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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.

2. Contributions and Objectives

Intelligent transportation is a global trend[4], with an active European action plan in the forthcoming age of connected cars[5]. EU member states, responded to this action plan through concerted Intelligent Transportation Service initiatives. Our investigation contributes to the knowledge base of this global traffic-management related agenda. Managing parking inventories in urban areas is part of this trend to exploit the emerging technological advances driven by connected physical objects. IoT unleashes data from physical objects such as parking spaces using embedded communication technologies across IP-based pathways. Thus, allowing a migration to an all-IP environment at a later stage[6], whereby full automation of service- oriented use cases reveals the potential benefits of the proposed framework in this work.

Besides horizontal contributions to contemporary research areas, namely Internet of Things, Sensing As A Service, Business Modeling, Computational Search, Big Data Analytics, Real-Time Processing and the deployment of smart (parking) applications on a cloud platform[7], this work-in-progress generates innovative results in security and privacy, which are paramount for managing access control across a range of levels including sensor, service and application levels. This framework is further discussed in Section 3, which lays the foundation for an integrated research agenda initiated by this work.

The broad objectives of the work-in-progress presented in this paper are elaborated along four dimensions of parking-systems related problems. The first dimension is interoperability of information and services in the globally interconnected continuum. In IoT world, applications need a common abstraction of, and a standard approach to interact with physical objects (such as parking spaces). We build a middleware that masks the heterogeneity and distribution of connected objects (such as parking sensors). While the IoT layer provides the infrastructure for sensing devices and communication technologies, the middleware layer provides an open interface between the infrastructure layer and the application layer.

The second dimension of parking-systems addressed in this work-in-progress streamlining services using a cloud broker. Cloud services are increasingly populating Internet resources under the management scope of dedicated providers. The cloud fulfils the governance role over these services to satisfy interdependency requirements involved in composite services, monitor SLA compliance, and preserve security aspects at the governance layer. The goal is to achieve a high level of autonomic computing for service management.

The third dimension is about learning from real-time data streams collected by parking-systems. The massive amounts of data being generated in real-time from several sources offer various classification options. Data fusion from machine-learning perspectives combines data from multiple sources to take decisions based on different perceptions. In doing so, this work-in-progress employs techniques for mining heterogeneous data streams from wireless sensor networks and IoT, while minimizing computational considerations and preserving information privacy across secure transmission of data streams.

Finally, the fourth dimension of parking-systems creates a domain-specific language for modeling collaborative business processes between actors. This dimension investigates also the transformation of business models in cloud-supported middleware where new metrics for specifying dynamic prices of (parking-related) services are defined and value-added service composition framework is specified.

3. Approaches and Methodology

3.1. New Business Model for Parking Services

Driven by the need to expand parking inventories and the prospects of new business models for parking services, this work-in-progress envisions to extend parking-systems' cloud architecture to house new opportunities offered by third-parties labelled parking service provides or PSP. PSP is a new business entity serving individual parking owners or intermediaries, which register their parking lot in the cloud directory of available parking spaces. This information is relayed to motorists who request parking spaces, after which the transaction is fulfilled directly between the service provider and seeker.

To enable this vision, a thorough analysis of parking activities shown in Fig. 1 is investigated to evaluate automation opportunities. Car-mounted or augmented devices are used as communication interfaces to interact with the cloud services and parking infrastructures. The analysis of parking-related needs and problems raise the requirement to adopt a modular research methodology that examines the state of the art for each element of the solution build-up shown in Fig. 2 and discussed further next.

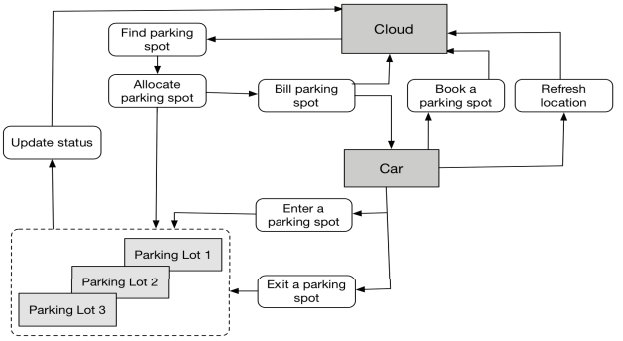

Fig 1. Parking activities

3.2. IoT Middleware

The architecture supporting the evolution of PSP business model is illustrated in Fig. 2. This architecture enlists a middleware layer to enable diverse connectivity to parking spaces via numerous sensing technologies. In doing so, the functionalities of the expected middleware support a cloud infrastructure for parking services, as illustrated further in Fig. 3. The cloud facilitates a service-oriented approach to parking, providing a managerial layer that monitors the provisioning process of parking services.

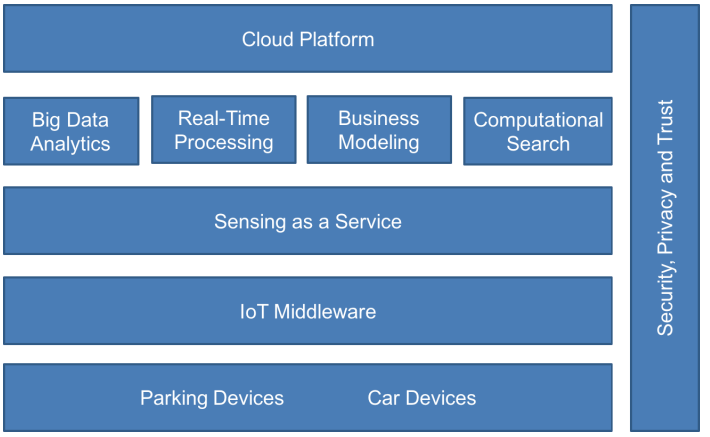

Fig. 2. Architectural building blocks

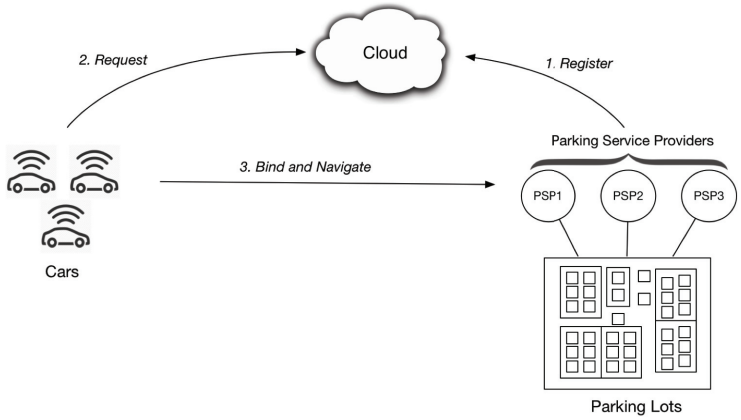

Fig. 3. Parking Service Providers interactions

3.3. Sensing as a Service

The cloud infrastructure provides a platform to conglomerate various services, including sensing services, which abstract the metadata associated with sensing devices. A suitable specification for creating standard dictionaries of sensor-related metadata is proposed. This approach is followed by the elaboration of an ontology and inference rules to allow applications to reason about parking services. The development of sensing as a service framework supports the integration of a parking-service registry and a knowledge base used for value-added services.

3.4. Data Analytics and Collaborative Search

IoT middleware and sensing service frameworks provide the needed data sources for analytical approaches to estimate or locate best parking spots. However, finding a parking spot is not an end by itself as congestion could result when ignoring the paths motorists follow to access or exit parking spots. Hence, the collaborative path-planning algorithm research is about planning paths towards vacant parking spaces, while considering mutual progress. In the search space, nodes are streets and metropolitan junctions. Concurrent agents traverse the search space to take decisions that best balance roads occupancy and reduce congestion.

Thus, 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[8]. 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. The goal of this research contribution is to find 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.

4. Conclusion

The economy is increasingly using cloud services to design new business models. For example, Amazon has created a platform where sellers and buyers can perform secure business transactions. The proposed work-in-progress described in this paper reveals a research agenda that aims at lifting the parking space management from a purely physical business to a business that transforms parking into a computational service. We outlined the agenda of this on-going work to enable value-added services around parking to both end consumers (car drivers) and parking service providers. Parking space owners profit from the new services by a more economic use of their parking space, which is represented as an economic resource in the parking management system.

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