Multi-Path Tcp In Vehicular Ad-Hoc Networks (Vanets)

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ABSTRACT

Vehicular ad hoc networks (VANETs) have an important role in the next generation of vehicular technology. The VANETs goals are to provide drivers and other users on the road with superior benefits such as improved safety, traffic management, and other related information, by combining information and communication technology into transportation infrastructure. A more effectient VANET routing protocol must be designed as a result. Conventional engineering of the network forces a specific communication solution execution. Due to regular TCP limitations, go-to transport protocols for (VANETs) are an efficient solutions. Nevertheless, it is well know one of the main drowbacks of regular TCP protocol is the communication reliability in congestion situations thar attribute packet losses. VANETs are characterized by high vehicular speeds and rabid (disconnect/reconnect) environments, both of which can cause frequent network disruptions. Degrading the performance of the network is unnecessary, as is a reduction in data rate and similar behavior. This paper will showcase and investigate this issue using ns-3 simulations and compare the behavior of the regular TCP against Multi-Path TCP using a group of vehicles in scenarios involving direct communication and relay points with various distances. Our study goal is to improve the behavior of regular TCP protocales using MPTCP. This is done by providing a clear evaluation of network performance in such reoccurring disturbances.

Keywords: Vehicular ad hoc networks, Transmission Control Protocol (TCP), Multi-path TCP. NS-3 (discrete-event network simulator).

I. INTRODUCTION

According to the global statistics, there are over 300,000 car accidents annually in different regions, with 90,000 fatalities [1]. Congestion on the highways is growing more common. India has the most traffic accidents worldwide, per data published by the International Road Federation. In addition, the congestion wastes a substantial quantity of resources in a direct manner. VANETs are self-organizing networks formed by vehicles equipped with wireless communication capabilities. They enable vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication, facilitating applications like traffic management, safety warnings, and multimedia delivery. Vehicular ad hoc Networks (VANETs) [2] are crucial for enhancing the general standard of the transportation system as a whole as well as ensuring the safety and convenience of all parties. The provision of a real-time data feed to motorists and road safety authorities is a final goal. Consequently, Vehicular Ad hoc Network (VANET) [2] is crucial for raising the bar of the transportation system as a whole and ensuring the convenience and safety of all parties involved in the process. Drivers and those in charge of the roads receive real-time data feeds to improve traffic flow, making the roads safer and more effective [3].

There are numerous VANET applications [5]. Examples include technologies for cooperative driving such as collision warning systems, safe distance warnings, toll collecting, mapping, automatic parking, and autonomous vehicle systems. There are two types of messages they transmit and receive across VANETs: safety messages and non-safety programs. High-tech vehicles called roaming nodes communicate through three channels: vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and hybrid forms [6]. The design of VANETs is shown in Fig. 1.

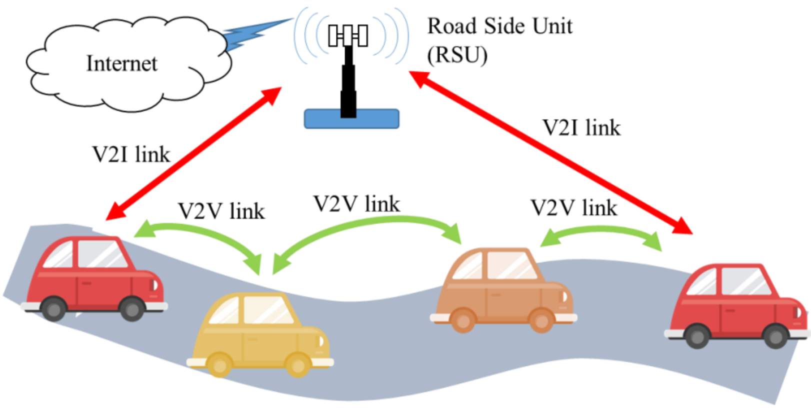

Fig. 1. VANET architecture.

VANETs differ from other mobile networks in that they are highly unpredictable in terms of their architecture, connection latencies, communication speeds, and other features [4]. The varying speeds of cars means that their position relative to each other will change over time, changing the network architecture, and locating the vehicles within the road can be challenging [5]. Real time control applications require low latency communication, while the demand for routing and mapping access will require high throughput access. These stringent requirements must be met by successful VANET systems [6].

Multi-path TCP (MPTCP) is a protocol extension to the traditional TCP that allows simultaneous utilization of multiple paths for data transmission [7]. It enables a single TCP connection to utilize multiple network interfaces, such as different cellular networks, Wi-Fi, or other available links, to enhance throughput, reliability, and resilience to network failures [8]. In the context of Vehicular Ad-Hoc Networks (VANETs), MPTCP can be beneficial for improving the performance and reliability of communication between vehicles and infrastructure [9]. MPTCP can be utilized in VANETs to allow load balancing across multiple available links, providing resilience to vehicular channel fading and fault tolerance. The multiple links can also be used to enhance throughput and performance. Finally the use of multiple channels can allow packets to be distributed so that security and privacy can be preserved even when a single channel is compromised by attackers [5]. In summary, Multi-path TCP (MPTCP) can be a valuable extension for improving the performance, reliability, and security of communication in Vehicular Ad-Hoc Networks (VANETs) [9].

It is important to note that deploying MPTCP in VANETs comes with certain challenges. VANETs have high mobility, frequent topology changes, and limited network resources. These factors can impact the efficiency of MPTCP's path selection and congestion control algorithms. Designing efficient path management and optimization mechanisms specifically tailored to VANET environments is an ongoing research area [2].

The potential of frequent interruption brought on by topological alterations' unpredictable nature is one challenge with VANETs. Additionally, the nature of wireless communication makes it prone to faults. Loss of packets due to factors other than congestion directly affects how the Transmission Control Protocol (TCP) functions. TCP is one of the well-known techniques to transport that accounts for a significant amount of data transfer volume on the web. It has been adjusted to function VANETs due to its extensive use and maturity. However, given the quirks of VANETs and the fact that TCP is created with a connection that is hardwired in mind, it might not function as well in this circumstance. Additionally, since VANETs adopt unique routing agents that support their characteristics and TCP is highly dependent on these protocols for it to function, the effect on productivity is questionable. The impact of alternative routes on TCP functionality has been the subject of numerous research [10]–[13]. In order to circumvent the wide range of evaluation frameworks, each of which has its own set of network parameters (variables such system size and network density) (MPTCP).

In this work, we will employ Multipath TCP with a single TCP connection (path) can now be shared by several interfaces thanks to MPTCP [7], and handover is permitted when new interfaces become available [8]. As a result, a moving vehicle may use a TCP connection to adjest infrastructure or other vehicles to schedule data for the best route. Multicast-MPTCP is a function that allows a single TCP connection to be broadcast to many IP addresses in order to improve TCP performance [7]. Because MPTCP is integrated into the kernel and works with current TCP socketing APIs, its functionality is hidden from programs. The program claims that MPTCP provides on-wire behavior that is comparable to TCP and that it can signal using TCP options. A new MPTCP category was created in response to this demand. An introduction to MPTCP session management and congestion control is given in this article.

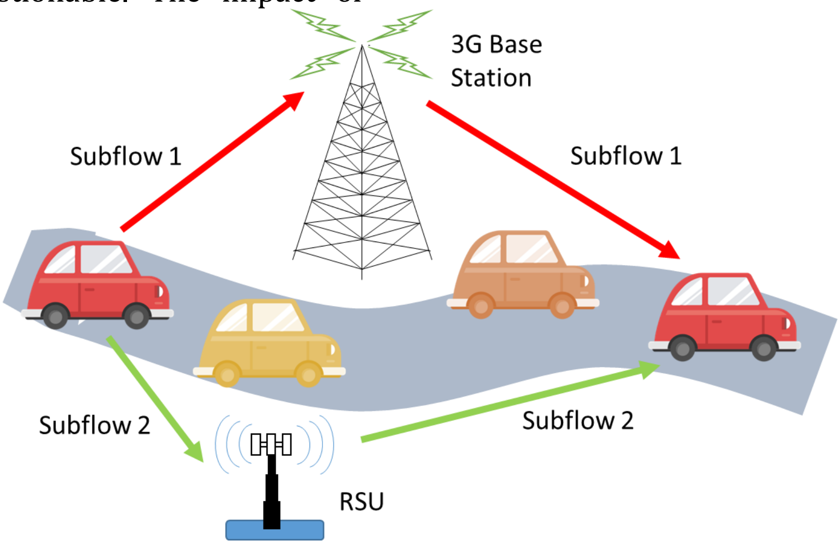

Fig. 2. VANET Multi-Path TCP Session Design [14].

II. Challenges in VANET

VANETs face several challenges due to their unique characteristics and requirements. Here are some of the key challenges in VANET: High mobility, scalability, network heterogeneity, communication reliability, security and privacy, QoS, routing and addressing, vehicular traffic management, and energy efficiency. Addressing these challenges requires interdisciplinary research efforts in the fields of wireless communication, network protocols, security, data management, and transportation systems. The VANETs challenges due to the unique characteristics of these networks, such as high mobility and frequent link outages. The mobility of vehicles in VANETs introduces rapid changes in network topology, which makes it difficult to establish and maintain reliable communication paths.

Finding trustworthy pathways through a network of relay nodes from the source to the destination is indeed a crucial challenge in VANETs. Due to the dynamic nature of the network, traditional routing protocols designed for static networks may not be suitable. Routing protocols in VANETs need to consider the high degree of mobility and incorporate mechanisms to handle frequent link disruptions and topology changes. Many existing broadcast protocols in VANETs aim to achieve efficiency and support mobility. However, some of these protocols may overlook the impact of mobility on data consistency and efficient data transfer. They might focus solely on low-level node movement without considering higher-level factors that affect data transport. To address these challenges, researchers have proposed various routing protocols specifically tailored for VANETs. These protocols take into account the mobility patterns of vehicles, anticipate link disruptions, and aim to establish reliable and efficient communication paths. Some of the techniques used in VANET routing protocols include:

1. Geographic Routing: Using location information to make routing decisions, geographic routing protocols take advantage of the mobility characteristics of vehicles. These protocols determine the next-hop based on the geographic position of the destination, enabling efficient data forwarding.
2. Predictive Routing: Predictive routing protocols utilize prediction mechanisms to estimate future network topology and vehicle movements. By predicting link disruptions and selecting appropriate next-hop nodes, these protocols can improve data delivery and reduce latency.
3. Cluster-based Routing: Cluster-based routing protocols divide the network into clusters, with each cluster having a cluster head responsible for inter-cluster communication. By organizing the network into clusters, these protocols can reduce the overhead caused by frequent topology changes and enhance data transfer efficiency.
4. Opportunistic Routing: Opportunistic routing takes advantage of the broadcast nature of wireless communication in VANETs. Instead of relying on a single pre-determined path, opportunistic routing allows multiple copies of packets to be forwarded by vehicles encountered along the way. This approach improves reliability and resilience to link disruptions.

Efforts are ongoing to design and optimize routing protocols that effectively address the data transport challenges in VANETs, considering the unique characteristics of these networks. Researchers are exploring novel approaches and taking into account mobility, topology changes, and efficient data transfer to ensure consistent and efficient communication in VANETs.

III. Methdology and the Proposed Scenrios

Four mobile nodes are used in our system to sustain communication between a group of moving cars on a road; the offered scenarios show connection failures between these vehicles as the distance between them changes. For these scenarios we will use: Ubuntu Linux distro, NS-3 (discrete-event network simulator), NetAnim, NS-3 Visualizer. For this Ubuntu Linux is chosen as an operating system and NS-3 as a network simulator for simulating the communication scenarios in the proposed system. NS-3 is a widely used discrete-event network simulator that allows you to model and simulate various network protocols and scenarios [15].

To visualize the network simulation, we can use NetAnim and NS-3 Visualizer, which are both built-in tools in NS-3. NetAnim is a graphical animator that provides visualizations of network simulations. It allows us to view the movement and connectivity of nodes, track packet transmissions, and observe network behavior in a visual form. NetAnim supports various animations and visual representations, enabling us to analyze and understand the simulated scenarios effectively. NS-3 Visualizer is another visualization tool provided by NS-3 that allows us to visualize the network topology and node movements during simulations. It provides a 3D representation of the network, including the positions and movements of the nodes. NS-3 Visualizer can be used in conjunction with NetAnim or as a standalone visualization tool. To simulate the communication between the moving cars on a road and observe the connection failures as the distance between them changes, we would need to set up the network scenario in NS-3. This would involve configuring the mobility models for the cars, defining the communication protocols, and specifying the distance-based connection parameters. Once the simulation is set up, we can run it using NS-3 and observe the results. NetAnim and NS-3 Visualizer can be used to visualize the simulation in real-time or to analyze the recorded data afterwards. It is good to mention that we have to remember to consult the documentation and resources available for NS-3, NetAnim, and NS-3 Visualizer to understand their usage, features, and how to integrate them into your simulation environment effectively.

The first scenario based (TCP)

We have three vehicles (Nodes) on a highway; in such scenario, we need an active wireless transmission system based regular TCP to conduct data among. Also, the distances between them are in the effective range of their communication ranges. Let's assume, the farthest vehicle is the leading one that sends a certain message to the lagging two vehicales on behind. On fot the following two cases could happen:

- if the farthest vehicle is in the range of communication distances, then everything is ok.
- if a vehicle is out of the communication range, then a problem would be issued because; only one vehicle in range and the farthest lagging one would not receive the transmission from the leading vehicle.

To simulate this, we generated a code that uses the regular TCP module in NS-3 to create such specific scenario. As seen in Fig. (3), the connection is alive among the nodes as long as the distance is in the effective range of their antennas and everything is ok. In Fig. (4), we made one of the nodes go much farther from the other two and as expected we can see in this run, it losses the connection to the other two vehicals.

IV. Results and Discussions

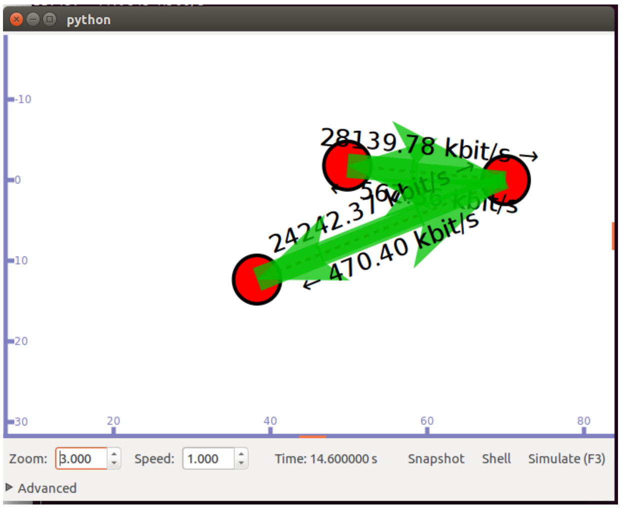

Fig (3) within the range

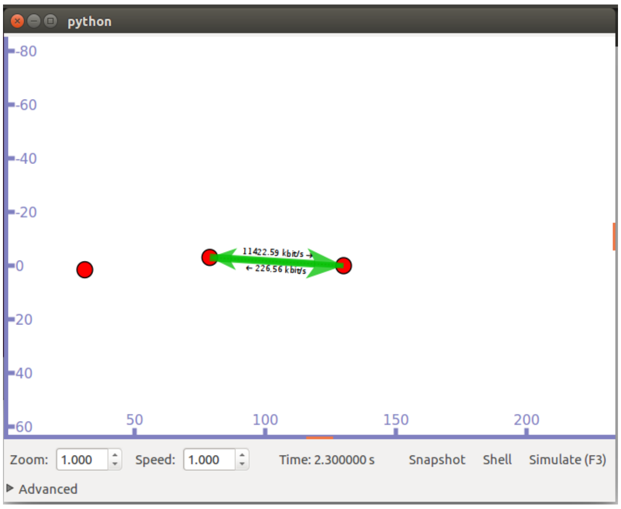

Fig (4) Out of range

To admit a solution to such issue, increasing the transmission power level between the vehicles, could realize an effective solution to maintain the link. However, this is not sistanble solution that consume high power with harsh enviromenet poluttions. Therefore, we would employ another solution based on introducing more nodes (vehicles) around these two vehicles with an assumption of the srounding traffic. Thus, we would use for that the MPTCP; which use more than one path to send the same messages between vehicles.

The second scenario based (MPTCP)

Here we would utilize the use of MPTCP with the same vehicles from scenario #1 to the MPTCP use in scenario #2. The surrounding vehicles as relay points to send/recive messages from/to the desired vehicles. So again, we established another code using NS-3 to simulate such scenario. It can seen from Fig. 5 and 6 the behavior of this protocol that conduct the use of node#1 and node#2 as relay points to pass the message from/to node#0 to node#3.

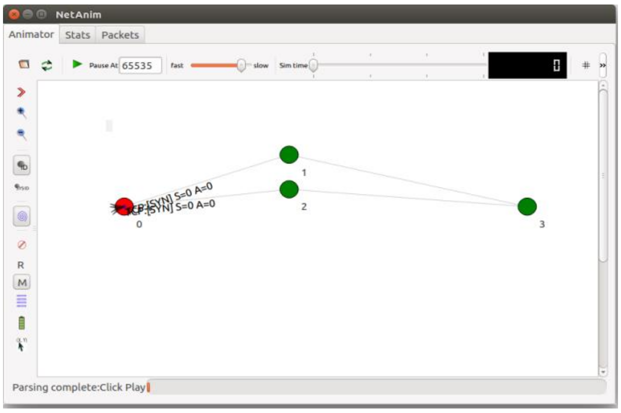

Fig (5) MPTCP packets migrating from the sender

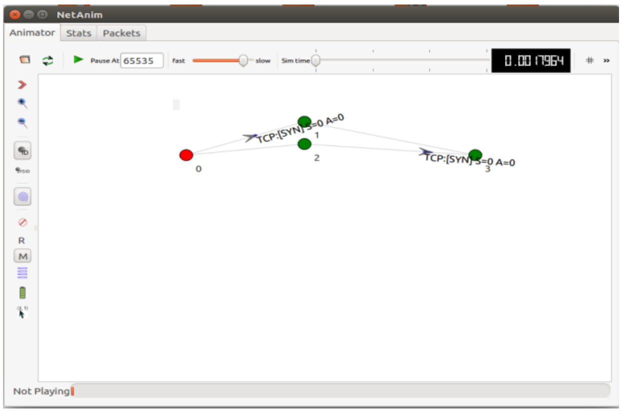

Fig (6) MPTCP packets on the way to the destination

Table (1) Information Of Nodes In Tracks

Number of node	Node (0)	Node (1)	Node (2)	Node (3)
First track	Node:0 IP:10.0.1.1 MAC:00:00:00:00:00:01 Other Node:1 Other IP:10.0.1.2 Other MAC:00:00:00:00:00:0	Node:1 IP:10.0.1.2 MAC:00:00:00:00:00:02 Other Node:0 Other IP:10.0.1.1 Other MAC:00:00:00:00:00:01	Node:2 IP:10.0.2.2 MAC:00:00:00:00:00:04 Other Node:0 Other IP:10.0.2.1 Other MAC:00:00:00:00:00:03	Node:3 IP:10.1.3.2 MAC:00:00:00:00:00:06 Other Node:1 Other IP:10.1.3.1 Other MAC:00:00:00:00:00:05
Second track	Node:0 IP:10.0.2.1 MAC:00:00:00:00:00:03 Other Node:2 Other IP:10.0.2.2 Other MAC:00:00:00:00:00:0	Node:1 IP:10.1.3.1 MAC:00:00:00:00:00:05 Other Node:3 Other IP:10.1.3.2 Other MAC:00:00:00:00:00:06	Node:2 IP:10.2.3.1 MAC:00:00:00:00:00:07 Other Node:3 Other IP:10.2.3.2 Other MAC:00:00:00:00:00:08	Node:3 IP:10.2.3.2 MAC:00:00:00:00:00:08 Other Node:2 Other IP:10.2.3.1 Other MAC:00:00:00:00:00:07

V. Conclusions

From the obtained results, it is found form scenario #1 and #2, significant differences between regular TCP and MPTCP. The regular TCP conduct a single communication link to establish connections. However, MPTCP has several benefits over the regular TCP such as: Redundancy in the connection by establishing more than a sigle communication link; in case of any fail, other pathes works as a bake up to carry the connections. Also, MPTCP detects which line of communication is best based on the algorithm currently in use with less congestion of minimum delay for broadcasting the packets.

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