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Effect of Noncooperation in Vehicular Delay Tolerant Network for Multicopy Routing and its Solution

Nandita Khobragade and Bharati Singh

Abstract — **Vehicular Delay Tolerant Network (DTN) is an extended application of Vehicular Adhoc Network (VANET) where small delay can be tolerated. In vehicular DTN, some selfish node may exist who may not want to forward other's message in order to save their own resources which results into degraded performance of the overall network. VANET is characterised by high mobility and rapidly changing topology, therefore it poses special challenges and high demands for cooperation among individual vehicles to contribute to the network performance. Practical Incentive Protocol is used as its solution to improve the overall performance of the network which is secure, fair and a hybrid protocol. When fair incentive is provided to selfish node, it is motivated to act as intermediate node in order to earn the incentive and use it further to avail the service. In this paper, effect of noncooperation is analysed in terms of delivery ratio and average delay in vehicular DTN for multicopy routing algorithm, specifically for unicast. The effect of Practical Incentive Protocol is analysed using ONE simulator for different level of selfishness and improvement in terms of delivery ratio and average delay is shown for multicopy routing protocol. Also the comparative analysis of Practical Incentive Protocol is done with latest similar technique i.e. A Secure Multilayer Credit based Incentive scheme for Delay Tolerant Networks (SMART)**

Keywords — **Credit and reputation, Incentive, noncooperation, selfish node, Vehicular adhoc network.**

I. Introduction

When vehicles communicates to exchange messages with each other or with any stationary node than it is called as vehicular adhoc network[1].Vehicular adhoc network is a network formed by vehicles for security and commercial applications. The origin motive behind VANET is security applications but commercial applications are also important for various reasons [2]. The initial deployment cost of VANET network is very high. Therefore it is unlikely that individual can afford such expensive set up. Also, commercial applications are needed to improve bandwidth efficiency and lots of new feature will be available to user with little increase in the existing cost. If commercial applications are taken into consideration, there are lot of application in which delays can be tolerated, such as traffic information, query regarding weather or any other query from road side unit (RSU). Hence it is called as vehicular delay tolerant network (DTN) [3]. Information such as the available parking spaces in a parking lot, the meeting schedule at a conference room, and the estimated bus arrival time at a bus stop can also be delivered by vehicle delay-tolerant networks. With a vehicular delay-tolerant network, the vehicle can send the query to the broadcast site and get a reply from it. In these applications, the users can tolerate up to a minute of delay as long as the reply eventually returns. The efficient routing algorithm should be used to achieve reasonable delay for such applications. For vehicular DTN, opportunistic routing is used such as epidemic, spray and wait, Maxprop etc. This type of routing is based on store and forward. When any message is received, the vehicular node will store the message in its buffer and forward it whenever it gets the correct opportunity. Hence buffer utilization is one of the important aspects in this case.

When social characteristic is taken into consideration, there may be some selfish nodes that are reluctant to cooperate in a network to save its own resources like buffer, computational complexity, bandwidth etc [4]-[6]. The presence of selfish node can severely degrade the performance of the network. In this paper, first the effect of selfish node on multicopy routing algorithm i.e. Maxprop is shown in terms of degradation in delivery ratio and average delay. In order to enhance the performance of the network, Practical Incentive Protocol is implemented in ONE simulator and results are analysed thoroughly. The comparative analysis with one of the latest similar technique i.e. A Secure Multilayer Credit based incentive scheme for Delay Tolerant Networks (SMART) is also done.

II. Related Work

Vehicular adhoc network is characterized by intermittent connectivity and rapid topology change [1]-[2]. When VANET is used for the nonsecurity applications, there may be a possibility that some user deny to cooperate in the network due to resource scarcity [4]-[6]. This will result in performance degradation of overall network [5], [7]-[9]. There are many incentive schemes proposed in MANET for noncooperation issue but they all are not applicable in VANET due to its unique characteristic such as intermittent connectivity, rapid topology change, high speed etc [10]. Hence, solution was to serve the node on the basis of its instantaneous behaviour rather than its historical record, but it fails to motivate node at the first place [11]. Reputation based scheme rate the node on the basis of service it offers in the network. The benefit to the high reputation node is given by either financial benefit or by offering any new service [12]. This scheme requires the reputation certificate for the time line of scored reputation. Few incentive schemes were specially designed for the commercial advertising which is based on broadcast and does not take into account unicast routing [13].Reference [14] is based on Tit for Tat scheme but it lacks security concerns. Credit based scheme is based on the philosophy that pay for the service and earn by serving others but the main problem with this scheme is source has to pay even the message does not reaches the destination [15]-[16]. Practical Incentive Protocol is the first fairer protocol. It is analysed for single copy in [17]. In this paper, we have extended the work to analyse it for multicopy routing protocol. In [17], when a node comes into contact with other node, the later has to identify the possible location to which it can carry the message, which is not the case here. In this paper, the message is carried to the location as per the routing algorithm and incentives are allotted accordingly.

III. Performance Degradation Due to Noncooperative Node

A. System Model

Vehicular adhoc network model is developed as a set of high mobility node N acting as a source node and L stationary destination node. Source node Ni randomly chooses any one destination from L node for uni-cast routing. These N nodes is further divided into selfish (S) and unselfish node (U), hence N = S + U. In case of network fully cooperative, S = 0 and all the nodes are unselfish.

B. Node Model

Each vehicular node in the VANET is equipped with On board unit (OBU), which allows different vehicle to communicate with each other based on 802.11p protocol. The equipped OBU communication device is considered resource-constrained, i.e., buffer and computation power constraints. Therefore, there may be many selfish vehicular nodes in the networks. It is assumed that selfish node is buffer constraint. In order to conserve buffer space, these selfish vehicular nodes may be very reluctant in the cooperation that is not directly beneficial to them. If selfish node is a destination node then only it will accept the message otherwise it will abort the message. Selfishness of a selfish node is measured in terms of selfish factor (α) which is a function of available buffer.

C. Performance Evaluation

In this section we study the impact of selfish node on delivery ratio and average delay for multicopy routing algorithm [19]. Selfishness of network is calculated in terms of selfish ratio i.e. no. of selfish nodes/ total no. of nodes. System model is implemented on a public available delay tolerant network simulator, namely the Opportunistic Network Environment Simulator version 1.5 [18] and performance is evaluated under a practical application scenario, i.e. vehicular DTN. The details of simulation parameters are summarized in Table 1.

Table I Simulation Setting

Simulation Area	4500m x 3400m
Duration	12 hours
Parameter of Vehicular nodes	
Number	100
Velocity	35-45Km/h
Data Rate	8Mbps
Transmission range	300 meter
Buffer size	20Mbits
Mobility Model	Shortest path map based
Router	Maxprop
Selfish ratio	[0,40%,60%,90%,100%]
Parameter for Bundle messages	
Generation interval	100sec
Size	2Mb
TTL	300 min, 20 min

We compare the delivery ratio and average delay under different selfish ratio. For TTL 300 minute, we can observe from Table II, that there is 2.59% decrease in the delivery ratio when selfish ratio increases from 0 to 60%, however Table III shows that average delay drastically increases by 251%.

Table II Effect of non cooperation on delivery ratio

Selfish ratio	Delivery ratio (%)	
	TTL = 300 min	TTL = 20 min
0	98.61	93.52
40	97.69	77.78
60	96.06	50
90	62.27	13.19
100	46.53	7.64

Table III Effect of non cooperation on average delay

Selfish ratio	Average delay (sec)	
	TTL = 300 min	TTL = 20 min
0	489	409
40	942	582
60	1716	714
90	5082	655
100	5678	499

While it is seen that after 60% selfish ratio there is significant degradation in both delivery ratio and average delay. In this condition, when a forwarding node seeks a next forwarding node but meets only selfish node who are not willing to cooperate and as a result the messages are aborted. In fully noncooperative scenario, delivery ratio reduces to 46.53% from 98.61% and average delay increases from 489sec to 5678sec. It is seen that delivery ratio is not much affected below 60%. This is because the source takes lot of time to search for unselfish node but still they are able to meet unselfish node because TTL is very high. When TTL is reduced to 20 min, there is significant decrease i.e. 16.8% in delivery ratio even at 40% while average delay is affected less as compare to high TTL but still 42.3% increase is observed at 40% selfish ratio. When selfish ratio is 100% i.e. fully noncooperative scenario, the delivery ratio degrades to 7.64% from 93.52% and average delay is increased by 22%. It is observed that average delay degradation at 40% selfish ratio is 42.3% while for 100% selfish ratio, it is 22%. The degradation in average delay should increase with increase in selfish ratio. This is because, when selfish ratio increases there will be increase in delay along with but when we further increase selfish ratio than there will be large percentage of messages whose delay fall above TTL time. It results in high drop which reduces the average delay. Still it does not compensate for large delivery ratio degradation.

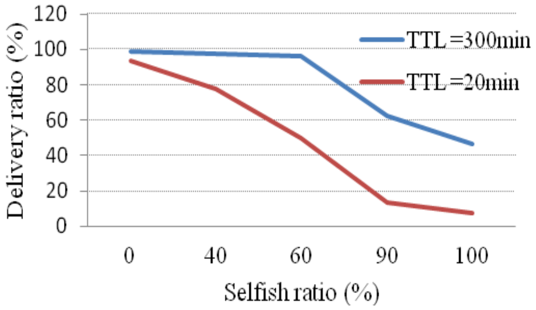


Fig.1. Effect of noncooperation on delivery ratio

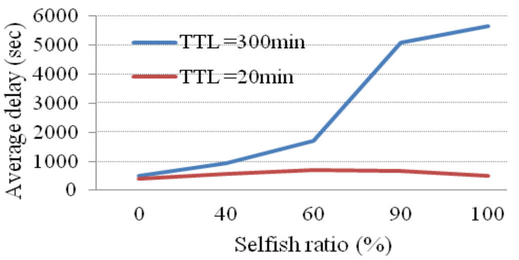


Fig.2. Effect of noncooperation on average delay

In fig. 1 and 2, the graphical analysis of delivery ratio and average delay is shown for all range of selfish ratio. It can be observe from the fig. that performance is severely degraded due to selfish nodes both in terms of delivery ratio and average delay.

IV. Practical Incentive Protocol

It is seen in previous sections that performance is severely degraded in vehicular network due to presence of selfish node. Hence, Practical Incentive Protocol [17] is used to address this problem. This protocol is hybrid protocol which takes into account both credit as well as reputation as an incentive mechanism. This leads to fairer protocol to both source as well as intermediate node. Even this protocol allows a node to behave selfishly, when there is resource constraint. There exists a trusted authority (TA) in the system which performs trusted fair credit and reputation clearance for vehicular nodes. Each vehicular node has to register itself to the TA to obtain its personal credit account (PCA) and personal reputation account (PRA) in the initialization phase. Later, when a vehicular node makes contact with some Road Side Units (RSUs), it can report to the TA for credit and/or reputation clearance.

A. Reputation System

When any node participates in the network by forwarding the message bundle, its reputation value is updated as per the distance that particular node has carried the message. Hence more the node cooperate in the network, more will be its reputation value. This reputation value should be time limited else once the reputation value is gained the motivation of a node to cooperate will decrease. Hence in this protocol, the reputation value is decayed with a factor λ.

If a node wants to avail any service such as traffic query or any other query, then node has to keep its reputation value greater than threshold else the query request will be aborted. Hence the participation of a node in a network benefits it by providing service [17].

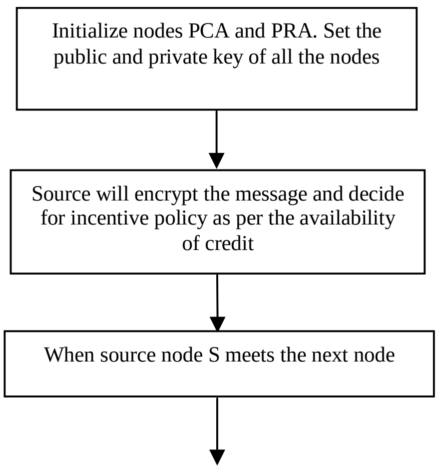
B. Credit System

Credit system is just like a virtual currency in which node has to pay to avail the service. It is also fair to source. The source node would not have to pay credits, if the message bundle doesn't arrive at the destination node. However, those intermediate nodes that helped forward can still get good reputation values from the TA.

Reputation punish selfish node by abducting it from availing service while credit system provide flexibility to a node to behave selfish in case of resource scarcity. Intermediate node makes sure that in case of resource scarcity it should get high incentive else it can behave selfishly once its reputation is higher than threshold value. Incentives are measured in the form of gaining factor (GF) [17].

C. Methodology

A secure Practical Incentive Protocol is implemented in the ONE simulator as per [17]. Layered coin model is used to guarantee the incentive strategy working well and incentives to be secure. In this protocol when two nodes meet each other, latter has to declare the possible location L1 to which it can carry the message at that instant only. This will be difficult in a vehicular network to decide and there may be a possibility of correct opportunity for a message either before or after location L1. A small modification is done which takes care of this. When two nodes N1 and N2 meet each other at location L1 and node N1 transfers the message to node N2. They will store the location L1 in layered coin structure. Later, when node N2 gets an opportunity to transfer the message to node N3 at location L2 it transfers it as per the routing protocol. This means the node N2 has carried the message from location L1 to location L2 and incentives are allocated accordingly. The flow chart which explains the methodology of practical incentive protocol is given below:



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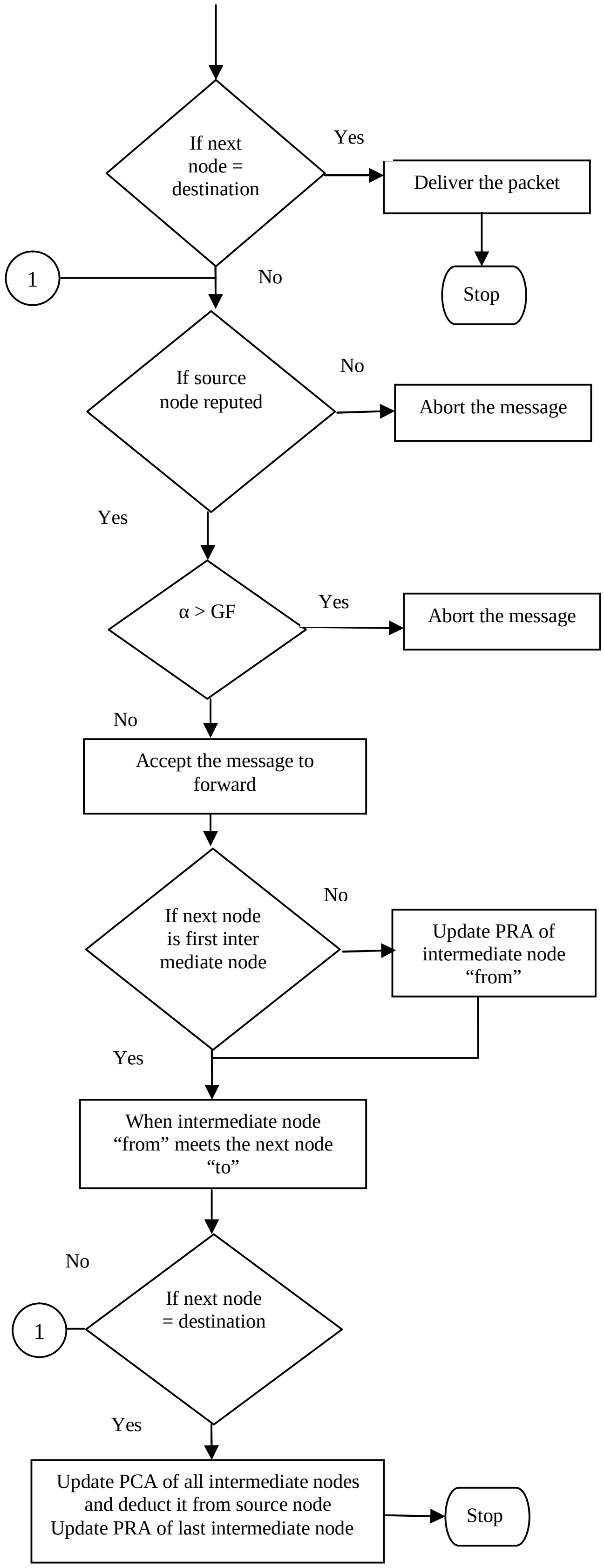

Fig.3. Methodology of Practical Incentive Protocol

V. Performance Enhancement Due to Practical Incentive Protocol

In this section, we will see the effect of Practical Incentive Protocol on delivery ratio and average delay under different selfish ratio and gaining factor. The simulation setting is same as in Table I. The only additional simulation parameter is gaining factor of value [0, 0.5, and 0.9]

A. Case I : When TTL is 300 minute

Table IV Effect of incentive on delivery ratio

Selfish ratio	Delivery ratio (%) for TTL = 300 min			
	Without incentive	GF = 0	GF= 0.5	GF = 0.9
0	98.61	98.61	98.61	98.61
40	97.69	87.73	93.06	98.61
60	96.06	78.94	87.73	98.38
90	62.27	57.64	82.18	98.15
100	46.53	47.92	80.79	97.92

Table V Effect of incentive on average delay

Selfish ratio	Average delay (sec) for TTL = 300 min			
	Without incentive	GF = 0	GF= 0.5	GF = 0.9
0	489	482	483	483
40	942	1130	665	493
60	1716	1948	915	516
90	5082	5230	1620	607
100	5678	5732	2008	558

When incentive policy is not incorporated in a network i.e. without incentive in Table IV and V, the performance is severely degraded. This is already shown in the previous section. When Practical Incentive Protocol is incorporated and gaining factor is set to zero, none of the selfish nodes are motivated to forward the messages. This leads to low reputation of selfish nodes and hence they are not allowed to act as source to avail service. This in turn results in decrease of delivery ratio compared to when no incentive protocol is implemented as shown in Table IV. Also, when intermediate node refuses to serve selfish nodes, selfish nodes are motivated to do direct delivery which in turn increases the average delay as shown in Table V. When gaining factor is set to 0.5, few selfish nodes are motivated to forward the messages. It is seen that when the selfish ratio is at 40% and 60% the delivery ratio decreases by 4.98% and 9.5% respectively due to the low reputed selfish node still present in the network. While the average delay significant improves by 41.65% and 87.54% respectively. There is improvement in both average delay and delivery ratio at selfish ratio above 60%. In fully noncooperative scenario, delivery ratio is increased by 42.41% and average delay is reduced by 52.48%.

When all the nodes are motivated to cooperate by increasing the gaining factor to 0.9, there is improvement in delivery ratio and average delay for all range of selfish ratio. When fully non cooperative scenario is considered, there is 52.48% improvement of delivery ratio and average delay reduces from 5678 sec to 558 sec.

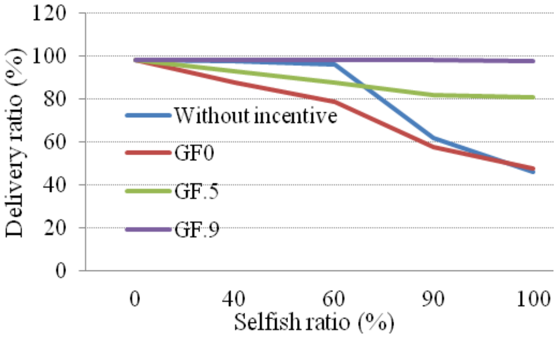

Fig.4. Effect of incentive on delivery ratio (TTL=300 min)

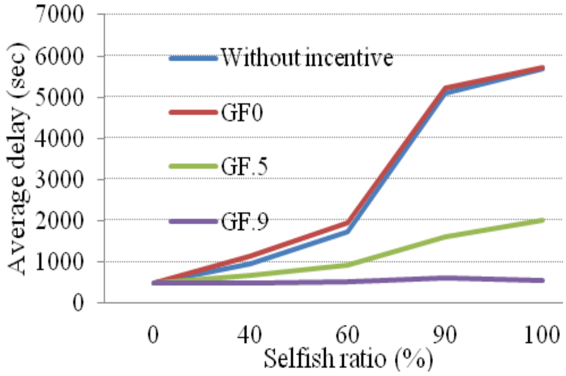

Fig.5. Effect of incentive on average delay (TTL=300 min)

The graphical analysis of the same is shown in fig 4 and 5 for delivery ratio and average delay for TTL 300 minute.

B. *Case II : When TTL is 20 minute*

Table VI Effect of incentive on delivery ratio

Selfish ratio	Delivery ratio (%) for TTL 20 min			
	Without incentive	GF = 0	GF= 0.5	GF = 0.9
0	93.52	93.98	93.75	93.75
40	77.78	68.06	83.56	93.52
60	50	41.67	76.85	93.06
90	13.19	11.11	53.7	91.9
100	7.64	8.56	48.15	91.44

Table VII Effect of incentive on average delay

Selfish ratio	Average delay (sec) for TTL 20 min			
	Without incentive	GF = 0	GF= 0.5	GF = 0.9
0	409	406	412	400
40	582	576	454	416
60	714	684	510	426
90	655	584	576	434
100	499	498	593	436

It is seen that nodes have sufficient time to search for unselfish node when TTL is high, hence TTL is reduced to 20 minutes for further analysis. From Table VI, we can see that when gaining factor is 0, delivery ratio is degraded due to the presence of low reputed node but there is significant increase in delivery ratio for all range of selfish ratio at gaining factor of 0.5 and 0.9. At 100% selfish ratio there is increase in delivery ratio from 7.64% to 48.15% at gaining factor of 0.5 and 91.44% at gaining factor of 0.9.

When gaining factor is 0, there will be increase in direct delivery by selfish nodes which in turn increases the delay but there will be high drop due to low TTL and average delay will get reduced as shown in Table VII. When gaining factor is 0.5, the average delay is significantly reduced except for 100% selfish ratio. The increase in average delay at 100% is due to low drop. When selfish ratio is 100%, average delay increases by 18.8% at a cost of high delivery ratio achieved. The improvement in average delay is observed for all range of selfish ratio at gaining factor 0.9.

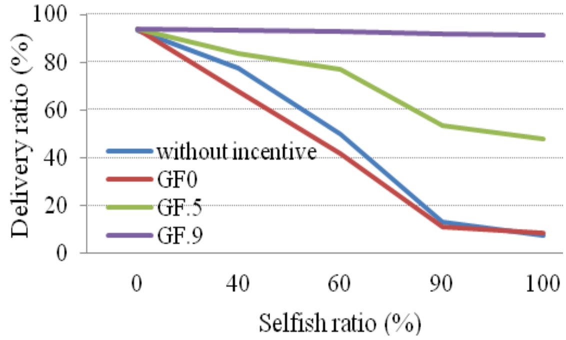

Fig.6. Effect of incentive on delivery ratio (TTL=20 min)

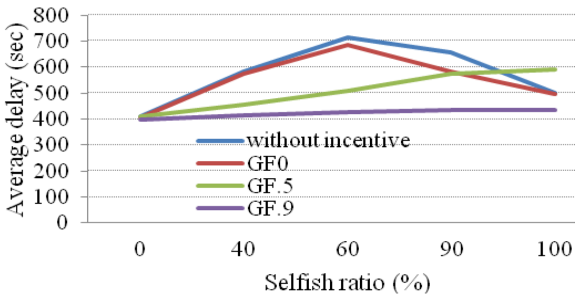

Fig.7. Effect of incentive on average delay (TTL=20 min)

The graphical analysis of the same is shown in fig 6 and 7 for delivery ratio and average delay for TTL 20 minute Hence, it is observed that overall performance is improved using Practical Incentive Protocol both in terms of high delivery ratio and low average delay.

A. *Comparative Analysis*

The comparative analysis of Practical Incentive Protocol is done with Secure Multilayer Credit based Incentive Scheme (SMART) [16] and are as follows:

1. Security with layered coin model is used in both the scheme.
2. In Practical Incentive Protocol, credit and reputations both are taken as incentive while in SMART only credit is taken as incentive.
3. Both the scheme needs central authority.
4. Practical Incentive Protocol is fair to the source. Source does not have to pay credit to the intermediate node on unsuccessful delivery path., while in SMART scheme; source has to pay a small amount of credit to all the nodes falling on the unsuccessful delivery paths.

5. Practical Incentive Protocol is fair to intermediate node as well, by giving good amount of reputation value to the nodes on unsuccessful delivery path. In SMART scheme, nodes on unsuccessful delivery path get less credit as compared to the nodes on successful delivery path.
6. In Practical Incentive Protocol, the credit needed to avail the service depends upon number of hops. In SMART, source sets the fixed amount of credit given to the entire node in advance.
7. There is problem of the source overspending the credit in Practical Incentive Protocol while this is not the case in SMART.
8. In Practical Incentive Protocol intermediate node will get fixed amount of credit. While in SMART scheme, intermediate node will get credit depending upon number of hops.
9. Incentives are calculated on the basis of distance the message is carried by the node in Practical Incentive Protocol while in SMART fixed amount of credit is given to the node for variable distance.

VI. Conclusions and Future Work

- In this paper, we have shown the effect of selfish nodes on the performance of vehicular DTN both in terms of delivery ratio and average delay. After analysing the values obtain for high and low TTL, it is concluded that presence of selfish node severely degrade the performance. At high TTL, delivery ratio has little impact for low selfish ratio but average delay is severely degraded for all the values of selfish ratio. At low TTL, delivery ratio is affected significantly for all the values of selfish ratio but average delay is little affected compared to high TTL but still there is significant degradation.
- When Practical Incentive Protocol is implemented, the overall network performance is improved in terms of delivery ratio and average delay.
- Practical Incentive Protocol is analysed for multicopy routing protocol Maxprop unlike previous work which was done for single copy. Also, identification of possible location to which the message can be carried is not necessary when two nodes meet each other.
- The comparative analysis with SMART scheme is also done and it is seen that Practical Incentive Protocol is fairer protocol.
- This work can be extended for more promising routing protocol for vehicular adhoc network for e.g. VADD i.e. Vehicular Assisted Data Delivery routing protocol and also for spray and wait routing which uses limited number of forwarding copy.
- This work can be extended to address the social selfishness.
- Credit system is to be improvised in such a way that source should know in advance the credit to avail any service.

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AUTHOR'S PROFILE

Nandita Khobragade
currently perusing a Masters in Electronics and Telecommunication from K J Somaiya College of Engineering, Mumbai. She has received the BE (Electronics and Telecom) degree from MACT Bhopal in 1999.
She has an industry experience of 10 years in the field of Telecommunication. She has also been in academics for 1 year covering subjects related to communications and microcontrollers

Bharati Singh
has done her Masters in Electronics and Telecom from VJTI Mumbai in 2007. She has received the B. Tech (Electronics and Telecom) degree from NIT Jaipur in 1992. Currently she is an Associate Professor in Department of Electronics and Telecommunication, K J Somaiya College of Engineering (KJSCE), Mumbai. She is working in KJSCE since 1993.
Prof. Bharati Singh is Life Member of Indian Society of Technical Education, New Delhi, India, since 2008. She has ranked second at Masters degree in the VJTI, Mumbai. Her area of interest is Microwave and Antenna Engineering, Wireless Communication and Optical fibre Communication