# Multi-Criterion Decision Making and Adaptation for Multi-path Video Streaming in WSNs

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**ABSTRACT**

**It is suggested that multi-path routing is advantageous for applications with high traffic data characteristics, especially in the WSN environment. Sensor networks which transmit video will have to respond to the high data characteristic inherent in video data. Throughput, delay and packet loss are important metrics when considering video traffic. This work measures the performance of four multi-path routing protocols, MAOMDV, AOMDV, AntHocNet and MP-DSR in the WSN environment. It is shown that MAOMDV outperforms the other multi-path routing protocols in terms of the aforementioned metrics.**

Keywords - **multi-path, WSN, video, throughput, delay, packet loss.**

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## I. INTRODUCTION

Multimedia security surveillance, storage of activities from networked cameras, city vehicular traffic monitoring and motor car collision avoidance are modern multimedia streaming applications over sensor networks. These applications have stringent QoS requirements of throughput, delay and packet loss. For example, the data rate of H.264 varies between 64 kbps and 240 Mbps depending on the level [4]. However, wireless sensor networks (WSNs) have restrictions in supporting these multimedia streaming applications because of the lack of raw bandwidth, poor link characteristics and limited power supply. Recent advances of multimedia source coding techniques such as Multiple Description Coding and inexpensive hardware, such as CMOS cameras and microphones, have made multimedia transmission over WSNs possible [9]. In many applications, only some video data need to be transmitted to the end-users. For example, in a surveillance sensor network, cluster heads receive the raw video data from member motes and determine whether to forward the video data clip to the base station depending on whether it comprises distrustful persons or behavior. This may be the analyzed work of some image object recognition techniques. At the base station mote, the human operator will make the final decision of any threat by more thorough analysis of the doubtful video clips.

WSNs built for multimedia data traffic have some separate differences from conventional data sensor networks, the sensor network paradigm has to be re-evaluated so that we are able to deliver multimedia content with a certain level of quality of experience (QoE). For example, vague picture images in surveillance WSNs could cause trouble in identification of a fugitive. The data generation rate of a video sensor is quite high, resulting in much higher network bandwidth requirement and power consumption, especially if the camera equipment is part of the mote equipment. This issue is especially aggravated when no efficient compression scheme is employed before transmission. Thus, the transmission of huge amounts of multimedia data, particularly video data, over bandwidth-constrained sensor networks is a big challenge [15].

In WSNs, especially video sensor networks, transmitting multimedia data requires the selection of paths that ensure high throughput and low latency. The fundamental reason leading to the degradation of the performance as the number of nodes increases is the fact that each node has to share the radio channel with its neighbors [11]. Standard NS-2 uses primitive propagation models, including Free Space, Two Ray Ground and Shadowing which set a signal strength threshold to determine whether one frame is received correctly by the receiver. To provide a more accurate error model that reflects real BER (bit error rate), SNR and BER models into NS-2 were added [10], which model interference accurately. Thus other frames received by a receiver concurrently are also modeled.

Real time video streaming in WSNs [5], [13] generally poses two requirements: 1) Guaranteed end to end transmission delay: Real time video streaming applications generally have a soft deadline which requires that the video streaming in WSNs should always use the shortest routing path with the minimum end to end transmission delay; To adhere as close as possible to this requirement, all routing protocols in this work were restricted to at most two paths. 2) Using multiple routing paths for transmission: Packets of streaming video data generally are large in size and the transmission requirements can be several times higher than the maximum transmission capacity (bandwidth) of sensor nodes [2]. This requires that multi-path transmission should be used to increase transmission performance in WSNs.

This paper explores the performance of the MAOMDV, AOMDV, AntHocNet and MP-DSR multipath algorithms in a video environment. It explores the area of multi-path routing for researchers and practioners alike. Its main contribution is to illustrate the usefulness of MCDM techniques in routing protocols [6]. The results can be used to further the field of multi-path routing in WSNs. Section II introduces the multi-path routing protocols. Section III presents the methods used to run the video simulations. The results are shown in Section IV. A discussion of the results obtained is presented in section V. Finally in section VI the conclusion is presented.

## II. MULTI-PATH ROUTING PROTOCOLS

### *A. MAOMDV*

The M-AOMDV [6] routing uses the same method as the AOMDV protocol to discover and populate the motes routing for multiple routes to a given destination. During the protocol's route discovery phase, the packet loss percentage is set to zero and stored in each mote's routing table. Since at this stage there is no packet loss information, the shortest path is used for initial data transmission.

The source mote sends 5 collection probe packets (COLL packets) at 12 second intervals to the last hop address (stored in routing table) for each path to a given destination. The last hop mote receive the probe packets and waits on a timer to expire and then replys to the source mote with a reply COLL packet carrying one of these values 20%, 40%, 60%, 80% and 100%, based on how many probes it receives. If the source mote does not receive a reply from the last hop mote within a given time period, then the packet loss percentage is set to 100% for that path.

After the PLD phase is completed multiple paths in a given routing table will have both hop count and packet loss information for a given destination mote. The information is then used by the SAW MCDM method describe in Section 2.2 to calculate a SAW value for each path. The shortest path selected at the RD phase is then replaced with the route to the destination with the highest SAW value.

During normal network operations the packet loss percentage metric is periodically updated during route maintenance to ensure that paths selected for routing have the most recent metric values for the calculation of the SAW path value in the PLD phase. This phase ensures that packet losses experienced along a path, due to current packet dropping motes, are taken into consideration. Hence new SAW values could invoke alternate paths to be used to send packets to a given destination. If all paths to a given destination go down then the M-AOMDV routing protocol initiates a new route discovery phase.

### *B. AOMDV*

Ad-hoc On-demand Multipath Distance Vector Routing (AOMDV) protocol is an extension to the AODV protocol for finding multiple loop-free and link disjoint paths [12]. The routing entries for each destination contain a list of the next-hops and last-hops along with the corresponding hop counts. All the next hops have identical sequence number. This assists in keeping track of a route. For each destination, a node keeps the advertised hop count, which is defined as the maximum hop count for all the different paths. It is used for sending route advertisements of the destination. Each duplicate route advertisement received by a node defines an alternative path to the destination. Loop freedom is assured for a node by accepting alternate paths to destination if it has a less hop count than the advertised hop count for that destination. Because the maximum hop count is used, the advertised hop count therefore does not change for the same sequence number. When a route advertisement is received for a destination with a greater sequence number, the next-hop list and the advertised hop count are reset. AOMDV can be used to find either node-disjoint or link-disjoint routes. To find node-disjoint routes, each node does not immediately reject duplicate RREQs. Each RREQs arriving via a different neighbor of the source defines a node-disjoint path. This is because nodes cannot be broadcast duplicate RREQs, so any two RREQs arriving at an intermediate node via a different neighbor of the source could not have traversed the same node. In an attempt to get multiple link-disjoint routes, the destination replies to duplicate RREQs, the destination only replies to RREQs arriving via unique neighbors. After the first hop, the RREPs follow the reverse paths, which are node disjoint and thus link disjoint.

### *C. AntHocNet*

AntHocNet makes use of both reactive and proactive strategies to establish routing paths [3]. It is reactive in the sense that a node only starts gathering routing information for a specific destination when a local traffic session needs to communicate with the destination and no routing information is available. It is proactive because as long as the communication starts, and for the entire duration of the communication, the nodes proactively keep the routing information related to the ongoing flow up-to-date with network changes. In this way both the costs and the number of paths used by each running flow can reflect the actual status of the network, providing an optimized network response. The reactive component of the algorithm deals with the phase of path setup and is totally based on the use of ACO ant agents to find a good initial path. Routing information is encoded in node pheromone tables.

The proactive component implements path maintenance and improvement, proactively adapting during the course of a session the paths the session is using to network changes. Path maintenance and improvement is realized by a combination of ant path sampling and slow-rate pheromone diffusion: the routing information obtained via ant path sampling is spread between the nodes of the network and used to update the routing tables according to a bootstrapping scheme that in turn provide main guidance for the ant path exploration. Link failures are dealt with using a local path repair process or via explicit notification messages. Stochastic decisions are used both for ant exploration and to distribute data packets over multiple paths.

### *D. MP-DSR*

When an application uses MP-DSR [8] for a route discovery, it supplies an end-to-end reliability requirement, $P_u$, where $0 \leq P_u \leq 1$. Given this requirement, MP-DSR determines two parameters for the route discovery: (1) the number of paths it needs to discover; and (2) the lowest path reliability requirement that each search path must be able to provide in order to satisfy $P_u$. We refer to these two parameters as $m_0$ and $\Pi_{lower}$ , respectively. These two parameters are decided based on the available state information.

The relationship between $m_0$ and $\Pi_{lower}$ and is straightforward: when there are fewer paths between the source and destination nodes, more reliable paths are preferable and therefore, a higher $\Pi_{lower}$ , and vice versa. Once the source node makes this decision, it sends $m_0$ Route Request (RREQ) messages to search for feasible paths. Each message contains information such as $\Pi_{lower}$ , the path it has traversed (T), the corresponding path reliability ($\Pi_{acc}$), etc. When an intermediate node receives the RREQ message, it checks whether this message meets the path reliability requirement (i.e. $\Pi_{acc} > \Pi_{lower}$ ). If this RREQ message fails to meet such a requirement, the node will discard the message. Otherwise, the intermediate node updates the RREQ message to include itself in as well as in $\Pi_{acc}$, and then forwards multiple copies of this message to its neighbors. The number of copies is based on the number of neighbors that can receive this RREQ message without failing the path reliability requirement. This number of copies is also bounded by $m_0$ to restrict the degree of message forwarding inside the network. When the destination collects the RREQ messages, it selectively chooses multiple disjoint paths from these messages, and sends Route Rely (RREP) messages back to the source node via these selected paths. Upon the arrival of these RREP messages at the source node, the source node begins to send data along these paths.

## III. METHODS

The experiment was carried out using the ns2 simulator. There were four UDP traffic agents (at the north-west, north-east, south-west and south-east of the network) sending video data to the sink (node 0) (cf. Figure 1). The first agent generated traffic at a rate of 250Kbps between 1 to 49 seconds, the second agent 605Kbps between 50 to 99 seconds, the third agent 1500Kbps between 100 to 149 seconds and the fourth agent 605Kbps between 150 to 200 seconds. For the measurement of video data at the network layer throughput, end-to-end delay and packet loss were recorded.

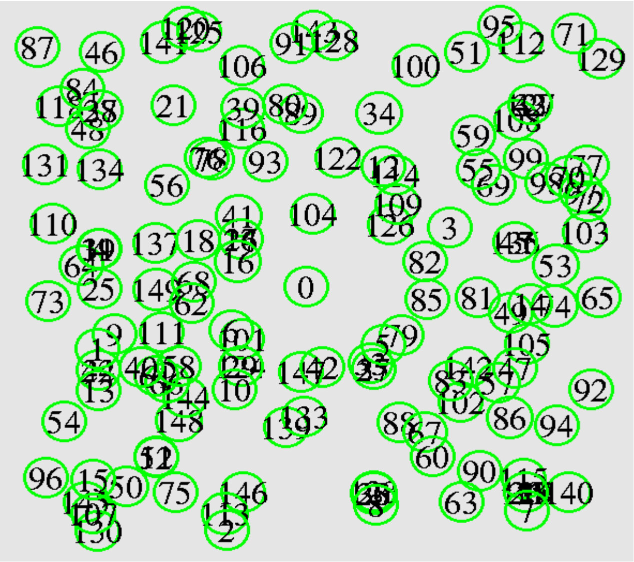

Fig. 1.150 node WSN layout

TABLE I. SIMULATION PARAMETERS

| Network Parameter | Details | |
|---|---|---|
| | ***Value*** | ***Explanation*** |
| val(chan) | Channel/WirelessChannel | channel type |
| val(prop) | Propagation/TwoRayGround | radio-propagation model |
| val(netif) | Phy/WirelessPhy | network interface type |
| val(mac) | Mac/802_11 | MAC type |
| val(ifq) | Queue/DropTail/PriQueue | interface queue type |
| val(ll) | LL | link layer type |
| val(ant) | Antenna/OmniAntenna | antenna model |
| val(ifqlen) | 50 | max packet in ifq |
| val(nn) | 150 | number of mobilenodes |
| val(rp) | MAOMDV or AOMDV or AntHocNet or MP-DSR | routing protocol |
| val(x) | 500 | X dimension of the topography |
| val(y) | 500 | Y dimension of the topography |
| packetSize_ | 1500 | Set Packet Size in bytes |
| rate_ | 250KB or 605KB or 1500KB | Set CBR rate in Kilobytes |

## IV. RESULTS

### A. Throughput

In Figure 2 the WSN uses MAOMDV as its routing protocol. The initial bandwidth was 250KB at the start of the experiment and the initial jump to 450KB is due to the buffers becoming overfilled with the sudden burst of traffic. However, the value soon leveled off to roughly 250KB until the second sensor agent began to transmit at 605KB with the first stopping transmission. The bandwidth reached and leveled to this value with the network not showing any unusual behavior. At 100s when the third sensor agent began transmitting 1500KB there was a sharp drop in bandwidth with a jump to a little over 1700KB. This occurs as the buffers were initially overwhelmed with the sudden increase in bandwidth and then with a bandwidth surplus when the buffers adjusted. The bandwidth leveled off to a high value just under 1600KB and can be explained by the buffers maintaining their full capacity. Finally when the fourth sensor agent transmitted at 605KB the network throughput at the sink maintained a similar value. This is natural for such network conditions.

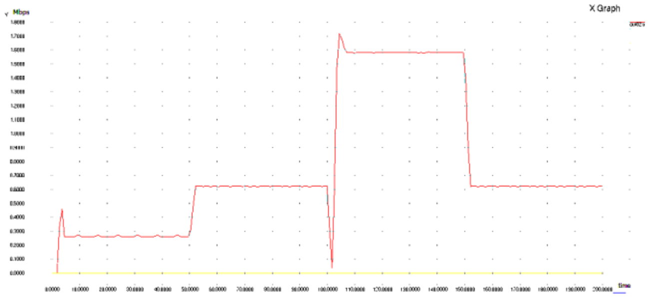

Fig. 2. MAOMDV Throughput

The WSN uses the AOMDV routing protocol with the simulation results shown in Figure 3. AOMDV maintained the 250KB and 605KB bandwidths when sensor agent 1 and 2 were sending traffic. However, the bandwidth fell just below 1500KB when the agent 3 was sending traffic. The traffic leveled off at this value. There was no unusual behaviour when agent 4 sent 605MB in the remaining 50s of the experiment.

Fig. 3. AOMDV Throughput

The WSN uses the AntHocNet routing protocol and the simulation results are shown on Figure 4. The initial traffic jump to 300KB when the first agent began transmitting is explained by buffers initially becoming filled. The resulting plateau of just above 250KB is due to the stabilizing conditions at the buffers. Agent 3 gave a burst increase of traffic to 605KB thus overfilling the existing buffers, first causing the bandwidth to drop to 210KB and then to increase rapidly to 700KB. However, when the buffers stabilized the bandwidth leveled off at 625KB. A similar occurrence of buffers becoming overwhelmed takes place when agent 3 starts transmitting video at 1500KB. However, the buffers stabilized after a lengthy period of 10s and so too bandwidth at just around 1400KB. The bandwidth returned to 630KB when the fourth sensor agent began transmitting video data.

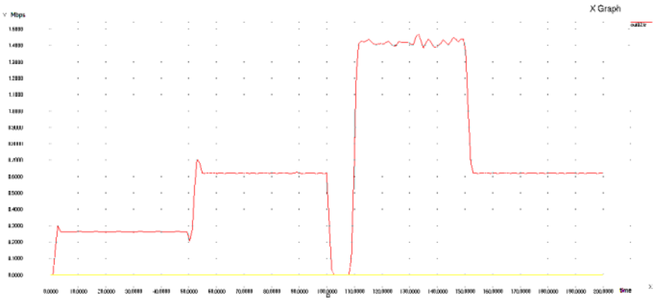

Fig. 4. AntHocNet Throughput

The throughput of the WSN transporting video data using the MP-DSR routing protocol is shown on Figure 5. Buffer allocation is relatively stable when the first sensor begins transmitting data. Bandwidth stayed approximately 260KB for the firs 50s of the experiment. Similarly up to 100s the bandwidth reached and stabilized at roughly 625KB. When the third sensor agent transmitted data the bandwidth was roughly 1550KB. However, initially there were jumps between 1475 and 1600KB. This is caused by buffers becoming filled with the high flow data traffic and then stabilizing. The bandwidth values stabilized to 625KB when the last sensor agent transmitted video data.

Fig. 5. MP-DSR Throughput

### *B. Delay*

The delay is commensurate to the throughput obtained (cf. Figure 3). The results show that higher the throughput the lower the delays and vice versa. The highest delay is 0.028 ms when the throughput data rate was 250KB.

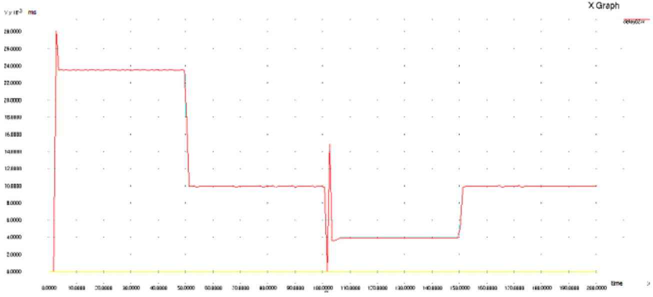

Fig. 6. MAOMDV Delay

The delay for AOMDV is shows a similar pattern to that of MAOMDV. The highest delay is 0.0253 when the throughput data traffic was 250KB.

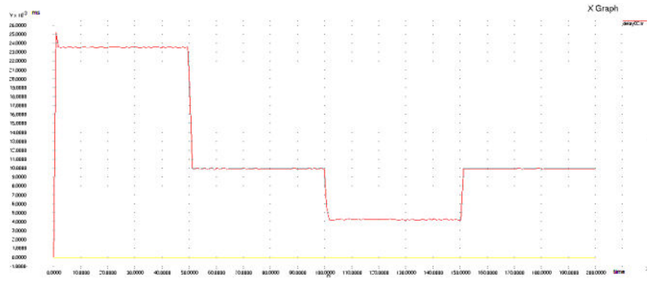

Fig. 7. AOMDV Delay

The delay was also consistent to that of MAOMDV and AOMDV. The highest delay was 0.400 ms when the data rate was 1500KB.

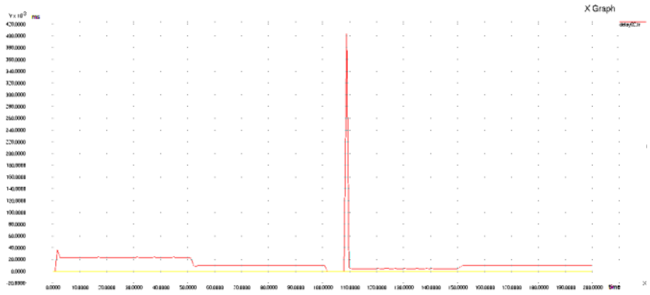

Fig. 8. AntHocNet Delay

The delay is consistent with the other routing protocols with the highest delay, 0.055 ms, occuring when the throughput data traffic rate was 250KB.

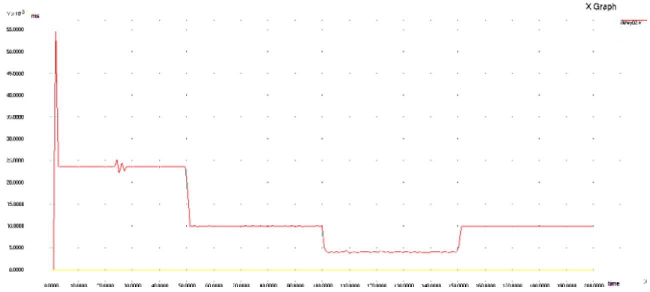

Fig. 9. MP-DSR Delay

### C. *Packet Loss*

There were high packet losses at the start of the experiment when sensor agent 1 started transmitting video data at 250KB and when sensor agent 3 started transmitting video data at 1500KB. These losses occurred at 3s and 102s respectively with duration of roughly 2.5s. The first loss was roughly 1 packet per second while the second was roughly 6 packets per second.

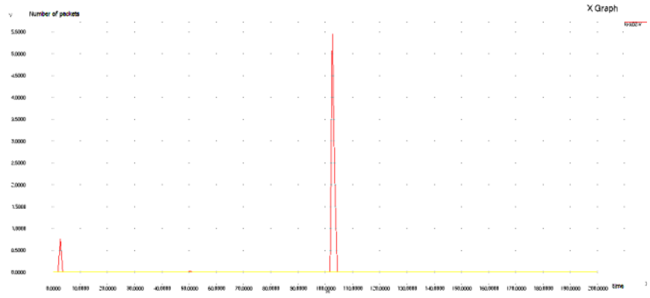

Fig. 10. MAOMDV Packet Loss

Packet loss occurred at 149s lasting rougly 2.5s with a peak of 115,000 packets lost per second.

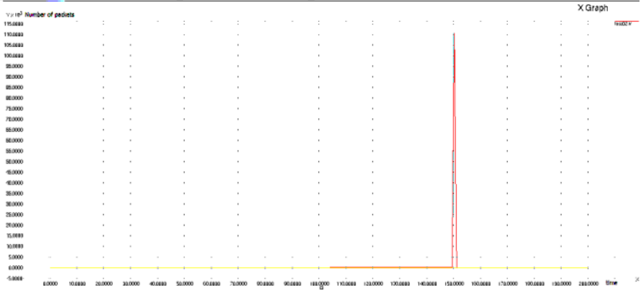

Fig. 11. AOMDV Packet Loss

Packet losses were roughly 83,000 packets per second. This loss was singular and occurred at 150s lasting approximately 2.5s.

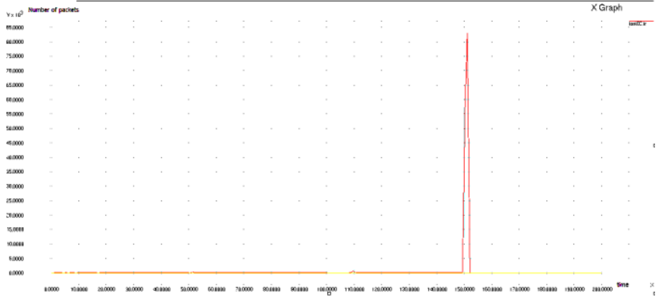

Fig. 12. AntHocNet Packet Loss

There were two major times when packet losses occurs at 1s and 122s. The first occurred at a rate of roughly 46 packets per second, while the second roughly 23 packets per second. Both lasted approximately 2s. There were four other notable times when packets were lost. These were at 57s, 71s, 86s, 97s and 110s. The rate for these were similar at one packet per second lasting roughly one second each.

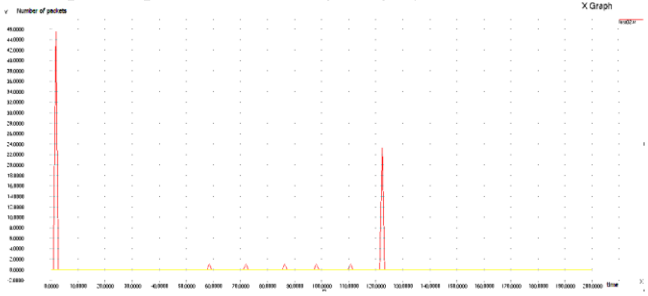

Fig. 13. MP-DSR Packet Loss

## V. DISCUSSION

MAOMDV had the best performance among the multipath routing protocols for video data delivery. Results are taken over the entire length of the experiment; however the performance under high video traffic load is the key distinguishing factor when the performance of the routing protocol is being discussed. The high throughputs, low delays and low packet losses will enable video data to be efficiently be transported from the source motes to the sink. This is attributed by the fact that for video data low packet drop rates will enable more data to be transported across the network. MAOMDV inherently uses packet loss as a routing metric, thus enabling such conditions to be effectively handled. The result is more data getting through. By comparing the result for the other routing protocols MP-DSR had the second highest performance, followed closely by AOMDV and finally AntHocNet. This is shown by MP-DSR having the highest throughput for high video data traffic. The delay had a maximum that was greater than AOMDV, but the average delay was similar and packet loss was much lower. AntHocNet had much lower throughput, high delays and huge packet losses when compared to the other routing protocols.

## VI. CONCLUSION

This work investigated the performance of four multi-path routing protocols in a video-based WSN environment. The analysis showed that the routing protocol with a packet loss routing metric, MAOMDV outperformed the others in terms of throughput, delay and packet loss. Other MCDM techniques, for example, ELECTRE [1], AHP [1], WSM [14], TOPSIS [14], and PROMETHEE [7] can be applied to routing protocols and the relevance of those techniques can be validated experimentally. Further work will discover the performance of other such routing protocols under the influence of higher video traffic loads. This will stimulate the relevance of improving video quality in such networks.

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