On the Interplay of Open Data, Cloud Services and Network Providers Towards Electric Mobility in Smart Cities

Nikolay Tcholtchev, Lena Farid, Florian Marienfeld, Ina Schieferdecker, Benjamin Dittwald and Evanela Lapi
{nikolay.tcholtchev,lena.farid,florian.marienfeld,ina.schieferdecker, benjamin.dittwald,evanela.lapi}@fokus.fraunhofer.de
Fraunhofer Institute for Open Communication Systems (FOKUS), Berlin

***Abstract*—Quality of life in an urban environment depends strongly on ecological, social and mobility aspects. A major innovation in that context is given by the emergence of electric vehicles. Additionally, the explosive growth of social networks has shown how the Internet can be used to maintain and create communities, thereby bringing mutual benefits to the involved participants. Combining both, there is an obvious potential for the realization of collaborative electric vehicle sharing within a city. In this paper, we investigate one of the key aspects required to realize the vision of electric vehicle sharing – a cloud infrastructure for handling the required data. We propose a distributed architecture for the realization of such data cloud. Further, we demonstrate how ISP networks and the electric mobility data cloud can collaborate in order to provide efficient streaming of continuous data.**

***Index Terms*—Smart Cities, Open Data, Electric Mobility, Load Balancing**

I. Introduction

Quality of life in an urban environment depends strongly on ecological, social and mobility aspects. During the past years, we could observe a research trend towards the development of green technologies. A major innovation in that context is given by the emergence of electric vehicles that enable the reduction of carbon dioxide emissions and slowly become part of our everyday urban environment. Additionally, the explosive growth of social networks has shown how the Internet can be used to maintain and create communities, thereby bringing mutual benefits to the involved participants. Given these developments, there is a need to establish innovative processes and tools that enable the collaborative sharing of electric vehicles at the same time improving the quality of life in an urban environment. Hence, it is required to investigate and implement the requirements which result towards the efficient interplay of the involved technologies - smartphones, electric vehicles, cloud services, charging stations, GNSS (Global Navigation Satellite Systems) etc.

Currently, there are a number of pilot car sharing systems deployed across different cities in the world [3][18][19]. Moreover, various car sharing concepts have emerged within the research community and resulted in prototypes [17] that allowed gaining experiences with respect to *on-demand* collaborative driven mobility. In addition, the concept of an *autonomously driving car* is turning from pure research [21] [23] to a given factor [22] of significant relevance for the future of mobility networks and systems. We believe, that all these factors will accelerate the deployment of fleets of electric vehicles (electric cars, electric bicycles, and segways) that would be managed as to enable collaborative car sharing.

In this paper we propose an approach to realize a data cloud for handling electric mobility data. This data is the key enabler for services and business models around the notion of collaborative electric mobility. However, the realization of such data cloud is a challenging undertaking given the resulting inherent requirements. Such requirements are constituted by the need for real-time data streaming (e.g. positioning data), data integrity, and special regulations for the reuse of the shared data. In this paper, we make a first step towards addressing some of these issues by devising a distributed architecture that has the capability to deliver electric mobility data streams over an Internet Service Provider (ISP) network. This architecture is based on a set of Open Data Platforms that operate in a cloud service environment, and achieve load balancing in collaboration with the belonging ISP network. In that context, we also bring arguments with respect to why the data should be predominantly openly licensed (i.e. Open Data). Finally, the concepts are demonstrated based on a prototype deployed in our testbed and illustrating the whole machinery on a particular electric mobility use case.

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The rest of this paper is organized as follows: Section 2 describes different scenarios for electric mobility in smart cities and motivates the need for the proposed data cloud. Section 3 elaborates on the relations between Open Data and electric mobility thereby motivating the requirement to use predominantly Open Data sources of information. Section 4 describes the proposed distributed architecture. Section 5 elaborates on the interplay between an ISP network and the electric mobility data cloud. Section 6 demonstrates a scenario based on existing prototypes deployed in our testbed. Finally, section 7 draws conclusions and outlines future research directions.

II. Scenarios for Electric Mobility in Smart Cities

In future smart cities electric vehicles will play a major role in transportation and in urban carbon dioxide reduction schemes. For electric vehicles to gain mainstream status, the whole electric mobility domain must be laid out for citizens in a flexible and efficient manner. One of the key aspects required to insure this is reliable mobility services including registration, localization, searching for an electric vehicle, multimodal routing etc. as well as data transmission through which users can be interconnected with various resources in the electric mobility domain. The mobility services would be utilizing different types of data such as public data (routes, schedules, quality of roads etc.), business data (ticket information, fees, charging stations), and private data (preferences, targets, profiles).

In this section we look at a couple of key scenarios that illustrate the above described interplay of data sources. Major components and data flows are shown in Figure 1. We start with the availability of electric vehicles and charging stations. In a car sharing scheme, a user needs to find a suitable electric vehicle in his immediate vicinity. In order to do so, the user utilizes a cloud based mobility service to receive a list visualizing electric vehicles. In that context, the cloud based mobility service obtains and makes use of the exact GNSS (Global Navigation Satellite Systems) coordinates of the user. With that knowledge, the service selects electric vehicles that meet the user's criteria and pushes the attributed data to the users' terminal (handheld/smartphone). The user in turn can choose and reserve a vehicle, again by using the cloud based mobility service. The next step for the user is to follow the path to the vehicle, which is delivered to his smartphone.

As soon as the electric vehicle is on the move, it is required to report its status and positioning data in real time to the mobility service provider. This allows the mobility service provider to control its vehicle fleet infrastructure.

Another scenario that contributes to increasing the convenience of electric mobility is having easy accessible charging stations. Charging stations in smart cities are geographically widely dispersed but are fortunately integrated into a single network. This highlights the need to interconnect electric vehicles with charging stations. Like previously described in the case of users searching for electric vehicles, the discovery of charging stations is done via cloud based services. Furthermore, a charging station is setup intelligently to emit its status, geographical location, electricity costs, consumption etc. to the cloud services.

A further scenario in smart cities is the autonomous driving in urban environments. This is aided by GNSS, lasers, sensors and cameras for tracking vehicles and obstacles on the roads. Moreover, vehicle localization is done via dynamic road models. In combination with cloud based mobility services an electric vehicle can receive real-time up-to-date dynamic routing data that enable its efficient navigation in urban environments.

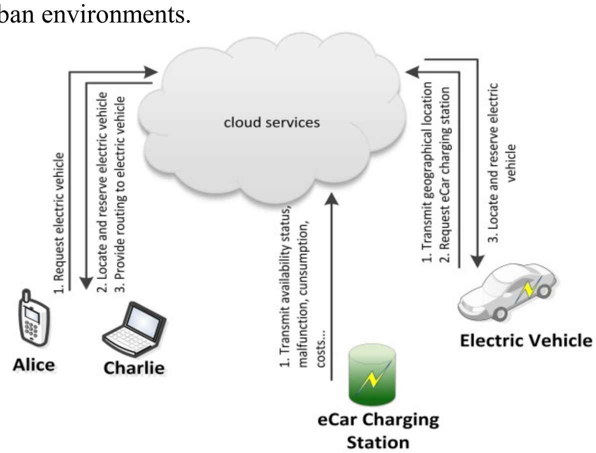

FIGURE 1: USE CASE FOR ELECTRIC MOBILITY INTERCONNECTION

All the scenarios presented in this section require efficient, real-time communication services capable of data streaming and load-balancing. In addition, we believe that the data in question should be made available under open licenses and free APIs (application programming interface) as to involve the community, including different service providers and application developers, in the dynamics of a smart cities eco system.

III. Open Data and Electric Mobility

Open Data is a recent movement that is similar to the open source initiative. Most notably, Open Data initiatives claim that data should be licensed in a way as to allow for redistribution, reuse – also in commercial cases – and derivative works, whilst at the same time acknowledging the key contributors that provide, maintain, and improve the data. The rationale behind this claim is that 1) electronic resources, once collected and digitalized, are not scarce anymore and thus should be shared. This allows particularly for mashup services and applications, i.e. (experimental) combinations of previously disconnected datasets. Moreover, it is often claimed that 2) useful applications are in many cases not developed by data holders, but by intermediaries between users and data holders.

Other two key aspects of Open Data, besides licensing, are constituted by the ease of access, i.e. allowing developers and citizens to discover data without detailed knowledge of the data providing institutions and structures, and machine readable formats that allow for interoperability.

Even though these claims are often challenged, especially by stakeholders whose business model is based on the provision of high quality data, one has to concede that at least some amount of government data, i.e. information gathered or generated by (city) administrations, does not suffer from funding issues, as they are covered by public budget. This holds without regard of the reuse model.

There are several aspects that make electric mobility data a special case of Open Data. First, transport information can benefit from the combination of different data sources, because transport is rarely self-contained, but rather a means for another activity. Additionally, a single company cannot provide multimodal routing (traveling based on different interconnected mobility systems), which can be only enabled by an entity that has data from all involved parties. Secondly, transportation is traditionally directly influenced by the governments that build and run, or at least supervise, networks and vehicles. This is a major difference to many other business domains, and allows authorities to adjust data publishing policies and practices.

Today mobility providers mostly build applications and online services that are exclusively based on and related to their own real world services and data. The vision of the open mobility data is that all involved parties provide their electronic interoperable resources into a single data space. This space of convergence is often referred to as mobility data cloud. It offers data to three groups: 1) other providers, 2) companies and developers who build integrated applications and services, and 3) individuals who can inspect and analyze the data for various purposes.

Key building blocks of such mobility data clouds are Open Data Platforms. Following components constitute the core of such platforms: 1) *data catalog* that handles metadata (data resource descriptions) of data sets/sources and can also point to external resources (files or APIs), 2) *data store* that allows for storing data inside the platform itself, and 3) *web portal* and *RESTful services APIs* for accessing and managing the data and metadata. That way Open Data Platforms offer a one-stop-shop experience for data seekers by providing a data catalog, i.e. consistent metadata for data resources which are normally dispersed over various providers. Additionally, they allow for harvesting as illustrated in Figure 2, i.e. for federating this metadata into other data platforms. This multi hop federation is essential, because no single platform can be the final and complete one, as there is always a top level platform that integrates several collections of the same level or domain specific collections hosting metadata for a particular topic.

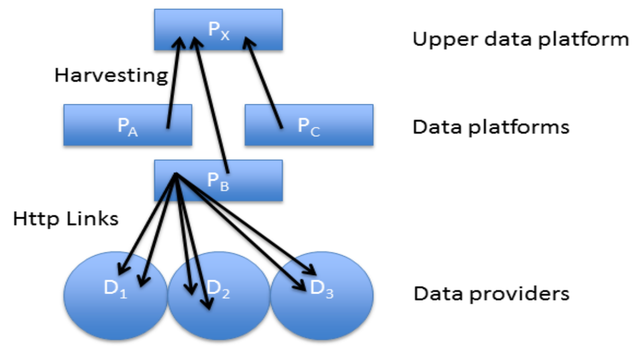

FIGURE 2: FROM DATA PROVIDERS TO DATA PLATFORMS TO PLATFORM FEDERATION

Available implementations of such platforms are given by the commercial Socrata [5], or by the FOKUS Open Data Platform [15][6], which is an open source solution. The latter consists of a Liferay [13] based web application server, a data catalog based on the Comprehensive Knowledge Archive Network (CKAN) [14] of the Open Knowledge Foundation, and a triple store data storage component based on the Virtuoso [16] database engine.

IV. DISTRIBUTED PLATFORM FOR ELECTRIC MOBILITY DATA

Based on the FOKUS Open Data Platform (ODP) presented in the previous section, the next step towards the realization of an *electric mobility data cloud* is given by extending ODP such that data streaming can be efficiently supported. Data streaming is of paramount importance for a number of applications and use cases such as availability of electric vehicles and charging stations, continuous dissemination of positioning data, etc. In that context, the presented data platform would be running as a service that communicates with involved end systems (smartphones, onboard units, charging stations etc.) over the Internet. However, communication over the Internet is running on best effort principles which might become a problem for timely information sharing over an electric mobility data cloud. In order to remediate this issue, it is imperative to devise an architecture that overcomes the bottleneck of a single point of reference/communication to the data platform. In addition, this architecture has to increase the scalability of the electric mobility data cloud with respect to serving a large number of end systems subject to (almost) real-time constraints for data delivery. Naturally, such architecture should emerge as a distributed set of components which are interconnected using a fast and reliable network infrastructure for the purpose of synchronizing their data.

Our proposed setup for the realization of the electric mobility data cloud is exemplified in Figure 3. On the left side, we have a number of end systems that seek to interact with the data cloud. In order to simplify the presentation, the diversity of access network (UTRAN, EPC, etc.) components that facilitate the connection to the Internet is omitted. The electric mobility data cloud is represented by a number of Open Data Platform servers which can be reached by the end systems over the Internet. The servers synchronize their data over a data sharing network infrastructure which may be based on a scalable and efficient Distributed Hash Table (DHT), a dedicated VPN (Virtual Private Network) or LAN (Local Area Network) within a city, or a network with special QoS features as realized by Integrated Services protocols such as RSVP (Resource Reservation Protocol) [7]. In that context, it is important that the data sharing network infrastructure (on the right side in Figure 3) offers better conditions for data exchange than the straight best effort Internet used by the end systems to reach the platform servers.

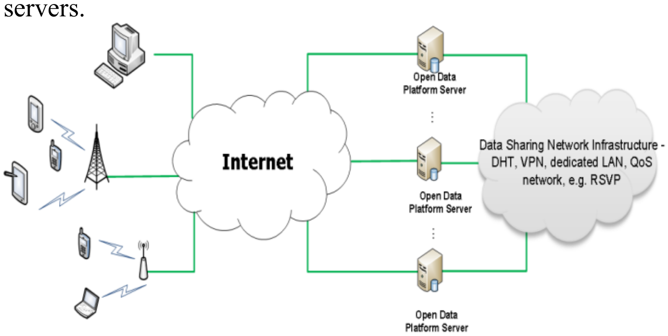

FIGURE 3: DISTRIBUTED PLATFORM FOR ELECTRIC MOBILITY DATA

An additional aspect is given by the requirement for load balancing among the available data servers. The load balancing would facilitate the redirection of end systems such that overload situations on a single data server are avoided, and an acceptable data streaming quality can be provided. The goal is to achieve a fair distribution of the number of clients (end systems) among the data servers. In addition aspects of the network connection between an end system and a data server can be taken into account as described in the coming sections.

V. NETWORK AWARE LOAD BALANCING AS AN ENABLER FOR REAL-TIME ELECTRIC MOBILITY DATA

Traditional load balancing is realized on the server side by dispatching incoming requests to the least loaded server. Thereby the servers of a provider form a so called Content Distribution Network (CDN) that provides the infrastructure and realizes the dispatching and load balancing. Techniques used for load balancing in practice include HTTP redirection and DNS routing [20]. During the past years there were research efforts that investigated the interplay between CDN and service provider networks [8][9] thereby revealing the potential and discussing on related technology and business models. In that context the load balancing is based on both: 1) the load on the servers within the CDN, and 2) the QoS provided by the service provider network towards the CDN servers.
In the course of the EFIPSANS [1] and ANA [10] European projects, we had the chance to develop an architecture for network aware load balancing that can play a key role for the efficiency of the proposed electric mobility data cloud. The combination of these results with the aforementioned Open Data Platform is the key towards the efficient and scalable dissemination of continuous streaming electric mobility data.

First, there is the CDN of the data cloud as illustrated in Figure 3. Moreover, we have a number of additional components inside the CDN and the service provider network that facilitate the network aware load balancing. The overall set of required components is presented in Figure 4. The end systems communicate with a dedicated *Content Provider Proxy* in order to get dispatched to the appropriate *Open Data Platform Server*. This dispatching process is based, on one hand, on the load of the network towards the data servers, and on the other hand on the load (number of clients) on the data servers. The information about the server load can be kept track of by the Content Provider Proxy itself, since each request from an end system is expected to pass through the proxy. In the course of obtaining the appropriate data server for a request, the Content Provider Proxy refers to a *QoS Agent*, which is the component that consolidates the information regarding the network load based on QoS parameters towards the data servers. Regarding the network load, we rely on so called *Autonomic Monitoring Agents (AMA)* that operate inside the edge routers of the service provider network and deliver up-to-date information regarding KPIs (key performance indicators) of the network such as *jitter*, *delay*, *bandwidth*, *out of order packets*, *lost datagrams* etc. The theory behind, the implementation and evaluation of such an AMA is presented in our previous work [11]. The AMAs communicate these KPIs to the QoS agent that evaluates a weighted utility function in order to obtain a network metric related to a path towards a data server. This utility function is given by a weighted sum that can prioritize different key performance indicators. The network metric value is communicated back to the Content Provider Proxy and used for a decision to dispatch a requesting end system. Finally, some words regarding the communication between the involved components. The end systems communicate with the Content Provider Proxy over standard TCP connections. The proxy, the AMAs, and the QoS agent communicate over a Chord [4] peer-to-peer overlay of *Information Sharing Servers*. The latter are deployed in a distributed manner and provide an efficient and scalable infrastructure for information exchange among the involved components.

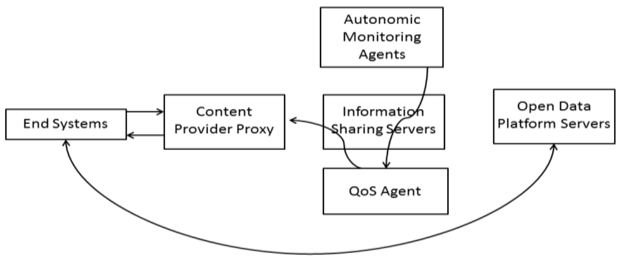

FIGURE 4: COMPONENTS FOR NETWORK AWARE LOAD-BALANCING

The next section illustrates the interplay of all involved components in a testbed at the Fraunhofer FOKUS institute in Berlin. Thereby, the way these components realize an efficient electric mobility data cloud is presented.

VI. SCENARIO: ELECTRIC MOBILITY DATA CLOUD AND NETWORK AWARE LOAD BALANCING

First, we describe the setup of our scenario based on Figure 5. On the left side there are three end systems which in our electric mobility context are given by an *eCar Charging Station*, as well as by the end user devices of *Alice* and *Charlie*. Alice and Charlie access the ISP (Internet Service Provider) best effort network over a WLAN access point. The eCar Charing Station is connected to the ISP's network over a wired access technology (e.g. fiber). The routers of the ISP network are named as Border Routers (BR) and Core Routers (CR) and provide IP connectivity to the ODP servers of the electric mobility cloud. In addition a set of Information Sharing Servers provide and overlay for information exchange between the ISPs network and the data cloud. These information servers are implemented in Java using the Chord [4] DHT protocol and its open source implementation [2]. Furthermore, within the ISP network there is a Java implementation of the QoS agent running on a server within the S4 sub network in the middle. The QoS agent calculates a single metric that reflects the traffic conditions on the paths between the edge routers (BR1-BR2, BR1-BR3, BR4-BR2, BR4-BR3). In order to achieve this, the QoS agent interacts with the Autonomic Monitoring Agents (AMAs) running on the border routers. As previously mentioned, the AMA concepts, implementation and evaluation, including performance and overhead measurements, are described in detail in [11]. The main goal of such an AMA is to provide adaptive monitoring services within the nodes of an IP network. In the current case, the AMAs on BR1 and BR4 orchestrate the monitoring of jitter, delay, bandwidth, packet loss, and out-of-order packets thereby employing the *iperf* [12] monitoring tool. The AMAs on the "server-side" edge routers (i.e. BR2 and BR3) are running the corresponding iperf-server components that enable the active measurement of the aforementioned metrics. As previously mentioned, the values measured by the AMAs are communicated to the QoS agent that computes a metric for the traffic conditions between the pairs of routers on the edges, and correspondingly for the conditions towards the electric mobility data cloud servers. This consolidated metric is shared over the overlay of Information Sharing Servers and thus communicated to the Content Provider Proxy attached to BR4. This Content Provider Proxy keeps track of the number of clients communicating with the servers in the mobility data cloud and is informed by the QoS agent regarding the metric values related to the network conditions on the paths towards the mobility data cloud servers. Based on these two values the Content Provider Proxy dispatches the requesting end users to the most suitable data server. This can be combined with the type of service provided to the corresponding end users. For example, it could be the case that for normal users only the load on the server side is taken into account, and for premium users both, the load on the server side and the network conditions are considered when dispatching.

Figure 5, Figure 6 and Figure 7 describe a specific case in which the above described setup influences the data streaming provided from/to elements of the electric mobility eco system. This scenario is realized in our testbed at the Fraunhofer Institute for Open Communication Systems in Berlin. The only difference between the testbed and the illustrated network is constituted by the AP1 (Access Point on the left side) which indeed is a straight wired link. However, for scenario purposes, the illustrations suggest a WLAN link there, which does not affect the logic of the described case study.

Presuming that Charlie is a normal user, we emulate (Figure 5) a traffic request from Charlie's end system to the mobility data cloud resulting in a data stream BR4-CR3-CR4-BR3-CP1B. Thereby, we presume that the Content Provider Proxy dispatches a user to CP1B first, in case CP1B and CP1A are equally loaded with respect to number of data consuming/sharing clients. The flow initiated by Charlie might be for example related to continuously obtaining the position of moving electric vehicles in his vicinity and visualizing this real time positions on a map, in order to give him the chance to stop an eCar for a collaborative drive to a particular direction.

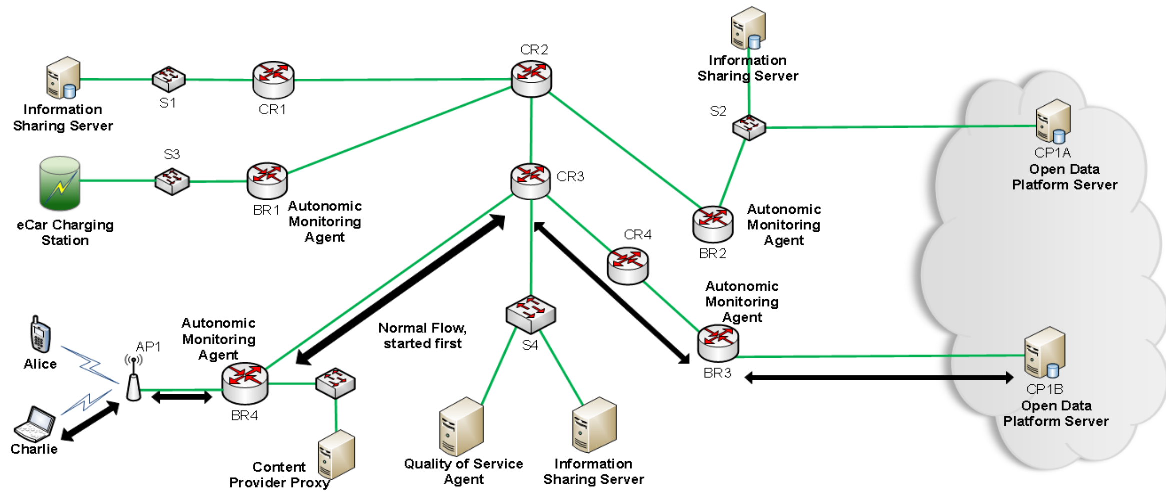

FIGURE 5: COMBINED SCENARIO – INITIAL SCENE WITH ONE REQUEST

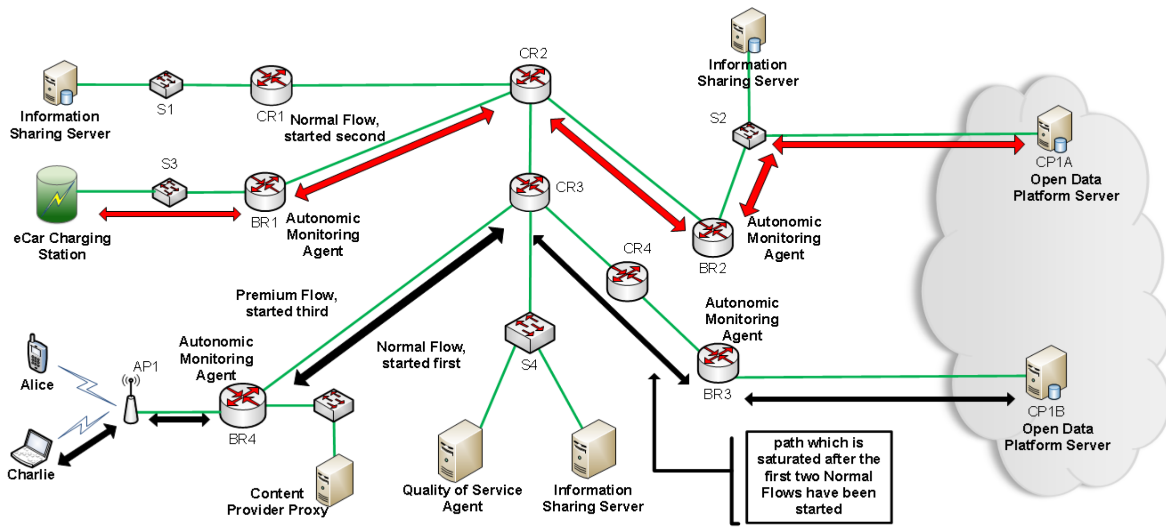

FIGURE 6: COMBINED SCENARIO – SCENE WITH TWO REQUESTS AND PATH SATURATION

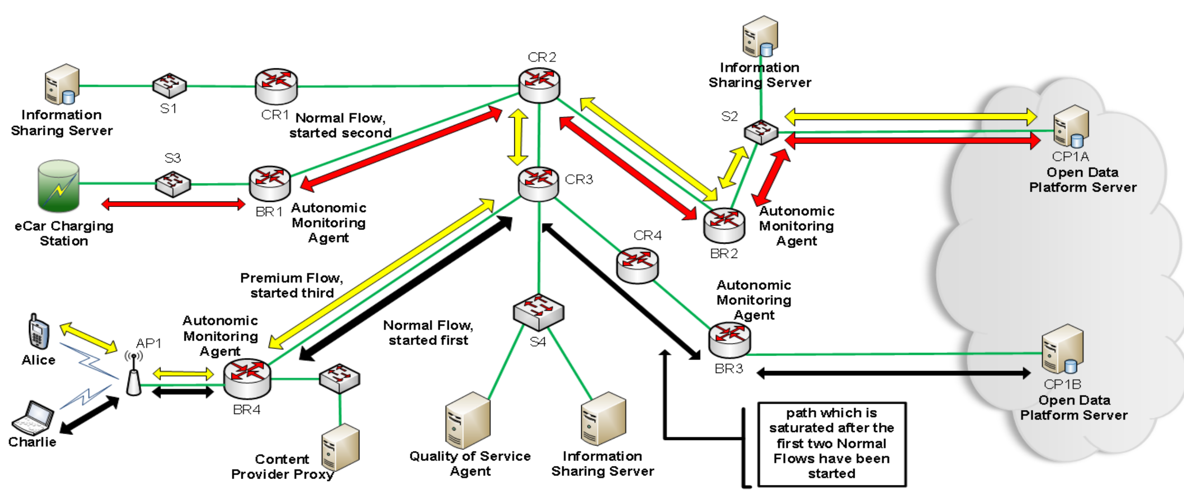

FIGURE 7: COMBINED SCENARIO – SCENE WITH NETWORK AWARE LOAD BALANCING

Secondly, a particular eCar charging station is switched on and boots up its IT subsystem thereby starting to push a data stream of information about its status (technical health and availability) to the mobility data cloud (Figure 6). We presume that this data stream is handled as a normal user data stream and dispatched to CP1A since there is already one user consuming data from CP1B. In order to demonstrate the network aware load balancing, we saturated the path between CR3 and BR3 by generating a large amount of UDP traffic using again the *iperf* tool. This influenced considerably the network conditions towards CP1B which was immediately reflected in increased values for jitter, delay, out-of-order packets and packet loss, as well as decreased bandwidth.

Starting "normal-user" data stream from Alice, which means that only the server load was considered, resulted in Alice being dispatched to CP1B and a situation where in most of the cases the establishment of the data stream failed or the data stream stalled very quickly. However, starting a "premium" data stream for Alice (Figure 7) influenced the Content Provider Proxy to consider not only the server load but also the metrics provided by the QoS agent. This resulted in Alice being dispatched to CP1A thereby enabling a fast and qualitative data stream, allowing Alice to use continuous information about the resources in the electric vehicle eco system. For example, such information could be related to the real time status (e.g. technical health and availability) of charging stations within an area. Hence, we see how the interplay between Open Data Platforms operating in a cloud environment and an ISP's network can bring substantial benefits towards the realization of electrical mobility in a smart city environment.

VII. CONCLUSIONS

Clearly the topic of Smart Cities is gaining on importance in the global context. The fact that a significant increase of the urban population is expected in the coming years leads to the assumption that the transport infrastructure in future cities will have to face a number of serious challenges in the next decades. Not only that the number of cars in urban environments might significantly increase, but also the potential pollution issues related to this should be considered as a serious threat to quality of life. One possible remedy for these issues is to go for a collaborative vehicle sharing system that is based on a green technology such as electric vehicles (electric cars, electric bicycles, and segways). This implies that on one hand there should be the infrastructure for electrical mobility, and on the other hand there should be an IT system that steers all the processes around the sharing aspects. Such sharing aspects include the registration, profiling, (multimodal) route planning, reservation etc. All these services have to operate on data which is to be shared among different entities and stakeholders, such as public transport providers, city administration, geographical data providers, charging station providers etc. Obviously, there is a need for an infrastructure that would enable the sharing and consumption of such data thereby managing it as openly available data, also known as open data.

We propose a solution based on existing Open Data Platforms in use within the community. The combination of several Open Data Platform (ODP) instances leads to the design of a distributed open data network that has the capabilities to deliver mobility data streams over a best effort network such as the Internet. The single ODP instances exchange information over a dedicated network infrastructure. The key to efficient data streaming is based on a load balancing that can be extended to consider the network conditions towards the data servers. Based on our experiences and prototypes from multiple European projects, we present an architecture that has the capability to enable the collaboration between an Internet Service Provider network and the electric mobility data cloud. This is further demonstrated by a scenario that we experimented with in our testbed. This scenario demonstrates the way streaming electric mobility data (e.g. positioning or availability status of components) can be efficiently shared in the scope of a city thereby exploiting the interplay between the Open Data Platforms and an ISP's network.

Obviously, the realization of a data cloud for mobility data bears a number of challenges such as data streaming requirements, real time aspects, as well as data integrity, trust and security issues. This work was our first attempt to realize the data streaming aspects based on a combination of available Open Data technologies, experiences and research prototypes. Our future work will follow the path of investigating further approaches towards enabling a scalable and efficient electric mobility data cloud thereby addressing aspects such as trust, confidentiality and integrity of data, as well as increased reliability of the cloud infrastructure. In that context, we believe that it is worth investigating the way personal data might be leveraged, in order to establish a personalized mobility space as an enabler for efficient collaborative electric mobility.

REFERENCES

[1] EFIPSANS project: http://www.efipsans.org/, as of date 25.05.2012

[2] Open Chord: http://sourceforge.net/projects/open-chord/ , as of date 25.05.2012

[3] Flinkster: http://www.flinkster.de/, as of date 25.05.2012

[4] Ion Stoica, Robert Morris, David Karger, M. Frans Kaashoek, Hari Balakrishnan: "Chord: A scalable peer-to-peer lookup service for internet applications", Proceedings of the 2001 conference on Applications, technologies, architectures, and protocols for computer communications, p.149-160, August 2001, San Diego, California, United States

[5] Socrata: https://opendata.socrata.com/, as of data 25.05.2012

[6] Fraunhofer FOKUS, Open Data Platform: https://github.com/fraunhoferfokus/opendata-platform, as of date 25.05.2012

[7] RFC 2205: Resource ReSerVation Protocol (RSVP)

[8] Ingmar Poese, Benjamin Frank, Bernhard Ager, Georgios Smaragdakis, Anja Feldmann: "Improving content delivery using provider-aided

distance information", Proceedings of the 10th annual conference on Internet measurement, November 01-30, 2010, Melbourne, Australia

[9] Wenjie Jiang, Rui Zhang-Shen, Jennifer Rexford, Mung Chiang, "Cooperative content distribution and traffic engineering in an ISP network", Proceedings of the eleventh international joint conference on Measurement and modeling of computer systems, June 15-19, 2009, Seattle, WA, USA

[10] C. Jelger, C. Tschudin, S. Schmid, and G. Leduc, "Basic Abstractions for an Autonomic Network Architecture", in the proceedings of World of Wireless, Mobile and Multimedia Networks, 2007. WoWMoM 2007

[11] Nikolay Tcholtchev and Razvan Petre, "Design, Implementation and Evaluation of a Framework for Adaptive Monitoring in IP Networks", in the proceedings of EASE 2012, 9th IEEE International Conference and Workshops on the Engineering of Autonomic & Autonomous Systems

[12] Ajay Tirumala, Les Cottrell, Tom Dunigan, "Measuring end-to-end bandwidth with Iperf using Web100", 2003, in the proceedings of Passive and Active Monitoring Workshop (PAM 2003)

[13] Jonas X. Yuan, "Liferay Portal Enterprise Intranets: A practical guide to building a complete corporate intranet with Liferay", book published by Packt Publishing 2008, ISBN:1847192726

[14] Comprehensive Knowledge Archive Network (CKAN): http://ckan.org/, as of date 25.05.2012

[15] Evanela Lapi, Nikolay Tcholtchev, Louay Bassbouss, Florian Marienfeld, Ina Schieferdecker, "Identification and Utilization of Components for a linked Open Data Platform", to appear in the proceedings of the 1st IEEE International Workshop on Methods for Establishing Trust with Open Data (METHOD 2012)

[16] Orri Erling, Ivan Mikhailov, "RDF Support in the Virtuoso DBMS", in "Networked Knowledge - Networked Media", Studies in Computational Intelligence, 2009, Springer Berlin / Heidelberg, ISBN: 978-3-642-02183-1

[17] Open Ride: http://www. open-ride.com/, as of date 25.05.2012

[18] Car2go: http://www. car2go.com/ , as of date 25.05.2012

[19] Siemens eMobility Infrastructure: http:// www.energy.siemens.com/hq/en/power-distribution/e-mobility.htm, as of date 25.05.2012

[20] Cardellini, V.; Colajanni, M.; Yu, P.S.; , "Dynamic load balancing on Web-server systems", Internet Computing, IEEE , vol.3, no.3, pp.28-39, May/Jun 1999

[21] C. Urmson, et. al. "Autonomous driving in urban environments: Boss and the urban challenge", Journal of Field Robotics, vol. 25, pp. 425 – 466, July 2008.

[22] Mary Slosson (2012-05-08). "Google gets first self-driven car license in Nevada". Reuters. Retrieved 25.05.2012

[23] V. Milanés, D. F. Llorca, B. M. Vinagre, C. González, and M. A. Sotelo,"Clavileño: Evolution of an autonomous car" in *Proc. 13th IEEE ITSC*, 2010, pp. 1129–1134.