Abstract

In the last few years, to fulfill the demand for sensor-based services, wireless sensor networks (WSNs) have been used where the end users acquire sensor nodes according to their service requirements and subsequently deploy and manage them to access the desired services. However, in recent years, service demands have increased so drastically that WSN is not sufficient. Therefore, WSN is combined with cloud computing infrastructure, forming a service-oriented architecture (SOA) called “Sensor-Cloud" (SC). In this architecture, the end users enjoy hassle-free services by only paying the sensor cloud service providers (SCSPs) as per their service demand, while sensor-owners manage the responsibilities of deploying and managing physical sensor nodes for provisioning the sensor-as-a-service (Se-aaS).

On the other hand, as SC follows an SOA, in recent years, the concept of SC is envisioned for provisioning Se-aaS in vehicular networks, named “Vehicular Se-aaS", where the sensors are installed in the vehicles. In this architecture, besides SCSPs and vehicle owners (VOs), roadside units (RSUs) play an integral part and serve as gateways for collecting vehicular sensor data. However, the widespread installation of RSUs over a large geographical area is not feasible for a single SCSP. Additionally, a subset of VOs registers with each SCSP, which makes it challenging to find specific sensor-equipped vehicles within a region of interest. Moreover, SCSPs need to identify an optimal subset of vehicles, ensuring no vehicle is oversubscribed and revenue is optimally distributed among VOs. Hence, existing research on SC considering single SCSP is not applicable for vehicular Se-aaS. To improve service availability, we consider the multi-sensor-cloud (MSC) for vehicular networks, where multiple SCSPs and multiple vehicle sensor owners are present. However, due to the limitations of resource-constrained sensor nodes, various challenges arise in provisioning vehicular Se-aaS.

In this thesis, we focus on different aspects of the vehicular MSC architecture. Firstly, we work on the problem of cache selection for provisioning vehicular Se-aaS, while ensuring the high quality of service (QoS). In a cache-enabled SC, each SCSP serves the applications from its internal and external caches, which may not be feasible in vehicular networks. To address these issues, we propose a game-theoretic cache orchestration scheme, named CALM, for vehicular MSC. CALM is performed in two stages. In the first stage, after receiving the end-users’ service request, the requested SCSP identifies

the optimal subset of internal caches using an expected utility theory. If the service is not executed in the first stage, we use a single-leader-multiple-followers Stackelberg game, where the SCSP and the RSUs act as the leader and followers, respectively. We evaluate the performance of CALM both theoretically and through simulation, while comparing it with the existing schemes.

In CALM, we assume that the required fresh data are available in either of the caches, i.e., external and internal caches, which may not always be true. Additionally, the presence of multiple VOs leads to varying charged prices and, hence, unfair revenue distribution. To address these problems, we propose a game-theoretic resource allocation scheme, named FRAME, in this work. We use a single-leader-multiple-followers Stackelberg game to decide the optimal set of sensor-nodes for serving a request. Thereafter, to address the inadequacy of resources, we propose a collaboration scheme for multiple SCSPs in which an expected utility theory is used to choose the optimal SCSP. We evaluate the performance of FRAME both theoretically and experimentally and compare it with benchmark schemes.

Moreover, in the presence of non-cooperative entities, vehicular MSC leads to an oligopolistic market, where the shareholders may adopt unfair means to maximize their revenue. Hence, we propose a trust-enforcing virtual sensor orchestration scheme, VISE, to ensure high QoS in green MSC systems. VISE is a multi-level expected utility game-theoretic scheme. We evaluate the performance of VISE both theoretically and experimentally and compare it with benchmark schemes.

Furthermore, we envision the vehicular MSC as an open-oligopolistic market and propose a scheme, named MAGIC, aiming to address the problem of optimal multi-access resource orchestration for provisioning green vehicular Se-aaS in MSC. Each VO can provide Se-aaS to any SCSP based on the availability of physical resources. In the existing literature on resource orchestration, the researchers considered that each VO registers with a single SCSP. We argue that multi-access MSC can ensure energy efficiency, high Se-aaS availability, and optimal revenue distribution along the VOs. We observe the existence of generalized Nash equilibrium in MAGIC using variational inequality. We also evaluate the performance of MAGIC through simulation and compare it with benchmark schemes.

Finally, we conclude the thesis, while emphasizing the limitations of the aforementioned works and suggesting the potential avenues for future work.

Keywords: Sensor-cloud, Game Theory, Resource Allocation, Cache, Vehicular Networks, Trust, Oligopoly, Green Multi-sensor-cloud, Multi-access, Open-oligopoly