Journal of Network and Computer Applications 58 (2015) 23–41

Contents lists available at ScienceDirect

Journal of Network and Computer Applications

journal homepage: www.elsevier.com/locate/jnca

Forward link quality estimation in VANETs for sender-oriented alert messages broadcast

Osama M. Hussain Rehman [a,*], Hadj Bourdoucen [a,1], Mohamed Ould-Khaoua [b,2]

[a] Department of Electrical & Computer Engineering, Communication & Information Research Center, Sultan Qaboos University, Oman
[b] Department of Electrical & Computer Engineering, Sultan Qaboos University, Oman

ARTICLE INFO

Article history:
Received 18 December 2014
Received in revised form
1 August 2015
Accepted 17 August 2015
Available online 14 September 2015

Keywords:
Alert messages
Link quality
Performance analysis
Relay selection
Sender-oriented
VANETs

ABSTRACT

Messages broadcasting protocols over vehicular ad hoc networks (VANETs) have strong potentials in enhancing road traffic safety and management including the reduction of high speed road accidents and chaotic traffic congestions. Reliable and timely reception of broadcast messages are two prime objectives in the development of safety alert messaging protocols in VANETs. This paper proposes a new sender-oriented broadcasting scheme for alert messages dissemination in VANETs, referred to as bi-directional stable communication (BDSC) protocol. A link quality estimation algorithm is exploited to recurrently quantify the quality of forward communication links. The proposed BDSC protocol improves the selection of the next relay nodes in multi-hop propagation environments, such as that formed by a platoon of vehicles. This results in achieving reachability improvement of the disseminated alert messages over densely populated vehicular network with high data traffic generation rates. Indeed, a quantitative analysis through extensive simulations reveal that the proposed protocol achieves higher reachability compared to existing sender-oriented relay selection protocols. Our study also assesses the impact of vehicles' relative mobility speed difference on VANET performance, specifically with respect to the end-to-end delay. Owing to the suggested BDSC protocol efficient relay node selection mechanism, our results show that the BDSC protocol achieves lower end-to-end delays compared to those exhibited by its sender-oriented counterparts as the maximum relative speed difference among traveling cars increases.

1. Introduction

Major efforts are actively being carried by governments, industries and academia for the deployment of vehicular ad hoc networks (VANETs) in order to facilitate vehicles with the ability to directly communicate with each other without the need for costly infrastructures (Sharef et al., 2014; Al-Sultan et al., 2014; Bilal et al., 2013; Panichpapiboon and Pattara-Atikom, 2012). It is envisaged that exchanged information through VANETs can play a key role in improving on-road driving experience by enhancing drivers' awareness of immediate and far distant road and traffic situations (Sharef et al., 2014; Al-Sultan et al., 2014), which in-turn can lead to better reaction to dynamic road related events. A diversified spectrum of applications is plausible by means of VANETs, ranging from road safety to infotainment services (Kakkasageri and Manvi, 2014; Cheng et al., 2011). Over the past decade and a half, reduction of road traffic accidents has been the mainstream focus of technology-enabled vehicles (Al-Sultan et al., 2014; Milanes et al., 2014; Sánchez et al., 2013), where research in VANETs-based safety messaging protocols have proved as a major shareholder among those technologies (Sharef et al., 2014; Al-Sultan et al., 2014; Bilal et al., 2013; Panichpapiboon and Pattara-Atikom, 2012; Cheng et al., 2011; Xuehai et al., 2014; Caveney, 2010; Chen et al., 2010).

Alert message dissemination protocols for VANETs have strong potential in the reduction of high speed road accidents by providing early warning messages to vehicles approaching dangerous situations (Xuehai et al., 2014; Bae, 2015). The timely received alert messages can increase vehicles' reaction time to advertised dangerous situations, hence increasing the ability to avoid accidents or road traffic congestions (Yanyan et al., 2011; Buchenscheit et al., 2009). Vehicles reaction to the advertised alert messages can be manually performed by drivers or automatically exerted using a built-in control mechanism, such as that envisioned by the adaptive cruise control (ACC) system (Milanes et al., 2014). Speculations have pointed towards high prevention of road traffic accidents while using active safety message applications (Marfia et al., 2013; USADoT, 2015). A non-exhaustive list of applications of the alert

* Corresponding author. Tel.: +968 24143695.
E-mail addresses: p091608@student.squ.edu.om (O.M.H. Rehman), hadj@squ.edu.om (H. Bourdoucen), mok@squ.edu.om (M. Ould-Khaoua).
[1] Tel.: +968 24143696.
[2] Tel.: +968 24142537.

http://dx.doi.org/10.1016/j.jnca.2015.08.020
1084-8045/

messaging protocols from which users could benefit include advertising accident events, traffic congestion, unexpected traffic stoppage on high speed roads, road blockage, bad weather conditions, new lane merging, construction sites and vehicles mechanical failure (Sharef et al., 2014; Al-Sultan et al., 2014; Yang et al., 2014).

For covering large physical areas in VANETs and to provide more controlled message broadcast over a shared wireless medium, alert messages are often disseminated while adopting a multi-hop mode of communication. Relay nodes are in charge of rebroadcasting the received alert messages towards vehicles falling further in distance from the original source. The relaying process can be based on “localized” or “distributed” information. A localized relaying does not require neighboring nodes information for relaying the received message, whereas a distributed relaying requires frequent updates on the neighboring nodes which is usually gathered through periodic *HELLO* packets. Various multi-hop alert messaging protocols have been proposed while considering localized (Biswas et al., 2006; Korkmaz et al., 2007) and distributed (Xiaomin et al., 2012; Amoroso et al., 2011; Palazzi et al., 2010) relaying techniques.

A proper selection of relay nodes is crucial in the design of multi-hop alert message dissemination protocols (Xiaomin et al., 2012; Amoroso et al., 2011; Bauza et al., 2013; Li et al., 2012). In fact, a good choice of the relay nodes highly influences the reachability of the broadcasted alert messages over large coverage area and in densely populated networks. On the other hand, a poor selection of relay nodes could lead to the loss of alert messages, hence significantly limiting messages reachability. High reachability and low end-to-end delays are among the key performance requirements of alert message dissemination protocols. Furthermore, the protocol should ensure efficient utilization of the channel bandwidth to be able to facilitate services in conjunction with other applications running over the same channel. However, attaining good performance levels in reachability, end-to-end delay as well as bandwidth utilization is a challenging issue in alert message dissemination in VANETs. There is a need for devising an efficient message dissemination scheme for VANETs that can fulfill the requirements of a wide range of applications, especially for safety-related messaging protocols. To the best of our knowledge, this problem has not so far been adequately addressed in the research literature, especially for high node density networks.

In an effort to fill the above described gap, this paper proposes a new alert message dissemination protocol for VANETs, referred to as bi-directional stable communication (BDSC), and investigates its performance mainly in terms of messages reachability, end-to-end delays and saved rebroadcasts. The objective of the proposed BDSC protocol is to improve alert messages reachability, especially over high node density networks, while managing to maintain low end-to-end delays that fall under recommended delay thresholds, as far as acceptable driver reaction times are concerned (Chen et al., 2010; Papadimitratos et al., 2009). Moreover, efficient bandwidth utilization is targeted by adopting a *sender-oriented* relay nodes selection mechanism for the proposed BDSC protocol. In order to understand the performance behavior exhibited by the different evaluated protocols within this research, a new performance measure is suggested, referred to as the “Relay Selection Optimality”. This metric counts the number of cases where a given selected relay node has indeed successfully relayed the message. The introduced measure attempts to capture the ability of a given protocol to make a “better” selection of the next-hop relay among the group of contending nodes. In the reminder of this paper, the terms “vehicles” and “nodes” will be used interchangeably as seen best fit within the context.

The rest of the paper is organized as follows. Section 2 discusses previous relevant research works with an emphasis on most recent ones and also provides the necessary background on *sender-oriented* relay nodes selection mechanism. Section 3 describes the building blocks of the proposed BDSC protocol. Sections 4–6 discuss the “*HELLO* Packets Exchange”, “Link Quality Estimation” and “Link Selection” layers of the BDSC protocol, respectively. Section 7 presents the metrics used for the performance analysis of the BDSC protocol. Section 8 describes the simulation scenario and the adopted system parameters. Section 9 presents and elucidates the obtained simulation results. Finally, Section 10 concludes this research work along with suggestions for possible future research work.

2. Preliminaries

2.1. Related work

Most of the existing research in VANETs has mainly emphasized on the reduction of end-to-end delays over a platoon of vehicles by selecting nodes falling furthest in distance from the source as relays (Caveney, 2010; Chen et al., 2010; Marfia et al., 2013; Amoroso et al., 2011; Palazzi et al., 2010; Ben Jaballah et al., 2014). In furthest-distance based protocols, nodes falling further from the source have less waiting time, as compared to nearer ones, when contending for becoming a relay. As a result, further in distance nodes have higher priority in rebroadcasting the received alert messages. Once a relay node rebroadcasts the received alert message, all other contending nodes will stop their waiting process upon hearing that rebroadcast.

The furthest-spanning relay nodes selection has been introduced in Marfia et al. (2013), Amoroso et al. (2011), which is a variant of furthest-distance based relay selection. The furthest-spanning scheme selects the set of nodes which have the largest sum of their distances from source and their transmission ranges. Nodes having larger furthest-spanning distance would have smaller rebroadcast waiting times and hence higher chances of becoming the next-hop relays. In the same work, asymmetric transmission ranges among single-hop neighboring nodes is considered. Intermediate nodes are used to convey *HELLO* packets between any pair of nodes in which one of the nodes is not able to hear the other directly. In Palazzi et al. (2010), Ben Jaballah et al. (2014), an application-generic message broadcasting protocol has been proposed for the reduction of end-to-end delays. The protocol reduced the delay by estimating the transmission range of each node and utilizes the estimated range for optimizing the relay nodes' waiting time before rebroadcasting the messages. Variants of *p-persistence* broadcasting scheme have been proposed in Tonguz et al. (2010), Wisitpongphan et al. (2007) which promotes nodes located further away from the broadcaster to become the next relay by assigning those nodes higher rebroadcasting probabilities as compared to nearer ones. Segmentation of the broadcast coverage area as a physical road segment has been suggested in Ming-Chin and Meng Chang (2013), where a fast forwarding mechanism was achieved by providing smaller waiting time to nodes residing in segments that are further away from the source.

The above discussed research select relay nodes based on their progress distance from the source without considering the quality of links between the source and the group of potential relays. However, it has been found that in high node dense scenarios and in the presence of high collision rates of broadcast packets, the packet reception rate drops at the receiver as the distance from the source increases (Killat and Hartenstein, 2009). As a result, more packets loss is expected when selecting nodes falling