Analysis of End-to-End Delay in Vehicular Networks

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Abstract: ***Vehicular Ad Hoc Network (VANET) is a sub class of mobile ad hoc net-works. Currently, car to car communication is a very demanding area of research because of the numerous application possibilities for driver safety and comfort. The earlier VANET models discussed only the communication among vehicles through the RSU used for low network density. Most of the researchers used standard 802.11 for VANET model considering the mobile nodes of the city environments when network density demands. Without using the RSUs, each vehicle in the network is treated as a router to communicate with the neighbouring vehicles. The performance of communication entirely depends on how better the routing takes place in the network. Routing of data always depends on the routing protocols being used in network. An effective routing protocol for vehicular ad-hoc networks (VANETs) should have decent performance regardless of the status of the network. When the network is sparse, routing protocol should work in a way to increase chances of delivery. On the other side, when network density leads to uninterrupted connection, routing protocol should always choose a policy to minimize delivery delay. I have to create a network which should be reliable secure and fast. Reliable by using back off counter, secure by using AES algorithm and fast by using increasing the transmission power at the time of low signal strength. Packet Delivery Ratio, End To End delay, Through Put and packet drop are the metrics used for performance analysis of MIN forwarding strategy with VADD protocol.***

Keywords: VANET, MIN, RSU, MAC, IVD, VADD

1. Introduction

With advances in electronics and wireless communications, intelligent transportation systems (ITS), composed of a network of connected vehicles, which are also known as vehicular networks, are now, more than ever, close to reality. The U.S. Federal Communications Commission has allocated 75 MHz of bandwidth within the 5.8–5.9-GHz frequency spectrum for dedicated short-range communication specifically for use in ITS [1]. The main motivation behind ITS is improving the safety of drivers and passengers on the road, although several non safety applications have been also proposed [2]. Both safety and non safety applications provide different services to drivers , passengers, and transportation authorities. Internet access is one of the emerging topics in vehicular networks, and it has been shown that different data demands require different infrastructure ranging from road side units (RSUs) for high data rates to the cellular network's base stations for low traffic rates [3].

ITS' goals and services can be achieved through fast and reliable information dissemination in vehicular networks [4], [5]. This is even more critical in safety-related applications such as accident and emergency brake notifications. Modelling the information dissemination in vehicular networks guides us in the designing of different parameters involved in this process, such as delay threshold and transmission power. We can extract bounds on delivery delay or the relationship between delay and reliability in message propagation. If network designers have a good model that closely follows the behaviour of the network, they can tune the parameters such as the transmission power, slot time, and back-off time accordingly to get the fastest while most reliable forwarding (scheduling/routing) policy. One of the main ingredients in many data dissemination schemes for vehicular networks is frequent broadcasting of the location by each car. However, this broadcasting could result in broadcast storm problem [6]; thus, the delay is hugely increased, and resources are wasted. There are two main reasons for an unsuccessful transmission, i.e., bad channel conditions and collisions with other transmissions. We have already studied the effect of channel conditions [5]. In this paper and as our first contribution, we study and describe the effect of the medium access control (MAC) layer, including the contention and the collision on the delivery delay. Studying traffic traces suggests that cars, particularly on highways, tend to form disconnected groups [7]. In other words, if one could look at the highways from above, they would see some islands of grouped cars. All cars in a group are wirelessly connected, and they can communicate with each other. A message in a vehicular network propagates only in two cases:

1) when vehicles are close enough to each other, in which case the message is transmitted hop by hop (within each is land of cars aforementioned); and

2) when the distance between two successive vehicles is larger than a vehicle's transmission range rt, in which case the last car carries the message until it finds a neighbour in its range. As our second contribution and by means of extensive simulations, we show the common hypothesis in the literature based on which the intervehicle distances (IVDs) are assumed to follow an exponential distribution with the same parameter [8]–[9] is incorrect. This is an interesting observation not noticed previously by researchers, which hugely affects the message delivery delay modeling. Only when different distributions for IVDs are considered for two cases aforementioned, the delay model can follow the actual delay. This observation is addressed by proposing a new two-part model for IVDs, which better represents the dynamics of

vehicular networks indifferent cases. Our third contribution consists of a Markov model for information dissemination in vehicular networks followed by a mathematical model for calculating the total delivery delay. To the best of our knowledge, this is the first delay model that both captures physical (presented in [5]) and MAC layers characteristics and addresses the partitioning problem. The results of this model can be used by urban traffic designers to enhance the traffic conditions and safety level in a city.

Finally, we run an extensive set of simulations to validate the effectiveness of the proposed model. Simulation results also showcase the performance of the proposed information forwarding mechanism [i.e., Middle Is Next (MIN)] with VADD protocol.

2. Proposed System

2.1 VANET system architecture

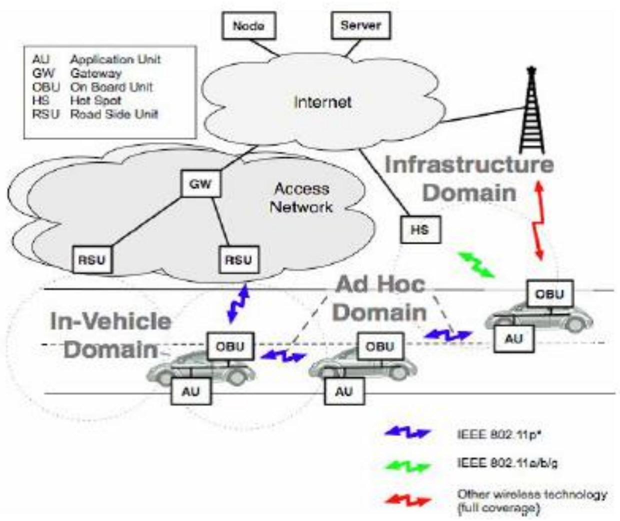

Figure 1: Wireless Technologies for V2V and V2I communications

The network will be reliable by using back-off counter. The back-off counter will work as that all the transmitter's neighbors that successfully received the message set a value for their back off counters and start counting down. The neighbor with the smallest BCi reaches zero first, and it starts transmitting when other neighbors stop counting. This is an effective way to alleviate contention and eliminate collisions without sacrificing delay. For a given transmitter i, MIN always tries to select the car closest to the middle of i's transmission range rt/2 as the next transmitter. If there are two cars on both sides of $z_i = r_t/2$ and with the same distance from it, MIN picks the farther vehicle (from *i*) to improve the delay. This decision is made in the receiver vehicle as it can easily determine whether it is located before or after the midpoint (using its location, the transmitter's location, and the transmission range).

MIN can be used as a sub layer for the MAC layer to have faster and more reliable message delivery in vehicular networks. As our model is complete, we are working on the security/privacy issue in vehicular networks and how our mathematical model can be utilized to propose a safe and secure information dissemination scheme for such networks. Here we are using AES algorithm for security It supersedes the Data Encryption Standard (DES), which was published in 1977. The algorithm described by AES is a symmetric-key algorithm, meaning the same key is used for both encrypting and decrypting the data.

AES comprises three block ciphers, AES-128, AES-192 and AES-256. Each cipher encrypts and decrypts data in blocks of 128 bits using cryptographic keys of 128-, 192- and 256-bits, respectively. (Rijndael was designed to handle additional block sizes and key lengths, but the functionality was not adopted in AES.) Symmetric or secret-key ciphers use the same key for encrypting and decrypting, so both the sender and the receiver must know and use the same secret key. All key lengths are deemed sufficient to protect classified information up to the "Secret" level with "Top Secret" information requiring either 192- or 256-bit key lengths. There are 10 rounds for 128-bit keys, 12 rounds for 192-bit keys, and 14 rounds for 256-bit keys -- a round consists of several processing steps that include substitution, transposition and mixing of the input plaintext and transform it into the final output of ciphertext.

The network will be fast by using increasing the transmission power at the time of low signal strength. The delay model presented in this paper can be used by network designers to tune important parameters such as transmission power, back-off duration. For example, if the network is sparse, i.e., for small values of λs, which means that the message is usually in the carry state, *delayC* and, consequently, *delayT* become very large. This is a sign that tells the network designer to increase the transmission power to have a higher transmission range. Similarly, if the value of *BCi* is big, it increases *delayF* and, consequently, *delayT* , in which case the network designer should try to set MAC layer parameters in a way that the average value of the back-off counter is reduced.

2.2 Mathematical Analysis

Table 1: Notation Definition

Notation	*Definition*
BCi	Back-off counter of car i
$\overline{BC}$	Average back-off counter
$\overline{delayC}$	Delay in Carry state
$\overline{delayF}$	Delay in forward state
$\overline{delayT}$	Total average delivery delay
k_{min}	Minimum required number of transmissions to achieve P_{min}
λ_s	Exponential distribution parameter for X
r_t	Transmission range
X	Inter vehicle distance
Z_i	Distance of car i from transmitter

Problem Description

Let MIN denote the proposed forwarding policy

In MIN, a given car i after receiving a message successfully sets a back-off counter of BCi defined as

$$BC_i = \left\lfloor e^{\frac{\left(\lambda_s\left(z_i - \frac{r_t}{2}\right)\right)^2}{2}} \right\rfloor$$

where
zi is the distance of car i i.e. receiver and transmitter
rt is the transmission range
λ_s is the exponential distribution parameter for X.
X is the inter-vehicle distance.

Studying traffic traces, particularly on highways, shows that vehicles tend to form isolated islands [7]. This means that the delay model captures only part of total message delivery delay, and we also need to address the other part. A message in a vehicular network propagates only in two ways: 1) forward phase, when vehicles are close enough, in which case they transmit the message to each other; and 2) carry phase, when the distance between two successive vehicles is larger than each vehicle's transmission range, i.e., rt, and the message is carried by the last vehicle until it finds another vehicle in its range. Since the speed of message dissemination in each of these cases is dramatically different, one solution is to calculate the delay in each phase and then add them together to get the total delay.

Then, the average total delivery delay delayT can be expressed as a function of delayF and delayC as follows:
delayT = (πF × delayF + πC × delayC) × E[Rd]min

where πF and πC are

$$\begin{cases} \pi_F = \frac{1+r_t\lambda_1}{2+r_t\lambda_1} \\ \pi_C = \frac{1}{2+r_t\lambda_1}. \end{cases}$$

delayF = kmin × BC × Ts and delay C = (1/λ2)/V , with V being the average speed of vehicles.

3. Simulation Metrics used

The following metrics are used in this paper for the analysis of MIN forwarding strategy with VADD protocol.

3.1 Packet Delivery Ratio (PDR)

Packet delivery ratio is the ratio of number of packets received at the destination to the number of packets sent from the source. The performance is better when packet delivery ratio is high.

3.2 Average End to End Delay (Avg. E2E Delay)

End-to-end delay is the time taken by a packet to route through the network from a source to its destination. The average end-to-end delay can be obtained computing the mean of end-to-end delay of all successfully delivered messages. Therefore, end–to-end delay partially depends on the packet delivery ratio. As the distance between source and destination increases, the probability of packet drop increases. The average end-to-end delay includes all possible delays in the network i.e. buffering route discovery latency, retransmission delays at the MAC, and propagation and transmission delay.

3.3 Throughput

Throughput is the average no of successfully delivered data packets on a communication network. Throughput is calculated in bytes/sec or data packets per second

3.4 Packet Drop

Packet drop shows total no of data packets that could not reach destination successfully.

4. Result

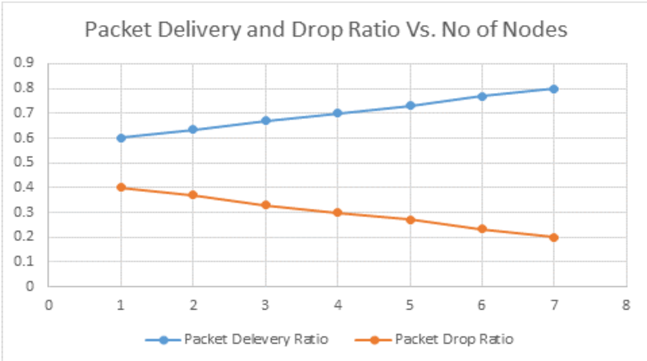

Figure 2: PDR and Drop ratio for MIN forwarding strategy with VADD protocol

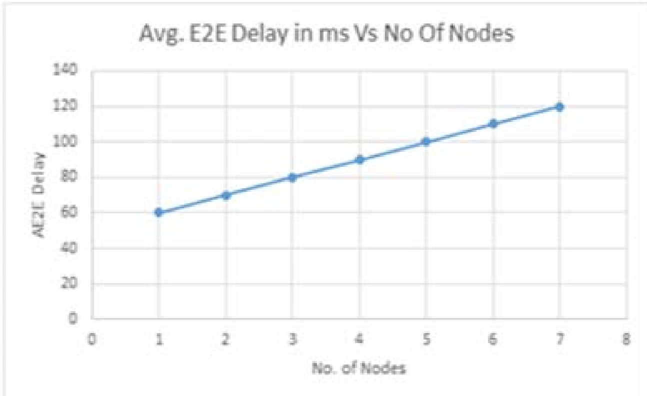

Figure 3: AE2E Delay for MIN forwarding strategy with VADD protocol

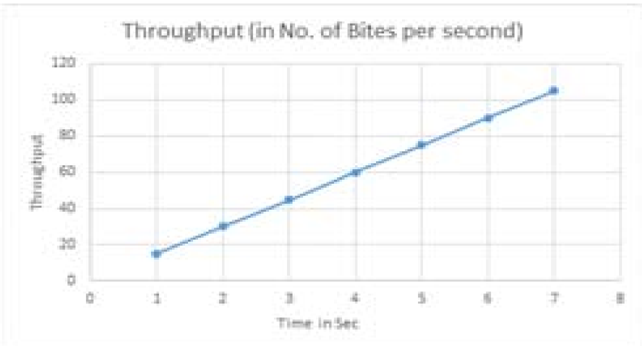

Figure 4: Throughput for MIN forwarding policy with VADD protocol.

5. Conclusion

- The proposed mathematical model for delivery delay in vehicular networks modeling the MAC layer part of delay and then including this into a Markov chain.
- This is the first delay model that both captures physical and MAC layers' characteristics and addresses the partitioning problem.
- The proposed model can be used by network architects to tune the parameters such as the transmission power, slot time, and back-off duration accordingly to achieve the fastest yet most reliable forwarding (scheduling/routing) policy and the network will be secure by using AES algorithm.

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Author Profile

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