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A survey on context-aware vehicular network applications

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ABSTRACT

Transportation is considered as one of the main human needs in any country for macro-level planning. Due to increased production of vehicles, problems and issues associated with transportation systems have been taken on wider dimensions. Thanks to rapid technological developments, Vehicular Ad hoc Networks (VANETs) have been used to provide effective opportunities for enhancing the safety of roads and for improving transportation networks. Various context-aware applications have been designed on vehicular ad hoc networks, offering a wide range of services to drivers, including traffic management, collision avoidance, and convenient supports, just to name a few. This paper reviews and classifies existing context-aware applications as used in vehicular networks. A classification framework with three dimensions including the environment, system-and-application, and context-awareness is proposed. This framework is then used to review the existing context-aware transportation systems for each dimension, which in turn consists of some parameters. Based on this framework, existing context-aware research projects are reviewed and classified. Finally, a clear vision of research directions in this area is described.

1. Introduction

Vehicles have become an essential part in people's daily lives, despite the inherent problems associated with them (e.g., accidents, pollution, etc.). It is estimated that each year more than 1.27 million vehicular accidents occur across the globe [1], ninety percent of which are attributed to human error [2]. This fact poses serious threats and challenges to the society. Moreover, traffic congestion, due to increased use of cars, leads to fundamental problems, including longer trip times, increased air pollution and huge fuel consumption.

Researchers and industry professionals have used information and communication technologies in the transportation area under the title of Intelligent Transportation Systems (ITS) [3]. In light of recent developments in computational and communication technologies, many researchers have become attracted to the new field of context-aware vehicular ad hoc networks as a technique to provide proper solutions to transportation system challenges.

The Vehicular Ad hoc Network (VANET) is a branch of the Mobile Ad hoc Network (MANET) and a component of the intelligent transportation system that have emerged thanks to advances in the wireless technology and automobile industry [4–7]. However, various reasons such as high mobility as well as driver behavior and decisions dramatically distinguish the VANET from the MANET [8]. VANETs have unique characteristics such as high mobility, high computational ability, rapid changes in network topology, and variable network density [9].

Over the past years, several research papers have focused on proposing communication protocols for VANETs [10]. As a result, various wireless solutions for vehicle-to-sensor, vehicle-to-vehicle, vehicle-to-Internet, and vehicle-to-road have been developed [11]. Today, the vehicular ad hoc network provides the required infrastructure for a wide range of context-aware transportation applications including safety, the improvement of traffic state, and drivers' convenient supports. In these networks, real-time traffic monitoring, traffic sign warnings, recognition of passengers, barriers, and road lanes, accident detection, and speed and distance estimation provide drivers with better decision making abilities. Among other applications of these networks are automatic payments of parking fees and highway tolls, multimedia communication, and access to the Internet. With VANETs, the vehicle or driver's "horizon of awareness" increases intensely [12]. In general, context-aware applications of vehicular ad hoc networks use driving context information to adapt various decisions according to the environment situation. These applications are able to sense, reason, and react to the environment. The key feature of them is "*context-awareness*".

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Due to the importance of VANETS to research community, several survey papers have been published recently. Most of these papers investigate VANETS from a communication viewpoint [3,9,13–15]. However, the scientific literature lacks a comprehensive survey from the application viewpoint. The main distinction of this paper from other surveys is the focus on the application layer as well as context-awareness. Reviewing and classifying context-aware applications of transportation network can help with the development of future research studies in this field. We propose a classification framework with three dimensions including environment, system-and-application, and context-awareness wherein each dimension consists of one or more parameters. Then, based on the proposed framework, context-aware applications in vehicular networks are classified from a technical perspective.

The environment dimension describes the domain assumed about the vehicular network applications, such as urban, rural, and highway environments. The system-and-application dimension consists of several parameters including the service type, system architecture, communication type, and application action pattern. The service type refers to the type of services and advantages provided by vehicular network applications such as safety, traffic management, and support for drivers. The system architecture indicates the structure of system components on the vehicular network. Some vehicular network applications have a centralized architecture, meaning that all operations of the application are performed on a central main server. In some other applications, the main component of the system is distributed on a set of servers, forming a distributed architecture. Vehicular communication refers to the wireless communication mechanism used in the applications of the vehicular network. Communications can take place directly among moving vehicles in vehicle-to-vehicle (V2V) form or between vehicles and fixed road-side equipment. The Action pattern characterizes the way in which the application is executed and performs action on the vehicular network. Vehicular ad hoc network applications are executed in different modes such as event-based, periodical, or based on user demand.

The context-awareness dimension consists of the two parameters of context type and context gathering method. Context-aware vehicular network applications make use of such driving context information as speed and acceleration of the vehicle, traffic information, and weather information, among others. These applications build on different technologies like on-board sensors and devices, road-side infrastructure, internet infrastructure, among others to collect driving context information. We aim to provide a comprehensive understanding of context-awareness in vehicular network applications.

This paper is organized as follows: After this introduction, related background information including pervasive computing, context-awareness, and context-aware vehicular network are described in Section 2. In Section 3, a framework is proposed for classifying context-aware applications in vehicular networks. Section 4 describes the existing research projects in vehicular networks. Sections 5, 6, and 7 review and classify the projects according to the criteria of the proposed framework. Finally, concluding remarks and open research directions in this area are discussed in section 8.

2. Background

Pervasive computing and ubiquitous computing are used interchangeably in the literature. It was Mark Weiser who firstly expressed his vision about pervasive computing in 1991: “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it” [16]. From the perspective of Weiser, in the era of pervasive computing, the presence of computing services is often overlooked, due to their widespread and vital roles in people’s daily activities. In fact, pervasive computing environments are saturated with computing and communication capabilities, and have integrated with users in such a way that it seems like an invisible technology [17].

Mark Weiser introduced ubiquitous computing as the third wave of computing technology [18]. The first wave refers back to the era of mainframe computing, wherein many people used to share a single computer. The second wave came with personal computers, allowing each individual to have their own computer. In the era of ubiquitous computing, however, many computers of different types could be shared for each person, which provides the user with a set of personalized services. Mark Weiser has predicted a transition from personal computers and distributed computing to pervasive computing during 2005 to 2020.

Pervasive computing aims to create a world in which objects have computational and processing abilities, communicating with the global network through wireless or wired links. Here, any person can automatically receive personalized services from computers that have been embedded in the surrounding environment and that are invisible from their sight.

In the past decade, advances in hardware technologies have given rise to complex and small computational devices, which can provide infrastructure for pervasive computing. Through integrated connection of several information devices embedded in the user’s environment, pervasive computing attempts to be aware of the user situation and his/her environment and to adapt services/actions accordingly [19].

Applications run within a pervasive computing environment are executable and available to users at any time and place. Instead of receiving inputs from users as in traditional methods, these applications sense the context information implicitly from the environment and perform the proper action accordingly. These applications, which are known as “context-aware”, form the building blocks of pervasive computing [20,21].

2.1. Context-awareness

Context is a fundamental concept in pervasive computing environment. Context has several definitions [22–24]; However, in a consensus definition, it is defined as “any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves [25,26]”. “A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task [25,26]”.

In the pervasive computing environment, context-aware systems use context information related to the user, at any time and any place, to adapt their operations to the environmental situation. In fact, context-aware applications are applications that are capable of adapting their operations to the user’s context, which is provided by sensing the environment contextual information [27]. In general, the development of any context-aware application consists of the following three main components [21,28]:

- **Context acquisition:** gathering contextual information by sensors.
- **Processing:** employing reasoning techniques in order to obtain high-level contextual information (such as user’s activities).
- **Acting:** providing services to the user according to his/her current situation.

2.2. The context-aware vehicular network

Recent advances in software, hardware, and communication technologies have facilitated the design and implementation of var-