Post-print version of the paper by Anthony Jr., B and Petersen S. A. in Lecture Notes in Business Information Processing 381(2020) 3-17
https://doi.org/10.1007/978-3-030-44322-1_1

A Practice Based Exploration on Electric Mobility as a Service in Smart Cities

Bokolo Anthony Jnr.* [1] and Sobah Abbas Petersen[1]

[1] Department of Computer Science, Norwegian University of Science and Technology, NTNU, NO-7491 Trondheim, Norway

{anthony.j.bokolo@ntnu.no,sobah.a.petersen@ntnu.no}

Abstract. With increase in urban residents and CO_2 emission from vehicles, there is need to deploy smart electric mobility services termed as Electric Mobility as a Service (eMaaS) facilitated by innovations in Information Communication Technology (ICT) to mitigate environmental issues, improve social inclusion, and enhance economic growth. However, citizens and stakeholders are faced with issues related to acquiring appropriate information needed to make decisions which impacts their wellbeing and natural environment due to heterogenous data being generated from various sources. Therefore, this study adopts Enterprise Architecture (EA) and integrates Application Programming Interfaces (APIs) to improve interoperability for acquisition, processing, retaining, and dissemination of mobility relevant data. Secondary data from the literature and ArchiMate modeling tool was utilized to model eMaaS case to verify the feasibility of EA to improve city transport services. Findings from ArchiMate reveal that EA provides a theoretical and practical approach that supports mobility services in smart cities.

Keywords: Smart cities, Smart mobility, Electric mobility, Big data, Enterprise architecture, ArchiMate modeling language.

1 Introduction

Presently, more than half of the world's citizens resides in cities and urban environments are facing challenges in areas such as in congested transport infrastructure, energy effectiveness, climate change, and environmental pollution [1]. Accordingly, the transportation sector is under pressure to reduce reliance on traditional combustion engine vehicles which releases CO_2 emissions that pollutes the environment and are utilizing Electric Vehicles (EVs) which are characterized as being lowly polluting, energy efficient, and noiseless [2]. Thus, the transition towards Electric Mobility as a Service (eMaaS) is believed to improve sustainable transportation in smart cities as it facilitates the reduction of carbon dioxide emissions [3]. eMaaS in smart cities comprises of deployment of fleets of EVs such as electric bicycles, electric cars, and segways to support collaborative sharing [4].

Furthermore, cities are faced with issues relates to silos which hinders smart services due to lack of interoperability and openness to produce value-added services

* Corresponding author. E-mail address: anthony.j.bokolo@ntnu.no

Post-print version of the paper by Anthony Jr., B and Petersen S. A. in
Lecture Notes in Business Information Processing 381(2020) 3-17
https://doi.org/10.1007/978-3-030-44322-1_1

across multiple platforms. Thus, there is need for interoperable standards to foster development of open ecosystems and expose the commercial potential of mobility data [5], where interoperability refers to the ability of different devices to communicate with each other and exchange information. Moreover, processing and visualizing mobility related data is not straightforward due to heterogenous data being generated from different sources such as position of EVs, routing, EV usage, EV parking stations, charging stations locations, EV battery status, and city transport data, etc. [6]. Such challenge entails deployment of innovative Information Communication Technology (ICT) solutions, such as Application Programming Interface (API) capable of enabling interoperability and providing access to processed and stored data needed to deliver information on mobility related services [7]. Thus, API serves as data adapters integrated for establishing connections to different mobility platforms, external databases, and real-time streaming data [8].

In addition, researchers such as Sánchez et al. [9] suggested developing architecture to address eMaaS requirements for the actualization of smart electric mobility (e-mobility) services. The authors mentioned that architecture supports the deployment of applications that access heterogeneous data produced from different sources in an open and standardized approach. Respectively, Enterprise Architecture (EA) is adopted in this study to provide information on the current as-is structure of mobility services thus serving as an informational foundation for making decisions for transportation development. Likewise, EA provide a medium to develop and envision to-be conditions for mobility planning [10]. EA provides a holistic scope and offers aggregate and broad view of the entire corporation comprising of business processes, organizational structure, strategic aspects, software and data, and IT infrastructure.

Besides, EA provide systematic support for transformation and is driven by IT and/or business-oriented application based on citizens and stakeholders' concerns [11]. Respectively, this study presents EA approach that integrates API for improving interoperability and handling e-mobility related data which is key enabler for improving transportation operation in providing collaborative, flexible, and efficient e-mobility service to citizens in cities. The structure of the paper is as follows section 2 is literature review. Section 3 is application of EA in eMaaS, section 4 is the results. Section 5 is discussion and implications lastly section 6 is the conclusion, limitations, and future directions.

2 Literature Review

2.1 eMaaS and Big Data in Smart Cities

Clearly the topic on smart mobility is gaining importance globally due to significant increase in number of cars within cities which causes pollution issues and serious threat to citizens quality of life [12]. Thus, there is need to employ sustainable mobility such as electric vehicles (for example electric bicycles, electric cars, segways, etc.), which comprises of infrastructure for e-mobility and IT system towards EV fleet management [2] as seen in Figure 1. This is because fossil fuel vehicles used in transportation are a significant contributor to CO_2 emission, and are considered as one of the main hindrances to sustainable development.

Figure 1 depicts the value chain of IT and electric system working together to facilitate eMaaS for EVs which are perceived as an important contributor in the reductions of greenhouse gas production and are one of the most prospective solutions for decarbonization of urban transportation [12]. Hence, in smart cities EVs play a major role in urban transportation in decreasing carbon dioxide emission. But, for EVs to be used there is need to depict the entire e-mobility chain to citizens in a

Post-print version of the paper by Anthony Jr., B and Petersen S. A. in
Lecture Notes in Business Information Processing 381(2020) 3-17
https://doi.org/10.1007/978-3-030-44322-1_1

flexible and resourceful manner. Accordingly, in cities eMaaS utilizes different categories of data such as public data (schedules, routes, road conditions, etc.), business data (fees, ticket information, charging stations), and private data (user preferences, user targets, citizens profiles) [6].

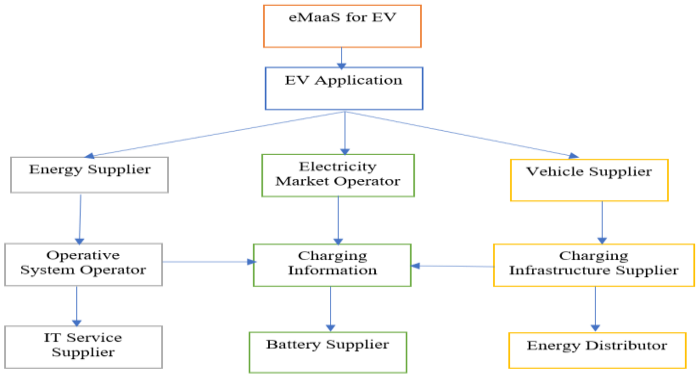

Fig. 1. Value chain of IT and electric players

These data are generated in volume, velocity, variety, and veracity and processing these data into actionable and valuable insights and making it open for mobility application usage is an issue that has not fully been addressed in the literature. Although, few studies have examined big data in mobility domain, they are mostly concerned with addressing functional requirements and designs of mobility services [3]. Hence, there is need to develop flexible and efficient big data processing platform between data sources and mobility applications.

2.2 API for Data Interoperability

Currently, smart mobility solutions are transforming data to services for citizens, stakeholders and city transport operators. Thus, integrating open and private data, static, open, and real-time data from different sources and there are issues related to aggregating, exploiting, and re-conciliating of data to facilitate eMaaS orchestration [7]. Furthermore, eMaaS provides standardized services that utilize heterogeneous data sources such as available transport data, real-time data regarding vehicles, ticketing pricing, etc. to provide customized mobility services to citizens, as well as to stakeholders for monitoring and planning [4]. eMaaS concept provides access to new markets for data services creating prospects for additional profits and market growth [6]. Likewise, eMaaS utilize data which is to be shared among citizens and stakeholders, such as geographical data providers, city administration, public transport providers, EV charging station providers etc. [13].

Clearly, there is a need for an approach such as API that would facilitate sharing and usage of such data thereby orchestrating open data interoperability [12]. API acts as a gateway, enabling smart mobility applications to access specific data seamlessly using Extensible Markup Language (XML) or other formats such as JavaScript Object Notation (JSON) [14]. Additionally, API uses Representational State Transfer (REST) protocol over HTTP using JSON in integrating several different data sources to retrieve raw data from a data source in its native format (XML, JSON, comma-separated values (CSV) or others) to provide mobility data [3]. API helps mobility service providers open-up data and offers the ability to collect data from diverse sources and make the data available and searchable. Thus, in this study API is integrated as a technology that supports interoperability of variety of data and protocols across diverse devices to support eMaaS in smart city.

2.3 Background of Enterprise Architecture

According to Chen et al. [15] an enterprise refers to one or more organizations sharing a definite objectives, goals, and mission to offer an output such as a service or product. Architecture models constitute the fundamental of an approach and serve the purpose of making the complexities of the real world manageable and understandable to humans [16]. Presently, cities are increasingly using IT not only to underpin existing mobility services but also to develop new opportunities that creates new source of competitive advantage. Thus, to improve transportation services cities must deploy IT related service. Likewise, mobility service providers need to tactically manage IT to strategically mange business operations. Accordingly, there is needs for integrating a standardized model such as enterprise architecture that holistically represent all component within e-mobility services, with the use of schematics and graphics to depict how parts of the components are interrelated.

The concept of EA was proposed by John Zachman in 1987 based on architecture in civil to be extended in enterprises to decrease complexity of developing Information Systems (ISs) [17]. Thus, EA is a structure for aligning IT and business within enterprise and aims to provide appropriate ISs based on business demands [16]. EA provides a well-developed, systematic approach to align corporations and their utilization of technology to offer alignment across mobility operations and design [11]. Many establishments adopt EA as part of their IT planning and management activities for strategic prioritization and alignment in guiding their decisions towards improving bottom line impact and managing innovative changes [16]. Moreover, EA describes the components that make up the complete system and offers a blueprint from which the system can be deployed [15], it entails the essential structure of an organization and facilitates transformation by providing a holistic perspective regarding as-is and as to-be processes and structures. It promotes integration and consistency across infrastructure, process, application, and information, for improved business performance, thereby lessens organizations complexity via reuse and sharing of components and standardizations [11].

EA can be applied in mobility domain to ideally help stakeholders to efficiently plan, communicate document, analyze, and design IT and business-related issues by providing decision support for stakeholders providing information for mobility service providers [16]. Moreover, EA provide systematic support to mobility transformation and change that affects both IT and business structures providing an aggregate and broad structure of the entire eMaaS operation driven citizens and stakeholders' concerns [18]. Furthermore, EA is suitable to be applied in eMaaS as it aids to envision, lead, plan, design, and manage transportation operations in current, transitionary, and future conditions within smart cities. It describes the e-mobility services in terms of structure, strategy, information flows, physical instantiations, and business process [11]. It improves the performance and quality of mobility processes and improves productivity across the city by integrating data sources. The blueprints designed by EA provide a basis for modelling and optimizing e-mobility services enabling mobility service providers to decrease complexity by outlining the operating principles and technical standards for guiding mobility operations [17].

2.4 Related Works

A few studies have investigated e-mobility services in smart cities, among these studies Ruohomaa and Salminen [19] researched on MaaS in relation to industry 4.0 approach. The authors focused on addressing main area of development to understand the opportunities and issues related to e-city bike services and how produced data could be utilized to improve city mobility services. Furthermore, Bellini et al. [20] designed an architecture for data ingestion and analytics in the context of mobility and transport integrated services grounded on ontology and tools for data aggregation and service creation in smart cities. Experiment was carried out to test the approach in a city. Besides, Kamargianni and Matyas [6] developed a business ecosystem for MaaS. The researchers depicted the actors and their respective roles in MaaS and provided a holistic method for MaaS concept development and identified the eMaaS areas that needed to be explored. Data was collected using interviews based on focus groups.

Similarly, Melis et al. [4] proposed a crowdsensing service-oriented architecture for smart mobility and demonstrated the implementation of microservice paradigm to actualize mobility services system. The authors utilized microservice to expose and orchestrate data service. Also, Brand et al. [21] designed an architecture for achieving interoperability of e-mobility. The architecture was developed based on The Open Group Architecture Framework (TOGAF) for enterprise architecture and it aimed to provides adequate integration of electricity system to support the charge process based on data from market parties. The authors adopted qualitative method and collected data using structured interviews to validate their approach. Likewise, Kuehl et al. [22] designed a service-oriented business model for e-mobility. Their research aimed to gain improved understanding of existing e-mobility services and provide an approach that is simple yet comprehensive and convenient to describe e-mobility services.

Moreover, Tcholtchev et al. [23] designed a mobility data cloud that provide a framework for collecting, aggregating, processing, and analysis of mobility data generated from numerous sources. The authors utilized various data to facilitate collaborative sharing of mobility resources such as EVs, charging stations, etc. A prototype was presented to evaluate their approach based on trials method. Additionally, Abdelkafi et al. [24] proposed an innovative business model to create value for e-mobility. The proposed approach enabled the categorization and adoption of business model patterns, identified via the integration of different dimensions to be adapted to fit into the domain of e-mobility. Likewise, Tcholtchev et al. [12] explored the integration of open data, network providers, and cloud services to improve e-mobility in smart cities. The researchers designed a distributed architecture for the provision of mobility data cloud in achieving EV sharing via a cloud-based system for data handling.

Additionally, Mäkelä and Pirhonen [25] proposed a business model to improve value creation of electric mobility in complex private service system. The researchers demonstrated how the model can be used as an analysis tool to understand and describe value creation complexity of e-mobility in developing industry. Action research method was employed using case study to collect data from nine e-mobility firms. The reviewed studies applied data to improve mobility services of EVs and non-EVs towards reducing pollution by supporting collaborative mobility sharing services. Although, architectures were proposed in the literature, there are fewer studies that adopted EA approach and APIs to improve interoperability of eMaaS apart from Brand et al. [21]. Nevertheless, the authors are more concerned about improving EV changing and enhancing energy markets. Thus, this study adds to the body of knowledge by presenting the application EA and integration of API for data interoperability in enhancing eMaaS in smart cities.

3 Application of EA in eMaaS

This study adopts enterprise architecture approach and presented an architecture to promote eMaaS in smart cities. The architecture is developed in prior study [26] based on TOGAF standard analogous to previous study Brand et al. [21]. Accordingly, Figure 2 depicts the architecture which comprises of seven layers.

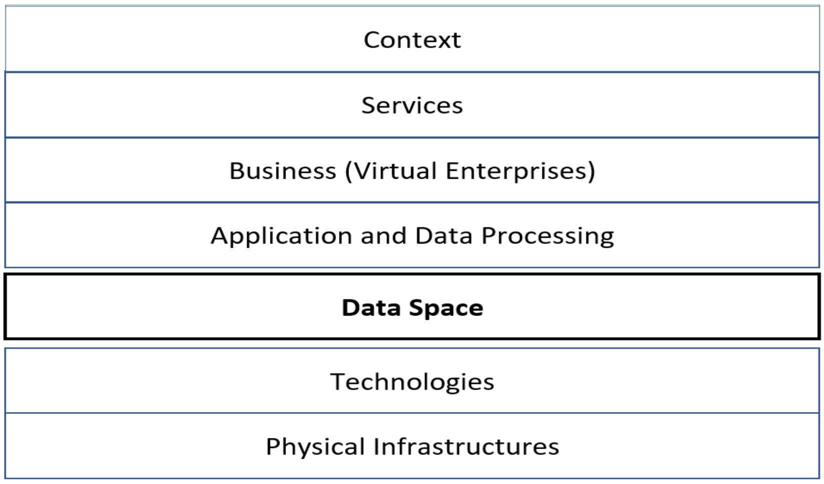

Fig. 2. Architecture for data interoperability of eMaaS

Figure 2 shows the architecture which comprises of context, service, business, application, data space, technologies, and physical infrastructures layers. Thus, each of the layers are discussed below;

3.1 Context Layer

This layer mainly entails the drivers, priorities, and important characteristics in delivering effective eMaaS to citizens and stakeholders. The context layer entails requirements that relates to stakeholders' concerns, wants, and associated drivers/enablers that improve quality of life [27]. Hence, this layer specifies the scope, goals, etc. related to citizens and stakeholders' necessities as regards to urban mobility. Accordingly, the context layer specifies the aims to be attained which in this study involves achieving an interoperable data oriented eMaaS.

3.2 Service Layer

This layer aims to effectively deploy specified outputs and competently achieving specified key performance goals [28]. In this research services are provided by trusted parties such as municipalities, EV provider, mobility service provider, payment company, etc. that facilitates eMaaS in smart cities. Moreover, this layer is linked to the application layers via business layer through HTTP protocols [3]. Therefore, this layer comprises of various smart services that are part of the mobility operations.

3.3 Business Layer

This layer includes enterprises or establishments involved in city mobility service such as municipality, city transport company, payment firm, EV rental company, energy company, etc. [21]. Accordingly, this layer encompasses virtual enterprises that collaborate towards providing e-mobility services to citizens to support transportation in smart city. The business layer depicts the flow of co-ordination of enterprise and business procedures deployed across each firm [27]. Besides, the business layer aligns each enterprise's daily routine with IT to provide business centric view for mobility operations.

3.4 Application and Data Processing Layer

The applications and data processing layer provide a set of APIs and systems to manage and post-process data coming from data space layers. This layer addresses interoperability among heterogenous data sources from different technologies and devices [10]. This layer allows remote access to e-mobility services via set of tools to users to access and visualize data coming from the physical infrastructures layer [26]. This layer also provides mobile applications and web portal to address the mobility needs and requirements of citizens and stakeholders via request/response and publish/subscribe protocols, exposing mobility data via RESTful API [9]. Further, this layer aids stakeholders to deploy existing tools to develop new application for improving mobility services to satisfy contextual information needs of citizens [29].

3.5 Data Space Layer

This layer mainly involves the retaining, exchange, publishing of processed data via application layer [26]. The data space provides massive data storage for historical, online, and real-time datasets to support e-mobility applications. It is responsible for managing, storing and providing access to wide range of retained data and data sources towards providing valuable insights [29]. It exposes mobility service via APIs to access data in several formats for querying and discovering data sources that facilitates seamless data access by application layer [21]. These data sources include physical devices, sensors, energy meters, public data, weather, transport, city transport data, etc. These data sources are compiled and stored as datasets in data space layer to provide citizens with mobility services that intensively depend on these data [9].

3.6 Technology Layer

The technology layer offers infrastructure needed to run applications, comprising of hardware, system software, and communication hardware [26]. Besides, this layer comprises of temporal storage, managing, and handling of big data by ensuring that acquired data are cleansed to confirm the quality of data. Thus, a context-aware component is introduced to filter out unrelated data and to implement quality check and data harmonization [3]. Moreover, the technology layer entails big data infrastructures needed to process, historical, online and real-time data [21]. Furthermore, this layer provides mechanisms to efficiently clean, analyze, and transform these large sets of diverse data simultaneously by executing batch processing of static and online data, and stream processing of real-time data [20].

3.7 Physical Infrastructures Layer

This layer comprises the production of real-time data from various sources such as physical devices, sensors, energy meters, EVs, etc. [20]. In terms of e-mobility, this layer is the core of architecture as its specifically designed for accessing and transmitting data coming from physical and IoT devices based on different protocols such as Message Queuing Telemetry Transport (MQTT) using subscribe and publish communication [3]. Thus, this layer entails meters and sensors that collects real-time data of EVs within the city to perform demand-supply mobility fleet management. Similarly, this layer enables interoperability across heterogeneous sources, both software and hardware via MQTT protocol [20]. Also, this layer deploys wired and wireless technologies such as IEEE 802.15.4, ZigBee and Bluetooth, LoRaWAN, etc. are employed for to facilitate remote communications through the Internet [9].

4 Results

This section depicts meta-model evaluation of the eMaaS case in ArchiMate, where metamodels are the fundamentals of EA and they describe the essential IT and business artefacts. They provide high level common language and precise view of the structure and dependencies between pertinent sectors of the organization [16]. Additionally, metamodels provides an approach that makes the complexities of the real world manageable and understandable to humans ideally supporting stakeholders of establishments to efficiently communicate, plan, document, and design IT and business associated issues.

In this study ArchiMate is used for designing metamodels in validating the presented architecture (see Figure 2) for eMaaS transport scenario towards EV usage in smart city. ArchiMate is an independent and open modeling language for EA. In addition, ArchiMate is a useful tool to model applications, business processes, and technology towards supporting collaboration on enterprise level. ArchiMate supports design modelling languages for IT solutions and business processes. ArchiMate was developed based on TOGAF to offer a generic and integrated model that enable communication and decision making across domains such as in smart cities [30].

It provides uniform illustrations for diagrams that describe EA, thus offering a graphical language for the representation of EA over time in relation to motivation (context), business, application, and technology layer [15]. In this study to conceptualize the eMaaS scenario, services, data space, physical infrastructures layer are included as an extension to ArchiMate. Moreover, we opted for the ArchiMate language as it a widely accepted open standard for modeling EA and it fits well with the TOGAF standard that was employed to conceptualize our EA (see Figure 2). According, Figure 3 depicts the meta-model for eMaaS operation for EV in smart city modelled in ArchiMate to evaluate the feasibility of each of the architecture layers.

The meta-model presented in Figure 3 provides a good overview of how APIs and EA can support eMaaS, where each elements of the model were identified from the literature (see section 2.4). The attaining of smart mobility through ICT lies in the usage of data from different sources and processing into valuable information delivered via application to offer services, consumed by citizens and stakeholders. This includes the collection of huge heterogenous amounts of data from the physical infrastructures layer, the aggregation and processing of historical, online, and real-time data in technology layer, and storage and usage of data to provide useful mobility information.

Therefore, in the physical infrastructures layer heterogenous real-time data is transmitted from surveillance cameras, traffic sensors, EVs, charging stations, buildings, metering devices, etc. via Bluetooth, ZigBee, Wi-Fi, WLAN communication protocols to the technology layer [31]. Next historical, online, and real-time mobility data are processed in the technologies layer which is the central processing component for data computation. This layer also comprises of data pre-processor, rules engine, message queue, data filter, Hadoop, and storage. Data pre-processing involves mobility data normalization which plays a critical role in dealing with different data parameters scaling the data to a specific small and accurate range. To normalize the gathered data, the Min-Max technique is employed as it is widely used technique to scale up and properly transform data values. Moreover, Message Queue (MQ) method is adopted which is based on defined rules utilized to store generated mobility data in a suitable format in MQ which offers a mechanism that positions and avoids delay and halt of processing. The MQ technique is deployed when it receives M message at t time which is sent accordingly as a filtered data to be processed by Hadoop which first stores the huge datasets in distributed format.

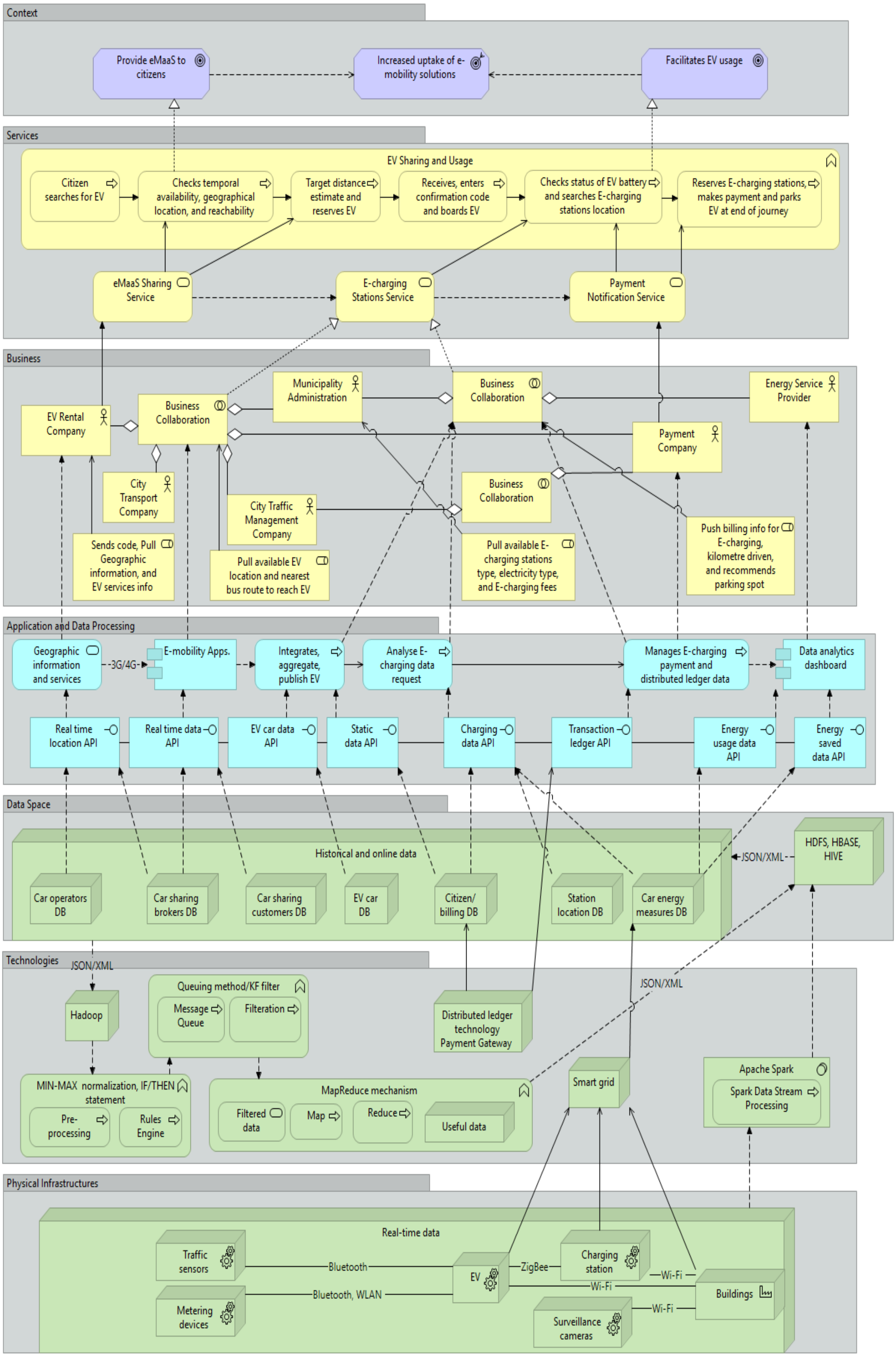

Fig. 3. Meta-model for eMaaS operation for EV

Next, data filtration is employed to filter the data and remove noise using Kalman Filter (KF) to speed up the data processing and separate the valuable and noisy data. Furthermore, Hadoop employs MapReduce technique for processing filtered mobility data. MapReduce employs mapping of filtered mobility data that are transformed to another set of mobility data. Then, the reduce process merges mobility data produced which results in some values that are reduced in size. Hadoop is employed to analyze online and historical data for offline/static processing. Therefore, to process real-time data Apache spark is integrated. Spark is a batch in-memory computing technique that perform micro-batch procession through Spark-streaming. Besides, spark is an open source program aimed at speeding up and mining meaningful information quickly for decision making. As compared to Hadoop MapReduce, Spark offers an efficient alternative as it provides faster performance and is suitable for real-time and online applications processing.

In the data space layer, for storage of the processed mobility data Hadoop Distributed File Service (HDFS) is employed as it is distributed, supplementing the MapReduce processing on smaller subsets of larger data cluster which supports the scalability demand of mobility data processing. Moreover, HBASE is employed to improve processing speed on Hadoop as it improves the fault tolerance and usability and provides real-time read/write lookups. Likewise, HIVE is integrated as it supports managing and querying of mobility data that is saved on the Hadoop cluster. Thus, HIVE is used for querying since SQL cannot be utilized to query, hence HiveQL is used to query mobility data on Hadoop cluster to support eMaaS in smart cities. Furthermore, the data space layer consists of distributed ledger technology payment gateway and smart grid which transmits energy and data from and to EVs, charging stations and buildings. In the data space layer processed data are stored in HDFS which comprises of HBASE and HIVE connected to other external data sources (car operators, car sharing brokers, car sharing customers, EV car, citizen/billing, station location, and car energy measures database).

Furthermore, in the application and data processing layer, sources of data related to mobility is accessed by citizens and stakeholders via RESTful APIs (real time location, real time data, EV car data, static data, charging data, transaction ledger, energy usage data, and saved energy data API) which resides in the application layer that provides a common standardized platform for utilization of mobility related data that are represented in JSON or XML format. Additionally, application and data processing layer comprise of e-mobility applications and data analytics dashboard that makes use of Geographic information and services data as well as application process (integrating, aggregating, publishing EV charging data, analyzing e-charging data request, and managing e-charging payment, and distributed ledger data).

Next, the business layer depicts the virtual enterprises (EV rental company, city transport company, municipality administration, city traffic management company, payment company, and energy service provider) that collaborates to provide mobility related services (sends code, pull geographic information, and EV services info, pull available EV location and nearest bus route to reach EV, and pull available e-charging stations type, electricity type, and E-charging fees, and push billing info for e-charging, kilometer driven, and recommends parking spot). Similarly, the service layer entails business collaborating to provides services such as eMaaS sharing service, e-charging stations service, and payment notification service for improving EV sharing and usage which helps to achieve eMaaS goals (provide eMaaS to citizens and facilitates EV usage) and target (increased uptake of e-mobility solutions) in making cities smarter.

5 Discussion and Implications

Over the years there have been development towards e-mobility mainly in the emergence of EVs that enable decrease of carbon dioxide emissions, improves collaborative e-bicycles, e-cars, and segways sharing, and management of EV fleets in urban environment [4]. Improving transport services and data management is just the first step towards realizing smart cities [32]. But processing and using big data into valuable and usage insights for various mobility applications is an issue [3]. Likewise, accessing and usage of such mobility data is also challenging due to interoperability issue. In this paper we presented an approach to realize eMaaS for handling mobility data by adopting EA and APIs to improve interoperability for management of mobility relevant data that enables collaborative e-mobility services for citizens in an efficient and flexible manner.

Furthermore, the presented EA for eMaaS provides access to open data via APIs that provide interoperable data formats. As recommended by Kamargianni and Matyas [6] the architecture provides an ecosystem composed new data markets for transport services by creating opportunities for additional incomes and market growth. Moreover, findings from ArchiMate modelling reveal that the presented EA approach for eMaaS provides standardized services which flexibly and efficiently integrates heterogeneous data sources, such as available historical, online, and real-time transport data regarding EVs and transport infrastructures to provide customized mobility information to citizens, as well as monitoring and planning tools to policy-makers.

Implications from this study provides innovative services for citizens and e-mobility operators in managing and providing solutions to integrate and produce support for interoperability towards sustainable transport systems. The presented EA for eMaaS provides integrated data via API for decision support towards decreasing public costs of mobility, streamlining use of mobility application, providing information for supporting connected citizens/drivers manipulating data, and defining solutions for improving interoperability within data sources. Findings, from ArchiMate modelling provides abstract model that facilitates eMaaS replication and interoperability of data solutions to facilitate data processing towards enhancing data processing performance, while enabling intelligent decisions to produce insights within e-mobility context.

Finally, this paper provides a solid case for data integration in smart mobility and presents a Meta-model (see Figure 3) of how this could work in practice. As such, it addresses an issue that is highly relevant in switching to a green society and could provide valuable input to cities and car sharing companies, as well as opening up avenues of future research.

6 Conclusion, Limitations, and Future Directions

The electrification of transportation has been prioritized in several European countries such as Norway, Finland, The Netherlands, United Kingdom, etc. To improve mobility operations in smart cities there is need for an infrastructure that provides distributed storage and processing of huge volumes and variety of mobility related data, generated at high velocity, without performance issues, and provides value-added services to achieve sustainable transportation services. Therefore, this study presented an architecture based on APIs that stores, processes, analyse and provides interoperable data to improve e-mobility services within smart city environment. ArchiMate modelling tool was employed to validate the feasibility of the presented architecture for eMaaS. Findings suggest that the architecture enables sharing and consumption of mobility data thereby managing transport data as openly available mobility data to improve EV sharing in smart cities.

Irrespective of the contribution, this study is faced with few limitations. First, empirical data was not collected to statistical test the architecture. Secondly, this study is more concerned with EVs sharing linked to mobility scenario only. Third, although this study discusses a mobility ecosystem with electric vehicles, electric bikes, Segways, etc. this paper is more focused on electrical vehicles only. Future works will involve collecting data from experts in transport companies located in Norway to statistically test the presented eMaaS EA. Additionally, EA will be extended to other urban services such as smart energy service. Also, the usage of other mobility means such as electric bikes, Segways, etc. will be further explored as the research progresses. Besides, experiments from big data analytics of eMaaS will be are presented in future using simulations where the developed architecture is to be deployed in a virtual mobility environment and tested to extract some pertinent evaluation in order to measure the feasible of the proposed approach as related to parameters such as time and cost (money). Future direction may also involve exploring the approximation as regards to time and money to be involved in implementing the proposed approach in a real-world scenario as a project.

Acknowledgements

This publication is a part of the +CityxChange smart city project under the Smart Cities and Communities topic that is funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 824260. The authors gratefully acknowledge the support of the project partners; Trondheim Municipality, Powel AS, TrønderEnergi AS, FourC AS, IOTA, and the participants of work packages 1 and 2 as well as the whole project team.

References

1. Jnr, B. A., Majid, M. A., Romli, A.: A Trivial Approach for Achieving Smart City: A Way Forward towards a Sustainable Society. NCC, pp. 1-6. (2018).
2. Dijk, M., Orsato, R. J., Kemp, R.: The emergence of an electric mobility trajectory. Energy Policy. 52, 135-145 (2013).
3. Cheng, B., Longo, S., Cirillo, F., Bauer, M., & Kovacs, E.: Building a big data platform for smart cities: Experience and lessons from santander. International Congress on Big Data, pp. 592-599. (2015).
4. Melis, A., Mirri, S., Prandi, C., Prandini, M., Salomoni, P., Callegati, F.: Crowdsensing for smart mobility through a service-oriented architecture. IEEE International Smart Cities Conference, pp. 1-2. (2016).
5. Kubler, S., Robert, J., Hefnawy, A., Främling, K., Cherifi, C., Bouras, A.: Open IoT ecosystem for sporting event management. IEEE Access, 5, 7064-7079 (2017).
6. Kamargianni, M., Matyas, M.: The business ecosystem of mobility-as-a-service. In transportation research board (Vol. 96). (2017).
7. Nesi, P., Badii, C., Bellini, P., Cenni, D., Martelli, G., Paolucci, M.: Km4City Smart City API: an integrated support for mobility services. SMARTCOMP, pp. 1-8. (2016).
8. Chaturvedi, K., Kolbe, T. H. InterSensor Service: Establishing interoperability over heterogeneous Sensor Observations and Platforms for Smart Cities, ISC2, pp.1-8. (2018).
9. Sánchez, L., Elicegui, I., Cuesta, J., Muñoz, L.,Lanza, J.: Integration of utilities infrastructures in a future internet enabled smart city framework. Sensors, 13(11), 14438-14465 (2013).
10. Aier, S., Gleichauf, B., Saat, J., Winter, R.: Complexity levels of representing dynamics in EA planning. In Advances in Enterprise Engineering III, 55-69, (2009).
11. O'Brien, C.: Enterprise Architecture Management: Insights in the digital context. Innovation Value Institute, 1-11 (2018).

12. Tcholtchev, N., Farid, L., Marienfeld, F., Schieferdecker, I., Dittwald, B., Lapi, E.: On the interplay of open data, cloud services and network providers towards electric mobility in smart cities. 37th Annual IEEE Conference on Local Computer Networks-Workshops, pp. 860-867, (2012).
13. Schleicher, J. M., Vögler, M., Inzinger, C., Dustdar, S.: Modeling and management of usage-aware distributed datasets for global Smart City Application Ecosystems. PeerJ Computer Science, 3, e115 (2017).
14. Raetzsch, C., Pereira, G., Vestergaard, L. S., Brynskov, M.: Weaving seams with data: Conceptualizing City APIs as elements of infrastructures. Big Data & Society, 6(1), (2019).
15. Chen, D., Doumeingts, G., Vernadat, F.: Architectures for enterprise integration and interoperability: Past, present and future. Computers in industry, 59(7), 647-659 (2008).
16. Lagerström, R., Franke, U., Johnson, P., & Ullberg, J.: A method for creating entreprise architecture metamodels: applied to systems modifiability. International Journal of Computer Science and Applications, 6(5), 89-120 (2009).
17. Rouhani, B. D., Mahrin, M. N., Nikpay, F., Nikfard, P.: A comparison enterprise architecture implementation methodologies. International Conference on Informatics and Creative Multimedia, pp. 1-6. (2013).
18. Saat, J., Aier, S., Gleichauf, B.: Assessing the complexity of dynamics in enterprise architecture planning-lessons from chaos theory. AMCIS Proceedings, pp. 1-8. (2009).
19. Ruohomaa, H. J., Salminen, V. K.: Mobility as a service in smart cities-new concept for smart mobility in Industry 4.0 framework. ISPIM Conference Proceedings, pp. 1-12, (2019).
20. Bellini, P., Nesi, P., Paolucci, M., Zaza, I.: Smart City architecture for data ingestion and analytics: Processes and solutions. IEEE Fourth International Conference on Big Data Computing Service and Applications, pp. 137-144 (2018).
21. Brand, A., Iacob, M. E., van Sinderen, M. J.: Interoperability architecture for electric mobility. In International IFIP Working Conference on Enterprise Interoperability, pp. 126-140. (2015).
22. Kuehl, N., Walk, J., Stryja, C., Satzger, G.: Towards a service-oriented business model framework for e-mobility. European Battery, Hybrid and Fuel Cell Electric Vehicle Congress, pp. 1-9. (2015).
23. Tcholtchev, N., Dittwald, B., Scheel, T., Zilci, B. I., Schmidt, D., Lämmel, P., ... Schieferdecker, I. The Concept of a Mobility Data Cloud: Design, Implementation and Trials. 38th International Computer Software and Applications Conference Workshops, pp. 192-198. (2014).
24. Abdelkafi, N., Makhotin, S., Posselt, T.: Business model innovations for electric mobility—what can be learned from existing business model patterns?. International Journal of Innovation Management, 17(01) (2013).
25. Mäkelä, O., Pirhonen, V.: The business model as a tool of improving value creation in complex private service system-case: Value network of electric mobility. 21st International RESER Conference. (2011).
26. Petersen, S. A., Pourzolfaghar, Z., Alloush, I., Ahlers, D., Krogstie, J., Helfert, M.: Value-Added Services, Virtual Enterprises and Data Spaces inspired Enterprise Architecture for Smart Cities, 20th Working Conference on Virtual Enterprises. (2019).
27. Abu-Matar, M., Davies, J.: Data driven reference architecture for smart city ecosystems. SmartWorld/SCALCOM/UIC/ATC/CBDCom/IOP/SCI, pp. 1-7. (2017).
28. Winter, R., Fischer, R.: Essential layers, artifacts, and dependencies of enterprise architecture. EDOCW, pp. 30-30. (2006).
29. Jr, B. A., Majid, M. A., Romli, A.: Green information technology system practice for sustainable collaborative enterprise: a structural literature review. International Journal of Sustainable Society, 9(3), 242-272 (2017).
30. Pittl, B., Bork, D.: Modeling Digital Enterprise Ecosystems with ArchiMate: A Mobility Provision Case Study. International Conference on Serviceology, pp. 178-189. (2017).
31. Anthony Jnr, B., Abbas Petersen, S., Ahlers, D., Krogstie, J.: API deployment for big data management towards sustainable energy prosumption in smart cities-a layered architecture perspective. International Journal of Sustainable Energy, 1-27 (2019).
32. Ahlers, D., Wienhofen, L. W., Petersen, S. A., Anvaari, M.: A Smart City Ecosystem Enabling Open Innovation. In International Conference on Innovations for Community Services, pp. 109-122. (2019).