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Internet of Things Approach to Cloud-Based Smart Car Parking

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Abstract

Concerns for parking are becoming imminent to best support the urban core. These persistent parking problems could be turned into new opportunities, brought by current trends in meeting the globally connected continuum. This paper reveals a work-in-progress to capitalize on private land properties for parking, in order to relieve stress on public agencies, create new sources of revenue, and enlist new entities in the intermediary market. These intermediaries, labelled as Parking Service Providers (or PSPs) play a broker role through advertising parking lots on a shared cloud platform. To streamline these business collaborations and related processes, physical parking lots are augmented with Internet connectivity allowing cloud-provided applications to congregate these lots into a larger inventory. The Internet of Things (IoT) paradigm expands the scope of cloud-based intelligent car parking services in smart cities, with novel applications that better regulate car-parking related traffic. This paper presents a work-in-progress agenda that contributes to new business solutions and state-of-the-art research impacts. We reveal a multi-layered system of PSP-business model through interdisciplinary research blocks where original results are expected to be made at each layer.

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Keywords: Smart parking systems; internet of things; sensor networks; cloud computing; web services; pervasive computing.

1. Introduction

Everyone who has ever been frustrated driving around urban areas in search of parking has wished for a solution that could quickly lead them to that elusive spot. This concern attracted strategic investments from dedicated industry sectors to boost parking revenues through technology-enabled solutions. Parking industry is being revolutionized by new technologies that enable cities to reduce traffic congestion and carbon emission. The Internet of Things (IoT) permeates with the world of parking to streamline processes that deliver intelligent parking solutions, which extend and manage parking inventories. In this context, IoT uses embedded wireless sensor networks to connect physical parking space infrastructures with information and communication technologies, where

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cloud-based smart management services are provided. This interconnectivity shift is also driving socio-economical changes, where data unleashed from physical infrastructures is leading to productivity gains through new applications and new business models.

The proposed solution in this work-in-progress turns unused parking spaces into revenues, allowing virtually all parking space owners, ranging from individuals to business entities, to market their assets with a Parking Service Provider (PSP). Motorists are empowered with this service to reach on-street and off-street parking through a better utilization of parking spaces. Both consumers and providers of parking spaces maximize their mutual benefits in this business model. The process is automated through meaningful data that calibrate demand and supply along dynamic pricing models, and plan parking based on real-time information that include special events, holidays and traffic considerations. Smart cities need smarter parking information and guidance systems that interoperate services in the interconnected continuum of parking spaces and vehicles.

The research challenges induced by parking-related problems revolve around searching and paying for a -vacant- parking space. A parking occupancy model could use infrastructure data to derive availability probability used to estimate in real-time parking availability when infrastructure data are limited. This analytical approach utilizes publically available parking data (such as Parkopedia available in www.parkopedia.se) and live traffic counts (using street cameras or satellite signals), as well as embedded location device and/or accelerometer to automatically estimate when and where drivers park their cars, and when parking spots are released. This prediction does not rely on sensors embedded in parking lots. Instead, this research contribution employs algorithms to compute the historical parking availability profile for an arbitrary street block and to estimate the parking availability in real-time for a given street block. However, parking accuracy is greatly increased when further infrastructure data feed the occupancy models.

Data-aware parking systems are enriched by extensive data collection infrastructures being developed and even implemented in many urban areas collecting traffic data with various technical characteristics. This gives rise to new opportunistic business models with the potential participation of new intermediaries (i.e. PSPs) conglomerating a fleet of parking lands owned by individuals or organizations. Reclaiming current and future unused parking spaces to generate revenues is a major objective of this work-in-progress. A broker-based framework integrates business and service level agreements using a utility-driven algorithm that constitutes another research contribution of this on-going work. A cloud-based monitoring infrastructure observes Service Level Agreements (SLAs) compliance during the service delivery using measurements obtained from the service provider infrastructure or third-party monitoring services[1].

A plethora of heterogeneous connectivity technologies are fueling the evolving Internet of Things trend that integrates sensing devices and smart applications in parking management domains. Interoperability is a challenge to be addressed in order to expand parking inventory and extend new business opportunities to parking service providers. The rapid technological development of Wireless Sensor Networks (WSNs) is key for IoT across a range of applications, including parking management. To overcome interoperability issues, an IoT middleware layer research contribution in this work agenda is investigated. This layer provides a common abstraction of, and a standard approach to interact with embedded sensors in parking spaces. IoT middleware masks the heterogeneity and distribution of connected parking sensors and delivers an open mediating interface to the application layer. In doing so, parking space sensor data are exposed as virtualized services. Sensing as a Service is a rising trend, for which we provide an integration model and combine it within a mesh of interoperable services to enable automated reasoning and composition of capabilities over connected objects (in IoT context). The resulting real-time data streams pose another challenge to fuse them into core benefits for parking service users and providers. The provision of judicious data fusion algorithms is investigated in this on-going work to extract useful knowledge and context awareness[2].

Finding parking spaces is essentially a search problem, that could be represented and optimized via an A* algorithm. However, concurrent agents are expected to traverse the search space to plan paths towards vacant parking spaces, while considering each other's progress. In doing so, agents take collaborative decisions that balance roads occupancy and reduce congestion[3]. Multi-agent search is computationally resource-intensive and this process is further exacerbated by dynamic real-time traffic considerations. This work-in-progress contributes to finding the most mutually beneficial paths when entering and exiting parking. This shall reduce the likelihood of sending motorists across the same routes or junctions while navigating towards targeted parking spaces.