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ScienceDirect

Computer Communications 31 (2008) 2907–2924

computer communications

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Kinetic mobility management applied to vehicular ad hoc network protocols

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Available online 9 February 2008

Abstract

Vehicular Ad Hoc Networks (VANETs) are a particular category of mobile ad hoc networks (MANETs) characterized by a high mobility and a reduced connectivity. In order to develop protocols for vehicular networks, the community may either create VANET specific approaches, or adapt already existing protocols to VANET. While the former may provide efficient specialized solutions, the latter offers an increased interoperability and universality, which is a key issue for industrial partners involved in the deployment of VANET and Intelligent Transportation Systems (ITS). An important aspect in the porting of ad hoc networks solutions to VANET and ITS is an efficient management of vehicular mobility.

Mobility Management is a principle aimed at updating network routes or structures in order to keep them coherent with mobile topologies. Mobility management may be proactive or reactive, depending if the updates are triggered with or without topology changes, or if and only if a change in the topology effectively requires to update the structure. Failure to develop efficient mobility management heuristics leads to a waste of network resources and suboptimal routes or structures. The optimal solution is obviously the reactive mobility management, as updates are optimally triggered only when necessary. However, due to its complexity, the reactive mobility management has not attracted as much attention as its proactive counterpart.

In this paper, we introduce a location-aware framework, called Kinetic Graphs, that may be followed by ad hoc protocols in order to implement a reactive mobility management. The Kinetic Graph framework is able to capture the dynamics of mobile structures, and is composed of four steps: (i) a representation of the trajectories, (ii) a common message format for the posting of these trajectories, (iii) a time varying weight for building the kinetic structures, (iv) an aperiodic neighborhood maintenance. We eventually provide a example of a successful application of this framework to broadcasting and routing in VANET.

Keywords: Reactive mobility management; Kinetic mobility management; Kinetic graphs; Mobility predictions; Broadcasting; Routing; ITS; Vehicular networks

1. Introduction

Inter-vehicular communication (IVC) is regarded as a key technology for improving road safety and comfort through Intelligent Transportation Systems (ITS). The growing interest toward the possible applications of wireless technologies to the vehicular environment has recently led consortia (US VII [1], EU C2C-CC [2]) and standardization bodies (IEEE [3], ETSI [4], ISO [5]) to develop technologies and protocols for transmission of data between vehicles, and between vehicles and road infrastructures. A network without any centralized coordinator and where communicating nodes compose cars or road infrastructures is called a Vehicular Ad Hoc Network (VANET). A VANET is therefore a generalization of a MANET to extremely mobile topologies. Due to the particular mobility and connectivity, standard protocols for MANETs have

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[1] Institut Eurécom's research is partially supported by its industrial members: BMW Group Research & Technology – BMW Group Company, Bouygues Télécom, Cisco Systems, France Télécom, Hitachi Europe, SFR, Sharp, STMicroelectronics, Swisscom, Thales.

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doi:10.1016/j.comcom.2008.01.060

been mostly criticized due to the latency and overhead required when used for vehicular networks. It has been notably observed that the OLSR routing protocol based on the Multipoint Relaying (MPR) structure was not adapted to highly mobile networks such as vehicular networks, and more generally that proactive routing protocols consumed a significantly large amount of energy and network resource only dedicated to the maintenance of their routing tables. The community working in vehicular communication therefore started to develop specific solutions for VANETs, such as Geographic Broadcast (geocast), Geographic Routing (georouting) with Greedy Perimeter Stateless Routing (GPSR) or Last Encounter Routing (LER) for instance, or more generally opportunistic routing.

Taking a different look, we can see that the limitation of standard routing and broadcasting protocols for highly dynamic networks comes from the lack of efficient management schemes handling nodes mobility, and not from a bad design of the protocols themselves. Indeed, routing information is built and optimized based on topology information gathered by periodic beacon messages. Beside the significant overhead of periodically sending topology information, this critical procedure is also limited by its stability with respect to the latency required to update routing information, and to the validity of that topology information. If nodes are moving too fast, the time needed to update routing tables might actually exceed the duration of the links composing the routing paths for instance.

One solution in order to improve mobility management is to increase the time interval during which the topology is assumed known and does not need any update. For that matter, mobility predictions could be used in order to avoid dead links by predicting alternate connectivity solutions. As long as topology information is correctly predicted, a maintenance is not required. Accordingly, the maintenance is optimized by updating routing data if and only if an unpredicted new topology information truly affects routing. Thanks to this enhanced mobility management, which we categorize as *kinetic*, the use of standard MANET routing protocols, such as DYMO, MPR or OLSR, could be envisioned again for VANET and ITS. That is also a significant argument for industries and standardization bodies working in ITS and vehicular communication, as this could ease the interoperability between vehicular networks, fixed networks, and MANETs where these protocols lead.

In this paper, we propose a Kinetic Mobility Management solution based on mobility predictions for optimizing standard MANET protocols for VANETs or ITS. We define a location-aware framework called the *Kinetic Graph* that may be followed by ad hoc protocols in order to reach a kinetic mobility management. We first provide a general description of how the trajectories are modeled, how structures are initially built and finally, how they are maintained. We emphasis that our objective is first to suppress the periodic beaconing process widely used by almost all ad hoc protocols in order to adapt to mobility, and also to increase the time interval during which the mobile topology is correctly anticipated. Then, we discuss two different kinetic link weights that could be easily adapted in most of protocols for VANETs. Finally, we provide a successful application of the Kinetic Graph approach to broadcasting in VANETs. We also would like to point out that this approach may also be applied to VANET and ITS specific protocols, as improving mobility management is also important for georouting or geocasting for instance.

The rest of this paper is organized as follows. In Section 2, we define a novel terminology for mobility management and describe the challenges behind this terminology in VANETs. Section 3 then formally introduces the Kinetic Graphs and covers the four steps of its framework, while Section 4 provides an application example of the Kinetic Graph framework to broadcasting and routing in VANETs. We finally conclude in Section 6 and shed some lights on future orientations of kinetic mobility management.

2. Reactive mobility management

In this section, we define a novel and optimal concept for mobility management called *Reactive Mobility Management*, which is based on mobility predictions and aims at optimally updating a structure when and only when required, regardless of any topology change. First, we define the concept, then address the challenges facing this concept, and finally analyze the expected performance of this concept.

2.1. Definition of concept

The MANET routing community classified routing protocols mostly in two classes *Proactive* and *Reactive*, depending if a route is created when data traffic needs to be transmitted, or if all routes are proactively created independently of the data traffic.

As mobility was not considered during the design of most routing protocols, it is only handled by a periodic maintenance process in order to detect any topological change and update the routes. This process is suboptimal and wastes network resources, as it is run even if nothing needs to be changed. Taking a similar vocabulary, but considering mobility instead of routing, routing protocols may therefore be considered to be using a proactive mobility management defined as follows:

Definition 1 (*Proactive Mobility Management*)**.** A Proactive Mobility Management protocol proactively triggers a maintenance process with or without topology changes. Moreover, as proactive protocols do not have any vision of future topologies, the process is usually repeated periodically.

According to this definition, a mobility proactive protocol may only adapt the routes based on past topologies, as nodes already moved when the process starts. Moreover,