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Urban Mobility Services based on User Virtualization and Social IoT

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Abstract— **Smart cities are characterized by smart heterogeneous devices that can interact and cooperate with each other by exchanging regularly low amounts of data in the context of IoT. Lately, there has been an increasing interest in enhancing the IoT paradigm to support exchange of multimedia data. This paper focuses on the concept of Urban Mobility Services and in particular on proposing a solution to enable best QoS and load balance in a 5G network context. The paper introduces a novel algorithm for *MobilIty Services uSer vIrtualizatiON (MISSION)*. MISSION employs cloud computing and broadcast of multimedia content in order to reduce the network load, the number of interactions, and user device energy consumption. It also relies on rating of network reputation in the 5G heterogeneous network environment and performing network selection in the quest to maximize QoS parameters. The performance of the proposed solution is compared against that of a TraffictYpe-based DifferEntiated Reputation (TYDER) algorithm. This performance was evaluated in terms of QoS parameters such as delay, latency, packet loss and prediction error. The results show how MISSION outperforms TYDER in urban mobility scenario.**

Keywords - multimedia for connected cars, multimedia IoT, networking and QoS, 5G, broadcast applications, smart cities.

I. Introduction

Always Best Connected (ABC) paradigm [1] represents the need to be connected to the network everywhere and anytime according to technological improvements, a wide offer of multimedia contents, and an ever-growing distribution of mobile applications. Among ABC actors, *ABC users* subscribe to ABC services and the *ABC service provider* provides someone with ABC services. Finally, the *application service provider* provides applications. Nowadays, cloud-based Internet of Things platforms are taking hold with the function of *application service provider* and in [2] the authors deal with Lysis platform for IoT distributed applications over socially connected objects that are capable of establishing social relationships in an autonomous way with respect to their owners with the benefits of improving the network scalability and information discovery efficiency. Moreover, the management of the updates in the application functionalities, the management of the ever increasing complexity in security aspects, the browsing of the exponentially increasing the number of used and available applications, and the difficulties in following the ever changing application interfaces are leading in search of IoT-cloud solutions, such as the Virtual User (VU) [3]. The development of the 5G new radio (NR) network environment [4] will give great support to IoT applications. On the other hand, the mobility model of vehicles under the time-varying vehicular speed assumption is quite challenging [5]. The concept of VU for the IoT defines the trusted digital counterpart of the user it represents. This aspect facilitates the integration into the technological digital world reducing the burden of processes of setting, configuring and updating IoT applications it is involved in information relating to the user profile, credentials, mobility and perceived Quality of Experience (QoE). It is built through the typically weekly observation of the user and is characterized by behavior marked by habits, free time and work planning.

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The user virtualization as well as the SIoT are two topics that allowed the production of lots of research articles in last years. A comparison between our proposed system and other previous solutions is outlined and detailed in terms of key aspects individuated during the analysis.

In [6] the authors introduced an open framework based on the Virtual User Model concept with the final goal to introduce simulation-based and Virtual Reality testing into the automotive, smart living spaces, workplace, infotainment and personal healthcare applications areas. The proposed framework also aims to ensure that future products and services are being systematically designed for all people including those with functional limitations. An open simulation platform parted of several tools provides automatic simulation feedback and reporting for guideline/methodologies compliance and quality of service. To achieve these reports, detailed virtual user physical, cognitive, behavioral and psychological models as well as the corresponding simulation models have been integrated to support simulation and testing at all stages of product planning and development. Moreover, personal information agents have emerged in the last decade to help users to cope with the increasing amount of information available on the Internet. These agents are intelligent assistants that perform several information-related tasks such as finding, filtering and monitoring relevant information on behalf of users or communities of users. In order to provide personalized assistance, personal agents rely on representations of user information interests and preferences contained in user profiles [7]. Cloud computing features have recently been integrated into the IoT landscape allowing the implementation of applications such as IoT congnitive frameworks. In [2] the authors define the virtual object (VO) as the virtual alter ego of any real world object (RWO), which are created and destroyed dynamically. Here, cognitive technologies guarantee a constant connection between RWO and VO and ensure self-management and self-configuration, also introducing social skills. Each object is an autonomous social agent, according to which objects are capable of establishing social relationships in an autonomous way with respect to their owners with the benefits of improving the network scalability and information discovery efficiency. The notion of social objects is used to develop an architecture that allows for deploying fully distributed applications.

Accordingly, the application is deployed as a collaboration among social objects that are running in different cloud spaces and that are owned by different users, whereas in past works all the involved system components are managed by the same entity. In order to propose the user a solution to improve its mobility in a smart city scenario, we combined the employ of virtualization level and Social IoT (SIoT) to optimize user perceived Quality of Experience (QoE). The performance of the feature of the VU are related to the learning of the user preferences and this reduce the number of required interactions with the IoT applications. This paper introduces a novel algorithm for **MobilIty Services uSer vIrtualizatiON (MISSION)** and the performance has been compared to a Traffic tYpe-based DifferEntiated Reputation (TYDER) solution [8].

II. Architecture of the Proposed Solution

Recent studies dealing with the optimization of multimedia content delivery mainly based on video type content appeared in the literature. User behavior has been classified by identifying different attitudes they can undertake. For example, in [9] the authors classified users as cooperative and non-cooperative. In the first case users are capable of establishing social relationships and cooperate to get the mutual benefit of meeting the bandwidth requirement by maintaining a good level of QoS. In case of limited resources, each user has a decrease in bandwidth in order to accommodate new users. In the Non-cooperative configuration users do not cooperate with each other and try to maximize their QoS level. In case of limited resources, they do not undergo bandwidth and no further users are accepted within the network. In [10] users are classified not only according to their device, but also considering their network connection type (i.e., payment free or payment due networks). In the first case, all users are considered equal, but for the case of payment due connectivity, from the wide range of commercial options Mobile Network Operators (MNOs) offer, this work considers two user profiles: typical (TU) and business (BU). The proposed P-ARMANS algorithm manages and shares the available resources in order to ensure user receive content at QoS levels according to user profile priority. In this context, BU has higher priority than TU. In [8] the authors proposed TYDER, a network selection solution based on network reputation and traffic differentiation in a 5G heterogeneous networks scenario, including NB-IoT networks. Taking into account the feedback from users, TYDER monitors the various networks QoS levels over time, allowing selection of the best network for user needs at any time.

The Client Side Module shown in Fig. 1 is composed by several blocks. The **Data Collector** block collects information contained in the **User Profile** and the **Service Profile** and pass it to the Network Filter. The **Network Filter** block eliminates all networks that do not meet the minimum/maximum criteria. For example, if the device speed exceeds the maximum quota supported by the network standard, it will be eliminated from the possible choices. It will then get the network that has the best reputation for the service requested at that time. In this way the device can connect to the network able to offer the best QoS. The block are summarized as follows:

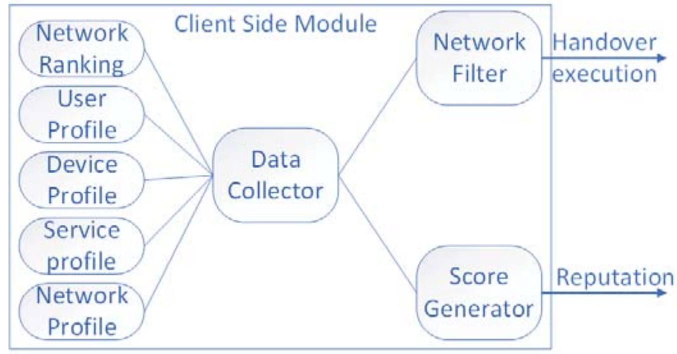

Fig. 1: Tyder client side module

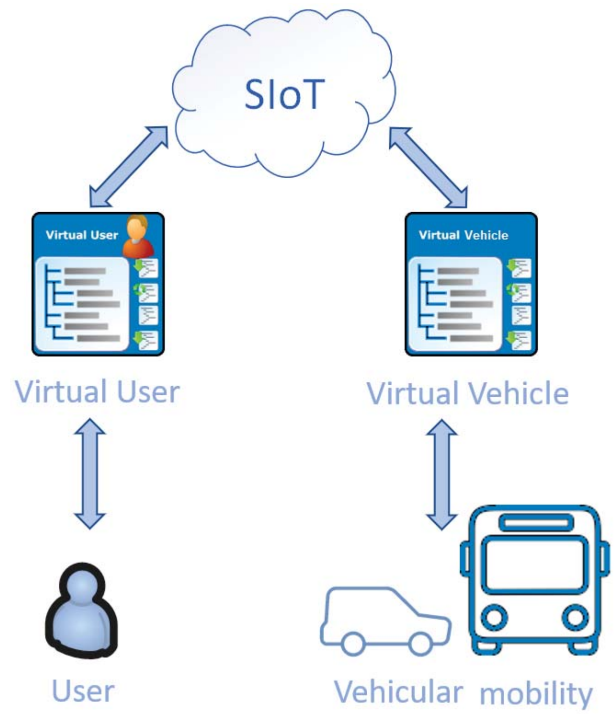

Fig. 2: Urban mobility Services architecture

- the **User Profile block** will contain all user preferences and will also be useful for managing information on the position of the device in order to store the user's mobility models;
- the **Device Profile** block contains the specific properties of the device, among them very important is the location service that allows us to identify the position of the device and its speed of movement. In terms of speed,

we can have three different types of speed: high speed (more than 15 Km/h), the speed of a user on a vehicle; low speed (less than 15 Km/h), the speed of a user on foot or a slow vehicle; stationary users when the user does not need mobility support;
- the **Service Profile** contains all the information regarding the type of service that the user is currently using. The services are grouped into four macro areas that correspond to the most used services and with greater scope for development: VI, GM, BR, and IoT, respectively. Each of them will be associated with an identifier that will enable the use of a specific function, most appropriate to that service type;
- the **Network Profile** contains all the information concerning the network, such as the ID, and type of network;
- the **Network Ranking** contains the ranking network scores that are received from the server database.

The architecture of the proposed solution has a deep relationship with the ABC paradigm/actors, and the application service provider is connected to the SIoT. Fig. 2 shows the scenario used in our study whose actors can be summarized as follows:

- the **user** represents the subject who interfaces with the digital world through applications;
- the **vehicular mobility (VM)** represents the vehicle which interfaces with the digital world through applications;
- the **virtual user (VU)** is a virtual alter ego of any real-world object owned by a user dynamically created and destroyed. It contains information relating to the user profile, credentials, mobility and Quality of Experience (QoE) perceived. It is the counterpart of the user and implemented as an agent running in the cloud/edge computing infrastructure able to pretend to be the user in the process of IoT service providing;
- the **Virtual Vehicle (VV)** is a virtual alter ego of any real-world vehicle, dynamically created and destroyed. VV represents the vehicular predictable movements as they are constrained by road or highway topology and layout. An analytical model based on a real traffic scenario is considered in our test. It considers the impact of vehicular traffic on public transport, the route they take, and the overall intensity of city traffic;
- the **SIoT** is a Social IoT platform that interfaces between the vehicle world and the user through the VU. It manages the relationships between the user and the vehicular world through knowledge on the one hand of traffic behaviors and real-time positioning of urban mobility and on the other through user behavioral attitudes. The SIoT platform is placed at the midlle of the scenario and it defines the optimal timing for the user according to urban mobility services.

In this work we propose an innovative MISSION approach where the old client-server concept (i.e., TYDER) is replaced by the concept of object virtualization (i.e., virtual user and virtual vehicle) with the benefits of improving the network scalability and information discovery efficiency.

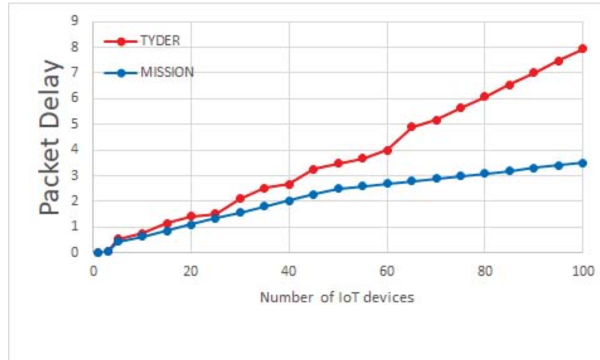

Fig. 3: Packet delay

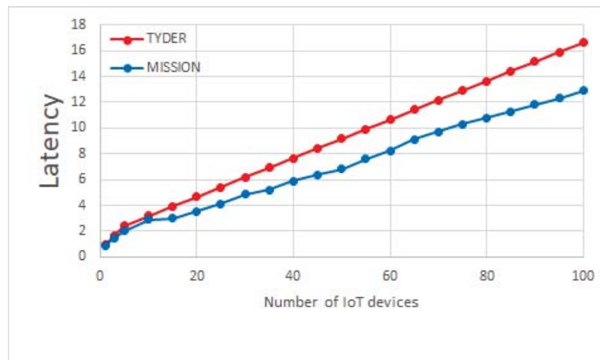

Fig. 4: Latency

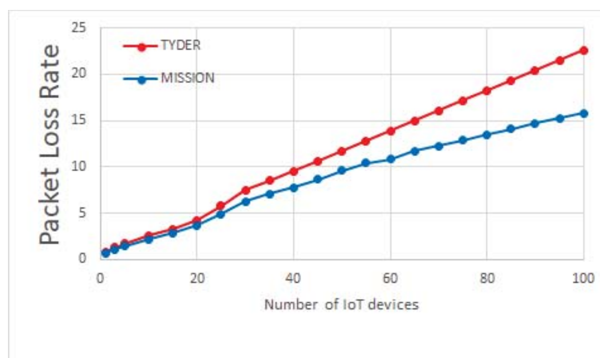

Fig. 5: Packet loss rate

III. Simulations and Results

The results obtained show that the proposed MISSION algorithm provides QoS metric improvements with respect to IoT performances obtained using TYDER algorithm. The evaluation of the MISSION algorithm, was carried out by integrating Python code in models built using the OMNeT++ [11] network simulator. In each scenario, simulations were performed comparing the above mentioned algorithms in terms of packet delay, packet latency and packet loss rate

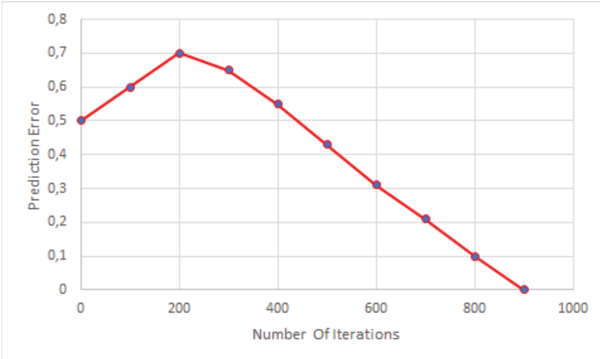

Fig. 6: User's preference prediction error of the VU

when increasing the number of IoT devices in steps of five new connections at a time.

Fig. 3 presents packet delay values when MISSION and TYDER algorithms are compared. In this scenario MISSION is more beneficial in terms of packet delay. When a user is moving at a constant speed of 3 m/s alongside and/or away from the urban vehicles packet delay-related performance slightly decreases when compared to TYDER.

Fig. 4 shows the latency trend. It can be seen that MISSION presents better values than TYDER. The trend of the two algorithms is substantially the same, although TYDER introduces a decline in performance.

Finally, Fig. 5 illustrates the packet loss ratio results. MISSION has a lower packet loss ratio than TYDER. The comparison between the two algorithms shows that the higher the number of IoT devices the higher the impact on packet loss ratio.

Fig. 6 shows how VUs learn faster the most requested preferences in about 200 interaction and the whole learning process has a long connection and is completed by around 900 interactions. The greater the number of interactions, the greater the accuracy of the information that reaches all users.

IV. Conclusions

In this paper, an urban scenario where cooperate a social IoT platform and VUs is proposed. These two actors exchange messages about urban mobility and user mobility behavior and a novel MISSION algorithm Cloud Computing-based for urban mobility services has been introduced. MISSION is compared against an existing solution TYDER which it outperforms in terms of QoS of individual devices, and computational load. The latter is the most important aspect, as any algorithmic-required computation is transferred from the individual energy-constraint devices to the Cloud, which takes care of the algorithm calculations. Tests were realized in a real traffic scenario in the city of Cagliari (Italy) during daylight traffic hours, and evaluating the performances when VU concept is considered or not. The future work will provide high variety of VUs used by several users with the final goal to analyze and evaluate the effect of a massive use of VUs in conditions of high interaction with the SIoT platform.

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