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ICT Express 3 (2017) 22–26

www.elsevier.com/locate/icte

Geographic information-based data delivery in vehicular networks: A survey[☆,☆☆]

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Received 3 January 2017; accepted 14 March 2017
Available online 21 March 2017

Abstract

With the convergence of IT and automobile technologies, one of the key challenges is to effectively deliver Internet-based data through the vehicular network. The conventional topology-based data routing mechanisms are not suitable in the highly dynamic environment of vehicular networks. The geographic location information acquired from the GPS can help in efficiently finding routes to the destination in the vehicular network. Therefore, in this paper, we provide the survey on geographic addressing and forwarding mechanisms for the vehicular network, especially focusing on the close relationship between addressing and forwarding.

Keywords: Geocast; Geographic addressing; Geographic forwarding; Geographic unicast; Vehicular network

1. Introduction

Nowadays, vehicles are becoming increasingly akin to huge smartphones on the road, hence attracting the attention of major IT companies such as Google and Samsung. Many IT companies are trying to develop IT-based utilities for vehicles. From the perspective of communications, vehicles can be considered as computing and communication devices with no energy limits and high computing power, which is a good aspect of the vehicular network. One of the major challenges faced in transforming vehicles to sophisticated communication devices is the dynamic network topology due to the rapid changes in vehicular speeds. From the service point of view, appropriate information distribution about safety and location-based advertising is the most important aspect of the vehicular communication environment. Therefore, the geographic information-based data forwarding capability is one of the must-have functionalities in the dynamically changing vehicular network.

The Internet is connecting everything on the globe, including vehicles. For vehicles to effectively communicate on the Internet, assigning Internet addresses to vehicles is essential. Due to the lack of IPv4 addresses, IPv6 [1] is the only available and the ideal option. In this paper, we focus on how vehicles can effectively communicate on the Internet.

There have been extensive studies on geographic forwarding (or routing) in vehicular networks [2]. However, geographic addressing [3] has attracted relatively less attention. Now, to support geographic information-based data delivery, geographic addressing has to be resolved on priority. Most of the work on geographic addressing deal with ways of including geographic information in addresses, but does not consider how the geographic address information is to be utilized in data forwarding. On the other hand, most geographic forwarding or routing mechanisms focus only on how to forward or route messages based on the given geographic information. In this paper, we explore the technologies for location-based data delivery in the vehicular network from the perspective of the inter-relationship between geographic addressing and forwarding.

The rest of the paper is organized as follows. In Section 2, the vehicular network system is described in brief. The enabling technologies for geographic addressing and forwarding in the vehicular network are described in Sections 3 and 4, respectively. Finally, Section 5 concludes this paper.

2. Vehicular network system for geographic information-based data delivery

The Vehicular Network System (VNS) with geographic forwarding capable vehicles, GVNS, is composed of On-Board

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Peer review under responsibility of The Korean Institute of Communications Information Sciences.

☆ This paper is part of a special section titled "Special Section on ICT Convergence Technology".

☆☆ This paper has been handled by Prof. Oh-Soon Shin.

http://dx.doi.org/10.1016/j.icte.2017.03.003

Units (OBUs), Roadside Units (RSUs) and Location Databases (LDBs). OBUs are vehicular gateways that can transmit and receive data from nearby OBUs or RSUs. RSUs are access points (APs), Base Stations (BSs) and the gateways for Roadside Sensor Networks. For an OBU to communicate with other OBUs and RSUs, the OBU has to be assigned with at least one address. Each vehicle is equipped with a GPS and the OBU obtains its geographic location information, such as longitude and latitude, from the GPS. For the proper operation of GVNS, the following functionalities are required to be provisioned:

- Geographic addressing
  - Address assignment for geographic forwarding
  - Inclusion of geographic location information
- Geographic forwarding
  - Geographic unicast
  - Geocast and geographic broadcast

3. Geographic addressing for GVNS

These days, almost all the vehicles are equipped with GPSs, so they can be identified by their own geographic locations to some extent (but not with high accuracy because of the discrepancy between the geographic information obtained from the GPS and the real position information). This implies that the geographic location information of a vehicle can be used as a part of the vehicle identifier.

3.1. Address assignment for geographic forwarding

The Mobile Ad hoc Network (MANET) and the Vehicular Ad hoc Network (VANET) are similar in terms of the nodes communicating via multiple wireless links without any wired infrastructure. However, VANET differs from MANET since it accounts for a large number of vehicles moving in semi-unbounded road layouts at relatively high speeds. Lots of vehicles require lots of addresses, so the 128-bit IPv6 addressing is a good scalable solution for a VANET. High speeds imply that the topology-based addressing such as the address assignment on the basis of the network prefix is not appropriate because a vehicle has to change its address upon encountering a new network prefix.

M. Fazio et al. [4] proposed the Vehicular Address Auto-configuration (VAC), which is the address configuration mechanism based on the Dynamic Host Configuration Protocol (DHCP) and the concept of *leaders* for VANET. VAC selects a set of vehicles as the *leaders*, acting as the distributed DHCP servers, in a linear chain for efficient dynamic address assignment. However, VAC is a topology-based addressing mechanism not appropriate for geographic forwarding and the maintenance of the leader chain is not a trivial task.

The Geographically Scoped stateless Address Configuration (GeoSAC) [5] includes longitude and latitude information in the IPv6 address by adapting the IPv6 Stateless Address Auto-configuration (SLAAC) for VANET. Thus, GeoSAC is independent of topology (i.e., free from the network prefixes) and good for identifying a vehicle based on its geographic location information. However, the geographic location of a vehicle changes as the vehicle moves, so directly including the geographic location information as a part of the identifier (e.g., the IPv6 address) is not meaningful in the time-wise aspect regardless of the accuracy of the geographic location information.

Similar to GeoSAC, W. Vandenberghe et al., in their research [3], proposed to include the geographic location information such as latitude, longitude, radius, heading, in the IPv6 address field.

In the research by B. Meijerink et al. [6], the authors divide the Earth based on latitude and longitude into sections (rectangles), each of whose address can be included in the IPv6 destination address. This addressing scheme can be used not only in wireless ad hoc networks but also in fixed networks. This mechanism is good for addressing a geographical region, but not for a specific location. Thus, the usage of this addressing scheme is limited to geocasting.

S. Ahn [7] proposed the usage of one or more address ranges for geographic forwarding, possibly from the address range with the prefix “100” [8]. In this case, IPv6 addresses in these address ranges are independent of topology and can be derived from globally unique identifiers assigned by automobile manufacturers. The major purpose of these address ranges is to indicate that the IPv6 datagrams with such addresses should be forwarded by geographic forwarding. One of the objectives of using the network prefix is topology-based routing. However, once we decide to use geographic forwarding, the network prefix is meaningless.

Distinct from the above-mentioned schemes, the research by T. Fioreze et al. [9] proposes to extend the Domain Name System (DNS) so that it can answer geographically scoped queries, with geographic location information of those RSUs that cover the area, with the corresponding IPv6 addresses. The GeoNetworking (GeoNet) protocol [10] of ETSI configures addresses on the basis of the data link layer addresses by separating out the geographic location information from the addresses. In other words, the address does not reflect the geographic location information.

3.2. Inclusion of geographic location information

For geographic forwarding to work, the geographic location information of the destination and/or that of the sender need to be specified in the message (e.g., the IP datagram) to be delivered. There are several ways to put the geographic location information in the message.

As explained in Section 3. A, GeoSAC includes the geographic location information of the source and the destination in the IPv6 source and destination address fields. However, as explained in Section 4, the geographic forwarding mechanisms may require the geographic location information of the sender. In this regard, they do not have the capability to satisfy this requirement.

The research by B. Meijerink et al. [6] specifies the translated geographic location information of a target region in the IPv6 destination address. The longitude and latitude information is translated into a binary bit pattern so that it can be included in the IPv6 address. This also does not have the