Types of IT Architectures in Smart Cities – A review from a Business Model and Enterprise Architecture Perspective

Position Paper

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Abstract

Many researchers overcoming the ICT challenges in smart cities attempted to propose frameworks and architectures. In this relation, existence of a well-constructed business plan has been recognized as a significant factor to ensure alignment of architecture with smart city visions and goals. However, some of the proposed architectures do not have a business plan and goals and just follow innovation spirit or resource saving goals. This study intends to explore some different architectures from with regard to their business layers. For this purpose, by in-depth analysis of the prominent enterprise architecture concepts, this study derives an evaluation framework in form of architectural requirements for business layer. Then, five types of the relevant smart service architectures are explored with regard to these requirements. Outcome of this research is comparison of different types of architectures regarding the architectural requirements for a comprehensive business layer.

Keywords: Enterprise Architecture, Business Layer, Smart City Frameworks

1. Introduction

The innovative concept of smart city is to use information communication technology (ICT) to provide services for citizens to improve quality of their life. As Townsend (2013) stated, one way to look at the smart cities is as a technological heaven that helps to monitor, control and facilitate security and better access to information for quick decision making. As such Booch (2010) described smart city as an innovative city that uses Information and Communication Technology (ICT) and other means to improve quality of life, efficiency of urban operation and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects. Therefore, in response to the smart city needs many different types of smart services were developed For example smart transport services that use GPS information to update arrival time of buses to any stop are from these types.

In relation with effectiveness of smart services as Kakarontzas et al. (2014) emphasised existence of a well-constructed business plan impact smart city viability significantly. According to a recent study by Kakarontzas et al. (2014), it has been realised that many smart initiatives do not have a business plan and just followed innovation spirit or resources savings as their potential business goals. Beside, enterprise architecture is defined as a way to plan an architecture to have the best performance and output (Booch, 2010). Over the years, many enterprise architecture frameworks, modelling concepts, and tools were proposed, including the Zachman Framework (1987), Department of Defence Architecture Framework (DoDAF), Federal Enterprise Architecture Framework (FEAF, 1999), Open Group Architecture Framework (TOGAF, 2011), and Architecture of Integrated Information Systems (ARIS) (Scheer, 1992). Common to these frameworks is reducing enterprise complexities by considering disparate viewpoints and organizing various aspects in ways that make an enterprise understandable. It is broadly accepted that the origins of the modern Enterprise Architecture (EA) lie with the publication of “A Framework

for information systems architecture" by Zachman (1987). At that time, the main goal for this framework was to use logical constructs to address the management of ever-increasing complexity of information systems within the organisations.
With this paper we utilise enterprise architecture concepts to examine selected types of smart city architecture from business layer point of view. The remainder of the paper is structured as follows: After presenting our research approach, we explore prominent enterprise architecture concepts to extract architectural requirements for business layer. Then, we inspect smart city frameworks and architectures to select the ones which proposed architectures to address ICT challenges. Afterward, selected types of architectures will be compared regarding architectural requirements. Finally, we discuss on advantages of utilizing TOGAF architectural development method to define a high performance architecture.

2. Research Approach

General research approach for this paper is examining existing smart service architectures against the architectural requirements for business layer. To this goal, first, prominent enterprise architecture concepts and their key requirements are reviewed to derive an evaluation framework in the form of architectural requirements for a business layer. Then, reviewing existing smart city frameworks, we will select the ones which proposed solution architectures for their recognized challenges. Next step would be evaluation of these selected architectures against the architectural requirements for business layer. Finally, this paper approaches TOGAF ADM to propose a solution to fulfil architectural requirements for business layer. According to this method, defining the problem, objectives and process to address the issues occurs in the first phase, i.e. architecture vision. Finally, we discuss that how this approach may assist architecture developers improve service architecture performance.

3. Architectural Requirements

An enterprise architecture is a plan of record, a blueprint of the permitted structure, arrangement, configuration, functional groupings/partitioning, interfaces, data, protocols, logical functionality, integration, technology, of IT resources needed to support a corporate or organizational business function or mission (Minoli, 2008). (Booch, 2010) explains that in Enterprise Architecture focus is on the human element, and the way to "architect" and plan the enterprise to have the best human performance and output. All the other elements in the Enterprise Architecture are secondary, meaning that they exist to facilitate the best outcomes for the human operations. As such Rouhani et al. 2015) stated that enterprise architecture is a strategy to align business and information technology within an enterprise. They expressed that an enterprise architecture is managed, developed and maintained through the enterprise implementation methodologies, e.g. TOGAF (2011), DoDAF and FEAF (1999). Recently, Meyer and Helfert (2011) by reviewing related literature, expressed that there are various types of enterprise architecture frameworks, from simple, three-layered frameworks by Hasselbring (2000) and TOGAF (2011), to multi-layered EA frameworks by Winter and Fischer (2007). For their research, Meyer and Helfert (2011) viewed enterprise architecture from a service perspective in which each layer offers a service to the business. They also stressed that business layer of an enterprise architecture contains business processes/services, organizational structures (including roles and responsibilities), and value drivers, which are aligned to a strategy divided into goals and objectives TOGAF (2011), Versteeg and Bouwman (2006). Following these researches, our evaluation framework is constituted of the architectural requirements as: goals, objectives, business services, business processes, roles and responsibilities. In the following section, we first explore some frameworks and architectures proposed to address smart city challenges. Then, we follow up with the selected architectures to investigate them from business layer requirements point of view.

4. Selected Smart City Architectural Types

Since last decade, various smart city frameworks and architectures have been developed to facilitate citizens' life. Each of these frameworks have had different approaches to address smart city challenges from technical to business and service oriented. In the next section we will inspect various types of frameworks and architectures. Afterward, for the purpose of this study we will focus on the ones which proposed an architecture solution for their services.

4.1. Overview of Smart City Architecture Types

As mentioned earlier, plenty of frameworks and architectures have been proposed to address smart city challenges to facilitated citizens' daily activities. However, there is a question that to how extend these frameworks have achieved this goal. Therefore, in this section referring enterprise architecture concepts we will explore various research works regarding their recognized problem, and their consequent goals and objectives as well. Ferguson et al. (2004) raised the question that what protocols are the most usable for the information city environment. In this lieu, they proposed number of web services to be offered on the basic level to the city population, as an open framework for information cities. Ferguson et al. (2004) described an open service architecture to enable flexible interaction, collaboration, integration, and participation, while incorporating advanced information navigation, trust, and access control. Therefore, here we have an architecture then we can explore its business layer.

Al-Hader et al. (2009) attempted to modularize the structure of utilities and develop a system for following up the activities electronically on the city scale. They stated that the main goal of this research has been provide the initial necessary guidelines to improve operations and maintenance, reduce the cost of operation, provide enhanced energy management capabilities and provide scalability and freedom for future. In this regard, they proposed a smart city components architecture which could be of interest of this research to be inspected from business architecture point view. Al-Hader & Rodzi (2009) debated smart city infrastructure architecture development framework and surveyed positional accuracy of locating the assets as a base of the smart city development architecture integrated with all the facilities and systems related to the smart city framework. Anthopoulos and Fitsilis (2010) concluded to a common enterprise architecture for digital city. This common architecture identified the blue prints for urban information based development. They proposed future research on the transaction of these architectures with social networks, either existing or others installed in city areas. Therefore, this enterprise architecture is required to investigate regarding business layer requirements for our research purpose.

Filipponi et al. (2010) presented an Event Driven Architecture that allows the management and cooperation of heterogeneous sensors for monitoring public spaces as a solution architecture. They implemented the main components of this architecture in a testbed on a subway scenario to demonstrate that their proposed solution can enhance the detection of anomalous events and simplify both the operators' tasks and the communications to passengers in case of emergency. We explore these architectures from business requirements perspective as well.

Harrison et al. (2010) described a framework which described foundation and principles for Information Technology in smarter cities containing: 1) instrumented (data from sensors); 2) interconnected (Integration of data) and intelligent (inclusion of complex analytics, modelling, optimization); and 3) visualization in operational business processes). Harrison and Donnelly (2000) presented the 'Urban Information Model' by depicting a layered view on the resources of the city. In this way, they classified different types of information that can be generated, produced, and consumed by any of these resources.

Chourabi et al. (2012) developed an integrative framework to explain the relationships and influences between 8 critical factors of smart city initiatives. They emphasised that each of these factors is important to be considered in assessing the extent of smart city and when examining smart city initiatives.

Wenge et al. (2014) proposed a smart city architecture from the perspective of the data that underpins all the functionality of smart cities. The proposed architecture discussed, outlining design challenges and offered insight into the development of smart cities. This framework explained data sources, required applications and technologies. Moreover, it elaborated critical success factors in a smart city including, administration requirements, security (sensor security, transmission security, data vitalization security and application security), and standards (standard framework, basic standards, application Standards, security standards).

Obviously, all the above mentioned researches attempted to tackle smart city challenges from different perspectives. Although each of these architectures may work properly, however, their performance depends on their business plan. Considering this finding that only some of these researches proposed architecture solution, therefore, we will follow up with fives selected architectures for this study's purpose. Our selected architectures are: open service architecture (Ferguson et al., 2004), smart city components architecture (Al-Hader et al., 2009), common enterprise architecture (Anthopoulos & Fitsilis, 2010), Event Driven Architecture (Filipponi et al., 2010), and Service-oriented architecture (Bawany & Shamsi, 2015). In the next section, we will inspect these selected architectures from architectural requirements point of view.

4.2. Review and Evaluation of Architectural types

In this section, we inspect selected architectures in previous section, with regard to the architectural requirements mentioned in section 3, i.e. goals, objectives, business services, business processes, roles and responsibilities. As we explained before, selected cases are the ones which proposed a solution architecture for their services. Business plan has been recognized as an essential factor impacting performance of an architecture. Whereas many precedent smart services have just followed innovation spirit and did not have any business plan. Therefore, we intend to evaluate selected architectures from business layer point of view. Now, we start with the first selected architecture. Ferguson et al. (2004) defined a goal for their research work to provide a foundation for secure and reliable interaction among consumers using internet standards. Therefore, they proposed a novel architecture called the Open Services Architecture based on such open standards as web services. In this relation, Ferguson et al. (2004) envisioned some potential services and exemplified 2 different scenarios and services for a digital city. However, there is no explanation about required process to provide such services. Indeed, Ferguson et al. (2004) discussed services in a very abstract level. As they themselves expressed by this architecture they only represented the bricks and mortar needed to construct complex information systems. Therefore, regarding the recognized requirements for an enterprise architecture, this framework does not have a comprehensive business layer.

Next Architecture we inspect is smart city component architecture for infrastructure by Al-Hader (2009). Indeed, they intended to modularize the structure of utilities and develop a system for following up the activities electronically on the city scale. For this purpose Al-Hader et al. (2009) discussed on an IT platform for data storage and data manipulation processes, operated, supported and managed by service oriented architecture bus. The basic scope for their research was enhancing the level of controlling and monitoring assets like network joints, house meters etc., in order to rise up the performance and reduce the operational cost as well. Apparently, as Al-Hader et al. (2009) emphasized this architecture only contains required components for modularization purpose and there is a lack of details about different parts i.e. GIS automation platform, system administration and buildings infrastructures and ultra-structure as well. Consequently, due to very abstract nature of this architecture, responsibilities and roles for different components did not describe at all.

Later, Anthopoulos and Fitsilis (2010) by summarizing applied architectures of city case studies and using experiences of a digital city, concluded to a common enterprise architecture for digital city cases. As they claimed, this common enterprise architecture could identify a blue prints for urban information based development. Along with, they presented a common architecture for service delivery in urban spaces. For this architecture, Anthopoulos and Fitsilis (2010) believed that both logical and physical architecture of the digital city have to align to their proposed enterprise architecture. The logical architecture contained: stakeholders layer, service layer, business layer, infrastructure layer, and information layer. They offered the physical architecture contained a metro Wi-Fi network together with a MAN for the infrastructure layer, mobile or social network storages for information layer, location based services for servi*ce* layer. Finally, they introduced business layer which supposed vertically transact with all other layers, applying its rules and blueprints to all unique applications and systems. Clearly, this is all they explained about business layer. In fact, to have the ability to implement such architecture, there is need to define the process of applying the rules to applications.

Similarly, Filipponi et al. (2010) presented a high level and event driven architecture for smart cities with the aim of management and cooperation of heterogeneous sensors for monitoring public spaces. This architecture contains different components like Knowledge Processes (KPs), Semantic Information Brokers (SIBs) to create Interoperability Open Platforms (IOPs). IOP allows different application domains and subsystems to inter-operate and share information. They implemented the main component of their architecture in a test bed on a subway scenario to demonstrate that their solution works. For this purpose they defined two different architectures, a 'Wireless Sensor Network' manager Architecture and an 'Event Manager' architecture. For wireless sensor network manager, they explained that it uses KPs to interact with the IOPs in order to receive commands or to dispatch row events. Indeed, they have described this architecture simply without going through process defining about how these interactions between KPs and IOPs supposed to happen. Similarly, they explained that event manager is a module to merge and correlate generated events by raw data sources like WSN manager. However, there is no more details about providing such correlations. As they expressed they have presented a general architecture of an event manger.

Later Bawany and Shamsi (2015) regarding the significance of effective data collection, storage, retrieval and efficient resource provisioning, proposed a high level architecture for smart cities. As such, as a solution to the security issues, they proposed a service oriented architecture to provide interoperability among diverse platforms and to support modular design, software reuse, interoperation and application integration as well. Similar to precedent studies, this architecture only shows high level interactions

between proposed components of a service-oriented architecture and there is a lack of defining the required processes to achieve stated goals for this research. A summary of the abilities for the explored architectures with an eye on business layer requirements is shown in Table 1.

Architecture	Goals	Objectives	Business Services	Business Processes	Responsibilities & Roles
Open Services Architecture, Ferguson et al. (2004)	provide a foundation for secure, reliable interaction among consumers using internet standards	Proposing an Open Services Architecture based on such open standards as web services	Two potential services have been exemplified very general.	-------	-------
smart city components architecture, Al-Hader et al. (2009)	enhancing the level of controlling and monitoring	modularize the structure of utilities	-------	-------	-------
common enterprise architecture, Anthopoulos and Fitsilis (2010)	Concluding a common enterprise architecture for digital city cases	Identifying blue prints for urban information based development	-------	-------	-------
Event Driven Architecture, Filipponi et al. (2010)	management and cooperation of heterogeneous sensors	Enhance the detection of anomalous events and simplify operators tasks and communications to passengers	Alert announcing	-------	-------
Service-oriented architecture, Bawany and Shamsi (2015)	Overcoming Security challenges for a smart city architecture	Exposing data as web service	-------	-------	-------

Table 1: Selected Architectures Abilities to Fulfill Business Layer

Obviously, precedent researchers had different viewpoints to tackle the challenges facing smart cities. Consequently, they have proposed various frameworks/architectures to overcome the recognized issues and problems. However, according to the three right columns of Table 1, there is a lack of sufficient details on business layer requirements. Indeed, these architectures have been defined in a very abstract level. In the next section, we will discuss that how an architecture can fulfil business layer requirements by going through first phase of TOGAF ADM.

5. Discussion and Conclusion

In previous section, we explored some of the architectures which have been proposed to address recognized challenges for smart cities. These architectures although own a stated problem and defined objective, however they have been defined in an abstract level. On the other world there is no details on the processes to achieve their objectives.

In this condition, defining the processes may distract from the main objectives of a smart initiative. For instance in many of these architectures they mentioned about exchanging the data between different levels. The issue is that there is not sufficient information about the process of data exchange, and required data principles for smart cities. In this situation, a question is raised about the processes to achieve defined goals and objectives.

In response to the above mentioned question, we believe that more details are required to fulfil business layer requirements. Firstly, there is a need to have clear definition of the problem. Consequently, with the aim of addressing the problem, clear objectives should be defined. Then, the processes of achieving the objectives are elaborated to clarify all the connections and relations. In this condition, roles and responsibilities of involved actors in the processes should be defined very well. Obviously, providing such details in abstract level is impossible.
As a solution, we propose using TOGAF architecture development method (ADM) as a general approach to develop an architecture with sufficient details. This framework contains seven phases starting by 'architecture vision' phase. Through the first phase of ADM, a clear problem, detailed objectives, process description, actors involved in the processed and their roles and responsibilities are defined. By following this approach, the developed architecture will have sufficient details to fulfil evaluation framework proposed by this research. In the follow, we explain a use case and then show the results of going through the first phase of TOGAF ADM to develop its architecture vision. Pourzolfaghar and Helfert (2016) proposed a digital environment to overcome the recognized challenges for design process of smart environments. They claimed that this digital environment helps to preserve design professionals' tacit knowledge as well as making it accessible for various stakeholders. A simplified version of the developed architecture vision for this digital environment is shown in Table 2. To develop this architecture vision an architecture vision template by TOGAF has been used.

#	Section	Description
1	Problem Description	- Design process is tacit dominant and there is a high risk of incomplete knowledge flow between professionals and not to explicating and preserving the knowledge;
2	Detailed objectives	- Explicating tacit knowledge during design phase in a database;
3	Process	1- Information request is sent to a team member; 2- Information request is received by a team member; 3- This member provide proper answers for the request; 4- This answer is sent and stored simultaneously; 5- Request sender receive the answer;
4	Actors and their roles	- Design professional: architects and engineers (creating and exchanging knowledge); - A knowledge storage area (repository);

Table 2- A Simplified Version of the Developed Architecture Vision for the Use-Case

Final output of the first phase of ADM is a business scenario (See Figure 1), which uses as an input for next phase meaning 'business architecture' phase. According to TOGAF, in practical terms, the business architecture demonstrate the business value to key stakeholders. For this phase, TOGAF emphasized that key elements of the business architecture may be done in other activities like enterprise vision and goals. Obviously, following an enterprise architecture approach like TOGAF, can provide appropriate answers for the raised questions facing explored architectures by this research. Finally, we believe that there is need to make these architectures more practical. This goal could be achievable by providing sufficient details for implementation purpose.

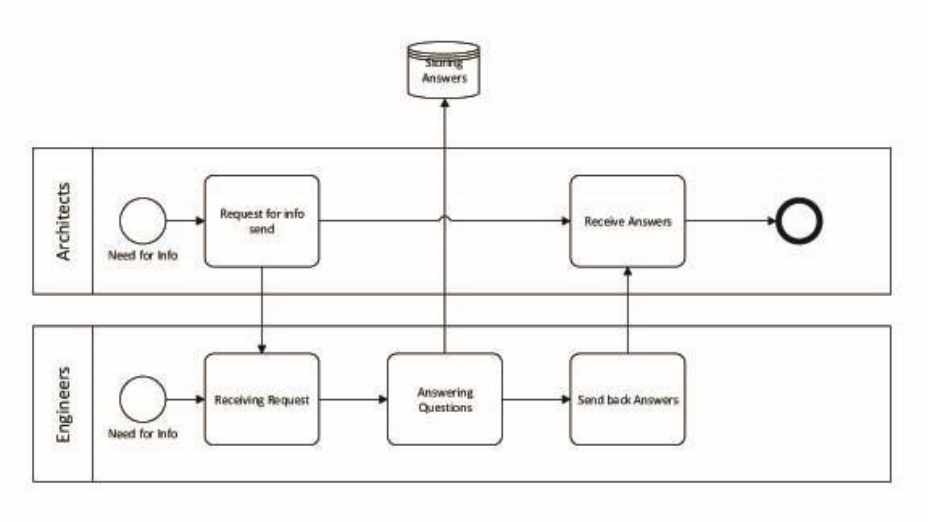

Figure 1- Business Scenario for the Use-Case

6. Conclusion and further Research

Many frameworks have been developed to overcome ICT challenges in smart cities. Accordingly, some architecture solutions have been proposed to address the recognized challenges for specific areas. However, it has been realized that many of smart initiatives did not follow a business plan. In this regard, some recent researches illuminated that business plan is an essential factor impacting performance of smart initiatives. Indeed, by defining a clear problem, objectives and processes to address the problem, authorities can make decision for investment regarding smart city priorities. In this vein, this study attempted to examine some selected architectures regarding architectural requirements for business layer. As a result, it has been realized that none of the explored architectures has fulfilled the requirements for a business plan. Although all of these architectures have their own advantages in terms of addressing their recognized challenges, however they have presented in very abstract level. To implement such architectures, there is a need to provide sufficient details on how it may address the recognized problem. Finally, we proposed that developing an architecture vision using TOGAF architecture development method could be useful to develop a business plan. By going through the first phase of ADM, (i.e. architecture vision), sufficient details will be provided for problem definitions, objectives, processes and responsibilities which are the requirements for business layer.
As the further steps for this research, we intend to define some principles based on the requirements for business layer, relying on TOGAF ADM approach. So far, we have extracted architectural requirements which were utilized by this study for evaluation purpose. As the principles, these requirements could be utilized at the time of developing a proposal for an architecture solution. In this way, developers could clearly define a problem, target stakeholders, goals and processes to achieve the goals. Therefore, performance of the proposed architecture in terms of achieving their specified goals and objectives could be ensured by provided details.

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