Traffic Congestion Detection and Avoidance using Vehicular Communication

Ajay N. Upadhyaya and Manish Chaturvedi

Abstract—**Traffic congestion is a serious problem in big cities. With the number of vehicles increasing rapidly, especially in cities whose economy is booming, the situation is getting even worse. Drivers, unaware of congestion ahead eventually join it and increase the severity of it. The ability of a driver to know the traffic conditions on the roads ahead enables him/her to seek alternate routes through which time and fuel can be saved. Due to recent advancements in vehicular technologies, vehicular communication has emerged. The objective of this work is to check feasibility of using infrastructure based vehicular communication for detecting and avoiding traffic congestion. In this paper we propose a Signal Agent (SA) and Car Agent(CA) based approach for detecting and avoiding traffic congestion. We analyze performance of the proposed approach for two different road network scenarios using simulations: structured grid network (like Gandhinagar City of Gujarat, India) and a part of typical city road network (Tiwan city). With the proposed approach we get reduction of 10.05% in trip duration of vehicles, reduction of 10.08% in number of vehicles in entire traffic road network and 9.82% in heavy traffic area. In an accident scenario, about 72.63% vehicles changed their route due to awareness of congestion. Error in trip time estimation and vehicle count estimation is observed to be less than 1%.**

Keywords: Vehicular Communication; Car Agent; Signal Agent; Traffic Congestion Detection; Estimation Error

I. INTRODUCTION

MOST current navigation systems are static in nature. They use only one-way communication: vehicles only receive information, usually through radio or satellite communication. They suggest distance based optimal path without considering real time traffic conditions on the route. This leads to hot spots in road network and in turn generates jam condition specifically during rush-hours. Traffic congestion in road network is formed by many factors. We can classify those factors in two main categories: the first, predictable factors like road construction/maintenance, rush hour and low capacity roads and the second, unpredictable factors like accidents, bad weather and human behavior. Drivers, unaware of congestion ahead eventually join it and increase the severity of it. The ability of drivers to know the traffic conditions on the roads ahead enables him to seek alternate routes saving time and fuel. In order to provide useful information about traffic ahead to drivers, the system must identify the congestion, its location, severity and boundaries. This establishes need for a dynamic navigation system which can use real time traffic information while suggesting optimal path.

Due to recent advances in vehicular technologies, vehicular communication has emerged. Now a days, many cars come with wireless communication capability. Also, many drivers use smart phones having wireless networking capability. This enables vehicle to vehicle and vehicle to infrastructure communication in real time. In this study we consider communication between vehicles and infrastructure for generating useful traffic information. We call it as Vehicle Infrastructure Network (VINET). In VINET two main entities are Road Side Unit (RSU) and On Board Unit (OBU). Each vehicle is equipped with OBU executing Car Agent (CA). An RSU is installed at each cross road and executes Signal Agent (SA). An OBU and RSU can exchange messages when they are in communication range of each other. We assume that all RSUs are connected through backbone network. While in communication range the CA executing on OBU can communicate vehicle's location, movement speed and other relevant information with SA. The SA running on RSU summarizes information received from all the vehicles in its communication range and can generate traffic state information of the region in real time. SAs running on RSUs communicates traffic updates with each other periodically. The CA running on OBU can query the traffic state from the SA and gets the real time traffic updates. Also, the SA can suggest optimal path to CA considering real time traffic state of the road network.

II. RELATED WORK

The main objective of congestion avoidance system is to generate and communicate traffic information using vehicle to vehicle and/or vehicle to infrastructure communication [1][13]. The real time traffic information can be provided to drivers for optimal route selection [2][4][5][9]. Various ways of traffic congestion detection are proposed in literature: using a standard GPS driving aid, augmented with peer-to-peer wireless communication [3][13]; sharing congestion information using a simple geo cast protocol and a dynamic Dijkstra algorithm for planning and computing least congested travel itineraries[6]; multihop inter-vehicle communication for generating traffic information[10]; and others [11][15][17]. We observe from literature that it is difficult to generate accurate traffic state information with out infrastructure support. Quality of traffic information generated using peer to peer based vehicular communication approach is affected by frequent communication topology changes, penetration of communication enabled vehicles, etc.. Most of the peer to peer communication based approaches focus more on addressing the above issues

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than on generating accurate traffic information. We strongly believe that without infrastructure support it is difficult to realize large scale traffic application. Hence, We decided to study infrastructure based vehicular communication scenario to focus on the accurate traffic state information generation without getting diverted by issues specific to peer to peer communication.

III. PROPOSED APPROACH FOR TRAFFIC STATE UPDATE AND OPTIMAL PATH ROUTING

As shown in Fig-1, on each cross road, Signal Agent (SA) works as a Road Controller. The SA gets details of each vehicle entering in its communication range. We assume that each SA can communicate with other SAs through backbone network. Car Agent (CA) can communicate with SA whenever it enters in communication range of SA. CA can send information like Car ID (CID), Current Position (CP), Current Speed (CS), Max Speed (MS), Number of CAs in neighborhood (NCA), Road Block ID (RBID). In a basic protocol setup an SA may maintain count of number of vehicles on road blocks in its communication range. Whenever a CA enters in the communication range of SA, counter is incremented by one and when the vehicle leaves, the counter is decremented by one. By using vehicle count, number of lanes in road block and communication range, we can compute Vehicle Density (VD). For each road block, a threshold density value is set based on type of road, number of lanes and length of road. At regular time interval SA communicates vehicle count and average vehicle speed (AVG_{speed}) for all road blocks in its coverage area with other SAs. Steps for the same are as follows:

Step 1: For each Road Block assign Road Vehicle Counter(RVC_i), which indicates the number of vehicle on that road block.

$RVC_i = 0$; Where i is Road Block ID.

Step 2: For each Road Block identify Road Vehicle Density Threshold value($RVTh_i$), which indicates the threshold value of number of vehicle on that road block. Threshold value indicates the maximum number of vehicles that can pass through road block smoothly without congestion. Assign appropriate value based on type of road, number of lanes, and length of road.

Step 3: When CA enters in communication range of SA, Road vehicle counter is incremented by one and CA sends its details to SA.

$RVC_i := RVC_i + 1$;

$CA(CID, CP, CS, MS, NCA, RBID) \rightarrow SA$;

The CA sends the above information to SA periodically to keep it updated about its presence on the road block. **Step 4:** If Car Agent goes out of the communication range, the Road vehicle counter is decremented by one

$RVC_i := RVC_i - 1$;

Step 5: If ($RVC_i > RVTh_i$) then congestion is declared and SA sends this information to other SAs. Declare "Congestion":

$SA_j(SAID, RVC_i, AVG_{speed}, Time) \rightarrow SA_{other}$;

Step 6: Each SA periodically (every 250 seconds) communicate traffic state with other SAs in its neighborhood.

$SA_j(SAID, RVC_i, AVG_{speed}, Time) \rightarrow SA_{other}$;

$SA_{other}(SAID, RVC_i, AVG_{speed}, Time) \rightarrow SA_j$;

Step 7: Suggest Optimal Path to user, when queried, based on vehicle density and average speed of Road Blocks.

$SA(OptimalPath) \rightarrow CA$;

An Optimal Path (OP) is computed and suggested as per the user preference for distance optimality and/or time optimality. For every path we compute optimal path congestion factor, CF_{opt}, as weighted sum of distance based congestion factor (CF_{dist}) and time based congestion factor (CF_{time}). Let D and T be the weigh factor for Distance and Time, respectively.

$CF_{opt} = D * CF_{dist} + T * CF_{time}$; $D + T = 1$

Where $CF_{dist} = (Dist_{actual} - Dist_{ideal})/Dist_{ideal}$.

$Dist_{actual}$ is the distance covered by vehicles to reach the destination through this route and $Dist_{ideal}$ is an ideal distance to reach destination and it is predefined based on ideal condition. Similarly,

$CF_{time} = (Time_{actual} - Time_{ideal})/Time_{ideal}$, where $Time_{ideal}$ is an ideal trip duration to reach destination and it is predefined based on ideal condition. $Time_{actual}$ is an actual time required to reach destination through this route based on current traffic condition. $CF_{opt} = 0$ is the best possible for any route suggestion, and smaller value of CF_{opt} is considered better. Following steps are performed when a CA queries for optimal path from source to destination:

Step 1: User provides source and destination information to CA.

Step 2: User provides preference for time and/or distance optimization to CA.

Step 3: CA queries SA for the optimal route as per the user input.

Step 4: SA computes routes using real time traffic state information and user preference.

Step 5: SA gets details of ideal distance ($Dist_{ideal}$) and ideal time ($Time_{ideal}$) for given trip.

Step 6: SA gets details of actual distance $Dist_{actual}$ and actual time $Time_{actual}$ for set of possible routes for given trip.

Step 7: Calculate CF_{dist}, CF_{time}, and CF_{opt} for each route.

Step 8: SA provides set of routes with corresponding CF_{opt} to the querying CA.

IV. SIMULATION

A. Simulation Parameters

We have used NCTUns [7][8] simulator in our work which supports micro level traffic movements, specification of RSU infrastructure, and communication among vehicles and RSUs. We have simulated two road network scenarios: structured grid network (like Gandhinagar City of Gujarat, India) of $25KM^2$ area (Fig-3) and a part of typical city road network (Tiwan city) of $48KM^2$ area (Fig-2). Table-I describes simulation parameters for both Structured/Grid network and typical city road network. In grid road network, length of each Road Block is 1 km with two lanes. Each vehicle is equipped with OBU with 802.11p based wireless communication capability. To check effectiveness of the proposed approach, we run simulations with and without communication capability and

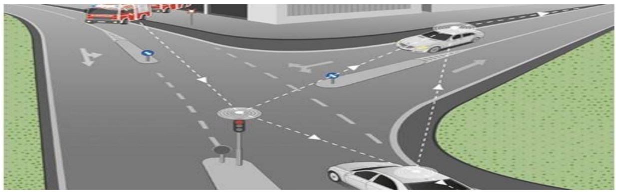

Fig. 1. Signal Agent (SA) as Traffic Congestion Controller

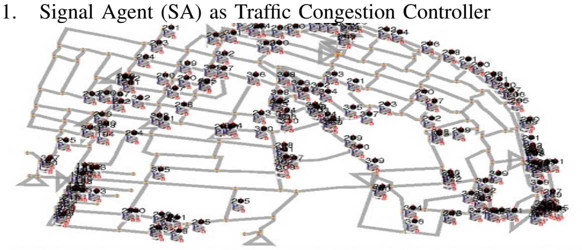

Fig. 2. City map with Vehicles

TABLE I. SIMULATION PARAMETERS

Parameters	Scenario -I	Scenario -II
Area	$5000 \times 5000\ meter^2$	$8000 \times 6000\ meter^2$
Description	Structured road network	Typical city road network
No. of Vehicle	2500	4200
Simulation duration	2200 Sec.	3000 Sec.
Type of vehicles	Car	Car
Traffic light support	Yes	Yes
Packet type	UDP	UDP
Max. speed of vehicles	10/20/30 m/s	10/20/30 m/s
Length of vehicles	6 meter	6 meter
Safe distance	Front and rear 2 m	Front and rear 2 m
Allow overtaking	Yes	Yes
No. of lanes on road	2	2
Width of lane	6m	6m
Wireless communication range of OBU	100 m	100 m
Wireless communication range of RSU	250 m	250 m

evaluate performance based on average trip time, and average vehicle density.

B. Processing User Query for Best Route

For finding best path, the CA queries the SA in its communication range with source, destination and user preference information. The SA finds set of paths connecting source and destination using all path routing algorithm and evaluates CF_{opt} for each path using real time traffic information. The SA sends set of routes along with their corresponding CF_{opt} value in response to the query. Fig-3 presents optimal route discovery example for a source-destination pair. The SA finds and suggests four routes connecting source and destination as mentioned in Table-II. User may chose Path-4 even though it is the longest among all suggested routes as it has optimal average speed and traversal time.

C. Comparison of with-CA and without-CA scenario

Performance evaluation of with-CA and without-CA scenario for structured grid road network: In case of without-CA scenario, the vehicles do not have communication capability and they are unaware of real time traffic condition in different parts of the road network. Fig-4 compares the with-CA and without-CA scenario with respect to the number of vehicles in entire road network at different times. As the Number of cars are inserted gradually in the road network, traffic increases and when cars reach their destination, the road traffic decreases in both the scenarios. In case of with-CA scenario, as the vehicles select optimal route for their journey, they complete their trip earlier than the uninformed vehicles. This leads to decrease in number of vehicles towards end of the simulation.

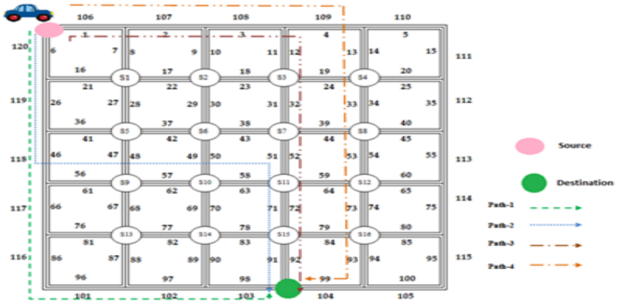

Fig. 3. Alternate path between Source to Destination in Structured Approach

TABLE II. TRIP TIME FOR ALTERNATE PATH

Path	Speed (km/hr)	Distance (km)	Trip Time (Minute)
Path -1	40	8	12.00
Path -2	36	8	13.33
Path -3	52	8	9.23
Path -4	72	10	8.33

We performed similar analysis for congested stretch of road blocks (RB41-RB45) in the road network to evaluate effect of vehicular communication in congested scenario. Length of this stretch of road blocks is 5 km. We declare congestion on a road block if number of vehicles on the road block reaches 30% of the maximum capacity. For a 5KM stretch of road blocks having two lanes, the maximum capacity is 1000 vehicles (i.e. 5000*2/10, where 10m is effective length of vehicles including safe distance between vehicles). Congestion time on RB41-RB45 is 768s to 1202s (19.72% of total simulation time) as shown in Fig-5. Due to optimal route selection in with-CA scenario, we observe decrease in number of vehicles towards end of simulation.

As can be observed from Fig-4 and Fig-5, the reduction in number of vehicles starts at about 1000 seconds. Table-III and IV present reduction in vehicle count for entire road network and congested road blocks RB41-RB45, respectively. Fig-6 and Fig-7 shows percentage wise reduction in number of vehicles for entire road network and for congested road blocks RB41-RB45, respectively. From table III and IV, we observe that with-CA approach reduces vehicle count by 10.08% for entire road network, and by 9.82 % for congested road blocks RB41-RB45.

Trip duration comparison for structured grid road network: We find trip duration of different vehicles for with-CA

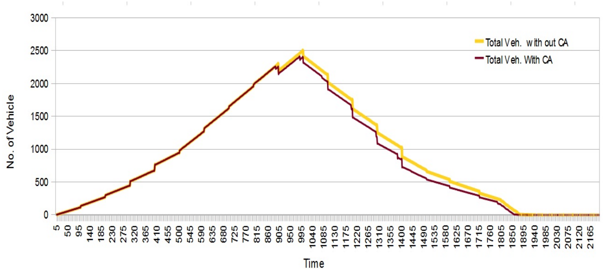

Fig. 4. Time vs Number of vehicles

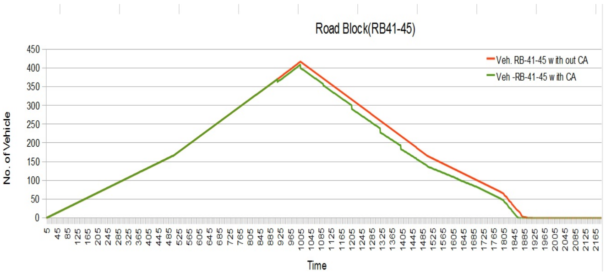

Fig. 5. Time vs Number of vehicles for RB41-45

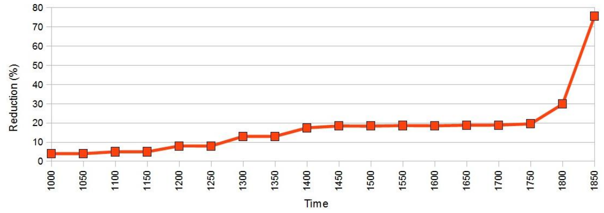

Fig. 6. Time vs Reduction in Traffic

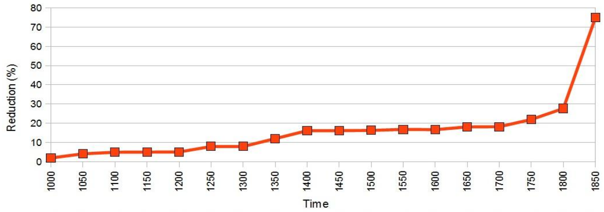

Fig. 7. Time vs Reduction in Traffic for RB41-45

TABLE III. REDUCTION IN NUMBER OF VEHICLES FOR ENTIRE ROAD NETWORK

Time	Without-CA	With-CA	Difference	Reduction(%)
1000	2502	2402	100	4
1050	2274	2183	91	4
1100	2129	2023	94	5
1150	1881	1787	94	5
1200	1744	1604	140	8.03
1250	1489	1370	119	7.99
1300	1362	1185	177	13
1350	1137	989	148	13.02
1400	1020	842	178	17.45
1450	787	642	145	18.42
1500	681	556	125	18.36
1550	596	485	111	18.62
1600	502	409	93	18.53
1650	441	358	83	18.82
1700	376	305	71	18.88
1750	287	231	56	19.51
1800	228	160	68	29.82
1850	82	20	62	75.61
Total Count Without-CA=19518, Total Count With-CA=17551				
% Reduction=10.08				

TABLE IV. REDUCTION IN NUMBER OF VEHICLES FOR RB41-RB45

Time	Without-CA	With-CA	Difference	Reduction(%)
1000	417	409	8	1.92
1050	392	376	16	4.08
1100	367	349	18	4.9
1150	342	325	17	4.97
1200	317	301	16	5.05
1250	292	269	23	7.88
1300	267	246	21	7.87
1350	242	213	29	11.98
1400	217	182	35	16.13
1450	192	161	31	16.15
1500	166	139	27	16.27
1550	149	124	25	16.78
1600	132	110	22	16.67
1650	116	95	21	18.1
1700	99	81	18	18.18
1750	82	64	18	21.95
1800	65	47	18	27.69
1850	24	6	18	75
Total Count Without-CA=3838, Total Count With-CA=3497				
% Reduction=9.82				

TABLE V. VEHICLE TRIP TIME

Veh.ID	Type	Time without-CA	Time with-CA	Difference(%)
8	CAR	846	760	10.17
125	CAR	1057	963	8.86
436	CAR	1016	904	11.02
736	CAR	980	870	11.22
836	CAR	1296	1160	10.49
1023	CAR	1143	1028	10.06
1324	CAR	540	500	7.41
1688	CAR	992	880	11.29
1734	CAR	940	830	11.7
1863	CAR	1110	1018	8.29
			Average Saving	**10.05%**

and without-CA scenario and compute average trip duration in each case (Table-V). Table-V shows about 10.05% reduction in average trip duration for with-CA scenario.

Performance evaluation of with-CA and without-CA scenario for typical city road network: In this section, we analyze performance of with-CA and without-CA scenario for typical city road network. Fig-8 compares the with-CA and without-CA scenario with respect to the number of vehicles in entire road network at different times. We observe clear decrease in vehicle count for with-CA scenario after 1500 seconds. Fig-9 shows comparison of with-CA and without-CA scenario with respect to average speed of vehicles. Average speed for entire network is computed every 250 seconds for with-CA and without-CA scenario. In with-CA scenario, the maximum average speed of vehicles in entire network is 10.23 m/s whereas that in without-CA scenario is 10.13 m/s. In with-CA scenario, the minimum average speed of vehicles in entire network is 9.06 m/s whereas that in without-CA scenario is 8.52 m/s.

Fig-10 shows average speed comparison between with-CA and without-CA scenario for congested road stretch of 8 kms. On the congested road stretch, the maximum average speed of vehicles is 8.98 m/s and 8.78 m/s for with-CA scenario and without-CA scenario, respectivel, whereas the minimum average speed of vehicles is 8.43 m/s and 7.88 m/s for with-CA scenario and without-CA scenario, respectively.

As can be observed from results, there is little difference in average speed for with-CA and without-CA scenario. We identified following reasons for the same: in free flow traffic condition, both, with-CA and without-CA scenario, has higher average speed and vehicular communication has little role to play. In case of the congested road stretch, average speed is computed using the speed of vehicles which has already joined congestion on that road block. So, they can not move faster just by having communication capability. We found that number of slow moving vehicles are lesser in with-CA scenario when compared to those in without-CA scenario. This leads to slight increase in average speed on the congested road stretch.

Performance evaluation of with-CA and without-CA scenario for Accident Scenario in structured grid network: We created an accident on one lane of Road Block-43 at t=1000 seconds and computed average speed at different times for with-CA and without-CA scenario. Fig-11 shows temporal average speed variations for with-CA and without-CA scenario. Due to accident on one lane the traffic gets congested and average speed reduces in with-CA and without-CA scenario and there is little difference between the average speed in both the scenarios. We identified following reasons for the same: average speed on Road Block-43 is computed using the speed of vehicles which have already joined congestion on that road block. So, they can not move faster just by having communication capability. Fig-12 shows that the number of slow moving vehicles are lesser in with-CA scenario when compared to those in without-CA scenario after accident generation on RB-43. Fig-13 shows count of rerouted vehicles at different times after getting congestion information.

Vehicle count estimation error in structured grid network scenario: Table VI shows computation of vehicle count estimation error for entire grid road network. To find error in estimation, we use the accurate vehicle count information available in simulator and the vehicle count estimated through CA-SA communication. Average vehicle count error is 21.74 which is less than one percent of total number of vehicles in simulation scenario.

Table VII shows computation of vehicle count estimation error for congested road stretch RB41-RB45. To find error in estimation, we use the accurate vehicle count information available in simulator and the vehicle count estimated through CA-SA communication. Average vehicle count error is 7.41 which is less than two percent of total number of vehicles on the road stretch in the simulation scenario. Similar results are observed in typical city scenario (not elaborated here due to space constraint).

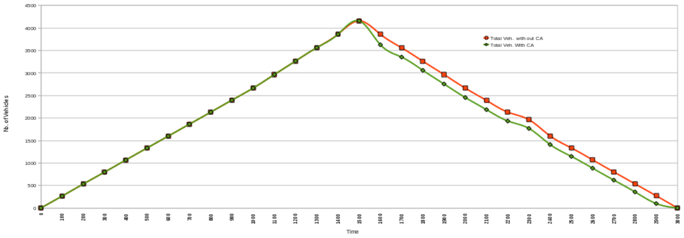

Fig. 8. Time Vs No of Vehicles for city scenario

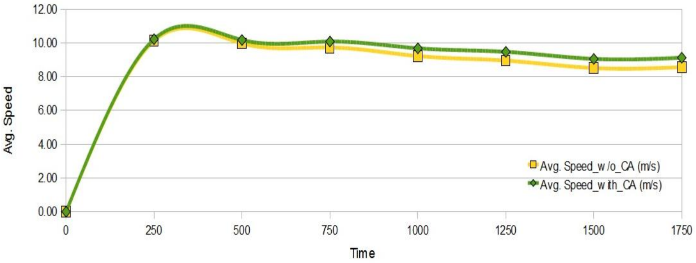

Fig. 9. Time vs Average Speed RB-1

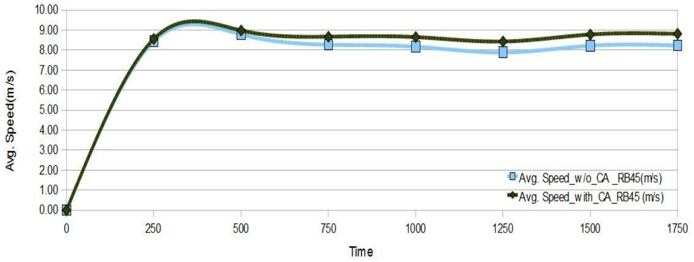

Fig. 10. Time vs Average Speed Road Block -45

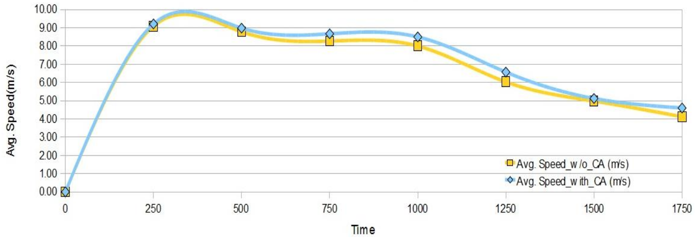

Fig. 11. Time vs Average Speed for Accident Scenario

Trip duration estimation error in structured grid network scenario: Table VIII shows computation of trip duration estimation error for all vehicles. To find error in estimation, we use the accurate trip duration information available in simulator and the trip duration estimated through CA-SA communication. Average trip duration error is 6.29 seconds which is 0.52% of average trip duration of all the vehicles. Similar results are observed in typical city scenario (not elaborated here due to space constraint).

CONCLUSION

In this paper we propose an infrastructure based vehicular communication approach for optimizing vehicle movements in

TABLE VI. Vehicle count estimation error in Grid network scenario

Time	Vehicle count [Simulator] (A)	Vehicle count [Protocol](B)	Difference (D)	D*D
0	0	0	0	0
120	164	159	5	25
240	360	357	3	9
360	612	607	5	25
480	912	896	16	256
600	1274	1253	21	441
720	1711	1663	48	2304
840	2107	2060	47	2209
960	2385	2346	39	1521
1080	2078	2072	6	36
1200	1604	1610	-6	36
1320	1051	1035	16	256
1440	659	637	22	484
1560	475	449	26	676
1680	327	312	15	225
1800	160	158	2	4
1845	33	32	1	1
1920	0	0	0	0
			Σ (D*D)	8508
			Mean Squared Error	472.67
			Average Error	**21.74**
			Percentage Error	**0.8696**

TABLE VII. Vehicle count estimation error in Congestion road stretch RB41-RB45 of structured grid network:

Time	Vehicle count [Simulator] (A)	Vehicle count [Protocol](B)	Difference (D)	D*D
0	0	0	0	0
120	40	43	-3	9
240	80	85	-5	25
360	120	121	-1	1
480	160	157	3	9
600	216	210	6	36
720	276	259	17	289
840	335	329	6	36
960	406	386	20	400
1080	362	360	2	4
1200	301	304	-3	9
1320	326	237	-11	121
1440	165	165	0	0
1560	121	115	6	36
1680	87	84	3	9
1800	47	48	-1	1
1845	10	12	-2	4
1920	0	0	0	0
			Σ (D*D)	989
			Mean Squared Error	54.94
			Average Error	7.41
			Percentage Error	1.7855

TABLE VIII. Trip duration estimation error in Grid network scenario

Veh. ID	Trip duration [Simulator]	Trip Duration [Protocol]	Difference (D)	D*D
8	760	765	-5	25
125	963	970	-7	49
436	904	910	-6	36
736	870	876	-6	36
836	1160	1168	-8	64
1023	1028	1035	-7	49
1324	500	504	-4	16
1688	880	886	-6	36
1734	830	836	-6	36
1863	1018	1025	-7	49
			Σ (D*D)	396
			Mean Squared Error	39.6
			Average Error	6.29
			Percentage error	0.2859

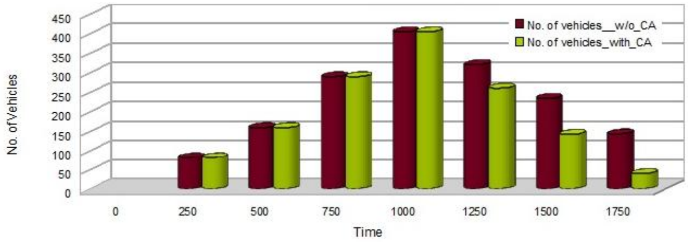

Fig. 12. Time vs No. of vehicles for Accident Scenario

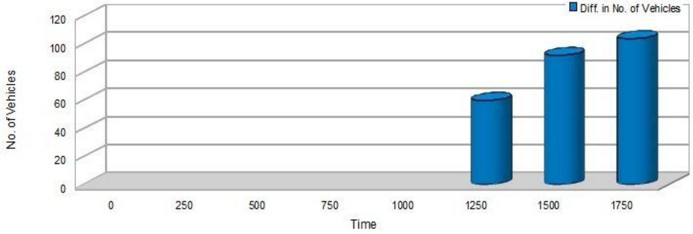

Fig. 13. Re-routing of vehicles for Accident Scenario

a road network. We show using simulations that the vehicular communications reduces trip duration by 10.05%. As many vehicles complete their trips earlier, we observe reduction in number of vehicles in road network (10.08% in entire road network scenario and 9.82% in congested road block stretch of RB41-RB45). In case of accident scenario, 72.63% vehicles changed their route due to awareness of congestion on the road block having accident. All these results establishes effectiveness of the vehicular communication in optimizing traffic movement in road network.

We also carried out analysis of vehicle count estimation error and trip duration estimation error using simulations. It is observed that the estimation error in total vehicle count for entire road network is 21.75 vehicles (0.9886%) and that on congested road stretch of RB41-RB45 is 7.41 vehicles (1.7941%). Estimation error in average trip time of all the vehicles is 6.29 seconds which is negligible (less than 1%) compared to overall trip time.

In this paper we have considered homogeneous vehicles in simulations and assumed that all the vehicles are VANET enabled. We have considered lane-based traffic for vehicle mobility. In future, we plan to analyze our approach for heterogeneous vehicles and lane-less traffic movement which is more realistic for representing traffic in developing countries like India. Also, we plan to analyze effect of penetration of VANET technology on error in estimating traffic information.

REFERENCES

[1] Trupti gajbhiye, akhilesh a. Waoo and p.s pathija, "Traffic management through intercommunication between cars using vanet system", international journal on advanced comp. eng. and comm. tech. vol-1 issue:1

[2] Dikaiakos, M.; Florides, A.; Nadeem, T. and Iftode, L. Location-aware services over veh.ad-hoc networks using car-to-car comm. Selected Areas in Comm.,IEEE Journal on, IEEE, 2007, 25, 1590-1602

[3] Dornbush, S. Joshi, A. StreetSmart traffic: Discovering and disseminating automobile congestion using VANET's Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th, 2007, 11-15

[4] Abderrahmane Lakas and Moumena Chaqfeh: A Novel Method for Reducing Road Traffic Congestion Using Vehicular Communication, IEEE Journal on, IEEE,2011, 978-1-4244-8329-7/11/

[5] Tamura, K. Hirayama, M. Toward realization of VICS-Vehicle Information and Communication System Vehicle Navigation and Information Systems Conference, 1993., Proceedings of the IEEE-IEE, 1993, 72-77

[6] A. Lakas, M. Cheqfah, ”Detection and Dissipation of Road Traffic Congestion Using Vehicular Communication”, Proc. of IEEE Mediterrannean Microwave Symposium, Tangiers,November 2009.

[7] S.Y.Wang and C.C. Lin, ”NCTUns 5.0: A Network Simulator for IEEE 802.11(p) and 1609 Wireless Vehicular Network Researches,” 2nd IEEE International Symposium on Wireless Vehicular Communications, September 21-22, 2008, Calgary, Canada.

[8] S.Y.Wang and C.L. Chou, ”NCTUns Tool for Wireless Vehicular Communication Network Researches,” Simulation Modelling Practice and Theory, Vol. 17, No. 7, pp. 1211-1226,August 2009

[9] Fan Bai and H. Krishnan. Reliability analysis of DSRC wireless communication for vehicle safety applications. In Intelligent Transportation Systems Conference, 2006. ITSC 06. IEEE, pages 355362, Sept. 2006

[10] M. Jerbi and S.M. Senouci, Characterizing Multi-Hop Communication in Vehicular Networks, IEEE Wireless Communications and Networking Conference, WCNC 2008, pp. 3309 3313

[11] M. Fiore, J. Harri, F. Filali, and C. Bonnet. Vehicular mobility sim. for VANETs. Sim. Symposium, 2007. ANSS 07. 40th Annual, pages 301309, March 2007.

[12] Jason J. Haas, Yih-Chun Hu.Comm. Requirements for Crash Avoidance, ACM 978-1-4503-0145-9/10/09, VANET10, September 24, 2010

[13] Dornbush, S. and Joshi, A. StreetSmart Traffic: Discovering and Diseminationg Automobile Congestion using VANET. Veh. Tech.Conference. 2007, pp. 11-15.

[14] Hartenstein, Hannes and Laberteaux, Kenneth P. A Tutorial Survey on Vehicular Ad Hoc N/w. IEEE Comm. Magazine. June 2008.

[15] Nidhi & Lobiyal, D.K., (2012) Performance Evaluation of VANET using realistic Vehicular Mobility, N. Meghanathan et al. (Eds.): Vol. 84, CCSIT , Part I, LNICST 84, pp. 477489.

[16] Yuwei, Xu., Ying, Wu., Gongyi, Wu., Jingdong, Xu., Boxing, L., Lin, S., (2010) Data Collection for the Detection of Urban Traffic Congestion by VANETs, In: IEEE Services Computing Conference (APSCC), Volume: Issue: , 6-10 Dec., Asia-Pacific pp. 405 410.

[17] Chulhee Jang and Jae Hong Lee. Path Selection Algorithms for Multihop VANETs, 978-1-4244- 3574-6/10/2010 IEEE Navigation, IEEE 2010, 978-1-4244-7489-9/10

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