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A systematic technical survey of DTN and VDTN routing protocols

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ABSTRACT

There are major challenges in establishing effective communications between nodes in Vehicular Ad Hoc Networks (VANETs). In them the systems are subject to wireless interference and disconnections, thus hindering the availability and reliability of source-destination connections. Another major problem arises when VANETs are sparse, causing excessive retransmissions and delays due to long periods without maintaing connection between pair of vehicles. In these environments traditional routing protocols proposed for VANETs suffer from the absence of end-to-end connections. From intensive studies and analysis, it was found that these problems are best overcome by using Delay Tolerant Network (DTN) routing protocols that can endure huge delays, connection disruptions and embolden applications to use a minimum number of roundtrip response confirmations. DTN routing protocols are considered to be the most suitable alternative to traditional routing protocols in VANET environments. They are designed for storing and forwarding messages through a series of *forwarders* to maintain network connectivity. Thus, we present a systematic technical survey and a comparative analysis of a taxonomy of DTN routing protocols, which we extended and adapted it to include a new set of VDTN (VANET/DTN) routing protocol categories with results.

1. Introduction

The TCP/IP architecture is largely resilient in dealing with disconnection issues, whereby a break in an end-to-end connection rarely occurs in fixed line networks. This characteristic is changed in a Mobile Ad Hoc Network (MANET). The mobile nodes are operating in hostile and fluctuating conditions, often causing transient disconnections. In such conditions, TCP/IP's performance degrades considerably [1]. Such problems become even more complicated in scenarios where the networks are sparse and the nodes are incapable of maintaining connectivity. These problems also occur in VANETs, but are compounded many times over through network traffic disruptions such as the loss of connections due to out-of-sight connectivity, long distances between vehicular nodes, long delays causing excessive number of timeouts and incessant network partitioning and reconfigurations.

In relation to these problematic conditions experienced by VANETs, the use of DTN architecture primarily designed for Inter Planetary Internet (IPN) routing protocols is considered and proposed as a suitable alternative [2]. These routing protocols are capable of withstanding huge delays and connection disruptions that minimizes the exchange of the number of response confirmations in roundtrips in hostile environments. Incidentally, from the analysis of these routing protocols it was found that the DTN framework architecture and ensuing family of routing protocols are also applicable in all other types of mobile networks, such as cellular [3] and wireless sensor networks [4]. It is under these circumstances deemed necessary to develop new routing protocols which know how to take advantage of the DTN offerings and paradigms. One such routing protocol in particular is the so called *store-carry-and-forward* applied to mobile nodes called *ferries*. These nodes carry the data packet in a random or predictable manner and stored at the forwarding node for a considerable time until delivery to the next available node is achieved.

There are many DTN routing protocols, such as: Spray-And-Wait [5], PROPHET [6], Epidemic [7] and MaxProp [8]. However, they do not consider the specific problems and restrictions of VANETs. Some of the existing protocols for VANETs that have been proposed based on the DTN, are: VDTN-ToD [9], FFRDV [10], VADD [11] and Geopps [12].

In our previous work, de Sousa Viera et al., [9], proposed the routing protocol VDTN-ToD. It uses a mechanism called Trend of Delivery (ToD) to assist in routing and forwarding decisions. In anotherwork

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the ToD mechanism was inserted into the Spray-And-Wait and PROPHET protocols [13].

This paper presents a systematic technical review and discusses the taxonomy of DTN unicast routing protocols, based upon what was proposed in [14], but we have extended and adapted it by including two new categories of VDTN protocols.

This paper is organized as follows: In Sections 2 and 3, an exposition of VANET and DTN are respectively presented. In Section 4, the concepts and fundamentals of DTN routing, taxonomy, technical explanation and discourse of various DTN routing protocols are presented. In Section 5 the results are presented. Finally the conclusion, future work and possible new research topic pertaining to safety and security are presented in Section 6.

2. Vehicular networks

2.1. Definition

In a MANET, all the network nodes are connected via a wireless link, regardless of a fixed infrastructure [15]. Thus, the nodes must manage the network in an ad hoc manner.

A VANET is a category of MANET, in which the network nodes are vehicles. These networks have the aim of improving the traffic environment. This is achieved through applications that not only can assist the driver in various maneuvers and traffic decisions, but also provide Internet access for the vehicles that are on the network for many other purposes such as communication and Web access.

2.2. Features

Despite VANETs inherited characteristics of MANETs, they have their own inherent features. They have a new set of issues, challenges and advantages/disadvantages [16][17]:

- **Predictable mobility:** in traditional MANETs the node mobility is usually performed by using the model Random Waypoint [18]. In VANETs the mobility is restricted by the constructs and limits of the roads, making the future pathways of the network nodes much more predictable.
- **No power constraints:** in general, MANETs have an inherent power restriction. An example of this is the Wireless Sensor Network (WSN). On the one hand the routing protocol of a WSN needs to recognize the best use of the battery in order conserve energy. While on the order hand, VANET nodes always have available energy through their respective energy supply system. This characteristic avoids concerns regarding power saving issues for VANET protocols and their operating ecosystems.
- **Variable density of the network:** the density of the network depends on how the state of the traffic is. There may be times when the network is either sparse or dense, or simply overcrowded. In the sparse case it is hard to establish an end-to-end connection because of the absence of vehicles. In the dense case may exist excessive packet retransmissions producing packet collisions and significant delays. Primarily overcrowding situations occur from heavy density and unsustainable network connectivity due to congestion, communication freeze and grid-lock.
- **Rapid changes in topology:** due to the dynamism and high speeds of the nodes of VANETs, the network topology is constantly changing in addition to the extremely short contacts between any two communicating nodes. These characteristics complicate the operation of the traditional TCP/IP in this environment. This difficulty is produced because there is no ability to differentiate between congestion and link failure. This incapacity of differentiation causes unnecessary reductions in the congestion window size parameter settings. The performance degradation of the TCP/IP in MANETs is discussed and illustrated in [1]. The performance degradation becomes worse in VANETs, especially in heavily dense or overcrowded situations.
- **High computational processing and information power possibility:** since the nodes of VANETs are vehicles, there is the ease of installing many resources that can assist in the operations of these networks. It is possible to install or activate a GPS device into the vehicles. They would enable routing protocols such as GPSR [19] and VDTN-ToD [9] to obtain the location of the target nodes. This acquired information allows improved routing decisions to be made. Obtaining service information by accessing the Navigational System could also further assist improved routing decisions to be made.

Any new protocol for a vehicular environment should always consider these characteristics in order to provide a better or optimum performance and scalability in their applications.

2.3. Applications

The VANET's applications are quite broad, and with its respective VANET technology, it is possible to disseminate useful information such as maneuvers, precautions or advertisements for vehicles on the road.

The VANET's applications are divided in into two main categories [20]: safety and comfort. As an example of safety (other than security, privacy, trust and identification management) category, there is the collision detection, road problem warnings, lane change assistance and overtaking applications. The messages generated by these applications have the highest priority of transmission under normal operation. For example, periodical management messages are sent on the control channel to keep everything synchronized. When sudden accident occurs, an alert message of this event will spread at a higher priority than those of the management, due to the importance and criticality of the incident.

As for comfort applications, which have Internet access, vehicle passengers may want to send e-mails or chat. In this case, Access Points (APs) that provide this service are necessary. One alternative to support the vehicle in a remote location is to use other vehicles as intermediate routers ("*hotspot*") in order to reach the AP. There is also another important problematic issue related to this case, whereby the network is sometimes sparse with no end-to-end path for routing protocols to create a route. One alternative is to use the DTN strategy in order to store-carry-and-forward packets to attempt to sustain some sort of connectivity. In this way, the intermediate vehicles store the packets until they can forward them to another vehicle to reach the target.

It is also possible to have comfort applications in purely ad hoc mode. For example, imagine if the vehicle traffic on the road were congested, passengers of vehicles could occupy themselves by establishing a chat communication between themselves, or even entertain themselves by playing in a multi-player game together in the VANET ecosystem. The potential of such applications with smartphones and tablets are huge.

3. Delay tolerant networks (DTNs)

3.1. DTN definitions used in this paper

Bundle: It is message of varying size data unit in DTN. It is the packet exchanged by DTN routing protocols.

Overhead: It is given by the transmission cost of the number of bundles required for delivery from source to destination.