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Designing Privacy-Aware Intelligent Transport Systems:
A Roadmap for Identifying the Major Privacy Concepts

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ABSTRACT

Intelligent transport systems (ITSs) play a key role in people's daily activities. ITSs significantly improve mobility offering a variety of services to a vast number of users that increase on a daily basis, as more and new services are introduced. These services are based on advanced information and communication technologies (ICTs) and rely strongly on connectivity and computing resources. However, technical vulnerabilities of the technologies used in ITS, as well as the increase in users' awareness has brought security and privacy concerns to the forefront. This article aims at identifying a set of privacy concepts that provide the bases for designing trustworthy ITS services identifying possible threats and users' privacy concerns. A key contribution of the article is a roadmap that presents in detail how for every ITS function corresponding to privacy concepts can be realized for overcoming specific threats and users' privacy concerns in a smart city context.

KEYWORDS

Design, Intelligent Transport Systems, Privacy, Privacy Properties, Security, Services, Software Engineering, Threats

INTRODUCTION

Intelligent Transport Systems (ITS) play an important role on contemporary smart cities by allowing for smart solutions such as information services provision; management of transport flows; traffic and vehicle surveillance; intelligent revenue systems; and intelligent infrastructure that allows for connectivity/communication (V2I, V2V). Privacy is a key component of smart cities as ITS affect a number of citizen's activities. For example, travelers generate massive quantities of detailed individual/ activity/ travel/ location information through a variety of channels (payments, subscriptions, social media, mobile Apps, internet cookies, etc.). This increases the exposure as well as the possibility of inappropriate use of individual information, raising severe concerns on data privacy, protection and

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security. The value of privacy in the context of mobile devices and mobility has been discussed in the work of Antoniou and Polydoropoulou (Antoniou et al., 2015). There is a trade-off that needs to be considered as additional personal information can improve quality of services but on the other hand this may lead to violation of users' privacy.

This paper attempts to shade light in the aspects of ITS which may be vulnerable to privacy violations and will contribute to the debate about ITS adoption by smart cities. Section 2 provides a brief overview of Intelligent Transport Systems and their significant role in Smart Cities. Section 3 presents the privacy properties a modern ITS should realize in order to provide trustworthy services to its users. The privacy properties are suggested after a clear discussion and linkage between the ITS main functional characteristics, technical functional services, indicative solutions used widely for the implementation of these services, thirteen identified privacy threats and respective privacy concerns expressed in the literature regarding the use of ITS services and their impact on users' privacy. Our previous work on cloud computing assisted a lot in the identification of the respective privacy properties since the nature and architecture of cloud environments are very similar to the ITS environments. Section 4 identifies a number of privacy requirements that ITS systems should implement for raising the users' trustworthiness. Section 5 concludes the paper and highlights directions for further research.

SMART CITIES AND INTELLIGENT TRANSPORT SYSTEMS

Smart Cities

The concept of smart urban spaces originated from the time when cities started facing problems of efficiency in sectors such as transport, health and environment. Smart cities are cities that utilise information and technologies for effective and intelligent usage of resources resulting in cost and energy savings, improved quality of life and reduced environmental footprint (Cohen, 2011). The concept of smart city is not static but rather a process by which cities become more liveable, resilient and responsive to new challenges. Recently a rising number of papers address issues regarding smart cities. Neirotti et al. (2014) present current trends in Smart City initiatives. Kramers et al. (Kramers et al., 2014) explore ICT solutions for reduced energy use in cities. Al-Hader et al. in (Al-Hader et al., 2009) discuss about development and monitoring of smart-city infrastructure. Nuaimi et al. in (Nuaimi et al., 2015) analyse applications of Big Data to smart cities while Batty in (Batty, 2013) and Goulias in (Goulias, 2015) set the case for big data in smart cities and city planning. Kavroudakis in (Kavroudakis, 2015) presents a methodology for constructing micro-data for smart decision-making. Furthermore, in (Kavroudakis et al., 2012, 2013) Kavroudakis et al. demonstrate the use of spatial microsimulation approaches for understanding population inequalities for smart policy evaluation in a smart city context.

ICT and Mobility

The rapid advances of Information and Communication Technologies (ICT) over the last decade as well as the introduction of mainstream mobile devices pushed innovation and smart solutions in cities across the world. That advances help overcome restrictions over space and time, while enabling faster and efficient transmission of data and information.

Smart mobility approaches are key components of smart cities. Actuators (sensors) measure, sense and observe transport conditions in any part of a city. Advanced communications allow people and systems to be interconnected and interact in entirely new ways. Finally, intelligent analytics are used to offer fast and accurate responses to changes and optimize future conditions.

Social networks and social media are also a vital part in gathering information regarding mobility in urban areas. Recent research focuses on social networks and detection of transportation information social network effect on travel choices (Goulias et al., 2015; Kamargianni et al., 2014; Lee et al.,