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Network Coding with MGM based Anycast Packet Transmission in Vehicular Ad-Hoc Networks

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Abstract
Mobile Ad-hoc Network routing protocols such as AODV, DSR etc. fail in scenario in which no contemporaneous path exists between source and destination because they try to find end-to-end path before data transmission which is not exist in VANET which increase delivery delay and decrease delivery ratio. So VANET uses 'store-carry-forward' paradigm. In network coding, source node or intermediate node allows to combine number of packets it has received or generated into one or several outgoing packets. Reliability is one of the issue in network coding. So we use network coding with multi generation mixing in which packets are grouped into generations and generations are grouped into mixing set. We propose Anycast routing protocol for VANET which uses 'Network coding with multi generation mixing' to improve the performace. By using simulation we compared the performance of proposed protocol in terms of delay, delivery ratio and throughput with the same protocol using network coding and using conventional scheme. Simulation results suggest, our protocol achieves significantly less delay, higher delivery ratio and higher throughput compared to network coding based scheme and conventional scheme.

Keywords
VANET, Network Coding, MGM, Anycasting

I. Introduction

VANET will form the biggest ad hoc network ever implemented, therefore issues of stability, reliability and scalability are of concern. VANET therefore is not an architectural network and not an ad hoc network but a combination of both [1], this unique characteristic combined with high speed nodes complicates the design of the network. As these networks have no fixed communication structure and may vary heavily due to which routing of data packets through VANETS is very crucial.However, due to dynamic network topology, frequent disconnected networks, varying communication conditions and hard delay constraints VANETS can be distinguished from other kinds of Adhoc networks.

There are number of different applications where the network is sparse and experiences frequent and long disconnection. As an example, consider a traffic management system in a city where vehicles are network nodes which generate and forward vehicular traffic data through other vehicles. There may never be contemporaneous path between source and destination through other vehicles. Many VANET applications need anycast service. For example, vehicle on road may send the packet requiring optimal route to destination, traffic information, weather information, gas station or restaurant location to one of the server on road side, it is necessary to transmit information from a server to a vehicle or vehicle may transmit information packet regarding accident to one of the server(ambulance or emergency service providers). However, traditional anycast methods proposed for the Internet or mobile ad hoc networks are not suitable for VANET, due to the challenge of frequent network partitions. Data transmissions suffer from large end-to-end delays along the tree because of the repeated partitions due to frequent disconnections. Also the traditional approaches may fail to deliver a message when the possibility of link unavailability becomes high. To increase chance of delivery and to reduce delivery delay, routing approaches in VANET make multiple copies of a packet in the network. However communication overhead and buffer occupancy increases as we increase number of copies per packet. If we can reduce number of copies per packet without impacting the performance, this overhead can be reduced.

Section II explains benefits of network coding with multi generation mixing. Section III discusses proposed anycasting prtocol for VANET. Section IV discusses simulation results. Conclusion and future work is given in Section V.

II. Network coding with MGM

Network Coding with Multi-Generation Mixing (MGM) is a RLNC approach which improves the performance without increasing buffer size. In MGM mixing set of size m generations can be coded together. A new set of generation packet is mixed with previously transmitted generations. Results show that MGM reduces overhead for a recovery of packets.

In MGM, N packets are grouped into generations where the size of each generation is k packets. Each generation is assigned a sequence number from 0 to N/k. In G-by-G Network coding encoding is allowed amongst packet belonging to the one generation. While in MGM generations are grouped into mixing sets where the size of mixing set is m generations. Each mixing set has an index M. Generation i belongs to mixing set with index M=i/m. Each generation in mixing set has a position index. Position index (l) of generation i in a mixing set of size m is i%m. G-by-G Network coding is a special case of MGM where m=1.

In MGM packets of different generations are encoded together. When node sends a packet belonging to generation i with position index l in mixing set, that node encode all packets that are associated with the generations of same mixing set and have the position indices less than or equal to l as shown in fig. 1 [2]. Size of encoding vector depends on the number of packets encoded together at sender node. Number of packets that are encoded together depends on the position index of the generation with which packet is associated. Packet in generation with position index l have the size of encoding vector is (l+1)k. So sender will generate (l+1)k independent packets.

In Network Coding with MGM goal is to enhance decodable rates in situation where losses prevent efficient propagation of sender packets. MGM allows the cooperative decoding among the different generations of a mixing set which enhances decodablity.

Compare to G-by-G Network coding with MGM extra encoded packets associated with generation protect more than one generation.

Computation overhead [3] is incurred at intermediate node to check the usefulness of received packets and at receiver node to decode received packets. In g-by-g Network coding computation are performed on packets within the generation so it is fixed due to fixed generation size. But in MGM encoding/decoding is performed on packets belonging to at least one generation in mixing set and so computational overhead is not fixed.

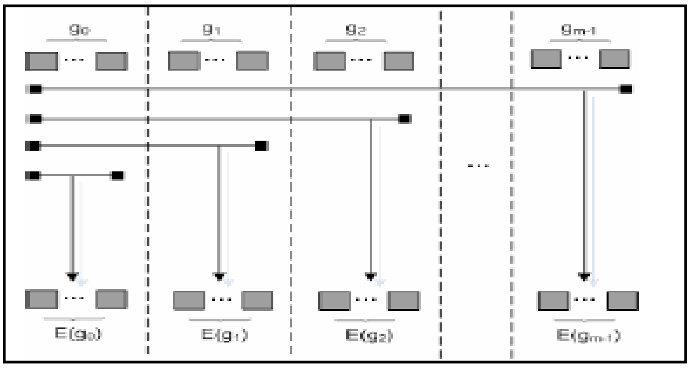

Fig. 1: Network Coding with MGM, Each Generation is Encoded With Previous Generations in Mixing Set

In MGM in case generation is unrecoverable due to the reception of insufficient encodings, it is still possible to recover that generation collectively as a subset of mixing set generations. Packets received with generation of higher position indices have information from generations of lower position indices and hence contribute in recovery of unrecovered generations of lower position indices in the same mixing set.

Redundant encoded packets enhance the reliability of communication. With MGM extra packets protects all generations with lower position indices. While in G-by-G Network coding extra packets protects that generation only.

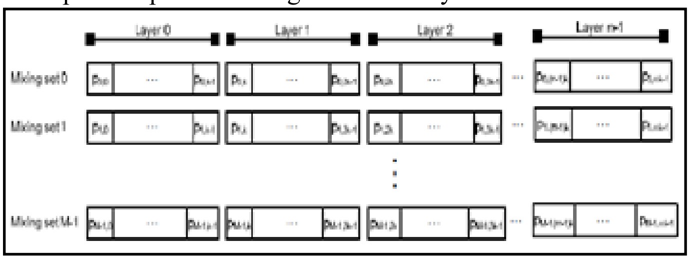

Fig. 2: Generation's Partitioning With MGM into Different Layers of Priority. Mixing Set Size is m, Generation Size is k.

In MGM there are different options for sending extra packets. One option is distribute the packets over all generations of mixing set. Another option is to send extra encodings with the last generation of mixing set. So, extra encodings protects all mixing set generations.

Enhancing reliability of communicating different groups of sender packets is QoS requirement of many applications where, there is systematic grouping of sender packets such that different groups have varying importance i.e. Scalable Video Coding (SVC), where video is encoded in layers base layer and one or more enhancement layers. MGM supports priority transmission by providing enhanced reliability for delivering different groups of sender packets. Due to the way, encoding/decoding is done in MGM; it provides different level of protection for mixing set generations. In other words different generations in mixing set can be considered as different layers of priority as shown in figure 2 [4]. Each layer has priority value depending on the generation's position index in a mixing set.

As shown in Table 1 for mixing set size m=2, overall number of useful packets received of generations g0 and g1 is greater than 2k which is sufficient for collective decoding of two generations.

Table 1 Guaranteed Delivery Conditions for the Generations of Size k Within Mixing Sets of Sizes m=1 & 2

Mixing set size	Generation position index	Condition for generation guaranteed recovery
m=1	g_0	k_0^+
m=2	g_0	k_0^+
		k_0^- , $(k_0+k_1)^+$
	g_1	k_0^+ , k_1^+
		k_0^- , $(k_0+k_1)^+$

Results in Table 2,3 and 4 shows that MGM with redundancy transmitted with the last generation of the mixing set achieves best decodable rate than distributed redundancy. At the same time MGM with distributed redundancy achieves best decodable rate than G-by-G Network coding. It has been also observed that increasing the size of mixing set improves decodable rate because it increases number of opportunities where a generation can be decoded.

Table 2: Decodable Rates (in Percentage) Achieved Over Different Generation Size of Mixing Sets of Sizes m=1 and 2 When the Redundancy is Sent With Each Generation and Redundancy is Sent With Last Packet. Packet Loss Rate is 0.1 [5]

Generation Size (k)	Distributed Redundancy			Redundancy sent with last generation		
	G_0 m=1	G_0 m=2	G_1 m=2	G_0 m=1	G_0 m=2	G_1 m=2
10	89	95	85	88.4	92	91.5
20	92	97	90	91.5	95.2	95.2
30	94	98	93	93.8	97.2	97.2
40	95.1	99	94	95.2	98.5	98.5
50	96	99.1	95.9	96.2	99	99
Average Decodable Rate	93.22	97.62	91.58	93.02	96.38	96.28

As shown in Table 2 and 3 in the case when redundancy is sent with each generation and when m=2 or 3 highest decodable rate is achieved for first generation (i.e. g0) compare to others for any generation size. It can also be observed that decodable rate is decreasing from first generation to last generation for both m=2 and 3. The reason is first generation of mixing set is protected by the second and second is protected by third and so on. Last generation in the mixing set is not protected by any other mixing set generations. So last generation (i.e. 1 or 3 for m=2 or 3 respectively) is delivered with lowest decodable rate compare to other generations of same mixing set. It can also be noted that the decodable rates achieved for the last generation of MGM, m=2 or 3 is close to that for the single generation of m=1 especially for larger generation size.

Table 3: Decodable Rates (In Percentage) Achieved Over Different Generation Size of Mixing Sets of Sizes m=1 and 3 When the Redundancy is Sent With Each Generation and Redundancy is Sent With Last Packet. Packet Loss Rate is 0.1 [5]

Generation Size (k)	Distributed Redundancy				Redundancy sent with last generation			
	G_0 m=1	G_0 m=3	G_1 m=3	G_2 m=3	G_0 m=1	G_0 m=3	G_1 m=3	G_2 m=3
10	89	97.5	89.9	83.5	88.9	94.1	92.8	93.9
20	91.9	99	94.9	89	91.8	97.3	97.3	97.3
30	93.9	99.5	97.1	92.5	93.9	98.8	98.8	98.8
40	95.7	99.9	98.2	94.5	95.2	99.5	99.5	99.5
50	96.1	100	99	96	96.5	99.8	99.8	99.8
Average Decodable Rate	93.32	99.18	95.82	91.1	93.26	97.9	97.64	97.86

When redundancy is sent with the last generation in the mixing set, very close decodable rates are achieved for each generations (i.e. g_0,g_1 for m=2 and g_0,g_1 and g_2 for m=3) compare to the case of distributed redundancy. At the same time the decodable rates achieved with MGM is higher than that achieved with traditional generation based Network Coding (m=1). By sending redundancy with the last generation in the mixing set, redundant packets protect all mixing set generations and hence the overall mixing set decodable rate is enhanced. At the same time in this scenario there is no prioritization among the mixing set generations.

There is an advantage in sending redundancy with the last generation in the mixing set but it will be on the cost of not supporting the priority transmission and increasing the delay for generation recovery. The increase in the delay of generation recovery is simply because an unrecovered generation with lower position index needs to wait for sufficient number of encodings that most likely will be received with the last generation in the mixing set.

Table 4: Average Decodable Rates (in Percentage) Achieved Over Different Packet Loss Rates. Mixing Sets Sizes m=1, 2 and 3 [5]

Packet loss rate	m=1	Distributed Redundancy		Redundancy sent with last generation	
		m=2	m=3	**m=2**	**m=3**
0.08	97	98	97.5	99	99.5
0.1	93	95	95.1	96	98
0.12	83	84	84.9	86	88
0.14	77.5	78	78.1	80	83

Table 2 and 3 also shows the average decodable rates for generations in mixing sets of sizes m=1, 2 and 3. There is an improvement in decodable rate when increasing the mixing set size for both the case distributed redundancy and redundancy sent with last generation.

As shown in Table 4 for different packet loss rate, achievable average decodable rate is higher for MGM compared to G-by-G Network Coding (m=1). For both scenario distribute redundancy and redundancy sent with last generation average decodable rate is close to each other for m=2 and 3. But compare to distributed redundancy scenario, average decodable rate is high for the scenario where redundancy is sent with last generation.

MGM can be applied in networks communicating scalable video contents [6]. By applying MGM on scalable video the goal is to prioritize the transmission of video layers to improve decodable rates and hence enhance recovered video quality.

III. Anycasting Protocol for VANET

In this section, we describe working of our protocol. Data packets are grouped into generations and generations are grouped into mixing set. Nodes store independent packets along with their coefficients according to RLNC scheme.

Below is the Pseudocode for Anycasting Protocol.

```
sendproc(packet)
   - call encoding(packet)
for each encoded packets generated by encoding()
   - create a packet
   - set des_id to Grp_id (G(A))
   - send packet when neighbor comes in contact
end for
end sendproc
```

```
recvproc(packet)
   if received packet is redundant discard the    packet
  else
  if des_id of incoming packet belongs to G(A)
      - store packet in buffer
      - call calc_rank(M)
      - call decoding(packet) if rank is sufficient
      - create anti packet with des_id=src_id of
        received packet and Grp_id=G(A)
      - call sendproc(anti packet)
else
      - call forwardproc(packet)
end if
end if
end recvproc
```

IV. Simulation Results

We have simulated the proposed protocol in NS2 simulator. The network contains 20 to 40 wireless nodes which move Randomly. The average speed of a node is 30 m/s. The communication range of a node is 100 m. Meeting rate is changed by varying field area of the network. There are 3 to 11 randomly placed sink nodes. Source node is sending packets to one of the sink node and sink node is sending anti packet of each received encoded packets. For network coding with multi generation mixing, packets are grouped in the generations and various generations are grouped into mixing sets. For encoding of packets coefficients are chosen randomly and addition and multiplication operations are done over the finite field.

Our performance parameter of interest are packet delivery ratio, delivery delay and throughput. The protocol parameters are Mixing Set Size (MSS) and Generation Size (GenSize). The network parameter of interest is meeting rate. We compare our protocol with the protocol using network coding and the protocol using conventional scheme. We have simulated the protocol by setting MSS=1 and GenSize = 1 in our protocol, which effectively disables the network coding, we will call it 'conventional scheme', by setting MSS=1 and varying GenSize, which disables network coding with multi generation mixing, we will call it `network coding'. We also compare packet delivery ratio, delivery delay and throughput of conventional scheme, protocol using network coding and our protocol with different meeting rate.

Once average speed of the nodes in the network achieves steady state, source node generate given number of data packets which are grouped into generations and generations are grouped into mixing sets. Number of mixing set and number of generations in each mixing set depend on size of MSS and GenSize. We run the simulation to measure block delivery delay for suffcient time period such that all the mixing sets are received by intended destination node from group of sink nodes. Anti-packets are generated for each received encoded packet.

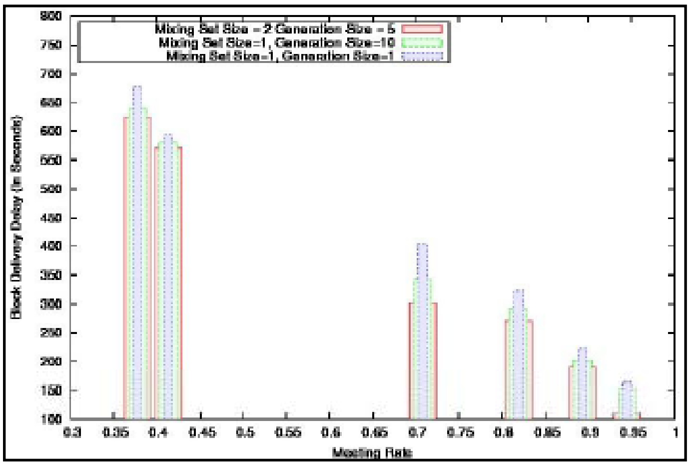

Fig. 3: Block Delivery Delay v/s Meeting Rate

We observe that for lower meeting rate the chances of meeting a node with other node decrease and hence number of packets to be forwarded by a node is less. As shown in fig. 3 as meeting rate increase delay to deliver all sufficient packets of particular mixing set is decrease for all three cases. We also compare the delay of our protocol when using network coding with MGM with our protocol when using network coding and conventional scheme. As shown in figure 3 network coding with MGM is taking less delay to deliver packets of particular mixing set compare to other two schemes.

Fig. 4 shows delay to deliver sufficient packets of particular mixing set with respect to Mixing Set Size for different Generation Size and meeting rate = 0.708. As evident from figure, with increase in mixing set size delay decreases significantly for different generation size. The reason behind this is as mixing set size is increase with increase in generation size more number of packets are mixed with each other as we have discussed earlier, and probability of delivering some of that packets increased. Compare to other two schemes block delivery delay in protocol with network coding with MGM is less.

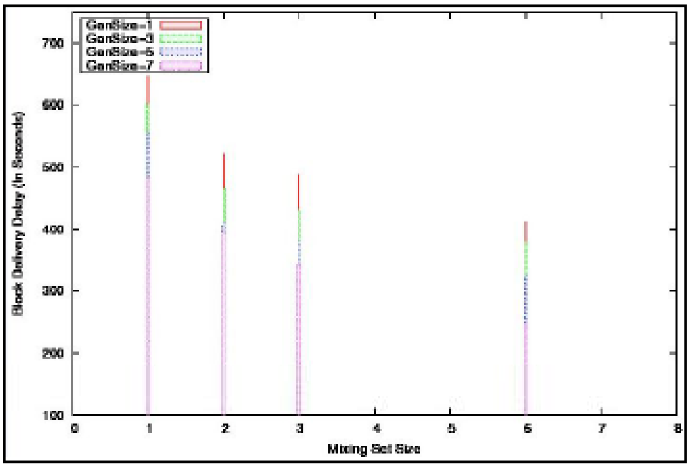

Fig. 4: Block Delivery Delay v/s Mixing Set Size

We also vary the number of sink nodes from 3 to 11 and placed them randomly. We measure the packet delivery ratio for different number of sink nodes for highermeeting rate as shown in fig. 5. As the number of sink nodes increase probability of delivering packets to any one node from all sink node increase. After delivery destination node can collect the encoded packets from any other node and hence destination node is receiving more number of packets. So packet delivery ratio increased for higher number of nodes. Protocol using network coding with MGM outperforms other two schemes.

As previously we have discussed as meeting rate increase probability of delivering more number packets increase. As shown in graph in figure 6 as meeting rate is increased average number of packets are delivered is more in all three cases. But compare to protocol using conventional scheme and protocol using network coding gain in delivery is more in the case of protocol using network coding with MGM.

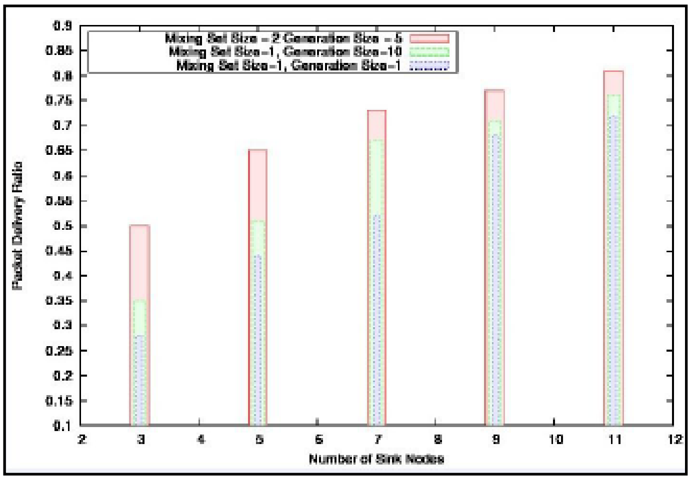

Fig. 5: Packet Delivery Ratio v/s Number of Sink Nodes

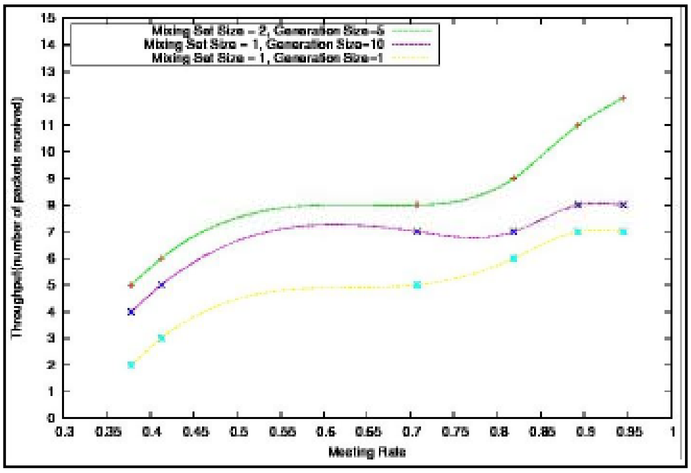

Fig. 6: Throughput v/s Meeting Rate

As shown in fig. 7, once the network reaches steady state, gain in successful delivery of packets of our protocol compared to other two schemes is higher. Please note that the result is for meeting rate = 0.945. The reason for this behavior is as follows:As in the case of network coding with MGM, packets of current generation are mixed with the packets of all previous generation of particular mixing set. So as we have previously discusses average decidable rate is high in the case of protocol using network coding with MGM compare to protocol using other two schemes. Also in network coding the successful reception of information does not depend on receiving specific packets but on receiving sufficient number of independent packets. Probability of the same is high in the case of protocol using network coding with MGM.

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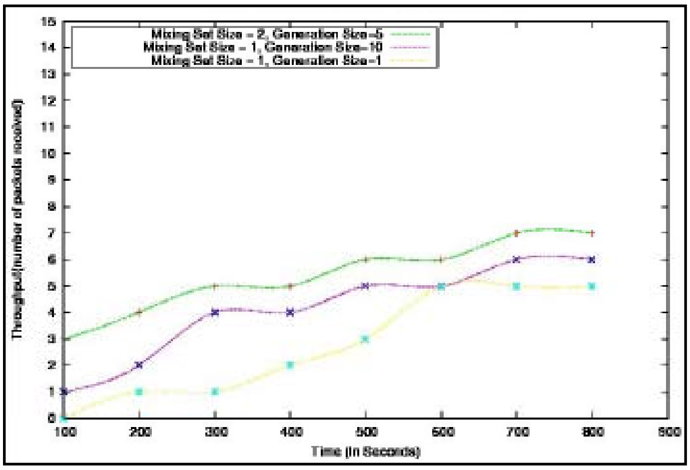

Fig. 7: Throughput v/s Time

V. Conclusion and Future Work

Due to dynamic network topology and frequent disconnected networks, VANET requires different routing strategy than other Ad-Hoc networks. Many VANET applications need anycast service. To improve reliability without impacting performance, we used network coding with multi generation mixing.Simulation results prove that the protocol reduces delay to deliver sufficient packets required to decode the mixing set or particular generation in mixing set. The protocol outperforms conventional scheme and scheme using network coding for delivery ratio greater than 10% to 15% and 20% to 25% respectively. Improvement of the protocol over conventional scheme and scheme using network coding has been observed for delivery ratio as number of sink nodes increase. Compare to conventional scheme and scheme using network coding throughput is high in our protocol.

We found protocol using network coding with multi generation mixing outperforms conventional scheme and scheme using network coding in terms of delivery delay, delivery ratio and throughput. In the case of finite buffer to utilize buffer efficiently we intend to introduce purging scheme. To improve chance of delivery, we intend to use multi copy scheme but in this case to control the number of copies and to improve efficiency in terms of buffer and bandwidth (energy) usage we use mechanism like binary Spray and Wait as suggested in[12]. We intend to find optimal mixing set size and generation size as a function of meeting rate, delivery delay and delivery ratio empirically and analytically.

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