Poster: Using Clusters of Parked Cars as Virtual Vehicular Network Infrastructure

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***Abstract*—In future smart cities, cars will be equipped with multiple communication technologies. The Car4ICT architecture aims to exploit such cars for providing services to users. Cars take the role of service hubs and support users in discovering services and utilizing them. So far, Car4ICT has been investigated in urban and rural scenarios, but parked cars have not been considered part of it. As such parked cars are ubiquitous in cities, they help improve the architecture even further by reducing the need to rely on Store-Carry-Forward (SCF) and adding more services. In this paper, we outline our integration of parked cars into the Car4ICT architecture. By combining them into clusters, we are able to add additional network nodes, thus improving the stability of the network topology. Furthermore, members of these clusters are then connected to the Car4ICT network and are able to provide/consume extra services. While there exist solutions for clustering, there are several research questions when integrating such virtual vehicular network infrastructure. We describe our approach and discuss some of the interesting research questions and the problems that have to be solved.**

I. Introduction

Cars in the foreseeable future will be equipped with multiple network technologies for vehicle-to-vehicle and vehicle-to-infrastructure communication. The Car4ICT architecture [1] integrates such cars as information hubs in future smart cities. Cars equipped with a Car4ICT module act as data/service providers for users. They do this by providing mechanisms for service discovery and assisting users in utilizing these services. Investigations by Altintas et al. [1] have shown that this architecture is able to provide robust service discovery with different vehicle densities. Currently, the architecture only considers driving cars, therefore, wasting the potential of parked cars providing additional services.

Generally, message forwarding and routing in Vehicular Ad Hoc Networks (VANETs) is a heavily investigated topic [2]. Currently, the consensus seems to be the use of simple broadcasting (or n-hop flooding) for local information and georouting for reaching farther destinations (e.g., ETSI ITS-G5 specifies CAM messages and geonetworking, respectively). For shorter, highly local transmissions (e.g., safety messages) these algorithms work quite well. However, if we consider longer data transfers over greater distances, which easily might happen using the Car4ICT framework, the rapidly changing network complicates things. For such messages traveling a larger distance, Car4ICT currently relies on Store-Carry-Forward (SCF) mechanisms, which potentially greatly increase the delay.

One option to mitigate these issues is to rely on infrastructure support, that is, deploying additional systems along the streets to support Inter-Vehicle Communication (IVC). The most popular option is to place Roadside Units (RSUs) at multiple locations throughout a city, thus adding a set of stable, stationary nodes to the dynamic vehicular network [3]. When interconnected, these nodes are useful in sending messages over larger distances and also support cars with load balancing in dense urban areas. One issue with RSUs is the short connection time in case of driving cars which only allows to exchange a small amount of data. A solution to this problem could be to rely on cellular networks (e.g., LTE or LTE Advanced) instead of WLAN-based VANETs. This obviously comes with some cost: for supporting a large number of users, additional resources are needed [4]. This means either smaller cells (hardware investment), additional spectrum (which is already scarce), or in some cases even both. Furthermore, data exchange in vehicular networks frequently happens between close-by nodes. For such use-cases, routing the data through the LTE core network would add additional delay and overhead.

We propose another option to mitigate these issues by providing a virtual network infrastructure based on parked cars. Such parked cars have already been proposed to be used as relays in safety critical scenarios [5]. We go one step further and have these parked cars forming clusters to create additional virtual network nodes. Therefore, no fixed RSUs are needed and no cellular connection is essential. Each cluster of parked cars aims to fulfill two roles: First, acting as an additional, more stable, node in the Car4ICT network. Second, enabling the parked cars to offer additional services to Car4ICT users.

II. Car4ICT & Parked Cars

Car4ICT [1] is a service discovery architecture based on cars in future smart cities. It provides modules for *providers* to offer a wide range of services (e.g., data storage, weather forecasts, traffic information) to *consumers*. The core of the Car4ICT architecture are cars equipped with various networking technologies (e.g., IEEE 802.11p, LTE, Wi-Fi). They support consumers in discovering services and provide data transfer capabilities between them and providers once a fitting service

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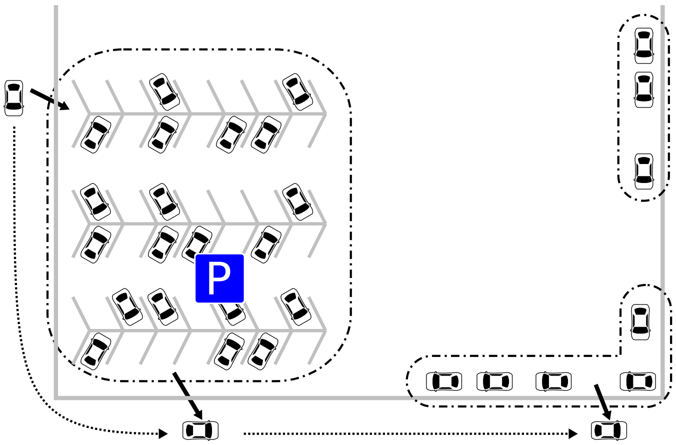

Figure 1. Example of two clusters and cars connected to them.

is found. Potential consumers/producers could be people using a smartphone, computers, or even sensors/applications in cars.

One part of the Car4ICT architecture is the transfer of data via SCF schemes. If a car has no fitting forwarder it chooses to cache the message until a fitting forwarder is found or the destination is reached. This can happen for various reasons, e.g., when the penetration rate of equipped cars is not high enough or outside of rush hours.

To reduce the usage of SCF, we now include parked cars as virtual network infrastructure into the Car4ICT architecture. These parked cars form clusters each of which provides a Distributed Hash Table (DHT) to store data. To form these clusters, many algorithms have been proposed in the literature [6], [7]. Organizing the cars in a DHT allows to let a cluster act as a single Car4ICT node where service offers are stored. This comes naturally as services are distinguished by *identifiers*, which consist of a hash and meta data. Downloading data from a cluster was already investigated by Dressler et al. [8]. Unlike their proposed approach, we do not want to require using Virtual Cord Protocol (VCP), but any potential clustering scheme which is able to provide a DHT.

The generated clusters provide two main advantages: First, the existence of additional nodes will make the network topology more stable. With this, the necessity of using SCF in Car4ICT is reduced, which in turn reduces the delay of service discovery and data transfer. Second, by adding a large number of parked cars to the Car4ICT network, the overall number of services increases due to potentially more cars offering them.

Figure 1 shows an example of the described scheme. A car comes from the top left, sends a request to a cluster on a parking lot via a gateway node. Later, it receives the result from another gateway connecting to the same cluster. Even later, it connects to a different cluster of cars parked curbside, which is not directly connected to the first cluster.

III. Open Research Questions

The proposed concept of combining Car4ICT with clusters of parked cars opens various research questions. We believe the following four questions to be central.

Which cars should form one cluster? There exist a multitude of clustering algorithms, but it is not clear how they apply to our use-case. By combining too many cars, bottlenecks might be created and cluster maintenance might become problematic. On the other hand, if the clusters are too small, cluster creation and data fragmentation between clusters could become weak points.

How to connect to the cluster? In Car4ICT, cars periodically send access messages to announce Car4ICT connectivity as well as services. If all cars in a cluster proceed to send these messages, the connectivity to the cluster is very good. However, this could also lead to a congested channel, so that selecting certain cars as *gateways* might be the better choice. The question is, which gateways to select how to improve the performance.

How to enable longer lasting data sessions? Having parked cars form a cluster has another advantage, namely the possibility to provide longer lasting data sessions between parked and moving cars. When passing a cluster, the connection time is much longer compared to just connecting to a single RSU. This allows to exchange larger amounts of data. But, to achieve this, the car has to connect to multiple gateways over time. The question is, how to keep the connection to the cluster (and the virtual infrastructure it provides) alive.

How can we connect clusters with each other? Sometimes, messages have to be sent from one cluster to another. Clusters are not necessarily disconnected from each other, therefore, messages may be delivered immediately. The research question is how to maintain a stable connection between clusters without overloading the channel or introducing too much delay.

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