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Highway Traffic Maintenance Using Broadcasting Protocol of VANET in Bangladesh

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ABSTRACT

Traffic maintenance in highway using broadcasting protocol in Bangladesh is a new theme. It is important to find a reliable broadcasting protocol that is especially designed for an optimum performance of public-safety and data travelling related applications. Using RSU and OBU, there are four novel ideas presented in this research work, namely choosing the nearest following node as the network probe node, headway-based segmentation, non-uniform segmentation and application adaptive. The integration of these ideas results in a protocol that possesses minimum latency, minimum probability of collision in the acknowledgment messages and unique robustness at different speeds and traffic volumes.

Keywords: *Vehicular Ad-Hoc Network (VANET), Broadcasting Protocol, Ad-Hoc Networking, Road Side Unit (RSU), On Board Unit (OBU), Latency, Probability of Collision, Semi-Poisson distribution.*

1. INTRODUCTION

Bangladesh is a country in South Asia with 150 million inhabitants. It has total length of road under the Roads and Highways Department around 7699.94 kilometres (Wikipedia, 2011). It is estimated that mechanized road transport carry about 70% of the country's total passenger and cargo volume. Its contribution of GDP (Gross Domestic Product) is 6.95%. According to police, road accidents claims 4000 lives and injure 5000 per year. But according to WHO (2009), the actual fatalities could well be 20038 per year. About 70% road accidents fatalities occur in rural area and 50% of them occurred on national and regional highways [1].

A VANET is a technology that uses moving cars as nodes in a network to create a mobile network. VANET turns every participating car into a wireless router or node, allowing cars approximately 100 to 300 meters of each other to connect and in turn create a network with a wide range. As cars fall out of the signal range and drop out of the network, other cars can join in connecting vehicles to one another so that a mobile Internet is created which can be operated without the need for a fixed infrastructure. Such a topology is suitable for rapid deployment of a wireless network i.e. VANET [2].

Broadcasting refers to a method of transferring a message to all recipients simultaneously. It is a method where a single node transfers message and all other nodes receive it within range. When a broadcast occurs, the broadcasting node can't receive any data unless it stops broadcasting.

Wireless ad hoc networks have special characteristics related to node mobility, node self-configuration and the lack of centralized access points (APs) [3]. Each car can behave as OBU that is as node and we can also have RSU. Thus the number of vehicles is never zero on highway in Bangladesh. And no other technology is possible in this regard. This topology will fasten the rate of deployment as the industry will not wait for the infrastructure to be built. Besides, it will offer the service at no charge.

The research work contribution is a novel reliable broadcasting protocol that is especially designed for an optimum performance of public-safety related applications. It can be used in Bangladesh with some modification of four novel ideas of broadcasting protocol, namely choosing the nearest following node as the network probe node, headway-based segmentation, non-uniform segmentation and application adaptive.

It is very important for a populated country like Bangladesh because accidents are very much common here and many people dies. Thus a lot of lives can be saved through proper utilization of VANET features and a lot of money also.

2. METHODS

2.1 Basic Algorithm

The Smart Broadcasting Protocol seeks the best performance as a dissemination protocol. It elects the furthest node to relay the broadcast it its followers. The election methodology is by logically dividing the transmission range into a number of adjacent and non-overlapping equal segments. The node located in the furthest non-empty segment should reply with a CTB (Clear to Broadcast) message containing its identity and prepare itself to be the relay node for the incoming broadcast [3].

On receiving of an RTB (Ready to Broadcast) message, every node in the message propagation direction should perform these steps:

- Find the segment number (based on its distance from the transmitting node).
- Choose a random back off period within the contention window assigned to its segment (assuming a contention window size of (4)).
- On receiving of a valid CTB, exit the contention phase.

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- On receiving of a colliding CTB messages, hold its countdown timer until the end of collision.
- On the end of its countdown timer, send a CTB message.

In this algorithm, decisions of the receiving node depend solely on information from the RTB message and GPS (Global Positioning System) device without using any prior information. The Smart Broadcasting Protocol assumes dividing the transmission area into ten segments.

2.2 Headway Based Segmentation

Time headway or headway for short (Figure 1) is the time interval between two vehicles passing a point as measured from the front bumper to the front bumper. The headway is the in-between distance divided by the following vehicle's speed. It may be of different meter lengths corresponding to different speeds, with a minimum length of 4m, which is the average length of a Toyota car [2].

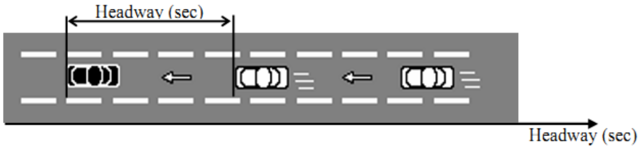

Figure 1: Headway

The only change we will introduce in this step is how the following vehicles will calculate the segment number; assuming that the communication range is divided into (10) segments, each is only of one second.

1. Get the source vehicle location (l_s) from the RTB message
2. With the receiving vehicle current location (l_r) and speed (s), calculate the Headway (H) with this very simple equation

$$H = \frac{l_s - l_r}{s} \tag{1}$$

3. The segment number is the headway rounded to +∞.

The probability density function (pdf) of the Semi-Poisson distribution () is recalled here;

$$f(t \mid p,\beta,\alpha,\theta) = p\frac{(\beta * t)^{\alpha-1}}{\Gamma(\alpha)}\beta * e^{-\beta * t} + (1-p)\frac{\gamma(\beta,\alpha * t)}{\Gamma(\beta)}(1+\frac{\theta}{\alpha})^{\beta} * \theta * e^{-\theta * t}$$
$$t > 0; \beta,\alpha,\theta \geq 0; 0 \leq p \leq 1 \tag{2}$$

Where, Γ is the Gamma Function and γ is the Incomplete Gamma Function. Parameters p and θ changes according to the desired traffic volume. However, the parameters β and α do not correlated with the traffic volume. Parameters chosen are considered at the traffic volume of 500 vehicles/h and 1500 vehicles/h approximately [3].

Using MATLAB commercial program, a simple program was developed to compute the Semi-Poisson equation and to perform the minimization process as indicated above for different number of segments ranging from (4) to (10) segments. The best points of segmentation are listed in Table 1 and Table 2.

Table 1: Best Segmentation Points for 500 vehicles/h (in headway sec)

10-seg	[1.02	1.75	2.52	3.35	4.26	5.27	6.36	7.52	8.75	10.00]
9-seg	[1.13	1.94	2.80	3.74	4.80	5.97	7.23	8.57	10.00]	
8-seg	[1.27	2.18	3.16	4.26	5.52	6.91	8.41	10.00]		
7-seg	[1.43	2.46	3.59	4.91	6.43	8.12	10.00]			
6-seg	[1.63	2.82	4.18	5.84	7.77	10.00]				
5-seg	[1.88	3.29	5.04	7.28	10.00]					
4-seg	[2.18	3.92	6.43	10.00]						

We note that the width of each segment is monotonically increasing as indicated earlier with an upper bound to 10 sec. In Table 1, the width of each segment is {1.19-1.36-1.66-1.93-2.23} for (6) segments. Using the above results, the probability of collision is computed using equation (2).

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Table 2: Best Segmentation Points for 1500 vehicles/h (in headway sec)

10-seg	[1.18	1.95	2.74	3.57	4.45	5.42	6.47	7.58	8.74	10.00]
9-seg	[1.30	2.15	3.03	3.96	4.97	6.10	7.32	8.61	10.00]	
8-seg	[1.45	2.40	3.40	4.47	5.68	7.03	8.48	10.00]		
7-seg	[1.62	2.70	3.84	5.11	6.60	8.25	10.00]			
6-seg	[1.82	3.05	4.38	5.97	7.86	10.00]				
5-seg	[2.07	3.51	5.16	7.33	10.00]					
4-seg	[2.38	4.11	6.43	10.00]						

In Table 2, for a traffic volume of 1500 vehicles/h, we have implemented the same simulation program using in the similar segmentation Table 1. We have compared the performances of Table 1 with Table 2. We have seen in our research work that the protocol that we are using is very suitable to implement and safe.

2.3 Proposed Algorithm of the Transmitting Node

In case of an OBU has a message to broadcast, the MAC layer of the system has to proceed with the following (Figure 2)

1. It sends an RTB message including its MAC address, current location, current speed, message propagation direction and the mode of operation.
2. It waits for a valid CTB message within SIFS (Short Inter-frame Space)+N+1time-slots (assuming N segments). If it received a valid CTB, then it should send the unencrypted broadcast to with intended receiver as that indicated in the CTB message. Otherwise (if not), repeat the procedure from the beginning (as long as the application requires).

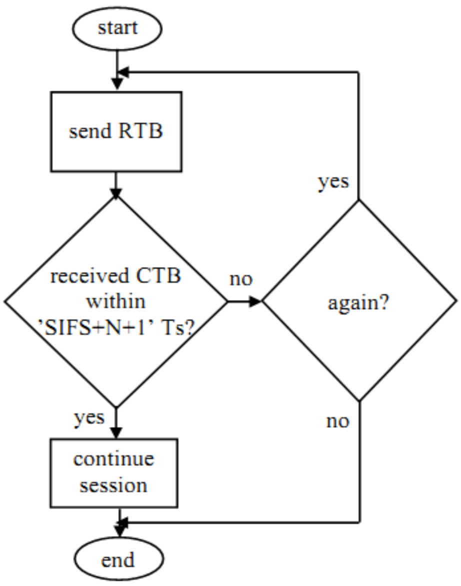

Figure 2: Actions of the transmitting MAC

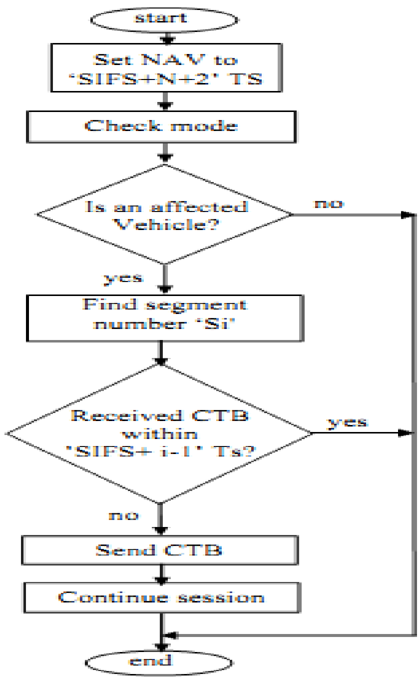

Figure 3: Actions of other vehicles

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2.4 Proposed algorithm of other Vehicles

Upon receiving of an RTB message, other nodes proceed with the following algorithm (Figure 3):

1. Set the NAV (Network Allocation Vector) to be SIFS+N+2 time-slots so that nodes will not start a new session until the end of the current broadcast.
2. Check the broadcasting mode field.
3. Compare the geographical coordinates of the transmitting vehicle with their own, and obtain its relative position. If the receiving vehicle is in the opposite driving direction or not in the message propagation direction, ignore the message and go to end. Otherwise, if the receiving vehicle is in the message propagation direction, continue to Step 4.
4. Compute the headway in seconds (or distance in meter) then determines its segment number with reference to the operating mode. Widths of each segment are implemented according to tables.
5. Assuming that the segment number equals Si where (i<= N) and (i) is the segment number. Set the back-off counter to be equal to (i-1).

So that, nodes wait for the SIFS then decrement the back-off counter by one in each time slot while listening to the channel for any valid CTB message, if locked with a valid CTB message then the node should exit the contention phase and listen for the incoming broadcast.

The node that reaches zero initiates a CTB message including its MAC address and continues the session with the transmitting node. Simulation was done using MATLAB.

3. RESULTS

These parameters are quoted from the 802.11p [4] standard. It is assumed that the length of ACK message is the same as the original broadcast. The ACK message is a mere repeat of the original broadcast setting the ACK field, which is considered as compensation to the expected collisions at far range nodes. The headway distribution is considered at a traffic volume of 500 vehicles/h and 1500 vehicles/h.

Table 3: MATLAB Parameters

Parameter	Value
Data rate	3 Mbps
CTB	14B(B=bytes)
RTB	20 B
Slot Time	16 µs
SIFS	32 µs
DIFS	64 µs
Message	512 B
ACK	512 B

Using these random variables, a simulation program was conducted for estimating the probability of collisions and the average latency within each segment of the communication range (10 sec). The width of each segment is taken according to Table 1. The probability of collision is shown in Figure 4, while the average latency is shown in Figure 5.

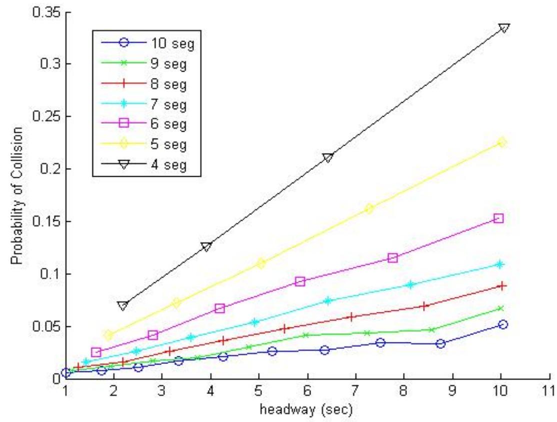

Figure 4: Simulated calculation for P_C for best segmentation for 500 veh/h.

In Figure 5, the curves are close to each other. The average latency associated with each segment reveals that the case of 7-seg gives the minimum latency (best performance) before over-segmentation begins to take place with 4 segments.

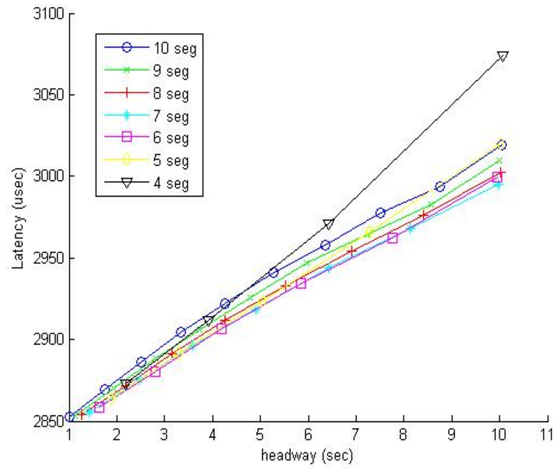

Figure 5: Simulated calculation of latency at best segmentation for 500 veh/h.

In Figure 6, we have seen that for 1500 vehicles/h, the probability of collision is higher than the 500 vehicles/h. The latency of the segmentation for 1500 vehicles/h has given in Figure 7.

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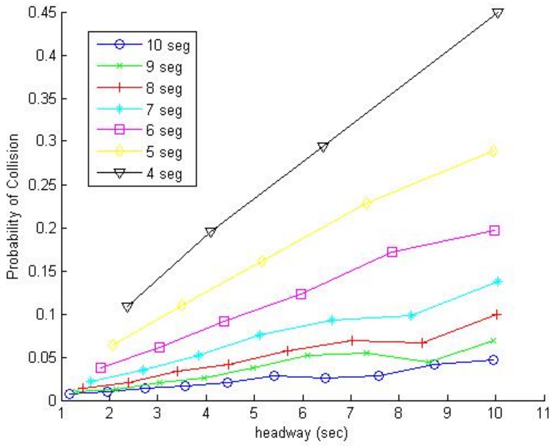

Figure 6: Probability of collision for 1500 veh/h

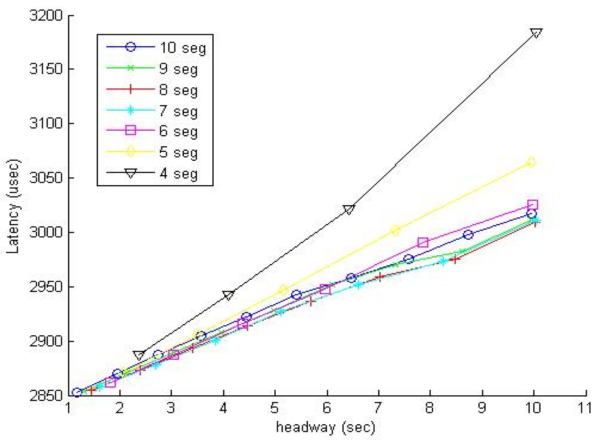

Figure 7: Latency for 1500 veh/h.

The headway distribution at traffic volume of 500 vehicles/h and 1500 vehicles/h (very low vs. very high) are shown in Figure 8 and 9.

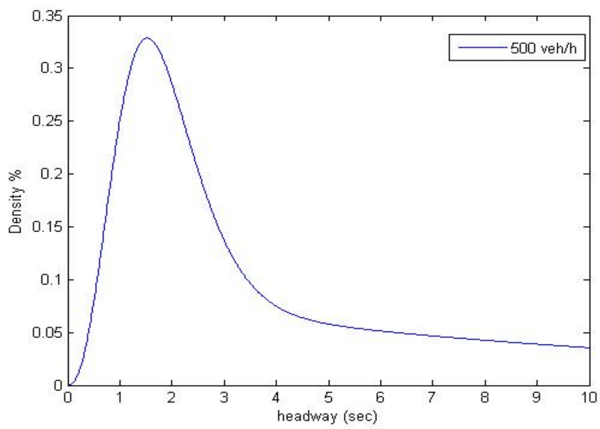

Figure 8: Headway Distribution at 500 veh/h.

We have seen that increasing the traffic volume results in increasing the ratio of short headways and decreasing that of long headways.

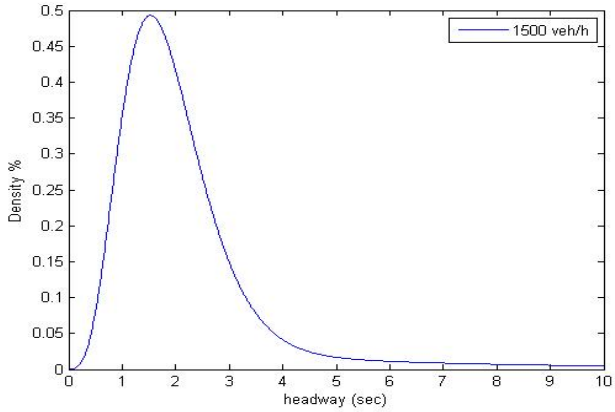

Figure 9: Headway Distribution at 1500 veh/h.

4. DISCUSSION AND CONCLUSION

In this research, we used novel broadcasting protocol in VANET for the highway environments of Bangladesh with these new features:

- To use the concept of headway-based segmentation and to include effects of human behaviours in its design with the headway model.
- Non-uniform segmentation achieving a unique minimum slope linearly increasing latency distribution.
- Unique robustness at different speeds and traffic volumes rooted to the headway robustness at different traffic volume variations. For example the latency difference between the traffic volume of 500vehicles/h and 1500vehicles/h is in a range of 10µsec.
- Superior minimum latency for public safety applications.
- Application adaptability with special multi-mode operations.
- Considered offering a solution to applications like “Approaching Emergency Vehicle”.

5. FUTURE WORK

The following are some areas of future work:

- Imply this proposed protocol in various parts of the country to see the actual effect on the road.
- Try to improve latency and effect of headway-based segmentation.

- Take more public safety measurements using this protocol.

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BIOGRAPHIES

Adnan Ahmed Hasan received his B.Sc. Engineering degree from the department of Computer Science and Telecommunication Engineering of Noakhali Science and Technology University, Bangladesh. His research interests include VANET, IP telephoning, IP 6, Cloud Computing, Fuzzy Logic in Telecommunication.

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