Towards Standard-Based Healthcare Ecosystems of Systems

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Introduction

Software systems have been historically evolving to become more complex and dependent. Nowadays it is rather rare that a system is completely developed from the beginning without reuse of components or parts of other systems. This tendency is also reflected in the popularity of the notion of Systems of Systems (SoS) where the collection of software systems results in new and bigger systems of more complexity that simply the collected systems. Systems of systems typically comply with strict requirements such as security, reliability, and scalability while they are known to be applied to, among other, domains of mission-critical nature [1]. In this position paper, we examine systems of systems in the medical and healthcare domain.

Medical systems are typically characterized by high requirements in security and privacy. These requirements, possibly in a lower grade, are extended to systems surrounding medical systems like apps that inform patients with advanced pacemakers how to detect and improve condition worsening [2]. The need for regulating healthcare systems is eminent [3].

Furthermore, healthcare systems have been growing more interdependent and interoperable with time. This has become more obvious with the increased requirements of centralizing systems as recently demonstrated in the case of the electronic medical records and more specific the example of the Danish healthcare [4]. These requirements of interdependency and interoperability bring healthcare systems closer to software ecosystems, i.e. systems that are characterized by the symbiosis of software and their actors (e.g. companies, organizations) on top of a common technology [5].

Software ecosystems have been traditionally found in non mission-critical domains such as smart phones with the example of the Apple AppStore and software development with the Eclipse platform. However, the notion of software ecosystems is lately becoming popular also in mission-critical domains like the automotive industry [6] and healthcare [7]. Software ecosystems typically evolve around a technological platform that facilitates development and supports the activities of the ecosystem. Recently it has been suggested that software ecosystems can also evolve around a set of standards that take the role of a common platform [8, 9].

Healthcare Ecosystems of Systems

In this paper, we argue for the combination of systems of systems and software ecosystem theories (as already discussed in previous work [10]). Our approach is studying the establishment and evolution of a system of systems in the healthcare domain, i.e. the extended medical domain to include systems that are not medical systems per se but are directly related to medical systems. We identify that an ecosystem of this nature is consisted of software systems that tend to be highly specialized and characterized by high requirements in safety, availability, and privacy. Moreover, these systems are created by several and many times specialized actors [11], thus the network of actors involved can be characterized by several actors with close to equal influence on the ecosystem, or rather by the lack of a dominating actor.
Furthermore, the business models that serve these actors, at least in the case of several European countries, are different than possible traditional software development models where the users pay the cost of the systems. In these ecosystems the involved actors gain revenues for their activity by payments from the state (or other healthcare organizations like insurances) [12]. It is, in other words, a state-funded software ecosystem.

Our approach is that the evolution of systems of this kind around a set of standards would support the activity and foster the well functioning of the ecosystem. We argue that a standard-based ecosystem of systems in the healthcare domain would support better the ecosystem characteristics compared to a traditional ecosystem based on a software platform. A standard-based ecosystem [13]:

- Supports the (co)existence of multiple actors. Especially in the case of the actors having different interests and potentially equal influence to the ecosystem.
- Allows for a wider control and influence of the architectural qualities of the produced systems.
- Facilitates ecosystem orchestration. Taken that the standards of the ecosystem are in place, orchestrations is more oriented towards ensuring standard compliance, thus relieving part of the effort that would normally be required in a traditional ecosystem.

**Conclusion**

In this paper, we discuss an approach to healthcare systems. Taken that healthcare systems evolve more complex, interdependent, and interoperable with time, we propose the combination of systems of systems and software ecosystems theory to support this evolution. Our approach includes the establishment of a set of standards as a central point that would facilitate system development and actor symbiosis. The establishment of standard-based ecosystem of systems in the domain of healthcare would support coexistence of actors, allow for requirement control, and facilitate the ecosystem orchestration.

**References**


