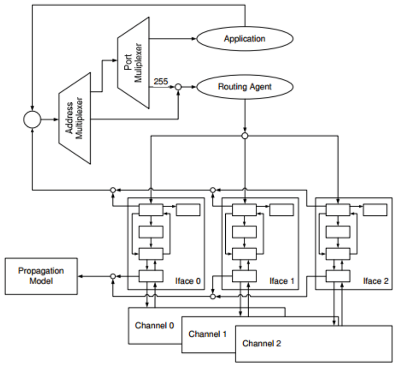

Figure 2. MobileNode Architecture without MIMC.

IV. EVALUATION OF MULTI-INTERFACES AND MULTI-CHANNELS APPROACH

A. Description of simulation setup

For the simulation experiments the latest version ns-2.35 simulator is used. The simulation environment is extended in order to support the mechanisms described in the previous section. For the video encoding we use Evalvid-RA v1.04_2 ([9]).

Our topology includes 13 nodes which are randomly positioned, as shown in Figure 3.

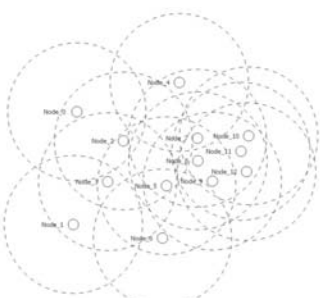

Figure 3. Topology of the simulated MANET.

There are four senders: nodes 0, 1, 4 and 6, and three receivers: nodes 10, 11 and 12. These have been selected as to create significant overlap in the paths used for transmitting the videos. The network is set to operate at 16Mbps.

During the simulations, all nodes move continuously, causing regular changes to the routing table. However, their motion does not cause the disconnection of any sender or receiver (as this would have disastrous effects on delay, and would not allow the comparison of results). The simulations give some time for the formation of the ad hoc network before starting the video transmissions (at time 0).

Videos contain scenes with intense movement, to simulate regular videos and real time situations, and have duration of 80sec; at 25fps (2000 frames in total) and width & height: 352x288. The mean VBR rate is set at 1Mbps.

There is no rate adaptation in order to have the same rate as possible and high quality.

The necessary code to run the experiments can be found at http://ru6.cti.gr/ru6/research_tools.php#MIMC.

B. Evaluation based on network metrics

In this section we discuss the effect of MIMC on the selected MANET routing protocol based on network metrics and more specific in average delay (Figure 4) and transmission rate (Figure 5). As Figure 4 shows, the use of MIMC has as a result an important reduction of average delay for all the three routing protocols. This is very important for the transmission of multimedia data and especially for the transmission of video.

However, the benefits are greater for AODV and AOMDV. On the other hand DSDV, which performed better than the other two routing protocols in the absence of MIMC usage, has lesser benefits. Thus DSDV becomes the worse routing protocol when using MIMC to transmit video streams.

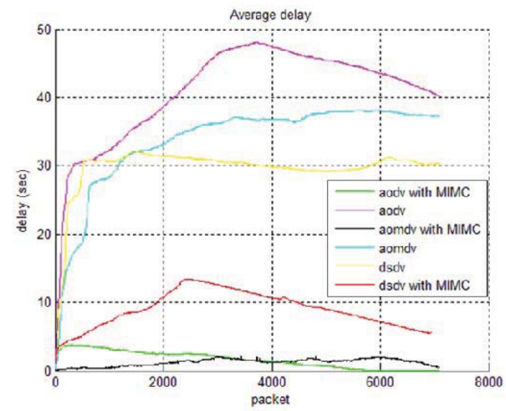

Figure 4. Average delay.

The same observations are made in the results of Figure 5 which presents the transmission rate during the simulation. Using the DSDV routing protocol results in slightly less bandwidth utilization.

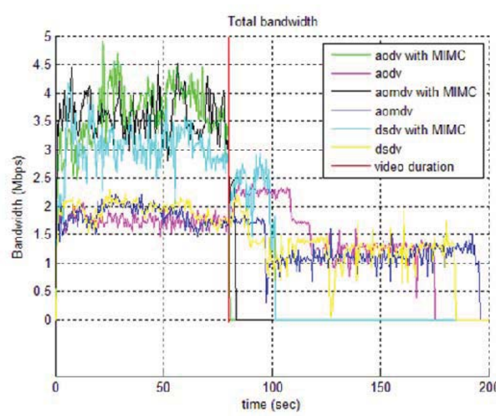

Figure 5. Total Bandwidth.

Thus, as already observed, the DSDV routing protocol is the worse choice when transmitting video streams in a MANET that uses MIMC per node. This results in the video transmission taking longer when the DSDV routing protocol is used. This means that video streaming is interrupted as it takes approximately 100secs to transmit an 80sec video.

The results are inconclusive when it comes to comparing the performance of the AODV vs. the performance of the AOMDV routing protocol. It seems that AOMDV is slightly better at the first half of the transmission, and AODV slightly better after that. Overall, AODV seems marginally better as the video transmission is completed in this case just before the case using AOMDV.

C. Evaluation based on media metrics

In this section, we evaluate the effect of MIMC in multimedia transmission over MANETs based on video quality assessment methods and metrics. First, we discuss video quality assessment methods and metrics that are used for the evaluation.

There are broadly two categories of methods for assessing the perceived video quality according to the involvement of human interaction during the evaluation process. In the subjective test methods, the perceived video quality is defined through human grading in which the individual viewer determines the quality level. Subjective video quality assessment methods are defined by ITU-T [10].

Objective test methods do not involve human interaction and are classified into three categories. In the first category, the evaluation of a transmitted video is performed by comparing the complete decoded video sequence at the end user to the original one sent by the sender. In the second category, we compare only a part of the features/metrics of the original with the decoded video and not the whole video sequence. In the third category we do not conduct any comparison between the original and the decoded video at the end user, but assess only the decoded video at the end user. The Video Quality Expert Group (VQEG) names these methods as the full, the reduced and the no reference methods [11].

QoE requirements for video and audio ([12], [13]) may be based on subjective evaluation metrics, such as the Mean Opinion Score (MOS) in which a number of viewers determine the video quality in a range 1 to 5, where 1 is the lowest perceived video quality and 5 the highest quality (Table I). Although MOS is an effective way to measure the QoE of any multimedia service for a user, it is considered as time consuming and requires a large number of users to provide reliable results.

To overcome the above limitations in our work, we use the objective full reference test method and calculate the Peak Signal to Noise Ratio (PSNR) [14] by directly comparing the original video file sent by the sender with the decoded video at the end user on a frame-by-frame basis. Then the PSNR values of all individual video frames are averaged to produce the mean PSNR of the complete video sequence. This is then mapped to the corresponding MOS value (Table I). However, we need to point out, that PSNR mapping to MOS values provides only a rough estimation of the perceived video quality by the end user.

Table 1: ITU-R Quality and impaired scale [15] and possible PSNR to MOS mapping [16]

PSNR (dB)	MOS	Perceived Quality	Impairment
>37	5	Excellent	Imperceptible
31-37	4	Good	Perceptible, but not annoying
25-30	3	Fair	Slightly annoying
20-24	2	Poor	Annoying
<20	1	Bad	Very annoying

Figures 6 through 9 show the MOS and PSNR when using DSDV both without and with MIMC per node.

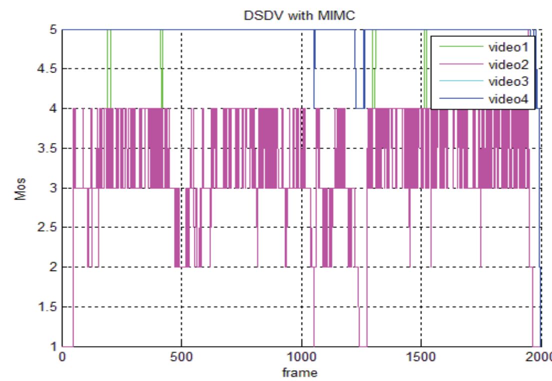

Figure 6. MOS values using DSDV with MIMC.

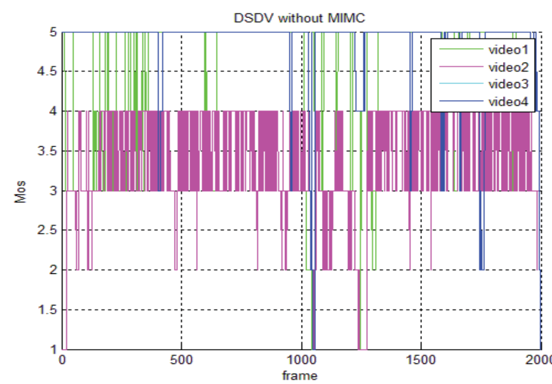

Figure 7. MOS values using DSDV without MIMC.

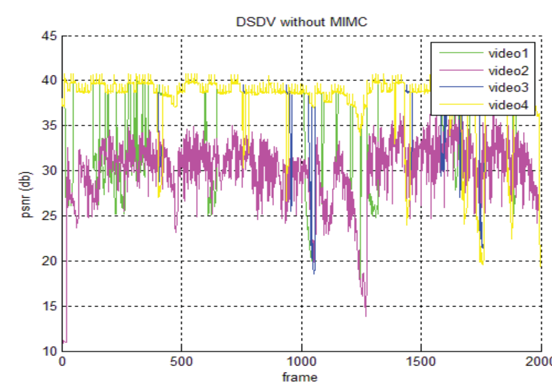

Figure 8. PSNR values using DSDV without MIMC.

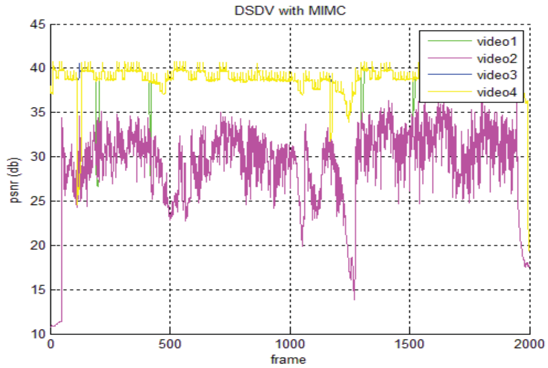

Figure 9. PSNR values using DSDV with MIMC.

In the case of not using MIMC, the quality of the received video seems to fluctuate more, but for some videos the overall quality is better than that with MIMC. The results indicate that video transmission when using the DSDV routing protocol does not benefit with the use of MIMC per node because the increased fluctuations may have important effect in the end user experience.

Figures 10 through 13 show the MOS and PSNR when using AOMDV both without and with MIMC per node. Contrary to the case for the DSDV routing protocol, it seems that when using the AOMDV, there are benefits in the received video quality when using MIMC per node. The received video quality fluctuates less and remains at higher values more time than when not using MIMC per node. The higher values have as a result a better end user experience.

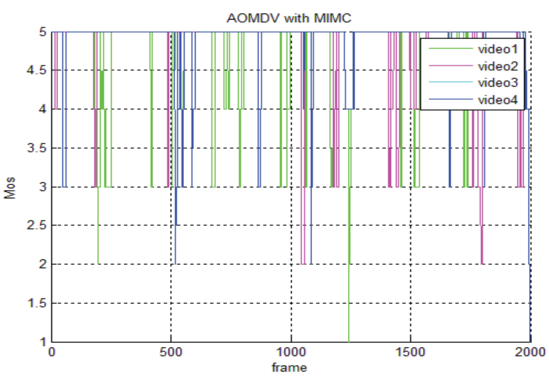

Figure 10. MOS values using AOMDV with MIMC.

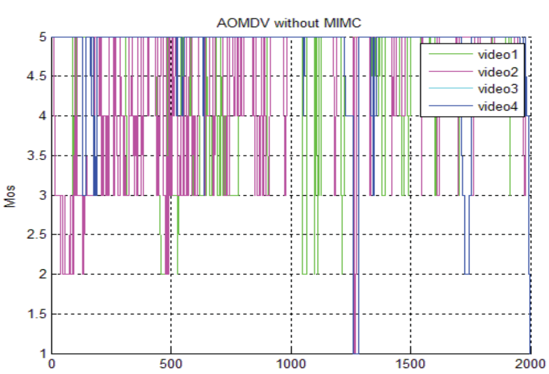

Figure 11. MOS values using AOMDV without MIMC.

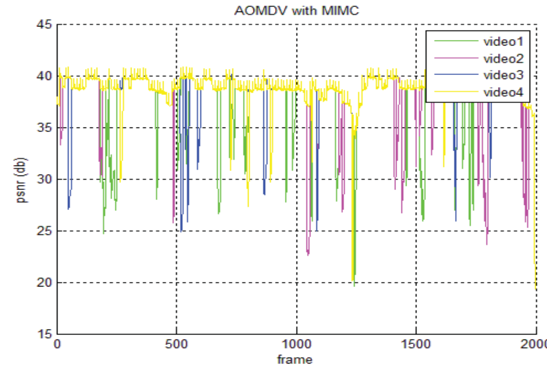

Figure 12. PSNR values using AOMDV with MIMC.

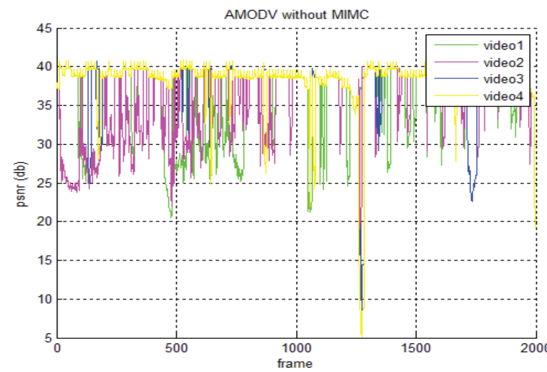

Figure 13. PSNR values using AOMDV without MIMC.

Figures 14 through 17 show the MOS and PSNR when using AODV both without and with MIMC per node. As with the case for the AOMDV routing protocol, it seems that when using the AOMDV, there are benefits in the received video quality when using MIMC per node. The received video quality fluctuates much less and remains at higher values more time than when not using MIMC per node. The higher values have as a result a better end user experience.

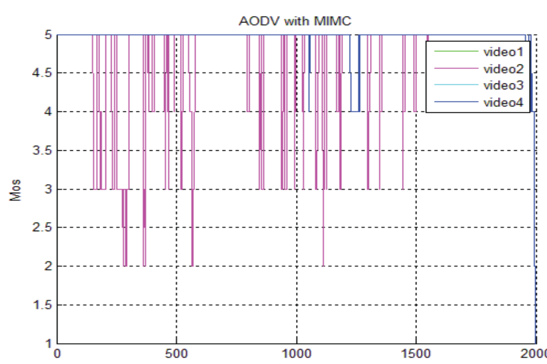

Figure 14. MOS values using AODV with MIMC.

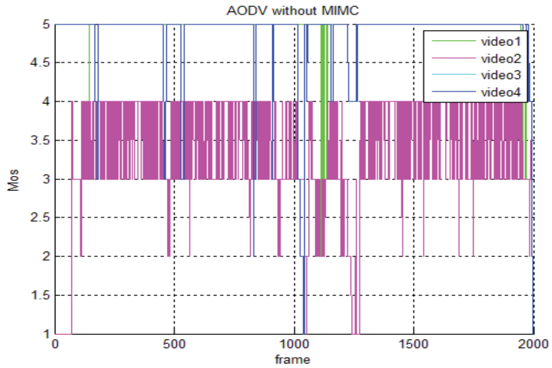

Figure 15. MOS values using AODV without MIMC.

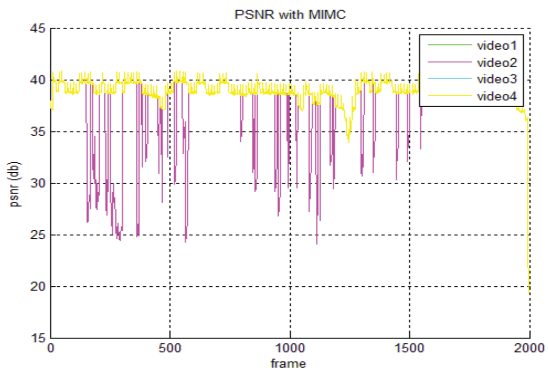

Figure 16. PSNR values using AODV with MIMC.

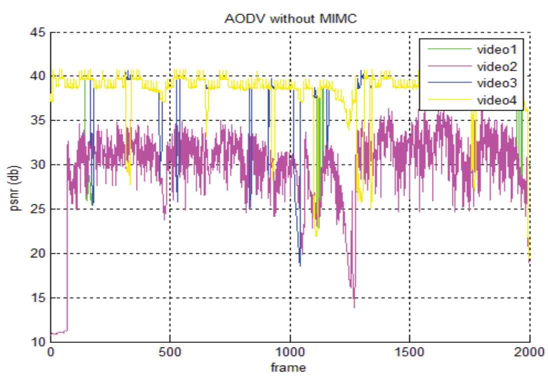

Figure 17. PSNR values using AODV without MIMC.

The benefits seem to be much more for AODV than for AOMDV. Even if the received video quality, without MIMC, is less for AODV, with the use of MIMC, the quality for AODV improves much more, and exceeds that of AOMDV.

Thus, the above simulation-based evaluation establishes AODV as a better choice for a routing protocol when transmitting videos in a MANET that uses MIMC per node.

V. CONCLUSIONS – FUTURE WORK

In this work, we presented the result of the evaluation of using different routing protocols when transmitting videos in a MANET that uses MIMC per node. The valuation is performed in a simulation setting. The results indicate that different routing protocols result in different performance enhancement when introducing MIMC per node. When using the DSDV routing protocol the benefits seems to be less, but when using the AOMDV and especially the AODV routing protocols the benefits are more. Therefore, in MANETs that are used to transmit videos, and use MIMC per node, it seems better to use the AODV routing protocol. Our future work includes the evaluation of MIMC in real world through experiments.

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