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Priority-based Routing Framework for VANETs

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Abstract

Vehicular ad hoc Network (VANET) is a collection of vehicles and associated roadside infrastructure which provide mobile wireless communication services. One of the significant use-cases is to transmit the images using VANET during emergencies like road accidents, traffic congestion, fire, or traffic hazards. Priority-based routing allows the network to route critical data on priority. This paper proposes a Priority-based Routing Framework for Image Transmission (PRoFIT) for VANETs. PRoFIT for VANETs delivers critical image features at high priority to the sink node for early processing. Simulations were carried out that use PRoFIT for VANETs during the mobility of vehicles in emergency scenarios. The detailed experiments show the impact of priority-based routing during the mobility of vehicles. Both grid topology and vehicular topology were simulated. Packet end-to-end delay and delivery ratios were analyzed. A comparison of results of critical image information delivery with PRoFIT and without PRoFIT shows the impact of using PRoFIT for VANETs.

Keywords: Smart City, Vehicular ad hoc network, Mobility, Priority-based routing, Cooja, Contiki-NG simulation.

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1. Introduction

Vehicular ad hoc network (VANET) consists of mobile nodes equipped with sensors. Typically, mobile nodes monitor the environment's natural and physical conditions and send them to the neighbor node. The aim is to send the data to the sink node for processing and action. The nodes are directly or indirectly connected to the sink node. Therefore, a VANET can comprise of many hundreds of nodes in a specific geographical area with some mobile and some static nodes.

Smart cities are proliferating. Safety and security in smart cities are major concerns. In emergencies, the response time of medical or law enforcement agencies is very critical. Vehicle-to-Vehicle communication (V2V) can play a vital role in getting quick action. The typical V2V communication cannot differentiate between priority and regular packets. Notably, the images captured during emergencies need to be delivered on a priority basis to the sink node for action. Previously, Priority-based Routing Framework for Image Transmission (PRoFIT) [1] was proposed for Visual Sensor Networks (VSN). PRoFIT is designed to deliver the features of critical images at high priority to the sink node for early processing.

For this work, PRoFIT has been adapted to work on VANETs. In this paper, the PRoFIT framework is used to transmit the critical messages on priority over the network using V2V communication. The biggest challenge in VANETs is the mobility of vehicles. The usefulness of PRoFIT on a VANET was evaluated by simulating multiple mobility scenarios. In this case, images were considered as priority data for the network.

Visual information was captured by cameras attached to VANET nodes. The captured images need to be sent to the sink for processing at a high priority. Grid topology was used for fixed nodes. BonnMotion [2] was used to create VANET topologies. End-to-end delays and delivery ratios of high priority and low priority packets were calculated at the sink node for both fixed and mobility models. The network was simulated on Cooja Simulator with Contiki-NG's RPL UDP.

In the rest of the paper, related work is provided in Section 2. PRoFIT architecture is discussed in Section 3.

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Mobility models are presented in Section 4. Details of experiments are given in Section 5. Section 6 discusses the results, and the paper is concluded in Section 7

2. Literature Review

Paper [3] provides a detailed survey of state-of-the-art routing protocols used in VANETs. A comparison among different protocols is also included, along with the pros and cons of each. The authors discuss real challenges, open issues, and future directions.

Authors of [4] perform another extensive survey in which they discuss the challenges faced by VANETs such as broadcasting overhead, optimum forward selection, and inaccurate positioning. This survey also provides a brief description of emerging technologies, their comparison, and some future directions.

A detailed study is provided in [5], which explains VANETs, its security attacks, countermeasures, and security challenges emerging from its access technologies and a detailed comparison of different access technologies.

Paper [6] discusses several problems in applying intelligent processing technologies in VANETs. It provides a review of strategies of these technologies, their advantages and disadvantages, and their performances.

According to a recent survey [7], protocols that use several metrics have proved to be more suitable VANETs due to their ability to deal with dynamic environment changes caused by vehicle mobility. The authors selected parameters such as distance, density, link stability, speed, and position for the best proposal. A complete review of routing protocols is provided based on more than one metric for best route selection in a VANET to help in the selection of protocols or the creation of metrics when a new protocol is designed. Distance and speed are suggested to be the most popular and versatile metrics.

Paper [8] presents literature on the state-of-the-art algorithms for geographical and topology-based routing in VANETs, and the issues and challenges they face.

The position-based routing protocols relying on **priority-based** forwarding are more suitable for the rapid-changing network topology of VANETs. In VANETS, vehicles receive data from a roadside unit (RSU) that acts as a router and high storage data repository for in-range vehicles. Vehicle mobility is usually very high in service areas, and RSU has limited range and time to communicate with a maximum number of vehicles.

Dubey et al. [9] propose the scheduling of data of in-range vehicles. The request is prioritized based on the deadline expiry. The proposed work helps in increasing the dissemination capacity of the system and manages better bandwidth utilization. It provides excellent results in dense networks and highway scenarios.

A hybrid algorithm is proposed in paper [10] based on opportunity and position-based routing protocol. This algorithm introduces a greedy forwarding scheme, in which the sender node chooses a neighbor node having the least number of hops from the destination node and finds the right priority for transmitting data. It neglects expired nodes from the routing process. The results show improvement in throughput, end-to-end delay, and packet delivery ratio.

Priority-based protocol Routing Protocol (PRP) for VANET is presented in [11]. This protocol focuses on safety driving applications in distributed environments. This protocol maintains MAC delay and quality of service (QoS) for different message priorities. The results show that it achieves both maximum dissemination distance and message prioritization in a fully distributed environment. The performance degrades in case of a large number of vehicles, the distance between transmitter and receiver, and high packet generation rate.

Paper [12] describes priority-based scheduling and drop policy along with a hybrid routing algorithm for Vehicular Delay Tolerant Network (VDTN). The scheduling policies discussed in the literature route a message based on some known policy. The proposed routing algorithm routes messages based on message priorities based on the type of messages such as traffic-related, accident relates, and general-purpose messages. It performs better in terms of average delivery latency overhead ratio and message delivery ratio.

Traffic aware routing is proposed in many researchers to adopt **mobility** in high-speed and time constraint communication links. In [13], the authors introduce a Lightweight Intersection-based Traffic-Aware Routing (LITAR) protocol for V2V communication in urban Vehicular networks. The paper presents two efficient algorithms to avoid network overhead of position and traffic status measurement to meet real-time requirements. LITAR uses road network connectivity, directional vehicular density and distance towards the destination to route data packets. LITAR shows remarkable performance in terms of packet delivery ratio, end-to-end delay, real-time measurement accuracy, and routing overhead.

In VANETs, it is essential to predict future moves of vehicles. Many routing protocols have been developed in last few years. In [14], A mobility-based reliable node selection method is proposed that selects an intermediate node by utilizing the mobility patterns included in beacons to improve the routing problem. The proposed method shows better results in packet delivery ratio as compared to existing methods.

Paper [15] presents a new Mobility Prediction Based Routing Protocol (MPBRP) in VANET for packet transmission, path recovery, and neighborhood detection. It uses prediction position and predefined angles along with driver intention to decide the transmission path. The protocol is tested over different area sizes, and the results show an improvement in average hops, end-to-end delay, and packet delivery ratio.

Another mobility-aware multimedia data transfer mechanism using Multipath Transport Control Protocol (MPTCP) is introduced in [16] for Vehicular Network. The author adopted MPTCP to allocate multimedia data to achieve a better transmission rate dynamically. A mobility-aware distance measurement is used to check whether mobile terminal (vehicle) is in the communication range of RSU or not and whether it is in the communication range of multiple roadside units. The authors introduce a handover mechanism that transfers data using MPTCP when the vehicle exceeded the communication range of RSU for stable transmission. In the case of several RSU's, a mechanism is used, which can trigger new path for multipath data transmission. The simulation results prove that this mechanism can considerably improve transmission performance over state-of-the-art solutions.

A mobile wireless sensor network works well for inter-vehicular communication in mission-critical applications. A cross layer architecture-based Network Condition Aware Geographical Routing Protocol (NCARP) has been proposed in [17]. This protocol ensures adaptive link adaptation, dynamic link quality estimation, congestion Awareness, dynamic neighborhood management, packet velocity estimation, congestion awareness, packet velocity estimation, and dynamic link quality estimation. A mobility simulation model is introduced, in which a moving vehicle sends its real-time data with priority to another moving vehicle within deadline time. This model proves to be a good alternative for low-cost, mission-critical mobile vehicular networks.

Paper [18] proposes another priority-based multi-hop routing protocol. This protocol prioritizes moving emergency vehicles e.g ambulance and fire trucks, during heavy traffic scenarios. The routing of data packets from priority vehicles to other vehicles is done using multi-hop routing protocol to secure emergency trips by priority vehicles and avoid danger for life.

Authors of paper [19] propose a novel routing protocol called Intelligent Routing Protocol (IRPANET) for VANETs. This protocol uses probabilistic, machine-learning, and heuristic-based approaches with a store-and-forward mechanism to predict the best path for forwarding packets using openstreet map (OSM). It uses several parameters to calculate the optimal path, e.g., vehicle position, packets priority, velocity/speed of the vehicle, distances between vehicle, the communication range of the vehicle, vehicle direction, and network congestion. The proposed protocol is well suited for medical emergency and security situations.

3. PRoFIT Architecture

The intermediate nodes, camera nodes, and sink nodes are generally encompassed in the network model used in the VSN. A sample surveillance network is shown in Figure 1. The conventional VSNs are presumably to be of this kind, where the outside edges will represent the camera nodes, while image information would be relayed from camera nodes to the sink, and intermediate nodes take this action.

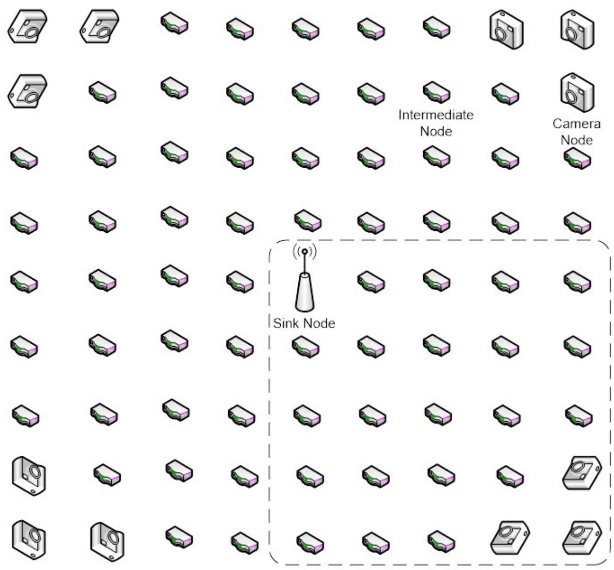

Figure 1. Conventional Visual Sensor Network

As shown in Figure 2, the network layer and medium access control layer of the protocol stack are responsible to perform the functionality of our PRoFIT framework. Moreover, the details of network layer and medium access control layer are encapsulated in a thin Application Interface Layer (AIL). The functional details of these layers are given to the below mentioned subsections.

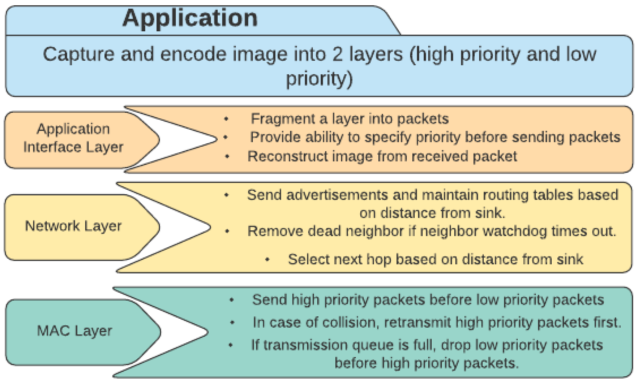

Figure 2. PRoFIT Layers

3.1. Application Interface Layer

Application Interface Layer (AIL) is the application layer of PRoFIT. It is an extremely slim layer, through which a set of primitives are provided to the VSN application. These have specific responsibilities, such as: dividing the image data into packets, forwarding and receiving them besides collecting them to re-generate image data. The AIL hides the implementation of the whole framework. With the help of the AIL, image data and its priority are passed to the routing framework by the VSN application. According to its configuration, the image data is fragmented by the AIL of the sending node into packets, which network layer can send onwards. The packet fragment number and image number are also appended by the AIL into the packets. For joining the fragments, the AIL of the sink node uses this information with an aim to construct image data.

3.2. Network Layer

Given below is the explanation of the network layer component of PRoFIT.

Network Configuration Phase

Upon introduction and deployment of the VSN, advertisements are then periodically sent by the VSN nodes to their neighbors, wherein their identities and number of hops from the sink are acknowledged. In the beginning, all nodes are arranged in a manner that they are away from the sink node. The sink node declares its number of hops from the sink as 0 after its advertisement. The respective sink node is added to their routing tables, and this action is done by the nodes receiving this advertisement. Moreover, their numbers of hops are marked from sink as one hop.

When an advertisement is released by such a node, it declares its number of hops from the sink rather than from infinity. The routing table of the nodes at multiple hops gets updated with sink address and their neighboring addresses, from which they obtain the advertisements. The neighbor with lesser hops is only maintained by the node in its routing table when it receives an advertisement of a sink from more than one neighbor.

The network is eventually established after various rounds of advertising, subject to the nodes of VSN. Each node knows the number of hops to the sink node and the next hop towards the sink node. It is possible to remove and add the nodes to the network since the system sends periodical advertisements. Furthermore, through a watchdog timer linked with every neighbor, each node follows the live neighbor, and its objective is to preserve the routing table.

Network Operation Phase

After the establishment of the network, the image data is transported from camera nodes to sink nodes, and our routing framework does this carriage. When the VSN application gets the image data, it then uses primitives offered by the AIL. The network layer chooses the next hop towards the sink, which is selected by the camera node from its routing table. The packet is dropped if the routing table does not contain the address of sink node that is specified by the camera node. Whenever a packet is received from that neighbor, a neighbor's entry keep-alive watchdog is reset. The routing table deletes the neighbor's entry, if a packet is not obtained from a neighbor within a threshold. Thus, the data transmission phase maintains the routing tables.

3.3. Medium Access and Control Layer

There are two levels of routing framework at the MAC layers. The intra-node is the first level, where it is ensured by the routing framework that the low priority packets will not be forwarded before the high priority packets. The internode level is the second level, where it is ensured by the routing framework that when there is a contest for transmission medium between two neighbors, a packet will initially be transmitted by the neighbor containing high priority as compared to the neighbor with low priority packet. These two levels are explained by the following sub-sections.

Queue Insertion

Whether or not the MAC layer is earlier sending or receiving the packet, but once it gets a packet for transmission, it is sent immediately. The packet comes in a queue and waits, if the MAC layer is busy. This queue is used by our priority-based routing. A packet with high priority is put on the head of the queue for its immediate departure. A packet is placed at the tail of the queue, if it is having low priority. It is ensured that a packet with higher priority is transmitted first at intra-node level since packets are always selected by the MAC layer from the head of the queue for transmission.

Differentiated Back-off Window

A collision is taken place, when two nodes simultaneously find and transmit the medium. As far as regular CSMA/CD is concerned, both nodes are retracted for a randomly selected time slot from a pseudo-fixed-size window. The window size is exponentially increased if collision happens again. The priority-based routing framework maintain different windows for different types of priorities.

In the event of a collision, the priority of collided packet is checked by the MAC layer, and back-off times are then determined from different windows. The window is comparatively smaller for high priority packets. Hence, the high priority packet nodes able to transmit its packet through these smaller windows as compared to low priority packet nodes. It ensures that high priority packets at the inter-node level transmit earlier than low priority packets.

4. Mobility Models

A vital attribute of VANET is "mobility." The researchers should choose a set of accurate and application-oriented mobility models to test the performance of the VANET network. Moreover, experts have suggested different mobility models that simulate real-life scenarios in the literature. Here, only four models are discussed, namely, Random Waypoint (RWPM) [20] [21], Manhattan Grid (MGM) [22], Semi-Random Circular Mobility Model (SCRM) [23] and Pursue Mobility Model (PRS) [24].

4.1. Manhattan Grid Mobility Model

As seen in Figure 3, a grid road topology is used in the Manhattan Grid (MGM) mobility model. In this particular type, the mobile nodes are either horizontally or vertically transferred on an urban map. A probable approach is highlighted by the MG model, wherein, the vehicle chooses between two choices, i.e., to move straight or to turn. This means that they can either turn on any side or go straight. An illustration of a Manhattan Grid Topology with Double-Way Roads is shown in Figure 3.

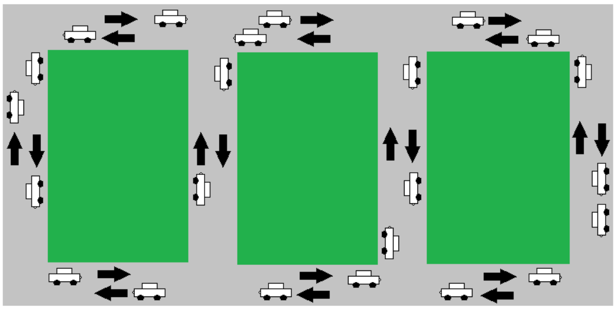

Figure 3. An Example of a Manhattan Grid Topology with Double-Way Roads

4.2. Random Waypoint Mobility Model

Random Waypoint Mobility model is a model entailing pause times prior to changing the direction and the speed of the nodes. Figure 4. shows an example of a Random Waypoint Model. The transmission of a mobile node is initiated by waiting in a location for some time period. After the wait, a random position and a speed from a certain range of minimum and maximum speed are selected by the mobile mode in the defined simulation area [20]. Subsequently, at the selected speed, the movement of mobile nodes is observed in the newly selected location in the defined area, as shown in (Figure 4). This procedure is iterated at another occasion, but before that node takes a break for a short time.

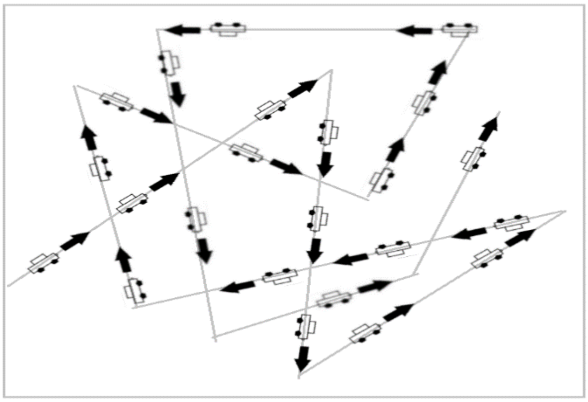

Figure 4. An Example of a Random Waypoint Mobility Model

4.3. Pursue Mobility Model

The mobile nodes chase a target in such type of mobility model, where, newer location can be determined by using the Equation 1.

$$New\ location = old\ place + random\ vector + acceleration\ [target - old\ place] \quad (1)$$

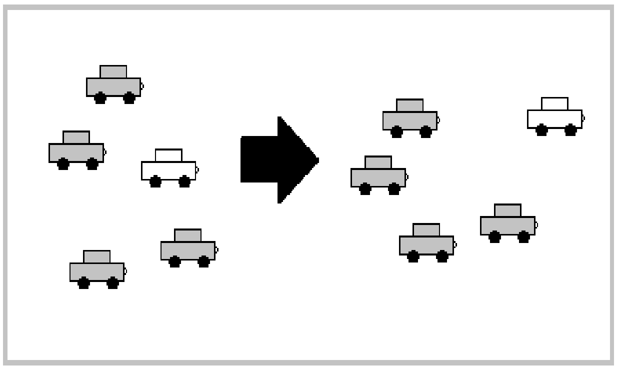

Figure 5. An Example of a Pursue Mobility Model

A random vector is a counterbalance for individually mobile node and acceleration, which is, how the mobile nodes are chasing the target, as shown in (Figure 5). The randomness degree of each node is confined to tracking.

4.4. Semi-Random Circular Movement Model [22]

The curved movement scenarios are best handled by the Semi-Random Circular Mobility Model and this model is suitable to acquire some information by turning around a specific position for replicating UAV's. Instead of Random Waypoint Mobility Model, this model has the hexagon shaped route having no predetermined plan. With respect to this model, aircrafts are held at different sites, where, the desired object is chosen by a square area.

6. Experimentation

In this work, we evaluated the usefulness of PRoFIT on a VANET. Four scenarios have been used. All scenarios consist of 25 nodes. One of them is equipped with a camera, and there is one sink in the network. Grid topology was used in the first two scenarios, whereas the latter two scenarios were run on mobile topology created using BonnMotion. Each scenario was simulated 9 times and averages of the results were extracted.

In each scenario, the camera node sent packets to the sink node over multiple hops. The image captured by the camera node was processed to extract critical information at the camera node. This information is useful for the sink node to take an efficient decision. The non-critical information was also extracted by the camera node. Therefore, for each image captured by the camera node, two types of information needed to be sent to the sink, critical data, and non-critical information.

For this work, PRoFIT was implemented on Contiki-Next-Generation (Contiki-ng) over its 6lowpan protocol stack. Cooja Network Simulator, along with its Mobility plugin, was used to simulate the movement and data collection. Simulations were run with and without PRoFIT. Packet delivery ratios and end-to-end delays were collected from simulations and compared. The effectiveness of PRoFIT in VANETs was quantified and analysis was presented.

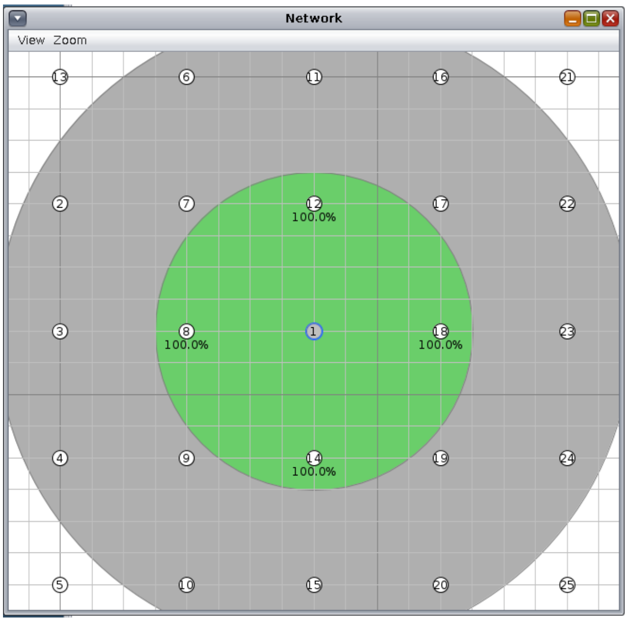

Figure 6. Grid Topology

6.1. Scenario 1: Grid Topology without PRoFIT

The first scenario consisted of all 25 nodes placed in a grid formation shown is Figure 6 above. The sink node (Node 1) was placed in the center. The camera node (Node 13) was placed at the top left corner of the grid. Each node was placed at a 40m distance from other nodes. The transmission range of the node was set to 50m, whereas the interference range was set to 100m. This is depicted in Figure 6 by the green and grey circles, respectively.

As this scenario was run without PRoFIT, it means that both the critical and non-critical information was sent at the same priority. So, here there is no differentiation between the the high and low priority packets by PRoFIT. The significant of running simulations without PRoFIT is to establish a base line.

6.2. Scenario 2: Grid Topology with PRoFIT

The second scenario consisted of all 25 nodes placed similar to the first scenario. This scenario was run with PRoFIT enabled. It means that the critical image information was sent at high priority through the network, whereas non-critical information was sent at the low priority.

6.3. Scenario 3: VANET without PRoFIT

The third scenario consisted of all 25 nodes randomly placed in 160 x 160m. As mentioned before the trajectory of the nodes had been generated with BonnMotion software using Random Waypoint Mobility Model (RWMM). The parameters used are given in Table 1.

Table 1. Bonn Motion Parameters

Parameter	Value
Number of Nodes	25
Trajectory Loop Time	400 seconds
Time Resolution	1 second
Min Pause Time	2 seconds
Max Pause Time	10 seconds
Maximum X-Coordinate	160 m
Maximum Y-Coordinate	160 m
Min Speed	1 m/s
Max Speed	2 m/s
Initial delay in mobility	60 sec
Radio Interference	100 m
Radio Reception Range	50 m

Cooja's Mobility plugin was used to provide mobility to all nodes. This scenario was run without PRoFIT to establish a baseline. The initial delay in mobility was added to allow Contiki-ng's RPL routing protocol to establish first DAG.

6.4. Scenario 4: VANET with PRoFIT

This final scenario was run with all the same parameters except for PRoFIT was enabled. This means that critical image information was sent with high priority, whereas non-critical image information was sent at low priority. As all the nodes were mobile in scenario 3 and scenario 4, the distance and number of hops between sink node and camera node kept of changing in order to depict a real-world scenario.

7. Results

Each scenario was run multiple times, and the results explained in this section are an average of all runs. For each scenario, end-to-end delays for high priority and low priority packets was collected. Also, the delivery ratio of both high priority and low priority packets was calculated at the sink. Note that all experiments were run on Contiki-NG's RPL UDP. Therefore, there were no re-transmissions or acknowledgements. This was done to evaluate PRoFIT without any optimization.

The queue length of CSMA's transmission queue is set to 16 packets. This means that when there are 16 packets waiting to be transmitted, the 17^{th} packet will be dropped if it is a lot priority packet. If the 17^{th} packet is a high priority packet and there is already a low priority packet in the queue, the low priority packet will be replaced with the high priority packet.

The radio duty cycle of CSMA is set to 16 seconds. This means that after every 16 seconds, the transmission module picks up all available packets in the queue and transmits them. This information will be useful in understanding the results.

7.1. End-to-End Delays on Grid Topology without PRoFIT

Figure 7 shows end-to-end delays of packets generated at the camera node and terminated at the sink node. Both high priority and low priority packets were sent without PRoFIT managing prioritized routing. As a result, both high priority and low priority packets have similar end-to-end delays. The x-axis shows the inter-packet interval of camera node. At packet generation interval below 16 there are more packets generated than transmitted, most of the packets must wait for their turn to be transmitted when the radio duty cycle allows. Hence, we have higher end-to-end delays. On the other hand, packet generation interval higher than 16 seconds, allows packets to be transmitted without having to wait in the transmission queue.

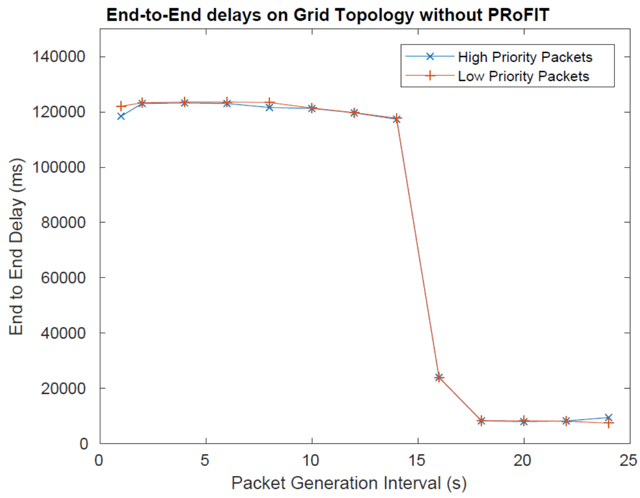

Figure 7. End-to-End Delays on Grid Topology without PRoFIT

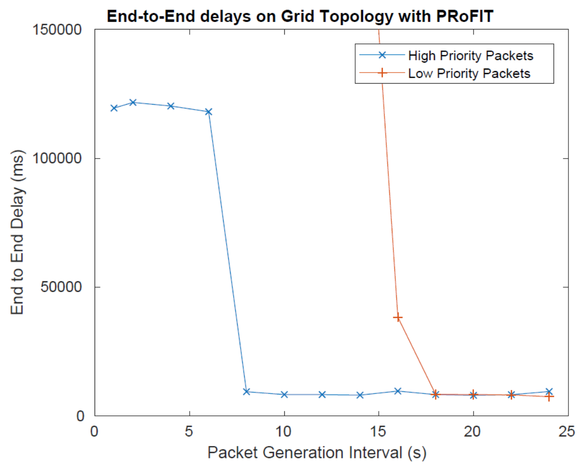

Figure 8. End-to-End Delays on Grid Topology with PRoFIT

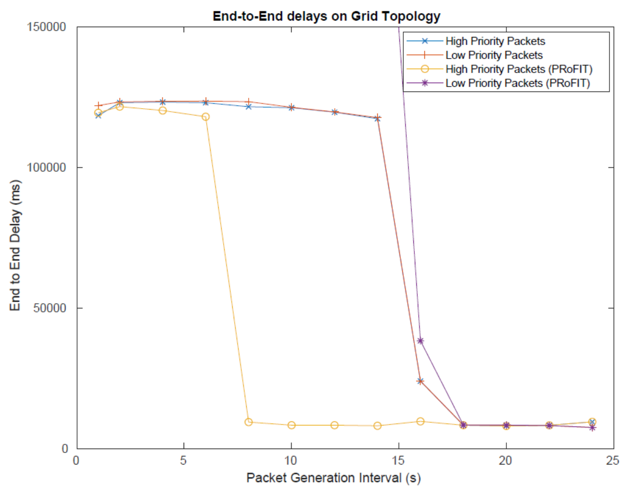

Figure 9. End-to-End Delays on Grid Topology

Therefore, the end-to-end delay of both high priority and low priority packets is minimum, which corresponds to the end-to-end delay of the entire network.

7.2. End-to-End Delays on Grid Topology with PRoFIT

Figure 8 shows end-to-end delays of packets generated at the camera node and terminated at the sink node. In this scenario, PRoFIT managed both high priority and low priority packets and different priorities when routing. As a result, high priority and low priority packets have different end-to-end delays. At higher packet generation rate i.e., low packet generation interval, only high priority packets make it to the sink. All the low priority packets had been dropped. Hence, end-to-end delay of low priority packet is infinite.

On the other hand, packet generation interval higher than 16 seconds, allows packets to be transmitted without having to wait in the transmission queue. Therefore, the end-to-end delays of both high priority and low priority packets are similar, which corresponds to the end-to-end delay of the entire network.

Figure 9 combines Figure 7 and Figure 8 for better comparison.

7.3. Delivery Ratios on Grid Topology without PRoFIT

Figure 10 shows the delivery of packets generated at camera node and terminated at sink node. As both high priority and low priority packets are sent without PRoFIT managing prioritized routing, it can be seen that the delivery ratios are similar. As a result, both high priority and low priority packets have similar end-to-end delays. The x-axis shows the inter-packet interval of camera node. At packet generation interval below 16 there are more packets generated than transmitted, most of the packets have to wait for their turn to be transmitted when the radio duty cycle allows. When the queue fills up, additional packets are dropped. Therefore, the delivery ratio is lower if packets are generated at high rate, i.e. if packet generation interval is low.

On the other hand, packet generation interval higher than 16 seconds, allows packets to be transmitted without having to be queued. Therefore, no packets are dropped. Therefore, delivery ratios of packets generated with higher inter-packet interval is 1.

7.4. Delivery Ratios on Grid Topology with PRoFIT

Figure 11 shows the delivery of packets generated at camera node and terminated at sink node. It can be seen that at high packet generation rate i.e., low packet generation interval, delivery ratio of high priority packets is higher than low priority packets. In this part of the curve, the delivery ratio is proportional to packet generation interval.

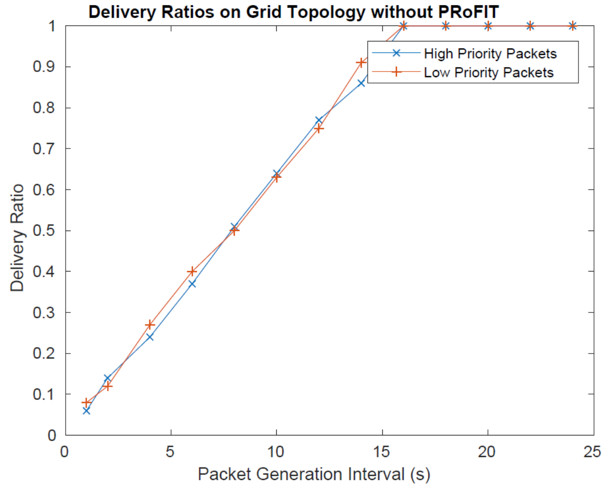

Figure 10. Delivery Ratios on Grid Topology without PRoFIT

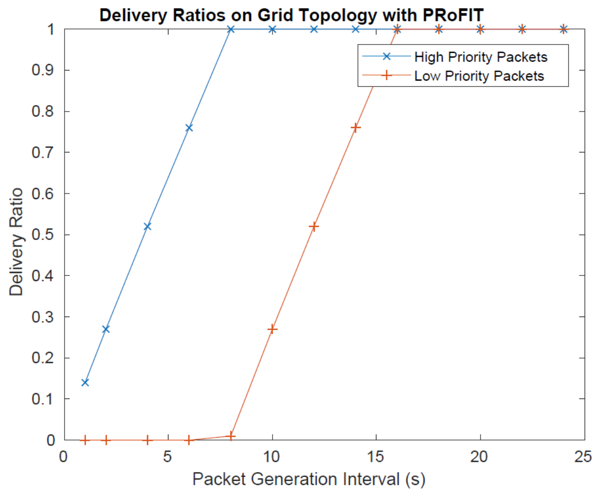

Figure 11. Delivery Ratios on Grid Topology with PRoFIT

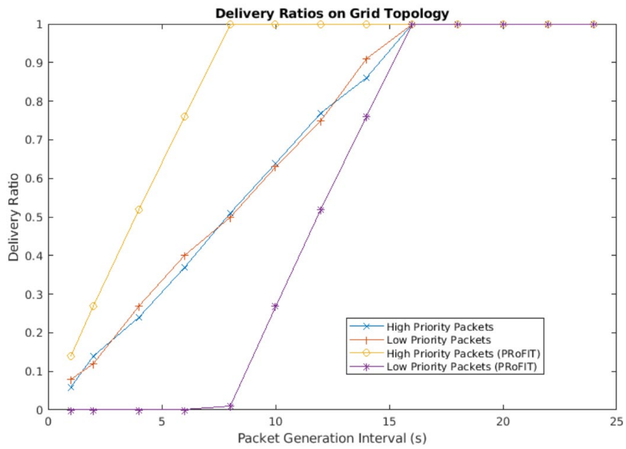

Figure 12. Delivery Ratios on Grid Topology

At about 7 seconds delay in packet generation, the low priority packet's delivery ratio starts to build up as some low priority packets get some space in the transmission queue. That means that the queue was big enough to accommodate all incoming high priority packets and still have some space for low priority packets.

Packet generation interval higher than 16 seconds, allows packets to be transmitted without having to be queued. Therefore, no packets are dropped. Therefore, delivery ratios of packets generated with higher inter-packet interval than radio duty cycling is 1.

Figure 12 combines Figure 10 and Figure 11 for better comparison.

7.5. End-to-End Delays on VANET without PRoFIT

Using Mobility plugin of Cooja, all nodes were mobile during this scenario. Figure 13 shows end-to-end delays of packets generated at the camera node and terminated at the sink node. Both high priority and low priority packets were sent without PRoFIT managing prioritized routing. As a result, both high priority and low priority packets have similar end-to-end delays. The x-axis shows the inter-packet interval of camera node. At packet generation interval below 16 there are more packets generated than transmitted, most of the packets have to wait for their turn to be transmitted when the radio duty cycle allows. Hence, we have higher end-to-end delays.

On the other hand, packet generation interval higher than 16 seconds, allows packets to be transmitted without having to wait in the transmission queue. Therefore, the end-to-end delay of both high priority and low priority packets is minimum, which corresponds to the end-to-end delay of the entire network.

It should be noted that end-to-end delays in mobile nodes are higher than static grid topology due to DAG restructuring.

7.6. End-to-End Delays on VANET with PRoFIT

Figure 14 shows end-to-end delays of packets generated at the camera node and terminated at the sink node. In this scenario, PRoFIT managed both high priority and low priority packets and different priorities when routing. As a result, high priority and low priority packets have different end-to-end delays. At higher packet generation rate i.e., low packet generation interval, only high priority packets make it to the sink. All the low priority packets had been dropped. Hence, end-to-end delay of low priority packet is infinite.

On the other hand, packet generation interval higher than 16 seconds, allows packets to be transmitted without having to wait in the transmission queue. Therefore, the end-to-end delays of both high priority and low priority packets are similar, which corresponds to the end-to-end delay of the entire network.

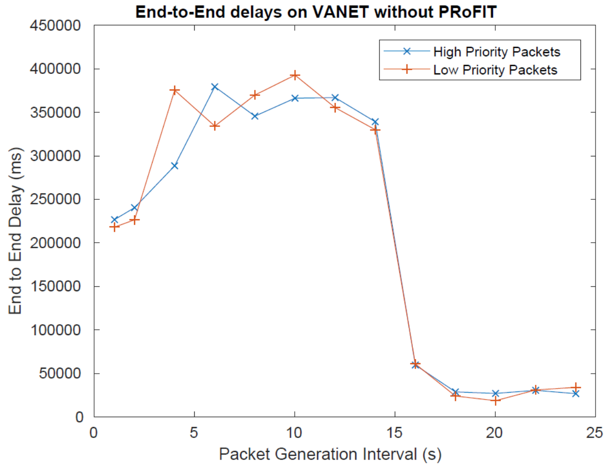

Figure 13. End-to-End Delays on VANET without PRoFIT

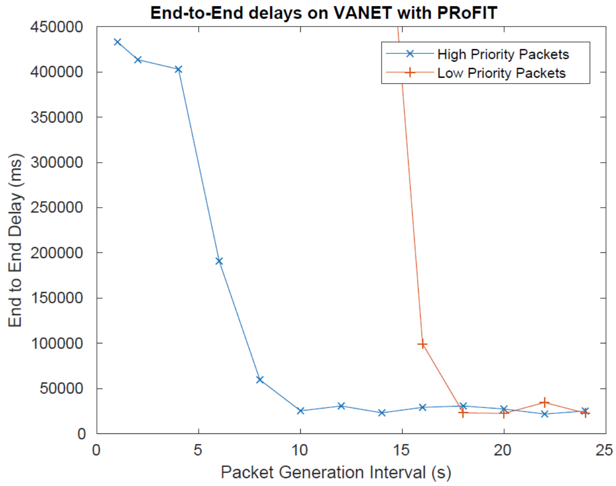

Figure 14. End-to-End Delays on VANET with PRoFIT

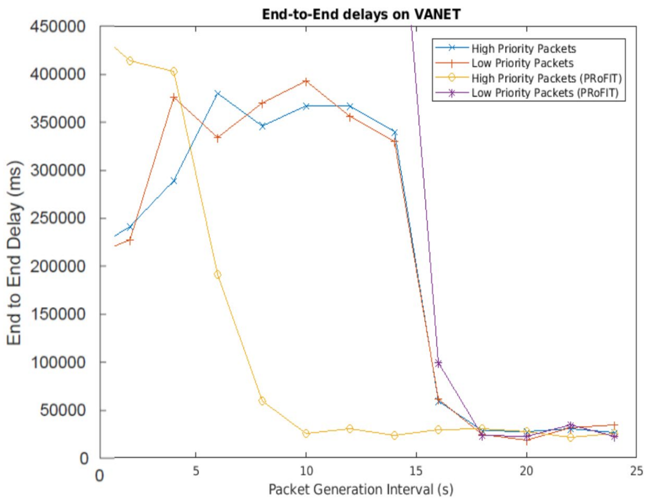

Figure 15. End-to-End Delays on VANET

It should be noted that due to mobile trajectories of nodes, average end-to-end delays are greater than those of static grid topologies.

Figure 15 combines Figure 13 and Figure 14 for comparison.

7.7. Delivery Ratios on VANET without PRoFIT

Figure 16 shows the delivery of packets generated at camera node and terminated at sink node. As both high priority and low priority packets are sent without PRoFIT managing prioritized routing, it can be seen that the delivery ratios are similar. As a result, both high priority and low priority packets have similar end-to-end delays. Transmission queue in mobile networks are dependent on availability of neighbors that have route to the sink node.

As the nodes were mobile, transmission queues fill up sooner due to non-availability of route to sink than in case of grid topology. As a result, more packets were dropped. Since PRoFIT was not active, the delivery ratios of both high and low priority packets are similar

7.8. Delivery Ratios on VANET with PRoFIT

Figure 17 shows the delivery of packets generated at camera node and terminated at sink node. It can be seen that at high packet generation rate i.e., low packet generation interval, delivery ratio of high priority packets is higher than low priority packets. In this part of the curve, the delivery ratio is proportional to packet generation interval.

At about 7 seconds delay in packet generation, the low priority packet's delivery ratio starts to build up as some low priority packets get some space in the transmission queue. That means that the queue was big enough to accommodate all incoming high priority packets and still have some space for low priority packets.

Even at packet interval greater than 16 seconds, delivery ratio is lower than grid scenarios. This is due to frequent packet drops because the transmitting node did not find a neighbor with access to the sink. At the same time, low priority packets and high priority packets have similar delivery ratio. This indicates that the packets were not dropped due to queues being full. Rather packets were dropped because forwarding node was not part of DAG.

Figure 18 combines Figure 16 and Figure 17 for comparison.

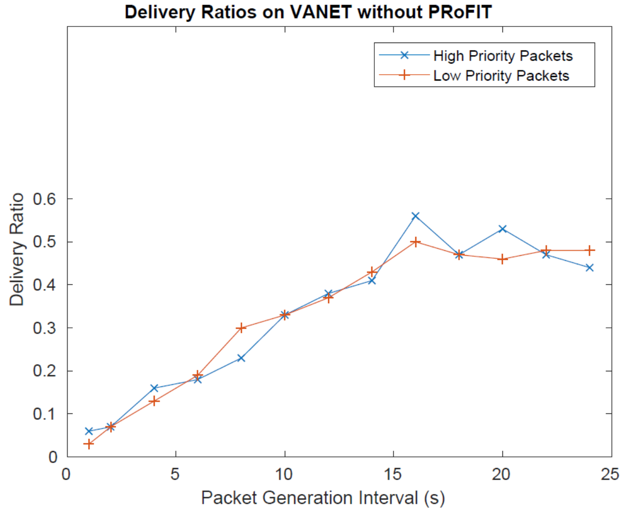

Figure 16. Delivery Ratios on VANET without PRoFIT

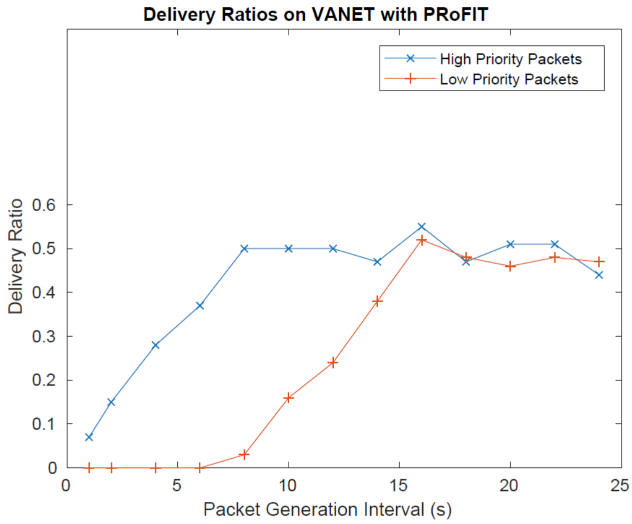

Figure 17. Delivery Ratios on VANET with PRoFIT

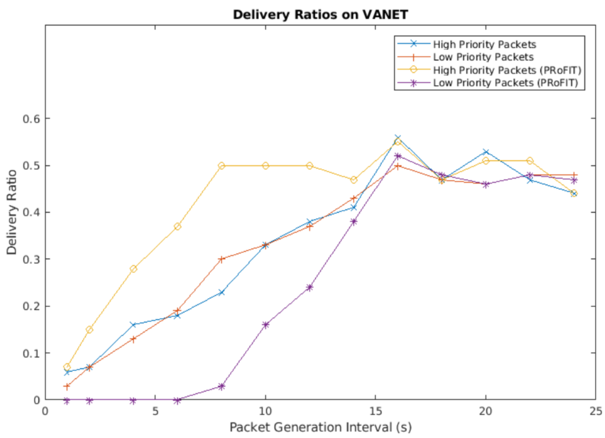

Figure 18. Delivery Ratios on VANET

8. Conclusion

In this paper we demonstrated the usefulness of priority-based routing framework for image transmission for VANETs. PRoFIT was ported on Contiki-NG's RPL and 6LoWPAN. We compared end-to-end delays and delivery ratios on grid topology network and VANET using Mobility plugin in Cooja Simulator. Results show that PRoFIT delivers packets sent at high priority with much lesser time than those sent with low priority.

The packet drop ratio of high priority packets is also much less than of low priority packets in both grid topology network and VANET. This makes PRoFIT a suitable candidate for VSN applications that require critical information to be sent to the sink node much sooner than other data.

In future, we plan to implement PRoFIT over real VANET and test it with intelligent transportation systems applications.

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