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Boosting named data networking for data dissemination in urban VANET scenarios

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ABSTRACT

Named Data Networking (NDN) is a data-centric networking architecture designed for the future Internet. Instead of establishing host-based end-to-end communications, NDN accomplishes the content retrieval and distribution through the delivery of named data. In this paper, we boost the NDN architecture to support efficient content delivery in urban Vehicular Ad hoc Networks (VANETs). First we propose a new geo-based NDN forwarding strategy to achieve efficient and reliable packet delivery in urban VANET scenarios. Then we investigate the caching redundancy problem with the default full-path caching scheme in VANETs, and present some heuristic strategies to reduce the unnecessary cached copies. Simulation results show that our forwarding strategy can greatly enhance NDN for data dissemination in urban VANETs, which achieves 27%∼75% higher request success ratio, and 40%∼80% lower delay compared with the original NDN strategy in scenarios with different vehicle densities. Besides, the caching strategies can reduce the cached copies by about 50% in dense scenarios with nearly no drops in the success ratio and negligible increase in delay.

1. Introduction

Vehicular ad hoc network (VANET) is a special kind of wireless ad hoc network, the communication nodes of which are moving vehicles. Although initially proposed to improve driving safety, sorts of informative applications can also be supported by VANETs to serve drivers and passengers, e.g., traffic information query, advertisements. Most of these applications aim to satisfy position-related information requests, e.g., "*what are the exhibitions currently on at XXX Museum?*", "*what are the shows recently on at XXX Theater?*". Existing work mainly employs geo-based routing and data dissemination mechanisms to support the information exchange, but it is difficult to achieve satisfactory performance. Especially when communication vehicles are distant from each other, the packet delivery ratio presents obvious drops and the latency experiences significant increase [1,2].

Named Data Networking (NDN, aka Content-Centric Networking) [3,4] is a clean-slate design for the future Internet. Existing researches have shown that NDN can provide good support and bring significant performance improvement for sorts of data-centric applications that are currently popular on the Internet, such as audio conferencing [5], video streaming [6], data synchronizing [7], etc. In this work, we concern about the availability and performance when applying the NDN architecture to VANET scenarios. We focus on the challenges and try to propose the corresponding solutions.

Instead of establishing host-based end-to-end communications, NDN focuses on the delivery of named data. Content consumers express the data requirement with *Interest* packets identified by data names, and content publishers reply with the corresponding *Data* packets. Data are cached at routers along the forwarding path, and any node with the cached data can also serve as the content publisher afterwards. Besides, NDN provides good support for multicast, so that multiple requests from various positions for the same data can be efficiently replied. Therefore, VANETs should benefit from NDN especially in the respect of data dissemination. However, each coin has two sides. Directly applying NDN into VANETs also confronts with great challenges in the forwarding and caching strategy.

In the forwarding plane, NDN relies on a priori information similar as the IP route table to efficiently forward data. NDN can easily support the mobile data consumers [8], and the design for the support of mobile data publishers is also presented [9]. However, for a whole mobile network scenario in which all nodes are moving, such as VANETs, challenges still exist. Due to the high mobility of vehicles, it is impossible to establish any stationary route beforehand, thus the default forwarding strategy degenerates to flooding which incurs much overhead and does not

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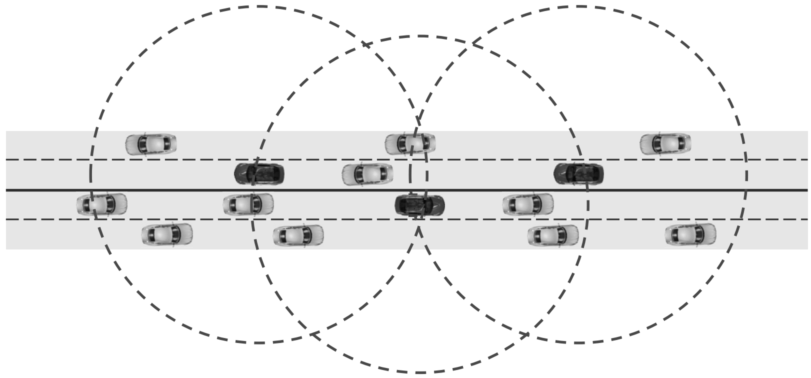

Fig. 1. Illustration of the caching redundancy in the VANET scenario. The dark vehicles are actual packet forwarders, and the dotted circles show the wireless transmission range. All vehicles covered by the transmission range make cached copies of Data packets which leads to redundancy.

perform well. Existing work has proposed some mechanisms to reduce the unnecessary broadcasts [10,11]. Comparatively, we make a step further based on the existing studies in traditional VANETs. We present a new forwarding strategy which utilizes the geo-location information to further improve the performance of data dissemination, thus to make NDN more suitable for urban VANET scenarios.

As for the aspect of caching, all NDN routers along the data forwarding path make cached copies by default, which can lead to much redundancy in the wireless environment. Fig. 1 gives an illustration of this problem. In the figure, dark vehicles are the actual packet forwarders, while there are also many other vehicles which do not participate forwarding locate in the wireless transmission range (indicated by the dotted circles). Therefore, in the NDN architecture, all these vehicles can receive the Interest packet and the corresponding Data packet so that the cached copies are generated. This leads to multiple cache copies for the same piece of data within a local area, which is obviously redundant. We present some heuristic strategies to reduce the unnecessary data caching without sacrificing the performance of data dissemination.

The main contributions of our work are listed as follows.

- We present a geo-based design of NDN forwarding strategy for urban VANETs to deal with the challenge caused by the high mobility of vehicles. We borrow ideas from the geo-based routing and data dissemination mechanisms to make NDN more suitable for urban VANET scenarios. To the best of our knowledge, this is the first forwarding strategy that makes use of geo-location information for NDN-based VANETs.
- We explore the cache efficiency when applying NDN into VANETs for the first time. We notice that the cache redundancy exists in the default full-path caching strategy. Thus we propose several heuristic strategies to eliminate the cache redundancy, and deeply investigate their effects on the performance of data dissemination.

The rest of this paper is organized as follows. Section 2 provides the background and some related work. Section 3 presents the forwarding strategy design for urban VANETs. Section 4 illustrates the sampling viewpoint of caching strategy and several heuristic mechanisms. Evaluation results are given in Section 5. Finally, Section 6 concludes the whole paper.

2. Background

In this section, we present the research background with some related work on VANETs, NDN and network caching.

2.1. Vehicular ad hoc networks

The characteristics of wireless transmission and the high mobility of vehicles together define the challenges of VANETs. Existing work mainly focuses on the efficient data dissemination to certain vehicles or areas, and three schemes are widely employed, i.e., geo-based routing, hop-by-hop forwarding and carry-and-forward technique.

Geo-based routing protocols use geo-location information to assist packet routing. GPSR [12] is a classical position-based routing protocol for general wireless ad hoc networks, in which nodes forward packets greedily to the destination. Many studies based on GPSR use additional information to improve the routing efficiency for VANETs. For instance, A-STAR [13] calculates the shortest path with roads weighted by the number of bus lines passing through. VADD [14] utilizes the digital map with vehicle density information to calculate the best path and find intersections that packets should pass through.

Hop-by-hop forwarding is widely used because it is difficult to establish the whole forwarding path beforehand in highly dynamic VANETs. The forwarder selection can be based on various metrics, e.g., GPCR [15] prefers vehicles located in the middle of intersections to avoid the obstacle effect on wireless communication, while CLWPR [16] takes multiple factors into consideration including distance, sending queue length, frame error rate, etc.

Carry-and-forward mechanism is used to cope with disconnected scenarios. Some vehicles are chosen to store the packets if no better forwarder exists. The packets are carried on the moving vehicles until better forwarders appear later. These chosen vehicles are called Store-Carry-and-Forward (SCF) vehicles. For instance, DFD-FSFD [17] selects vehicles moving to the destination as SCF vehicles, and UV-CAST [18] chooses boundary vehicles of connected network components as SCF vehicles.

Although amounts of mechanisms have been proposed, VANETs still suffer from poor performance when the distance between sender and receiver is large [1,2].

2.2. Named data networking

Different from using IP addresses to establish host-based communications, NDN adopts a data-centric design. A content consumer sends an *Interest* packet (sometimes we use Interest for abbreviation) which contains the name of the requested data, and a content publisher responds with a *Data* packet (sometimes we use Data for abbreviation). Interest packets are routed based on the name of requested data, and Data packets follow the reverse path back. Meanwhile, the data are cached at routers along the forwarding path, which can be used to satisfy future requests for the same piece of data.