FOUR-LAYERED STRUCTURE OF E-GOVERNMENT SYSTEMS

Dalibor P. Drljača[1], Dušan Starčević[2], Siniša Tomić[3]

[1]Pan European University APEIRON Banja Luka, drljacad@gmail.com

[2] Faculty of Organisational Sciences, University of Belgrade, dusan.starcevic@fon.ac.rs

[3]Pan European University APEIRON Banja Luka, sinisa.m.tomic@apeiron-edu.eu

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Abstract: The structure of the e-government systems plays a vital role for provision of quality of e-services offered. These systems are quite complex deploying the most advanced technologies and developed and rich countries minimised this complexity with centralised systems. However, the less developed and countries with limited financial support are creating distributed and decentralised systems trying to keep the pace with more developed in provision of e-government services. The common identifier for both types of the systems is four-layered structure, which provides quality of service provision. This paper discusses the four-layered structure of e-government systems on cases of Estonia, Serbia and Bosnia and Herzegovina. The four-layered structure was found as the quality solution for distributed and decentralised e-government systems.

Keywords: e-government, quality, structure, four-layer, X-tee, X-road.

INTRODUCTION

Information systems have a number of functions (data collection, processing, storage and distribution), so in relation to them and their application in business systems, information systems can appear in the form [1][2]: **a) Centralized information systems** that involve processing and storing data and information on a central computer (Mainframe); **b) Decentralized information systems** - as opposed to centralized - logically centralized (each doing its job or function independently of each other), and decentralized in a physical sense (in different locations or departments), where each unit has its own database managed by maintains, and **c)Distributed information systems** - created as a combination of the two mentioned above, combining their best characteristics (e.g. use of a central database)

There are examples of partially or completely centralized e-government systems, such as examples in Estonia, Bahrain, Singapore, India, Korea, Sweden, etc. These are countries that have invested significant funds in the infrastructure of these systems and educating the population to use the e-services they provide through these systems. However, many less rich and less developed countries, such Bosnia and Herzegovina, have electronic public administration systems (e-government) usually in the form of complex and distributed systems with centralized management and organization. For such countries, the development of the centralised e-government is less likely due to the lack of investment funds. Therefore, the system emerges gradually and without a systematic approach causing different problems, leading to the lack of the quality in provision of services. Depending on the capabilities and financial capacity, the units of the public administration system are developing their systems with different speed, quality and with engagement of different contractors. There is no single system for managing the functional units of the system (as is the case with centralized systems), so we can assume that these systems are physically decentralized because only one part is connected to a central local computer network (for example, ministries in the Governmental building), while the other part of the public administration system is decentralized (physically separate and remote, such as local governments or some agencies) and distributed (because each of these units has its own data processing and its own database that

it maintains). This means that these systems are very complex for managing and achieving a higher level of services automation by the public administration system, which is one of the main objectives of the e-government introduction. In other words, the quality of services provided by e-government will be strongly related to the effectiveness of the system architecture. According to the International Telecommunication Union, the quality of services depends equally on network performance and non-network performance [3]. In this respect, we can say that the layered architecture is seen as a part of non-network performance and, as such, influences the quality of the whole e-government system, including the quality of services provided.

The recent study [4] analysed 28 different architectures observed in more than 100 papers discussing it. This paper analysed primary architecture characteristics and building blocks (related to standards, technologies, and recommendation and not as the elements of the architecture) not paying attention to the layer structure of the analysed architectures. From the other hand, Helali at all [5] define seven architecture types concerning mainly developed countries, excluding Jordanian type as developing country.

Analysing and comparing existing architecture of e-government systems, less developed countries can prevent quality problems with introduction of proposed four-layered architecture by Ebrahim and Irani [6]. Although this solution is not fully replacing centralised e-government solutions in respect of accomplishing interoperability, it will significantly minimise lack of interoperability and will provide user experience of seamless functioning. The intention of this paper is to point on use of four-layered architecture as a temporary and transition solution for achievement of full functional e-government.

METHODS AND MATERIALS

Talking about e-government architecture, we primarily consider defined standards, infrastructure components, applications (software), technologies, business models that we try to regulate facilitated interaction between users and public administration systems, but also increase public administration productivity. The introduction and organization of the e-government system itself is a very complex, time and financially demanding undertaking that cannot be realized "overnight" but requires a systematic and informed approach that will minimize the initial costs of introducing e-government. These costs can be very high, depending on the state of infrastructure in public administration institutions, but it is very important in such a strategic approach to pay attention to the architecture of such a system. There are several studies from the early 21st century that have discussed the architecture or components of e-government [7] [8][9][10]. Each of these studies gives its own view of the organization of e-government systems and each of them has its advantages and disadvantages., The study of Ebrahim and Iran from 2005 on four-layer architecture [6] was used as the most comprehensive. Also, already mentioned papers by Baheer and Helali [4] [5] provided significant variety of solutions explaining the architecture, which were considered in structuring and writing of this paper.

To establish e-government with quality and with as few problems as possible, as well as to understand other factors that condition quality establishment, it is necessary to study and accept the generally accepted and most common structural model of e-government based on four-layer architecture. This model of the architecture of the public administration system is the most frequently discussed model by the scientific community [6]. The described architecture is conceived as a hierarchical one which seeks to integrate technologies to provide unhindered flow of information and data, as well as quality communication and customer service. The authors propose a four-layer architecture, as shown on Figure 2, consisting of:

- Access layer
- E-government layer
- E-business layer
- Infrastructure layer

Logical layers are merely a way of organizing e-government system from the software development point of view. Typical layers include Presentation, Business and Data – the same as the traditional 3-tier model in software engineering theory and practice. Analysing different sources of information for this paper, we have observed that there is a need of clarification of the term „layered architec-

ture". Namely, the software engineering literature recognises terms „layer" and „tier" in respect of the architecture. In this paper, we shall use term „layer ", which explains the logic of the organisation of the architecture. These layers might run on different computers or in different processes on a single computer or even in a single process on a single computer. This is important to notice as we are here dealing with the decentralised systems. Therefore, we are discussing a way of organizing a system into a set of layers defined by specific function(s).

From the other hand, „tiers" are not in focus of this paper as they deal with the physical location of the implementation of the tools and devices. Therefore, for the purpose of this paper we consider layers more important as the systems in focus of this paper are classified as highly complex, distributed and decentralised. Physical tiers, however, are only important if looking where the specific code runs. In other words, the tiers are places where layers are deployed and where layers run. In other words, tiers are the physical deployment of layers.

Efforts of e-government are to enable centralization and achieve cohesion of public administration services that are available to users. Therefore, the integration of e-government is seen as a critical success factor for achieving a higher and more mature level of e-government development [11] [12]. One of the most important factors preventing this integration is the lack of interoperability of the e-government system architecture caused by the inflexibility of inherited IT resources and systems, as well as the inherited business processes that make up the e-government system. [13]

As early as 1998, the Estonian Government initiated a strategic approach to addressing the efficiency of public administration. Thus, already in 2000, a pilot implementation of networking of institutions appeared by connecting three databases and their exchange using XML-RPC (XML Remote Procedure Call) standard protocol. Estonia has simply used existing technologies and applied them in a new way in the context of state governance. The outcome of this new application of existing technologies in 2001 was named X-Road [14] [15]. After that, additional improvements were made and new items were added, and as of 2018, X-Road has been renamed X-tee, which includes the entire collaboration system, while X-Road only implies the technology underlying X-tee.

An example of a solution in the direction of centralization of public administration e-services is given in Figure 4, which shows the possible centralized logical architecture of the electronic public administration system from the study according to Starčević [16]. Centralization has been established through the e-government backbone and the central portal, as well as a resource dictionary that supports the integrity of the system's functioning. Users can access the services through the central portal, or directly through the information system of the competent first instance body in charge of working with users.

Both of studied cases are following four-layered structure as in the work of Ebrahim and Irani.

RESULTS AND DISSCUSSION

Further is the discussion of the four-layered structure by Ebrahim and Irani [6], as well as examples of e-government structures of Estonia, Serbia and Bosnia and Herzegovina.

Access layer

At the top of the architecture proposed by Ebrahim and Irani is an **access layer** whose main task is to be an intermediary layer between the end-user and the e-government system. This layer describes who can use publicly open administration e-services, but also shows the channels for access to the services. The model dates from 2005 the model shows communication channels existing at the time. Of course, the model should not be understood as finite and immutable, and therefore the number of channels depends on the available technologies and solutions.

Also, it is important to mention that the access layer covers communication channels that work in both "online" and "offline" mode, which, again, seeks to emphasize the constant availability of e-government. The essence is that this layer exists to enable communication between the user and the system, thus representing a kind of interface to the system.

A two-way arrow at the figure 2 indicates two-way communication of the access layer with the e-government layer enabling different communication models (G2B, G2C, C2G, C2B, etc.). This is very in case of "more mature" public administration systems in which various e-services are provided including the

transaction services. What is an important feature of this layer is that this layer is the simplest in the whole architecture because it is managed by users of e-government services.

E-government layer

The **e-government portal** is a key element of this architecture. It is a place of single access to e-government services (Single sign-on portal) that facilitates improved access to services. The role of this layer is to integrate data and information from several data repositories, from different agencies and public administration institutions that is typical for distributed systems. Integrating data from different databases is invaluable for both users and creators of public administration services, because in this way it is possible to solve a certain problem or provide a certain service with a significantly smaller number of steps for the user. As represented by the scheme, this unique portal consists of a series of elements (sites and applications) through which the user can interact with the unit or public administration that provides selected service. Complexity is reflected in the structure of the portal and the number of links between the elements and the portal. The functionality of the portal, as a single point of access, depends mostly on quality of communication thorough these links. Single sign on portal enables savings in terms of costs associated with the provision of public administration services, raises the quality-of-service delivery, but also facilitates the work of units or institutions of public administration that no longer have to suffer the pressure of physical presence of clients in the service area.

As the most important element of the portal is, from users' point of view, the construction of the portal user interface. The user interface of such a complex system must meet the highest standards in terms of functionality and especially the visibility of the functionalities and services it offered. It is very important that the user finds and use the requested information or service in the easiest possible way, with minimal number of clicks thus reducing the overall occupancy of resources on both sides (the client and the server).

Between the access layer and the e-government layer is also duplex communication enabling exchange of communication and information in real-time or delayed communication. This also shows that the e-government layer behaves as the presentation layer of the e-government system.

An example of such a e-government portal is the portal of the European Union (http://www.europa.eu) or the European Commission (https://ec.europa.eu) which serve as a starting point for further use of services offered by these institutions to users, such as European Funding and Tender portal (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/home) presented in Figure 1. This is the only and the starting point for applying to available funds,

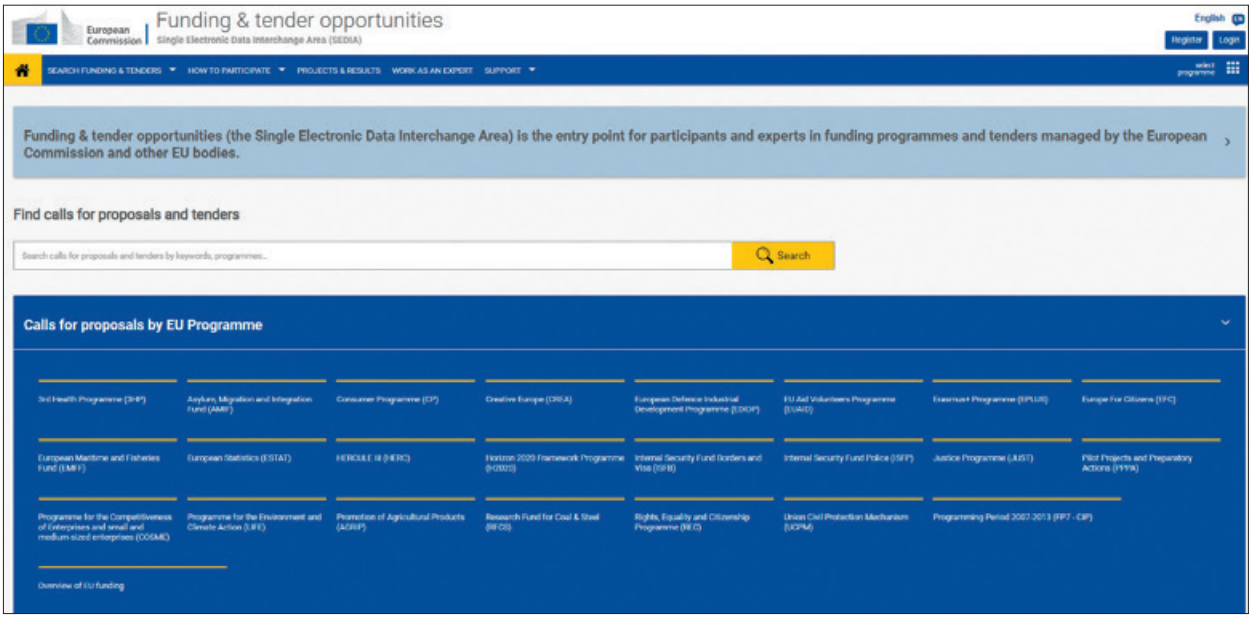

Figure 1. *Example of the single-sign-on portal of the European Commission's funding*

from where the portal leads you to different parts of the system related to the competitions, applications, payments and other necessary functionalities.

E-business layer

Despite the complexity of such a system, the real problem solving is enabled using applications, catalogues, and other elements of the public administration **e-business system**. This layer aims to ensure automatic, high-quality, and real-time feasible communication between the various subsystems that make up a single system of public administration. This is a key layer of G2G communication, including G2E and E2G (communication of employees with public administration institutions) since this layer is maintained by engagement of employees in public administration themselves. In this way, employees are enabling quality exchange of data and simplification of work processes, including automation of certain business processes. In essence, this layer enables the true connection of the elements of the public administration system into one functional unit.

The following applications stand out as the most important:

- **Document Management System** - enabling uniform and quality document management within the system;
- **Customer Relationship Management -** to monitor users and organize business processes according to customer needs;
- The **Enterprise Resource Planning** – enabling monitoring of business in the system as well as integration of information flow through the system (including modules such as financial module, human resources module, etc .);
- **Web Service Applications** – enabling the use of e-business applications in a web environment (most often on the principle of "search" and "answers" (Request and Reply), "search" (Search), etc .);
- The **Enterprise Application Integration (EAI)** – enabling the integration of intra- and inter-organizational systems reducing development and integration costs;
- The **Electronic Data Interchange** - for the transfer of structural data and services using standardized messages between computer applications;
- The system of **collaborative tools (Groupware)** - enabling cooperation, sharing and organization of information for a particular group of people with the aim of facilitating different tasks.

A two-way communication between the layers of e-government and e-business indicates cooperation and interaction between these layers, and thus complements one of the previous views on duplex (two-way) communication both within the system and with users (in this case civil servants working in e-government system).

Infrastructure layer

Agreed standards and applied best practices, as well as communication protocols between systems that communicate with each other, represent a significant component of the infrastructure layer in addition to hardware as the foundation of quality public administration system infrastructure. **The infrastructure layer** technologies aim to support and unify the operations of the information system and related e-business applications using the necessary standards and protocols in network access, such as:

- A **Local Area Network (LAN)** - computer network connecting computing devices and enabling the exchange of data within a narrow environment such as a company, a building, or a department, etc .;
- **Servers** are specialized computer machines enabling the operation of applications and databases that "run" on them, including the servers enabling the communication via the Internet, intranet and external communication channels;
- The **Internet** - a key medium for wide use of public administration services facilitating exchange of data or connection with users;
- **Intranet** - enabling connection, communication and sharing of resources to employees of one institution in a secure way using web-based technologies and protocols;
- An **extranet** - a controlled private network, accessible to those who are not employed but with prior authorization and assignment of access credentials and can be seen as an "extension" of the intranet to key business associates.

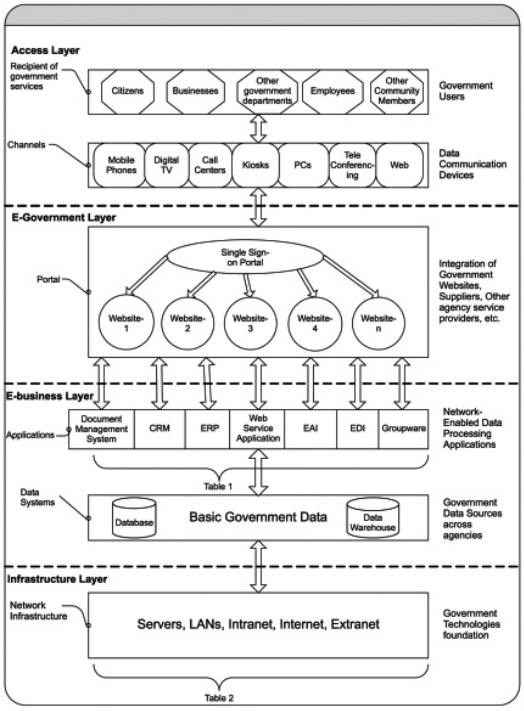

Figure 2. *The four-layer model of Ebrahim and Irani [6]*

Estonian model

At the core of Estonia's success is the visionary approach to the use of modern and up-to-date technologies in daily work of the public administration. Back in 1996, the Estonian government started a national project to establish a national broadband network infrastructure called "Eebone" at the end of 1998. This network connects state and local levels of government and is centrally funded, and every public institution has the right (not the obligation) to use Eebone for free, while clients only pay for access to the network [17].

Most state and local government institutions use EEbone based on the X-tee (initially called X-Road), which is essentially a national "middleware" that provides unified access to all government databases that uses web services as support technology, and allows easy access to data in government registries without compromising the security of flows and with minimal impact on existing systems. X-tee was initially developed as an environment that facilitates the query formulation of networked databases in a standardized manner. The architecture of this complex system is given in Figure 3 showing this central "backbone" of the system based on the Internet, in part related to the central management of this system, as well as repositories provided by security servers to private sector.

The architecture of X-tee enables distributed, secure, unified web services based on a framework for inter-institutional data exchange. Distribution is reflected in the fact that X-tee does not centralize data and does not change ownership of the data. The databases and registers are not centralized and the data is managed by the same institution that created it. Each institution is responsible for the quality of the data and can determine which other institution will have access to the data. X-tee does not limit the way registries and institutions will implement their information systems - all platforms and host-

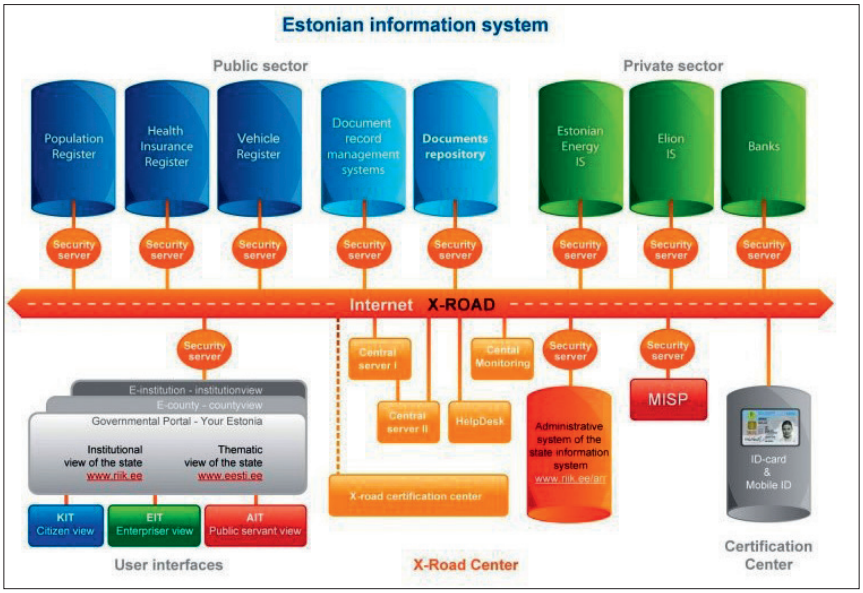

Figure 3. *Estonian model of e-government infrastructure called X-tee (former X-Road)*

ing models are supported, including cloud-based setups, allowing for system heterogeneity.

The basic elements of trusted infrastructures in the e-Estonia system structured in four-layer logic are:

1. Access layer
   - Electronic identification card (eID),
   - PKI infrastructure,
2. E-government layer
   - Personalized portals for citizens (KIT), industry (EIT) and administration (AIT),
3. E-business layer
   - Secure layer for X-tee data exchange,
   - Document Exchange Center,
4. Infrastructure layer
   - EEbone Broadband Network,
   - Register of registers with service catalogs,
   - Data addressing infrastructure, and
   - Spatial information infrastructure.

The Estonian model can be said to be based on *Service Oriented Architecture* (SOA). This type of architecture is typically concerned with building independent business solutions based on services as building blocks. Services, as software units, are combined into the desired business processes and services can have a lifespan, i.e. they can be easily withdrawn from use, which is an advantage in business process modelling, which achieves scalability and flexibility of the business as a whole. The basic characteristics of this architecture are tolerance to the diversity of employed technologies and platforms, easier transfer and sharing of services, as well as increased reliability in distributed systems.

Centralized e-government systems on the European continent are becoming a general trend, as is the case with Estonia. Each state authorizes one or more ministries to carry out the process of centralization of e-government, which enables the creation of an organized, integrated and functional environment for providing services to citizens from one place (one-stop-shop). The application of a centralized digital system of public administration, according to a study by the European Commission from 2014, would lead to significant annual savings in the work of public administration, with additional economic effects of such business for the immediate environment. The study estimates that applying digital strategies in public administration at the level of the 28 EU member states would save approximately € 10 billion a year, implying a significant number of transactions [18].

Serbian model

The Serbian model in the direction of centralization of public administration e-services is given in Figure 4, which shows the possible centralized logical architecture of the electronic public administration system from the study according to Starčević [16]. Centralization has been established through the e-government backbone (e-government bus) and the central portal, as well as a resource dictionary that supports the integrity of the system's functioning. Users can access the services through the central portal, or directly through the information system of the competent first instance body in charge of working with users as shown in Figure 4.

The basic elements of trusted infrastructures in the Serbian system structured in four-layer logic are:

1. Access layer
   - Users,
2. E-government layer
   - Central portal,
3. E-business layer
   - Information system units,
4. Infrastructure layer
   - e-government bus,
   - Dictionary of e-government resources
   - e-payment, and
   - e-security

Bosnia and Herzegovina model

Bosnia and Herzegovina (B&H) is an example of a decentralised and distributed system. The public administration system itself is divided (decentralized) into several basic levels of government:

- state (competence of the Council of Ministers of B&H),
- entity (entity governments),
- cantonal (cantonal governments) in the Federation of B&H, ie local self-government institutions in the Republic of Srpska (city and municipal authorities), and
- Brčko District (District Government) as a separate administrative unit.

Each of these levels of government is independent in terms of organizing and equipping the pub-

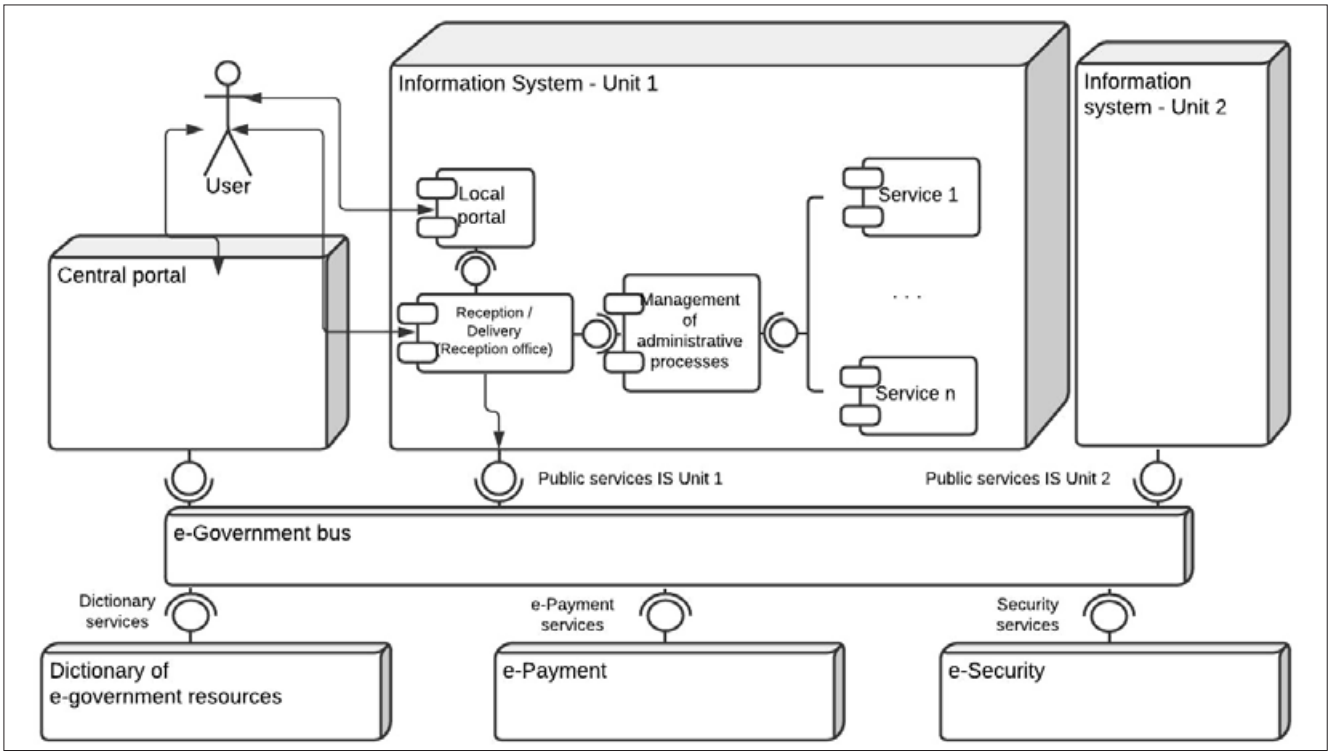

Figure 4 *Example of the proposed Serbian model for e-government architecture (from [16])*

lic administration system in its domain. Therefore, the establishment of a centralized system as such is not even defined by the B&H Constitution. However, when we talk about centralization, this is possible at individual, lower levels of government and in accordance with their competencies and powers.

To meet the requirements of the project and ensure that the interests of stakeholders are met, the proposed architecture is shown in Figure 5. This architecture takes into account all the advantages of a four-layer architecture that integrates the management system in a quality way to meet user needs.

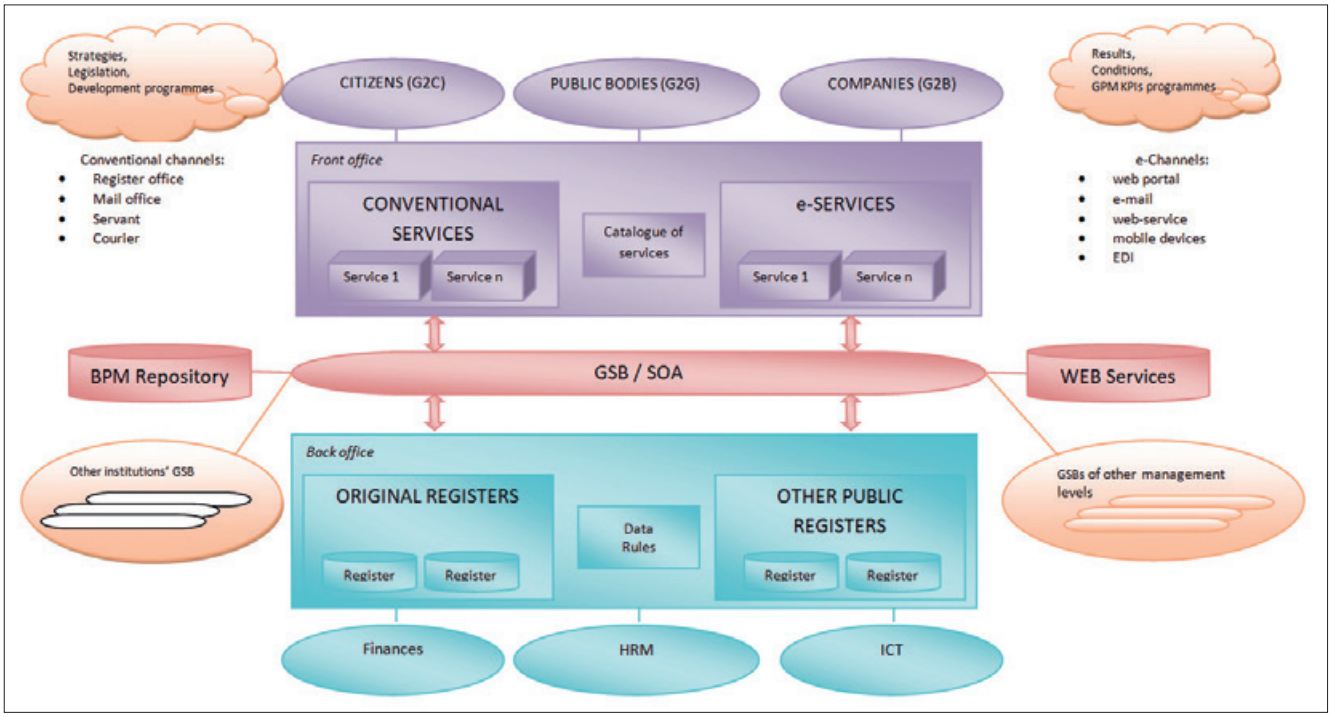

Figure 5. *Example of proposed Bosnia and Herzegovina's model [19]*

Thus, the presentation layer is singled out as special and connected to all public administration services offered, which are divided into two categories: conventional services and e-services, depending on the communication channel. This model proposes the establishment of the so-called Government Service Bus, which is the counterpart of the Estonian X-tee, and which would be based on a service-oriented architecture. This would enable flexibility and scalability of the system because it would be based on the services offered by the public administration system and thus could "orchestrate" business processes and adapt to user needs.

The Public Administration Reform Fund in B&H financed the project "Development and establishment of an interoperability framework and standards for data exchange" which created the document "Guidelines and standards for system architecture and application development" [19] The project and document was implemented by Infodom d.o.o. from Zagreb (Croatia), which in the mentioned document proposed a solution for the architecture of the system, which was based on positive experiences from Germany and the application of SAGA [20] standards. This standard defines a multi-layered architecture on three or four levels, depending on whether the presentation layer is separated from the e-business layer, i.e. from business logic, and where, in fact, the user represents a special layer.

The basic elements of trusted infrastructures in the B&H system structured in four-layer logic are:

1. Access layer
   - Citizens (G2C),
   - Public bodies and municipalities (G2G),
   - Companies (G2B),
2. E-government layer
   - Front office with conventional and e-services,
3. E-business layer
   - Finances,
   - HRM (Human Resource Management),
   - ICT (Information-Communication Technologies),
   - Web services,
4. Infrastructure layer
   - government service bus,
   - service buses of individual institutions,
   - source registers,
   - other public registers,
   - BPM (Business process modelling) repository.

CONCLUSION

The aim of this paper was to explain the four-layered structure of e-government systems and to propose it as a quality solution for distributed and decentralised systems. We provided insight in three models: one from the country with very advanced e-government system (centralised, Estonia), one from the developing country (centralised, Serbia) and one from the country with strongly decentralised system (Bosnia and Herzegovina). The advantage of the four-layered structure lies in its universality for implementation, as it was proven by these three systems with quite different advancement in implementation of e-government and governance. It is proven that this structure is feasible even for low-income countries with highly decentralised system of governance, such as Bosnia and Herzegovina.

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About the authors

Dalibor Drljača is a Ph.D. with main research interests are in e-Government, audit of information systems and e-Commerce. He is employed at the University Clinical Centre of Republic of Srpska and part-time engaged as a Senior teaching and research assistant at Pan-European University APEIRON Banja Luka.

Dušan Starčević is a full professor at the Faculty of Organizational Sciences, University of Belgrade. His main research interests include human–computer interaction, distributed information systems, multimedia, and computer graphics.

Siniša Tomić was born on October 10, 1972 in Doboj, Bosnia and Herzegovina. He is an assistant professor at the Faculty of Information Technologies at Paneuropean University APEIRON, Banja Luka. His special interests are in computer multimedia and graphics, 3D animation and special digital visual effects.

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