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Security and Traffic Constrained Routing Protocol for VANET

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Abstract

Vehicular data transmission operations are supported by the wireless communication mediums. The data communication is carried out with Vehicles and Road Side Infrastructure (RSI) elements. Each vehicle is equipped with On Board Unit (OBU) to manage data transmission process. Data and network information transmission is carried out with the vehicles and RSIs. Location and vehicle movement factors are analyzed to manage the data communication process. Data providers are also deployed in the Road Side Infrastructures.

The Vehicular Ad-hoc Network (VANET) data communication is initiated to transfer safety and road network details. Three types of communication models are supported by the VANET. They are unicast, multicast and broadcast schemes. One to one data delivery is achieved in unicast data transmission model. The multicast data delivery scheme transfers the data into a group of vehicles. Trajectory based Multicast Communication (TMC) protocol is adapted for the multicast communication process. Data dissemination to all vehicles in the network is carried out under the broadcast communication process. RObust and Fast Forwarding (ROFF) protocol supports broadcast communication under the VANET environment.

The TMC protocol uses the Message Forwarding Metric (MFM) and trajectory information for the data communication process. The ROFF protocol uses the Empty Space Distribution (ESD) bitmap for the data communication tasks. The Integrated Multicast and Broadcast (IMB) protocol is build with the TMC and ROFF protocols. The forwarder node selection process is optimized with priority and Message Forwarding Metrics. Local and global network information is utilized in the IMB protocol model. Data replication models are adapted to reduce the traffic levels. Data security is ensured in all types of data communication process.

1. Introduction

Vehicular networks have been given considerable attention for the past decade and several standards have been developed to render such networks more organized and realizable. The primary goal of vehicular networks was to increase safety and transportation efficiency in applications that include emergency-response operations, adaptive cruise control, lane keeping and assisted braking. One of the first steps was the adoption of the IEEE 802.11 technologies and modifying them to develop a suitable version for vehicular environments, namely 802.11p that provided lower MAC and PHY layer specifications for granting vehicles wireless access. The IEEE 1609 family of standards, known as the Wireless Access for Vehicular Networks (WAVE) protocol, were developed to provide specifications for the higher layers for offering vehicles multi-channel capabilities to enable them to access infotainment services in addition to the safety ones. More specifically, vehicles are able to access 6 other service channels (SCH) in addition to the control channel (CCH). Besides the safety-related messages broadcasted on the CCH, vehicles can send non-safety-related message on an SCH. Vehicles synchronously tune to the CCH for 50 ms to receive all periodic and event-driven messages and then switch to any SCH of their choice for another 50 ms.

VANET has some unique characteristics which make it different from MANET as well as challenging for designing VANET applications. The topology of VANET changes because of the movement of vehicles at high speed. Suppose two vehicles are moving at the speed of 20m/sec and the radio range between them is 160 m. Then the link between the two vehicles will last 160/20 = 8 sec. From the highly dynamic topology results frequent disconnection occur between two vehicles when they are exchanging information. This disconnection will occur most in sparse network. The mobility pattern of vehicles depends on traffic environment, roads structure, the speed of vehicles, driver's driving behavior and so on.

In modern vehicles battery power and storage is unlimited. Thus it has enough computing power which is unavailable in MANET. It is helpful for effective communication & making routing decisions. The current position & the movement of nodes can easily be sensed by onboard sensors like GPS device. It helps for effective communication & routing decisions. The communication environment between vehicles is different in sparse network & dense network. In dense network building, trees & other objects behave as obstacles and in sparse network like high-way this things are absent. So the routing approach of sparse & dense network will be different.

2. Related Work

To the best of our knowledge, there are no previous studies on the development of a secure [1] MCQrouting algo-rithm using the ACO technique in VANETs. MCQrout-ing and securing the routing process in ad hoc networks have been separately studied. Recently, much work has been carried out on ACO-based QoS routing algorithms for mobile ad hoc [2],[3],[4] and sensor networks [6], [7]. Little attention has been given to providing MCQrouting in VANETs utilising the ACO technique. With regard to ACO-based QoS routing algorithms for Mobile Ad hoc Networks (MANETs), Liu *et al.*propose an improved ant colony QoS routing algorithm (IAQR). IAQR introduces a routing problem with four QoS constraints associated with nodes or links including delay, bandwidth, jitter and packet loss constraints. The algorithm can find a route in a MANET that satisfies more QoS requirements of the incoming traffic. It starts by removing links and nodes that do not satisfy the defined constraints, starting with the bandwidth con-straint, from the network. It then initialises the pheromones on each link with a constant value and positions a set of ants at the source node. At each iteration *Nc*, each ant chooses its next hop based on the transition rule and updates the pheromone value of the link using a local pheromone evaporation parameter.

Once it reaches the destination node, the ant calculates the objective function based on the achieved QoS metrics. Each ant continues searching for a route until the termination condition, $Nc > Nmax$, is met. A QoS-based clustering protocol for VANETs, named VANET QoS-OLSR, is proposed in [9]. The goal of this protocol is to form stable clusters and maintain their stability during communication and link failures while satisfying QoS requirements. Bandwidth, connectivity and mobility are the metrics considered when computing the QoS value per node. VANET QoS-OLSR utilizes the ACO technique to present a Multipoint Relays (MPRs) selection algorithm with respect to QoS and mobility constraints. Once elected, a cluster head sends ANT-HELLO messages to its 2-hops away nodes. Each 2-hops away node that receives this ant message calculates its QoS metrics and inserts them in the message. The updated message is then propagated 2-hops away and the updating process is followed until the ant reaches the destination cluster head. Once reached, the destination cluster head extracts the QoS metrics information from the ant and calculates the pheromone value of the whole route. The nodes belonging to the route having the highest pheromone value are then selected to send an ANT-HELLO message back to the source cluster head. Finally, the source cluster head selects the nodes belonging to the discovered route that are located within its cluster as MPRs.

It can be noticed that most of the ACO-based routing algorithms, including the above two mentioned algorithms, employ the ACO technique without optimising its components for the network environment it is proposed for. For instance, pheromone deposit and evaporation processes are performed using constant parameters in most cases. Furthermore, in the context of vehicular net-works, sending a set of ants to find feasible routes may not be a practical option. It implies a long delay waiting for the ants to finish their tours,and it is highly likely the network topology will have changed to a certain degree over that time, so that the discovered solutions may not be viable anymore. The efficiency of ACO technique in the context of vehicular networks has not yet been well established in the literature.

In the context of securing the routing process of ad hoc routing protocols proposed for VANETs, much work has been done to defend the routing process against potential external and internal adversaries. Security mechanisms such as digital signatures and message authentication codes are used to protect immutable information within the routing control messages, while mechanisms such as per-hop hashing and hash chains are used to protect the mutable information. Since these mechanisms are not enough to mitigate security attacks mounted by internal adversaries, two security mechanisms have been pro-posed: reputation systems [10], [11] and plausibility checks [5], [8]. In the reputation system mechanism, each vehicle is assigned a reputation score based on its behavior and feedback from other nodes. The message, generated by a node, is considered legitimate if this node has a sufficiently high reputation score. Centralized reputation system is proposed in [11] where a reputation system server collects feedback from vehicles, produces the reputation scores for vehicles, propagates these reputations scores and admits or revokes vehicles from the system. Vehicles are supposed to communicate with the reputation server via RSUs. Digital signatures and message authentication code schemes are used to secure the communications between vehicles and the reputation system server.

The plausibility checks mechanism aims to build a model for the current network at each node then checks the consistency of the received mes-sage's contents against the network model. Golle *et al.*assumed that each vehicle maintains a model that contains all the knowledge available to it about the vehicular network. The network model at each vehicle is based on formal definitions and logical reasoning of events and vehicles and is used to determine if a reported event is consistent with the network model or not. For instance, if the contents of a received message claim that its sender is at a location that exceeds the maximum communication range of the receiver, then this message is considered in-consistent with the network model, *i.e.*, cannot be accepted as valid.

It can be noted that reputation systems produce extra communication overhead and introduce higher delays into the routing process. Therefore, applying plausibility checks is preferable in VANETs since vehicular traffic information, road trajectory and other related traffic information make it relatively easy to design formal definitions of events for the vehicular network.

3. VANET Data Communication Models

The advances in mobile communications and the current trends in ad hoc networks allow different deployment architectures for vehicular networks in highways, urban and rural environments to support many applications with different QoS requirements. The goal of VANET architecture is to allow the communication among nearby vehicles and between vehicles and fixed roadside equipments leading to the following three possibilities

Vehicle-to-Vehicle (V2V) ad hoc network: allows the direct vehicular communication without relying on a fixed infrastructure support and can be mainly employed for safety, security and dissemination applications. Vehicle-to-Infrastructure (V2I) network: allows a vehicle to communicate with the roadside infrastructure mainly for information and data gathering applications.

Hybrid architecture: combines both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I). In this scenario, a vehicle can communicate with the roadside infrastructure either in a single hop or multi-hop fashion, depending on the distance, i.e., if it can or not access directly the roadside unit. It enables long distance connection to the Internet or to vehicles that are far away.

A VANET has some particular features despite being a special case of a MANET and presenting some similar characteristics, such as low bandwidth, short transmission range and omni directional broadcast. Highly dynamic topology: a vehicular network is highly dynamic due to two reasons: speed of the vehicles and characteristics of radio propagation. Vehicles have high relative velocities in the order of 50 km/h in urban environments to more than 100 km/h in highways. They may also move at different directions. Thus, vehicles can quickly join or leave the network in a very short period of time, leading to frequent and fast topology changes. Frequently disconnection: the highly dynamic topology results in frequent changes in its connectivity, thus the link between two vehicles can quickly disappear while they are transmitting information. Geographical communication: vehicles to be reached typically depend on their geographical location. This differs from other networks where the target vehicle or a group of target vehicles are defined by an ID or a group ID;

Constrained mobility and prediction: VANETs present highly dynamic topology, but vehicles usually follow a certain mobility pattern constrained by roads, streets and highways, traffic lights, speed limit, traffic conditions and drivers' driving behaviors. Thus, given the mobility pattern, the future position of the vehicle is more feasible to be predicted. Propagation model: typically, VANETs operate in three environments: highway, rural and city. In a highway, the propagation model is usually assumed to be free-space, but the signal can suffer interference by the reflection with the wall panels around the roads. In a city, its surroundings make the communication complex due to the variable vehicle density and the presence of buildings, trees and other objects, acting as obstacles to the signal propagation. Such obstacles cause shadowing, multi-path and fading effects. Usually, the propagation model is assumed to not be free-space due to those characteristics of the communication environment. In rural environments, due to the complex topographic forms is important to consider the signal reflection and the attenuation of the signal propagation. Therefore, in this scenario, the free space model is not appropriate. As in any other network, the propagation model in a VANET must consider the effects of potential interference of wireless communication from other vehicles and the existence of largely deployed access points. All these features bring new challenges to the communication in VANETs. The spatial temporal constraints of this type of network and the heterogeneity of vehicles in terms of speed and mobility are design factors to be considered in the development of algorithms and protocols for vehicle networks. For instance, consider cars and trucks versus buses and trams: cars and trucks have different speeds and tend to follow an unpredictable mobility model, whereas buses and trams have a regular, slower speed and a predictable mobility model.

4. Problem Statement

Multi hop broadcasting schemes are used to disseminate safety messages. Forwarder node manages the data transmission process in multi-hop broadcasting protocols. Forwarder node selection process is carried out with reference to the waiting time details. RObust and Fast Forwarding (ROFF) protocol solves the unnecessary delay and collusion issues in data dissemination process. A forwarder candidate is allowed to use the waiting time is inversely proportional to its forwarding priority. Empty Space Distribution (ESD) bitmap describes the distribution of empty spaces between vehicles. A forwarder candidate acquires its forwarding priority using the concept of ESD bitmap. Collisions are avoided by control the waiting time differences than the predefined lower bound. The following problems are identified from the current VANET routing protocols methods. Multicast data delivery is not supported, Data security is not provided, Forwarder node selection is not optimized and Sparse vehicular network conditions are not managed.

5. Integrated Multicast and Broadcast (IMB) protocol

The RObust and Fast Forwarding (ROFF) and then its three key components are presented: construction of an ESD bitmap, forwarding priority acquisition and waiting time assignments. The ROFF protocol is designed under two assumptions: 1) each vehicle is equipped with a GPS system and a digital map. 2) In VANETs, it is assumed that each vehicle periodically broadcasts its beacon message including its current GPS position, velocity, braking/acceleration status, etc. The time interval between two consecutive beacons is called a beacon interval. The default beacon interval is approximately 100 milliseconds. Vehicles can become aware of their surroundings from periodic beacons received Note that ROFF allows each vehicle to simply utilize the information specified in the received beacon messages. ROFF does not cause any additional message overhead (MO) to collect surrounding information.

Trajectory based multicast (TMC) exploits vehicle trajectories for more efficient multicast transmissions in sparse vehicular networks. The system is focused on information dissemination among public vehicles such as taxis and buses which run for the most time of a day. In TMC, a novel message forwarding metric is used to characterize the capability of a vehicle to forward a given message to a group of destination nodes, which is defined as a vector of delivery potential of the message to each of the destination nodes. With this metric, a vehicle can simply forward a message to a vehicle that has a higher multicast delivery gain over the vehicle itself. To compute the metric, the key challenge is to predict the chance of encounter between two vehicles based only on their trajectories without accurate timing information. The travel time of a vehicle is modeled as a Gamma distributed random variable and verifies the modeling with real vehicular GPS traces. Then, a novel method is designed to predict the chance of inter-vehicle encounters. The salient feature of TMC is that it is a fully distributed approach in which vehicle trajectories are shared through inter-vehicle exchange and a vehicle makes its message forwarding decision based on the trajectories it learns instead of relying on a central point for information management.

The Vehicular Adhoc Network (VANET) data communication is carried out with different set of routing protocols. Broadcast and multicast communication schemes are adapted to transfer data over the vehicles. Data dissemination tasks are carried out through the Robust and Fast Forwarding (ROFF) protocol. Empty Space Distance (ESD) bitmap is constructed with neighbor vehicle information. The data dissemination is managed with the forwarder nodes. The forwarder node selection is carried out with the ESD bitmap information. The ROFF protocol uses the distributed information to handle the data broadcast process. The multicast data transmission schemes are adapted to perform data transmission over a group of vehicles. The Trajectory based Multicast Communication (TMC) protocol is constr5ucted to handle the multicast communication under VANET. Network trajectory information is used to select the forwarder candidate. Message Forwarding Metric (MFM) is estimated for all vehicles. The data forwarder is selected with the Message Forwarding Metric (MFM) values.

The Integrated Multicast and Broadcast (IMB) is constructed to handle the broadcast and multicast data communication in a combined manner. The IRT protocol uses the vehicle distance and trajectory information for data forwarder selection process. Security features are also integrated with the IRT protocols. Data confidentiality and integrity verification operations are carried out under the IRT based data communication models. The Advanced Encryption Standard (AES) algorithm is employed to handle the data security operations. The data verification process is managed with the Secure Hash Algorithm (SHA). The replication concept is adapted to improve the data transmission process. Frequently requested data values are maintained under the replicas. The data values are provided from the data provider and the replicas. The IMB manages the infrastructure and bandwidth in an efficient way.

6. Performance Analysis

The Vehicular ad-hoc network data communication system is designed to handle the data dissemination operations between the vehicles. Broadcast and multicast data transmission operations are supported by the system. The Robust and Fast Forwarding (ROFF) protocol is used to perform the broadcast operations. The Trajectory based Multicast (TMC) protocol is employed to perform group level data transmission operations. The Integrated ROFF and TMC protocol is designed to perform the broadcast and multi cast data transmission tasks. The Integrated Multicast and Broadcast (IMB) protocol is also enhanced with security and replica features. The system is tested with three performance measures.

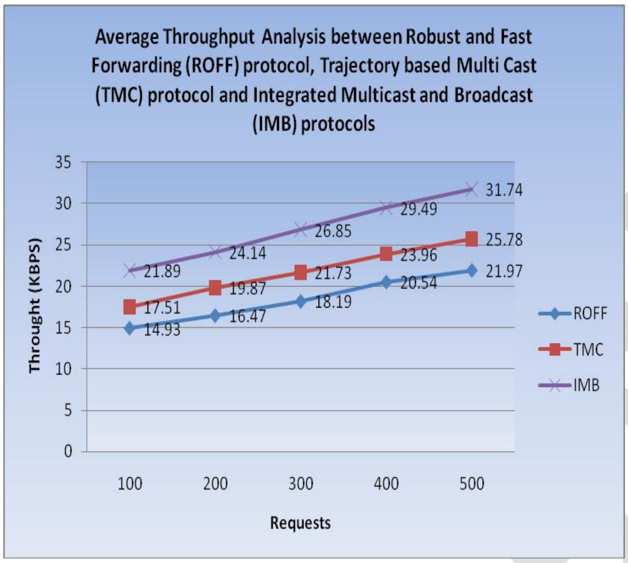
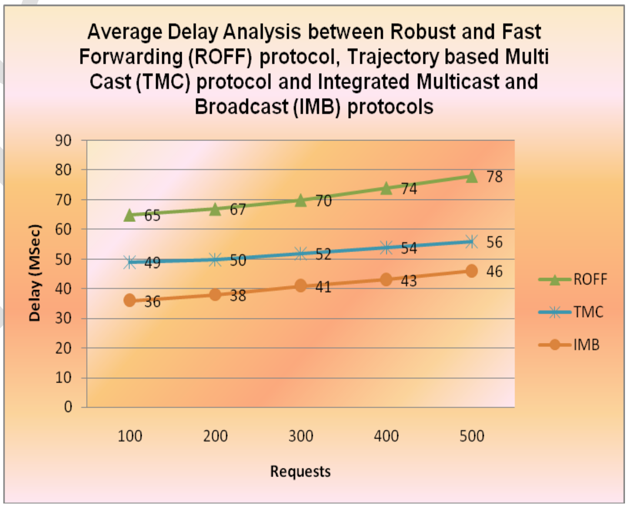


Figure 6.1. Average Throughput Analysis between Robust and Fast Forwarding (ROFF) protocol, Trajectory based Multi Cast (TMC) protocol and Integrated Multicast and Broadcast (IMB) protocols

They are average throughput, delay and average traffic rate parameters. The average throughput parameter is estimated with the average data transmission rate values. Figure 6.1. shows the average throughput analysis between Robust and Fast Forwarding (ROFF) protocol, Trajectory based Multi Cast (TMC) protocol and Integrated Multicast and Broadcast (IMB) protocols. The TMC protocol increases the throughput 20% than the ROFF protocol. The IMB protocol increases the The traffic rate parameter is analyzed to measure the messages during the data transmission process. Figure 6.3. shows the average traffic rate analysis between Robust and Fast Forwarding (ROFF) protocol, Trajectory based Multi Cast (TMC) protocol and Integrated Multicast and Broadcast (IMB) protocols. The TMC protocol reduces the average traffic rate 20% than the ROFF protocol. The IMB protocol reduces the average traffic rate 10% than the TMC protocol. The analysis result shows that the IRT protocol produces better performance than the ROFF and TMC protocols throughput level 15% than the TMC protocol.

The data transmission delay is calculated with the difference between the requested time and delivered time values. Figure 6.2. shows the average delay analysis between Robust and Fast Forwarding (ROFF) protocol, Trajectory based Multi Cast (TMC) protocol and Integrated Multicast and Broadcast (IMB) protocols. The TMC protocol reduces the average delay 25% than the ROFF protocol. The IMB protocol reduces the average delay 10% than the TMC protocol.



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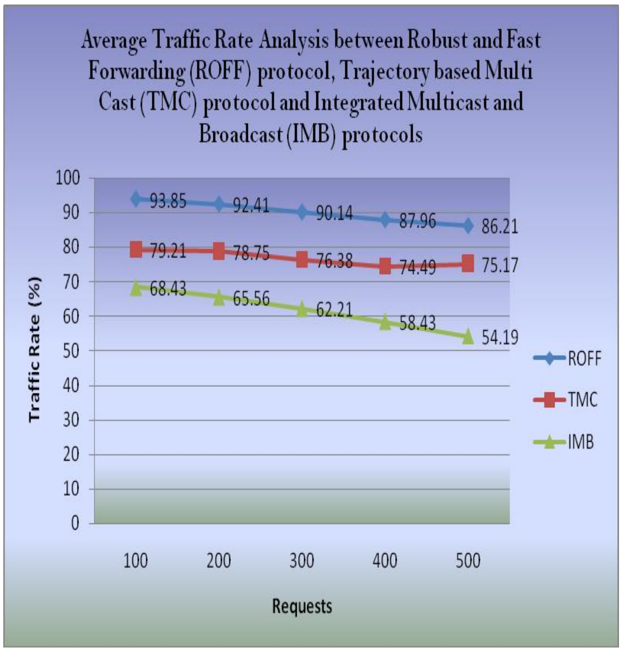

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7. Conclusion

The system provides solution for multicast and broadcast data transmission over VANET. Data security is integrated with the system. Trajectory and distance between the vehicles are used in the data transmission process. Data traffic overhead is controlled by the system. The system can be performed the following features. They are Clustering techniques can be integrated to improve the bandwidth scheduling process. The VANET data delivery system can be improved to analyze the traffic status to perform traffic diversion decision making process.

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