Cars as the Base for Service Discovery and Provision in Highly Dynamic Networks

Florian Hagenauer†, Christoph Sommer†, Simon Merschjohann†, Takamasa Higuchi*, Falko Dressler†, and Onur Altintas*
†Dept. of Computer Science, Paderborn University, Germany
*Toyota InfoTechnology Center, Tokyo, Japan
{hagenauer,sommer,simon.merschjohann,dressler}@ccs-labs.org
{ta-higuchi,onur}@jp.toyota-itc.com

***Abstract*—In the smart cities of tomorrow huge amounts of data have to be processed. Cellular networks alone are unlikely to be able to cope with the amount of data and would introduce a critical dependence. Cars, on the other hand, are ubiquitous – even after massive disasters – and will be equipped with abundant communication technologies. This makes them a salient basis for connecting users and machines of smart cities. Discovery and providing services in such a highly dynamic network is a challenging task. We tackle this problem in our Car4ICT architecture which could be shown to work very well in simulations. The next logical step is to investigate the performance in experiments. To perform experiments we built a prototype which is able to emulate multiple vehicles on just a few machines. We show the feasibility of the proposed service discovery protocol and our emulation approach.**

I. Introduction

In the next years the way cities process data to provide services will change substantially as they will evolve into smart cities [1]. Some examples of envisioned Information and Communication Technology (ICT) services are traffic monitoring, highly localized weather forecasts, or providing communication in case of disasters. To realize this, a major change will be the deployment of various sensors throughout these cities to provide the necessary data for such services. A downside of these services will be the sheer amount of generated data that has to be transferred throughout the city.

One option is to do this via cellular networks only, but there are two major downsides: First, using cellular networks in densely populated areas could easily overload the network [2]. Second, cellular networks introduce a dependency on infrastructure. This implies costs for its use. Moreover, in case of an area being struck by disaster (e.g., earthquakes, blizzards, or tsunamis), the network will not work anymore and it can take a considerable amount of time to rebuild it.

Another more preferable option is to rely on cars for transferring these huge amounts of data. Cars will be ubiquitous in future smart cities independent of infrastructure. Future cars will not only have access to large processing powers but are also equipped with the necessary communication capabilities. Various communication technology standards are already finished or are in the process of standardization: Aside from WLAN-based standards such as WiFi, or WLAN adaptations for vehicular networking (like IEEE WAVE, ETSI ITS-G5, and ARIB-T109), a whole wealth of technologies are available – from Bluetooth LE to optical technologies like visible light communication [3]. With these technologies it is possible to realize these networks for future smart cities. In such an architecture, cars will be the connectors between the different entities providing and consuming the data. These entities can be both machines and people. Machines might gather weather information from sensors in a city and process them to generate a highly localized forecast. People might use a smart phone to connect to the cars, again using any of multiple short range communication technologies. For them, using services provided by the networks can be made as simple as joining a WiFi network advertised by a Car4ICT equipped car. Such user-centric services in future smart cities are providing storage space and processing resources, or offering up-to-date pictures of a certain area. Common to all discussed services is that a service *provider* offers some kind of resource while service *consumers* search for it and make use of it. Thus an efficient mechanism for service discovery [4] is a key component of the Car4ICT framework.

However, high mobility of cars around cities poses a significant challenge since it makes the network topology severely unstable. Therefore, two main issues have to be solved: How to design such a Service Discovery Protocol (SDP) and how to identify the services. We address these issues in our *Car4ICT* framework [5].

II. Car4ICT

To tackle the first problem, there are three steps which need to be done to successfully use a service. First, service providers send their offers to cars, which then store the offers in their service tables and potentially share these tables. Second, service consumers search for available services and the *Car4ICT* network supports them in finding appropriate ones. This is done by cars by checking their local service tables, and, if necessary, propagating the request through the network. Third, *Car4ICT* takes care of transferring the data between service providers and service consumers. The flow of the messages can also be seen in Figure 1.

The second challenge, identifying services, is addressed by so called *identifiers*, inspired by recent developments in the fields of Information-Centric Networking (ICN) [6] and Named Data

978-1-4673-9955-5/16/$31.00

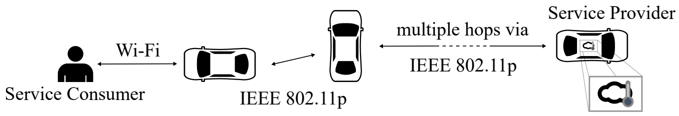

Figure 1. An overview of the data transmission between a service consumer and a service provider.

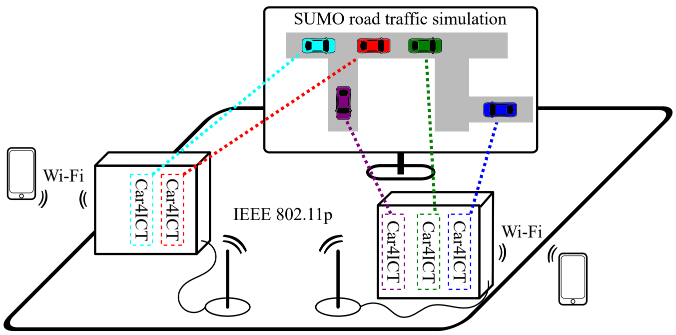

Figure 2. The experimental setup used in the demonstration. Users join a car's WiFi network to access the Car4ICT network and use its services. Cars communicate wirelessly to discover and provide these services. To reproduce a large test scenario, we run a computer simulation of cars' mobility and emulate multiple cars per On-Board Unit (OBU) – illustrated as dashed lines.

Networking (NDN) [7]. They consist of two components, a hash and metadata. The hash is a unique descriptor of the provided service (e.g., a unique MD5 hash of a stored file or a general string describing an offer like `STORAGE` for providing storage). Metadata consists of multiple key-value pairs to further describe the service. For example, the identifier `hash=video.mkv, fileType=video, size=1GB` describes a video file with a size of 1 GB. By omitting the hash, such identifiers can be used as queries when searching for services.

Initial simulations [5] indicate that the protocol can support such a dynamic network and adhere to the necessary delays. We looked at the delay until a fitting service is discovered and found that, even with a very small density of available cars (85 vehicles per km^2) and a very low rate of exchanging service tables (once every second), 95 % of requests can be fulfilled in less than 2 s.

The next logical step is to implement a prototype of the architecture and perform experiments. We instantiate multiple copies of the prototype on each On-Board Unit (OBU), in effect creating multiple virtual OBUs per real OBU. For sensor input (first and foremost, GPS position data), each is coupled to a running road traffic simulation. The position data also allows to decide when to use IEEE 802.11p between OBUs, when to forward the packets from one instance to another one on the same OBU, and when to drop packets as no communication is possible. This allows us to mimic a massive, dynamic network using only a comparatively small number of real OBUs.

III. Experimental Setup

The experimental setup (illustrated in Figure 2) consists of multiple OBUs and the road traffic simulator (SUMO) running on a dedicated machine. Each OBU consists of a *PC Engines Alix 3d3* system board, equipped with two wireless interfaces: First, a UNEX DCMA-86P2 card with an Atheros AR5414A-B2B chipset; second, a Compex WLM200N5-23ESD card with an Atheros AR9220 chipset. One interface is used to communicate between cars, using IEEE 802.11p in the 5.9 GHz band. The other interface is used to provide a regular WiFi access point to users. This access point can be used to let visitors connect to the *Car4ICT* network by using their personal devices. Afterwards, the OBU provides them with a chat application to try out the framework. Such a chat application is representative for communicating with an area struck by disaster and therefore having lost all infrastructure. More abstractly, it is prototypical for the average data exchange service, where end devices are interested in each other's data.

Figure 3. Photo of the experiment setup: the OBUs communicate via IEEE 802.11p among them. In the background, the position of the virtual prototypes in the road traffic simulation is visible. In the bottom right, an end user is logged into the WiFi access point of one of the OBUs, using a web browser to access a service offered via the network, on another OBU.

Figure 3 shows a photo of the experimental setup: a few Alix boxes represent the many more cars in the network (the simulation of which is shown in the background). In the foreground, an end device displays data received via the network established between the cars.

References

[1] A. Caragliu, C. Del Bo, and P. Nijkamp, "Smart Cities in Europe," *Journal of Urban Technology*, vol. 18, no. 2, pp. 65–82, 2011.

[2] F. Dressler, H. Hartenstein, O. Altintas, and O. K. Tonguz, "Inter-Vehicle Communication – Quo Vadis," *IEEE Communications Magazine*, vol. 52, no. 6, pp. 170–177, Jun. 2014.

[3] C. Sommer and F. Dressler, *Vehicular Networking*. Cambridge University Press, Nov. 2014, p. 384.

[4] A. Mian, R. Baldoni, and R. Beraldi, "A Survey of Service Discovery Protocols in Multihop Mobile Ad Hoc Networks," *IEEE Pervasive Computing*, vol. 8, no. 1, pp. 66–74, Jan. 2009.

[5] O. Altintas, F. Dressler, F. Hagenauer, M. Matsumoto, M. Sepulcre, and C. Sommer, "Making Cars a Main ICT Resource in Smart Cities," in *34th IEEE Conference on Computer Communications (INFOCOM 2015), International Workshop on Smart Cities and Urban Informatics (SmartCity 2015)*, Hong Kong, China: IEEE, Apr. 2015, pp. 654–659.

[6] B. Ahlgren, C. Dannewitz, C. Imbrenda, D. Kutscher, and B. Ohlman, "A Survey of Information-Centric Networking," *IEEE Communications Magazine*, vol. 50, no. 7, pp. 26–36, Jul. 2012.

[7] L. Zhang, A. Afanasyev, J. Burke, V. Jacobson, k. claffy, P. Crowley, C. Papadopoulos, L. Wang, and B. Zhang, "Named Data Networking," *ACM SIGCOMM Computer Communication Review*, vol. 44, no. 5, pp. 66–73, Jul. 2014.