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Service Delivery for e-Health Applications

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Abstract. E-Health applications have to take the business perspective into account. This is achieved by adding a fourth layer reflecting organizational and business processes to an existing three layer model for IT-system functionality and management. This approach is used for designing a state-wide e-Health service delivery allowing for distributed responsibilities: clinical organizations act on the fourth layer and have established mutual cooperation in this state-wide approach based on collectively outsourced IT-system services. As a result, no clinical organization can take a dominant role based on operating the IT-system infrastructure. The implementation relies on a central infrastructure with extended means to guarantee service delivery: (i) established redundancy within the system architecture, (ii) actively controlled network and application availability, (iii) automated routine performance tests fulfilling regulatory requirements and (iv) hub-to-spoke and end-to-end authentication. As a result, about half of the hospitals and some practices of the state have signed-up to the services and guarantee long-term sustainability by sharing the infrastructural costs. Collaboration takes place for more than 1000 patients per month based on second opinion, online consultation and proxy services for weekend and night shifts.

Keywords: e-Health service delivery, business layer, infrastructure, 3LGM², GCM

1. Introduction

E-health Service delivery between two organizations or between a larger organization and associated smaller ones has been successful for a variety of applications, e.g. teleradiology, teleneurology, telepathology. Typically, the implementation reflects the professional relationship between the organizations involved. However, larger regional or state-wide e-Health services have to take additional requirements into account:

- Frequent changes in cooperation according to clinical needs, business opportunities and personal relationships.
- Availability and continuity management as part of a professional IT-Service Management [1, 2], as well as scalability, training and maintenance [2].
- Compliance to directives and regulations [3] and
- Sustainability, in particular for e-Health projects.

The objective of this paper is to present an approach for state-wide e-Health service delivery based on embedding the concept of the Revised Three-layer Graph-based Meta Model (3LGM²) [4, 5] in a business perspective and presenting a reference implementation compliant to the above requirements.

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2. Materials and Methods

The 3LGM² comprises of three layers (domain layer, logical tool layer, physical tool layer) for modeling enterprise functions, associated applications and physical components. It has been applied to information management in hospitals [6] and telemedicine [7]. However, it is focused on IT-related aspects and less targeted to business perspectives which have become the driving forces in e-Health based co-operation.

Table 1. Structure of e-Health Services

Layer	Contents	Example related to teleradiology
organization, business process	medical / clinical cooperation	weekend and night shift, external teleradiology services
domain	enterprise functions, entity types	second opinion, providing online consultation
logical tool	application components	DICOM and Web Services for image/report handling
physical tool	infrastructure components	network and IT systems

Mapping bilateral cooperation or cooperation of a larger organization with associated satellites to the structure proposed in Table 1 reveals that each organization has to deal with all four layers resulting in disadvantages:

- Linking the organizational with IT related layers limits mutual cooperation.
- In larger settings several cooperation clusters (bilateral, one to satellites) will exist in parallel and the lower three layers will be implemented multiple times. This will result in cost increase and technical incompatibility between clusters.
- Organizations which are located in between two clusters or needing multiple cooperations due to their medical specialty have to establish connectivity to more than one cluster. This again causes costs and leads to re-implementation.

In addition, a lesson learnt from several years of providing e-Health service delivery is, that cooperative relationships between organizations change frequently. Consequently, for the design of a state-wide e-Health service the responsibility has been split: The organizational and business process related layer stays with the organizations themselves, thus allowing for varying contractual, financial and organizational arrangements. The IT-related lower three layers are contracted to an independent service provider.

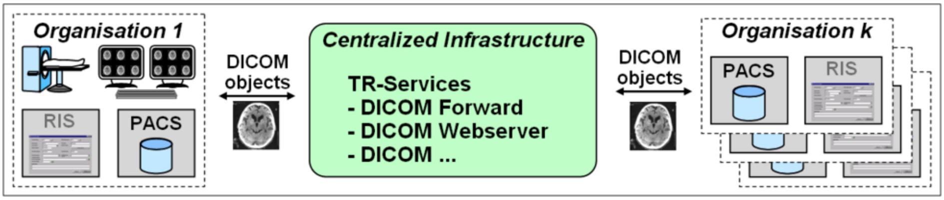

Figure 1. Teleradiology with central infrastructure

This decoupling paves the way for a centralized infrastructure exhibiting significant advantages (Figure 1):

- The cost for the infrastructure is shared by all organizations.
- Each organization (1 … k) is relieved from infrastructure services and benefits from only one communication channel to the central infrastructure.

- Mutual cooperation becomes possible without individual organizations imposing on partnerships.
- Change management with regard to cooperation stays with the organizations involved and is not passed-through to the lower layers.

The reference implementation targets three teleradiology scenarios: (i) second opinion, (ii) emergency consultation and (iii) remotely supervised radiological examination.

Due to the fact, that a central infrastructure is a single point-of-failure its system architecture has been designed to be fully redundant (Figure 2, left). In case of hardware failure the task is taken over by the corresponding device.

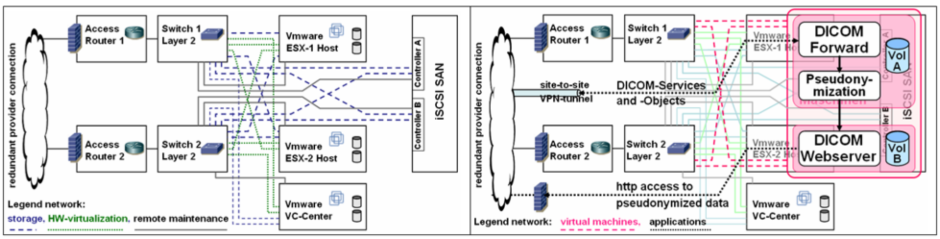

Figure 2. Physical layer (left) and logical tool layer (right)

Applications on the logical tool layer (Figure 2, right) rely on virtual machines for high-availability. Connections between organizations and the infrastructure use VPN for privacy. The DICOM Webserver only holds pseudonymized data accessible via http.

The tool Nagios [9] is used for active monitoring. Besides a standard "ping" on network level, Nagios has been enhanced with DICOM C-Echo (Figure 3).

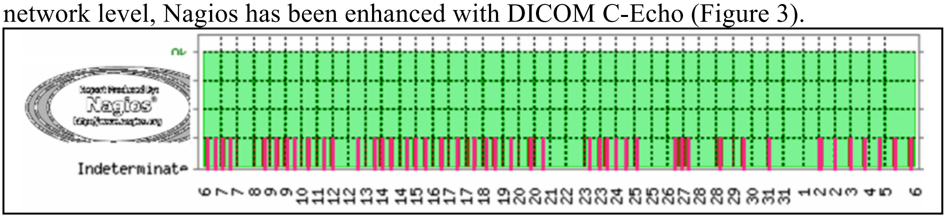

Figure 3. Monitoring on application level (red bars reveal a limited availability of this DICOM node)

The methods described so far are initiated from the central infrastructure and do not provide an organization to organization performance test. Such a test has become compulsory due to a standard [8] and requires the following tasks (Table 2).

Table 2. Tests required by the DIN 6868-159

task	daily	monthly
Functional test, max. two trails	x	x
Measurement of the transfer time of a reference data set, maximal 900s		x
Check for the completeness and correctness of the reference data set		x
Documentation of the test results	x	x

To avoid cumbersome manual testing the tool TR-DIN has been to developed (using Java and pixelmed[10]). To measure the transfer time a reference data set is sent to the receiving organization which replies with a DICOM conformant acknowledgement, but with no pixel data included. The transfer time is easily determined by rating the transfer time for the acknowledgement negligible. Transfer times recorded for one month using a 65MB data set show acceptable variation and are far below the required 900s limit.

On site-to-infrastructure level authentication and authorization is achieved by VPN tunnels, AET (Application Entity Title) and port. For end-to-end authentication the PKI functionality of the national health telematics infrastructure is used. Since it does not support the transfer of large amounts of data, a hybrid approach has been implemented by the so-called TISP (Telematics Infrastructure Subscriber Proxy) (Figure 4).

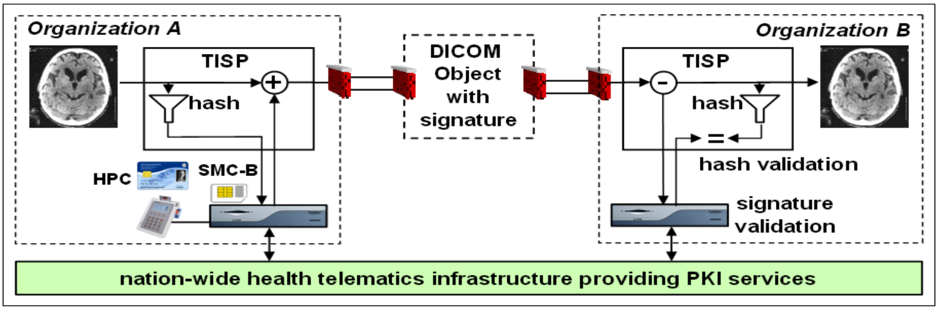

Figure 4. End-to-end authentication using a hybrid method

The TISP receives DICOM objects, calculates a hash, manages the digital signature of this hash via the PKI and inserts the signature information in the DICOM object prior to transmission. At the receiving site the TISP verifies the signature by using the PKI.

3. Results

e-Health Service delivery has to take the business perspective into account. This has been accomplished by adding a fourth layer to an existing three layer model for the management of IT systems. Splitting the responsibilities between the fourth layer and the IT-system layers (outsourced to an independent service provider) has resulted in a sustainable e-Health Service with the infrastructure costs being shared by 15 hospitals and 2 practices. In a previous experience where all layers had been under control of one large hospital this had lead to an enforcement of centralized collaboration. In contrast, this split approach has motivated significant mutual collaboration between all partners with each partner benefiting from the flexible and highly available infrastructure. The exchange of about 1500 studies and 50000 images per month confirm this approach.

4. Discussion

Authenticating DICOM objects has been done previously [11] and DICOM supports signatures by a supplement [12]. However, providing a generic approach using the TISP in combination with a nation-wide PKI is a step forward and can easily be extended to non DICOM document types, e.g. reports and referral letters with an even stronger request for authentication, when compared to DICOM images.

Even though services like the TISP and TR-DIN have to operate at the organizations' site for allowing end-to-end authentication and quality control, they can be easily integrated in an IT environment. As such, they contribute significantly to the stated availability and the business continuity requirements.

The concept of using a DICOM Forward service as central dispatcher for teleradiology confines administration and maintenance to one place. From the viewpoint of an organization the DICOM Forward concept avoids the installation of specific software or hardware, a direct link to the existing PACS / RIS is sufficient. This allows the users to work with their known and accepted applications. DICOM email [13] could be used comparable, but the partition of images into emails appears to be less suited for an immediate online consultation or remotely supervised examination.

The central infrastructure is a logical consequence of the shared responsibility developed for e-Health service delivery. Adding a business perspective to the 3LGM² reflects the relevance of organizational and economical issues in e-Health services. In a more formal way, the Generic Component Model (CGM) [14] addresses business concepts at its top layer. With the CGM being more focused on architectural perspectives it provides a more detailed approach using three dimensions (RM-ODP compliant views for system design on a second axis and representing different domains on a third axis). As such the proposed structure correlates to mainly a column in the GCM.

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