Ph.D. Thesis

Summary

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The Framework of a Real-time Patient Monitoring System

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1. Problem statement and research questions

Scientific research on the health system in Kosovo has shown that, 19 years after the war, serious problems remain in accessing health services. Every year, increasing deaths provide sad evidence of malfunctioning of health care. The lack of digitalization of day-to-day work and management processes in hospitals contributes to the poor picture. In addition, a number of social indicators give cause for concern in this respect. Kosovo citizens do not have a thorough knowledge of e-health and health in general, and no one thinks about virtual communication between patient and doctor. In fact, the implementation of the Health Strategy from 2010 to today has been unsuccessful and there is still no information system to support the health system processes. Other information about hospital processes and services and patients is based on paper. The human and technological resources available for public health services are lower than in other European countries. Inadequate use of existing resources is an obstacle to positive change.

Middle-aged and elderly people, representing a large proportion of the population, have limited access to health services and their illnesses represent a major economic burden for their families and society in general. An analysis of the state of health of the population shows that the number of deaths in 2016-17 is 421.9 per 100,000 inhabitants. Apart from the predominantly paper-based documentation, the problem continues to be a lack or migration of qualified health personnel.

1.1 What Do We Want?

Health information is important. Improving health care is based on making good decisions and having the right strategy. Good information will allow better management, more efficient management of health institutions, and ensure that the population of Kosovo receives adequate health care.

Based on the current situation, I plan to use the results of this research in a proposal for the design and implementation of a health management system. The strategy focuses on one of the cornerstones of development, ICT. The main element is monitoring the most common diseases in the country. The use of ICT in

the health system can lead to better budget management, more effective prevention and an improved mortality rate.

Understanding the national requirements and problems is a prerequisite for the development of the Kosovo system. Engineering, management and various IT design and development solutions are required. A consistent approach is provided by TOGAF, which has helped develop a number of international strategies for the successful implementation of health information systems in the information systems world.

Therefore, in this dissertation, I strive to develop and thoroughly review a strategy for implementing a functional health information system that meets the current health situation and requirements of Kosovo, in accordance with the WHO's objectives for developing countries.

The main idea of the dissertation is to improve the health of the patients and to raise the awareness of the patients towards the conscious choice of lifestyle.

- Reduction of the overall morbidity and mortality rates of the population.

- Improving resource management and quality of services.
- Functionalizing, re-organizing and supplementing the existing infrastructure of the healthcare system and medical devices, in accordance with European standards.
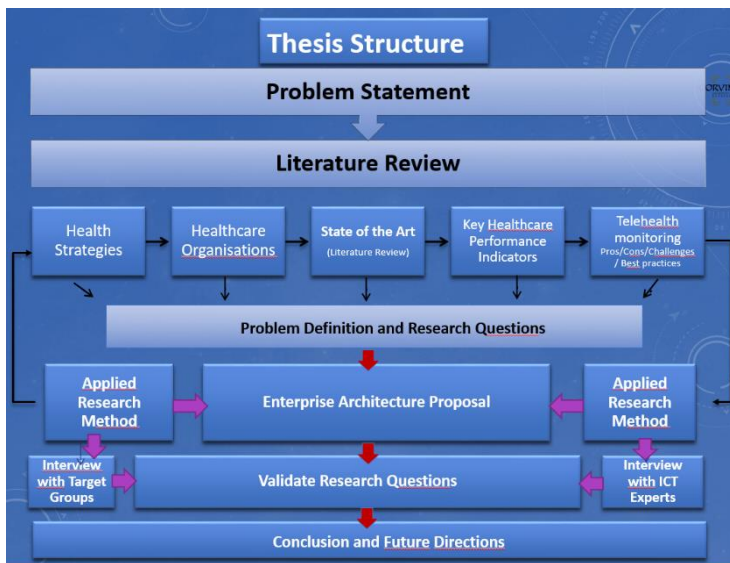
1. Figure Structure of thesis

1.2 What Can We Do? Architecture Principles

In my dissertation I propose a high-level architecture of the e-health system in Kosovo and outline the important cornerstones of the implementation of the e-health information system.

Developing an architecture involves defining the resources needed, taking into account organizational barriers, and the implementation schedule to be followed from the baseline to the target architecture. Implementation aspects include the ICT equipment and services to be procured.

A key success factor is the creation of an eHealth ecosystem consisting of multiple tools, applications and support systems. Another key success factor is taking security risks into account, avoiding data misuse. As a priority for high-level standardization, architecture fits in with foreseeable technological innovation.

1.3 Research Questions

The national health system will also improve if the information system addresses national needs and

problems. Therefore, research focuses on both the current situation and the objectives set out above. It is assumed that the information system implementation strategy (cf. Chapter 9) responds adequately to the needs expressed in the research questions. The interviews allowed me to confront the proposed architecture with user needs and discuss local and global barriers, implementation and deployment issues mentioned by various target groups. From a technical point of view, ICT experts agreed with the proposed system, both architectural and operational context.

A detailed description of the interviews can be found in the appendix (Chapters 15-16). The figure below illustrates how we tried to connect the individual questions, from the problem to the research question, our proposal, and the results of the interviews.
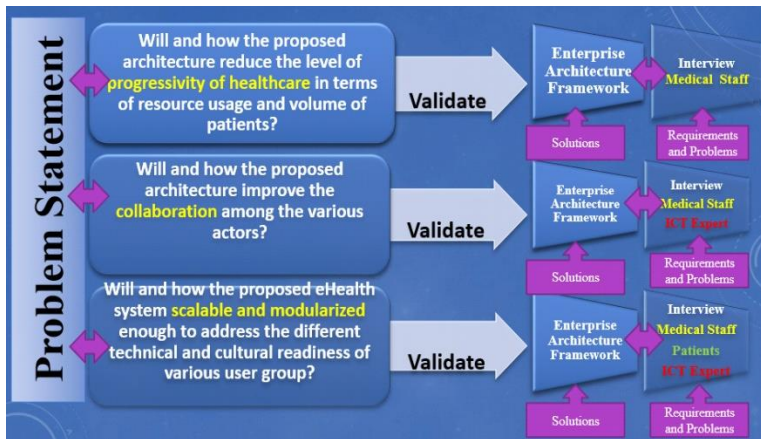

2. Figure Research Question

2 E-Health Enterprise Architecture Proposal

The overall eHealth architecture is based on the best and successful practices of European countries published in the literature. I propose an architecture that meets the current situation in Kosovo and includes the requirements of all stakeholders, including the requirements for information exchange using ICT. Above all, this approach includes information system design principles and methods, data management, technology platforms, implementation and deployment, stakeholder requirements management, and organizational aspects. In short: who does what, why, when and where? We need to emphasize three very important principles that are the cornerstone of the approach: architecture (building blocks, artefacts), storage, reusability, standardization and interoperability.

2.1 Application Architecture

The application architecture includes generating various reports, recording and transmitting data from different devices, displaying data, and access modules for health

and non-medical stakeholders. A high-level overview of the application architecture follows the segmentation of the target groups as shown in Figure 3 (Chapter 7.1):
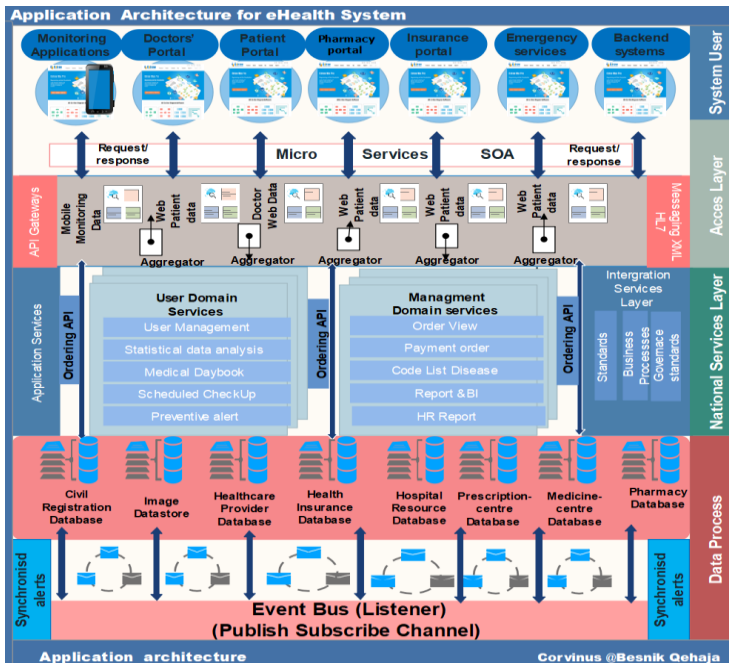
3. Figure Application Architecture

2.2 Data Architecture

Interoperability of an eHealth system only works if the data architecture allows for the transfer of information between two or more systems, processing the information independently and through a single standard. I have tried to compile a data flow where architecture stakeholders

have unique data from different databases Figure 4 (Chapter 7.5).
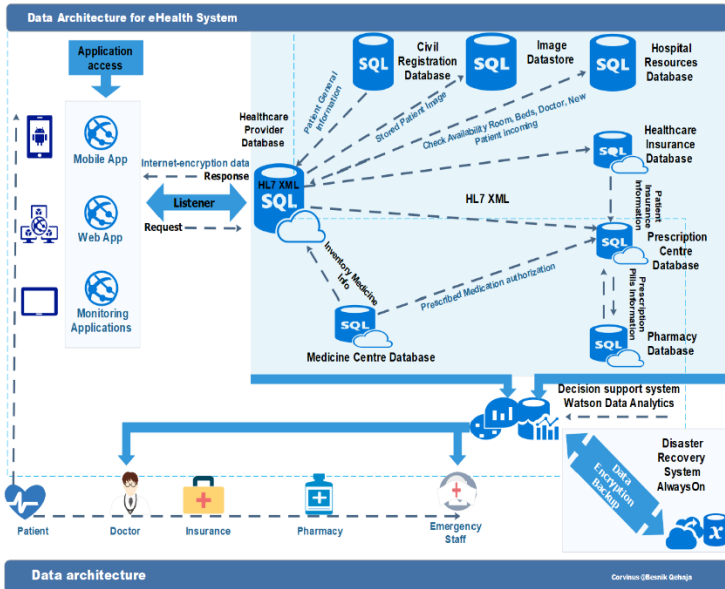
Figure 4. Data Architecture

2.3 Technology Architecture

To propose a technological architecture solution for the eHealth information system, it is very important to emphasize the life cycle of different entities and their interactions in the ecosystem. The longevity of equipment and data lifetime is a critical part of the understanding the technological architecture at every level. Architecture can be analyzed in three relevant aspects that meet the

requirements and objectives outlined earlier. The three aspects it was addressed during the technical architecture development are as follows: Access Layer, Network Connection, Access Security and Privacy.
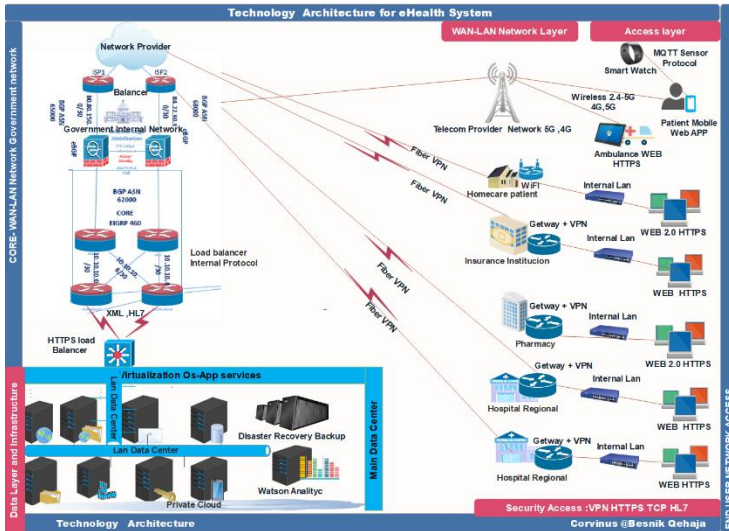
4. Figure Technology Architecture

2.4   Roadmap and Strategy implementation

The next phase of the architecture proposal is the timetable for implementing the strategy, step by step (Chapter 8.3). Each phase of the implementation of the strategy has been designed based on the TOGAF framework (ADM phases), I also use an agile approach,

and the application of the waterfall methodology depends on the situation (Chapters 8, 9 and 16, Appendix 3).

The strategic implementation proposal for the eHealth architecture requires a harmonized schedule of planning activities for each sub-architecture. In Chapter 8, I only highlighted the part of the roadmap that ends with implementation. A very important aspect was the timeframe of all activities. The proposed roadmap covers system design, development, installation, system testing and user training. Strategic implementation is based on a clear overview of the development process of the eHealth architecture, where goals and indicators specific to the process are defined, measured and occasionally reviewed. The objectives follow the requirements of the Ministry of Health, WHO recommendations, social, legislative and stakeholder requirements (Chapter 9).

3   Research Methodology

In this study, a combination of the three methods is used because of the nature of the research. The literature review presents health systems used in different countries. I used case studies to analyze systems, development, benefits, advantages, strengths, weaknesses, and disadvantages. First, I outlined the architecture of the real-time patient monitoring e-health system (RPMeHS) based on relevant literature and especially my knowledge of ICT. Second, during my research, I identified the current application of technology and the standards used in information systems. Third, using the TOGAF framework, I proposed an implementation strategy for the eHealth System (RPMeHS). The validation process aims to evaluate the functionality and usability of the proposed RPMeHS architecture using qualitative methods.

3.1   Empirical data (Interviews)

The purpose of the personal interviews is to gain a better understanding of the working conditions of doctors, nurses and administrators, their views on the digitization of health services, the specific requirements for their role,

and finally their willingness to adopt the digital system. As an additional input for the dissertation, I asked IT experts about the proposed information system. All three layers of the information system architecture were evaluated.

4 The main scientific findings and Validation of the Research Question

The research will focus on the objectives indicated above, taking into account the current situation. It is assumed that the information system implementation strategy responds adequately to the needs expressed in the research questions. From a technical point of view, the proposed system has been validated by ICT experts from both an architectural and an operational point of view (the interviews are detailed in the Appendix).

4.1 Healthcare progressivity (RQ1)

"Will and how the proposed architecture reduces the level of progressivity of healthcare in terms of resource usage and volume of patients?"

Interviews with medical staff, nurses, hospital managers and patients provided input for the validation of research question 1. Lack of adequate and up-to-date patient information often leads to misdiagnosis or misdiagnosis, which is obviously followed by more resource use and requires more patient care. On the one hand, on the basis of interviews assessing the problems and needs of

physicians, my proposal is closely correlated with the needs and problems of all users of the health care system. At the same time, health staff responded positively to the digitalization of the health system, judging it as a major improvement over the traditional form of health services. The training of older staff in modern patient management technology remains a challenge for most physicians. Our application architecture proposal significantly increases the efficiency of physicians' work while reducing the number of patients in health care facilities.

4.2   Collaboration (RQ2)

"Will and how the proposed architecture improves the collaboration among the various actors?''

In interviews with medical staff, we observed that lack of communication between medical / non-medical staff and patients leads to incomplete reporting and poor treatment. In implementing the strategy, it is important to examine and understand stakeholder needs and expected behavior in the health system and translate them as functional user needs as functional points of the system. Communication with real stakeholders plays a key role in our technology architecture proposal, which includes all stakeholders,

including hospitals, pharmacies, outpatient services, insurance companies, health data centers and, ultimately, patients. The technology architecture fully supports communication, the data architecture covers the data sharing requirements of all stakeholders, and the application architecture provides a good opportunity to provide information to all stakeholders. This was confirmed by the experts. Computer network experts pointed out that real-time communication is possible with the recommended topology. Interviews with database experts have proven that, at a data level, a micro-service based communication plan is an acceptable and appropriate choice.

4.3   Scalability (RQ3)

"Will and how the proposed eHealth system scalable and modularized enough to address the different technical and cultural readiness of various user group?"

Based on the summary of interviews, all respondents believe that digitalization is the only way to move away from Kosovo's current health system. While elderly patients and older healthcare workers are challenging to adapt to the digital health ecosystem, they agreed that ICT

affects every aspect of their lives. Monitoring equipment and the various platforms for monitoring their health are welcomed. On the other hand, some believe that long-term monitoring can affect their mental health, while others believe that continuous monitoring has a mental barrier. From an architectural design point of view, the architecture of the information system plays a crucial role, especially for the different types of interoperability. From the point of view of adapting the architecture to the users' requirements, our proposal largely corresponds to the majority of the target groups. Considering user needs and issues, expert recommendations, and recommended architecture, we find a close relationship between user requirements and recommended architecture proposal. The architecture is highly scalable and easily adaptable to changes depending on user needs, especially changes to add new features and performance enhancements, and requirements in line with advances in new technologies.

5   The publications of the author in the topic of thesis

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2   Qehaja, B., & Hoxha, V. (2018). Principal steps for monitoring real time patients through ICT in developing Countries. *IFAC-PapersOnLine*, *51*(30), 166–170. https://doi.org/10.1016/j.ifacol.2018.11.280

3   Qehaja, B., Bajraliu, A., Shabani, A., & Hajrizi, E. (2016). Enterprise Integration, Networking and Virtual Communications. *IFAC-PapersOnLine*, *49*(29), 144–147. https://doi.org/10.1016/j.ifacol.2016.11.090

4   Abazi, B., Qehaja, B., & Hajrizi, E. (2019). Application of of biometric biometric. *IFAC PapersOnLine*, *52*(25), 543–546. https://doi.org/10.1016/j.ifacol.2019.12.602

5   Ahmet, S., & Besnik, Q. (2017). Orthogonal frequency division multiplexing (OFDM) methods for the multiplexing in Worldwide Interoperability for Microwave Access (WiMAX). *KNOWLEDGE-INTERNATIONAL JOURNAL*, *20*(4), 1919.
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6   Jashari, Arton; Qehaja, Besnik; and Berisha, Diellza, "Privacy and Security Data communications issues in HealthCare Ecosystem" (2018). *UBT International Conference*. 106.
https://knowledgecenter.ubt-uni.net/conference/2018/all-events/106

7   Ymeri, Exhevit; Qehaja, Besnik; and Hoxha, Ramiz, "Synchronization and High Availability of Data by Using Technology of SQLServer 2012 Always On" (2017). *UBT International Conference*. 104.
https://knowledgecenter.ubt-uni.net/conference/2017/all-events/104

8   Alidema, Fitim; Vokshi, Valbona; and Qehaja, Besnik, "Experiences of medical staff with ICT in Kosovo Hospitals" (2019). UBT International Conference. 315.
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9   Jashari, Xhelal; Vllaço, Edin; Fetaji, Bekim; and Qehaja, Besnik, "Conceptual Design and Software Development of Clinical Management System based on Microservices" (2019). UBT International Conference. 259.
https://knowledgecenter.ubt-uni.net/conference/2019/events/259