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A teleradiology concept for entire Greenland

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Abstract. The goal of this project was to plan and establish a teleradiology network to include all hospitals on the island of Greenland, consisting of 15 district hospitals and one central hospital (Queen Ingrid's Hospital) in the capital city of Nuuk. All medical images produced in Greenland should be stored in a central PACS where they can be accessed by all district hospitals. An existing HIS/RIS system should be integrated with the PACS, so that medical users can access, display and process images via a link in the electronic patient record. The paper describes the applied technologies and the final software architecture of that network.

Keywords: Teleradiology; PACS; HIS; RIS; CHILI; Telemedicine

1. Introduction

Greenland is part of the Kingdom of Denmark and, covering an area of 2.1 million square kilometres, is the largest island in the world. More than 85% of its territory is covered by an ice cap. The population of approximately 55,000 lives in 18 towns and some 60 settlements, mainly along the ice-free rim of the coastline [1]. 14,000 residents live in the capital, Nuuk. Greenland's territory is divided into 16 healthcare districts. Queen Ingrid's Hospital in Nuuk is the national hospital and has about 150 beds and numerous associated specialist physicians [2].

Each health district has a healthcare centre (district hospital) with one or more physicians, nurses and other healthcare personnel and is responsible for primary healthcare in towns, villages and other small settlements. The centres have a number of in-patient beds proportional to the number of people in the health district. People with more complicated illnesses are referred to Queen Ingrid's Hospital in Nuuk or for specialised treatment in Denmark [2].

No roads or railways connect the towns and settlements of Greenland. As a result, dogsleds and kayaks were the main transport means in the past. Transport by sea is possible from spring to autumn, but not during winter as the sea is then frozen, prohibiting transport by sea. Helicopters and planes are used nowadays.

All towns and the vast majority of smaller settlements in Greenland are linked by telecommunications, either by radio link or by satellite. The network bandwidth varies between 128 and 2.048 kbit/s. The network is relatively unreliable due to the climatic conditions (heavy snow storms) and frequent power cuts.

The first telemedicine projects started in 1996 to provide teleconferencing, e-mail and other services. By 2001, more than 50% of the population of Greenland had access to telemedicine services [2] [3].

An additional challenge for Greenland is that the turnover of personnel is quite high and many of the staff are not very experienced with IT systems. Medical personnel from Denmark tend to work in Greenland for a couple of months and then return.

There are no local IT people in the district hospitals and IT companies have no subsidiaries in Greenland. A central IT team at the hospital in Nuuk has to take care of all IT installations. In case of hardware failures they have to contact the next subsidiaries of IT companies in Denmark. On-site support is not provided by any hardware supplier. As a result, a high priority request is that the hardware for a teleradiology network be as reliable as possible and that untrained personnel can replace defective hardware themselves.

The goal of this project was to plan and establish a teleradiology network to include all the hospitals in Greenland, consisting of the 15 remote district hospitals and the central national hospital (Queen Ingrid's Hospital) in the capital city of Nuuk. All medical images produced in Greenland should be stored in a central PACS where they can be accessed by each district hospital. The existing HIS/RIS should be connected to the PACS, so that medical users can access, display and process images via a link in the electronic patient record. The following sections describe the applied technologies and the final software architecture of that network.

2. Material

The objective was to connect the teleradiology network with existing IT systems or systems which were currently in the planning or installation process, such as a global hospital information system, resp. radiology information system and a central PACS server in the central Queen Ingrid's Hospital in Nuuk (all provided by Medos AG, Langenselbold, Germany). New modalities would be installed along with the establishment of the teleradiology network.

3. Methods

3.1 Global Architecture

A star-like network architecture has been created. The 15 remote district hospitals produce computed radiographs (Fuji XG-1) only. The technician sends all produced images to a local teleradiology gateway (TR-GW) using DICOM protocol. The TR-GWs are the key components in this network. They have been established from components of the CHILI Software Family (CHILI GmbH, Heidelberg, Germany) [4]. CHILI is a set of software components which can be easily configured for different application scenarios and protocols. Systems are in daily clinical use in several countries, such as Germany, Switzerland, Belgium, USA and China. CHILI supports the usage of different protocols (DICOM, HTTPS, DICOM-E-Mail, etc.) and has integrated security and failure measures. The software runs on powerful PACS servers [5] as well as on PDAs [6]. The existing software components have been adapted and expanded to the specific needs of this project.

The teleradiology network is established by a central teleradiology gateway in Queen Ingrid's Hospital in Nuuk (see Fig. 1). This gateway is connected to the central PACS and RIS which hold all image data and reports for the whole of Greenland. Greenland’s other 15 district hospitals are equipped with teleradiology gateways (TR-GW) which are connected to the central gateway. The purpose of the TR-GWs is to transmit all incoming data to the central system in Nuuk. The central gateway auto-routes all images to the existing PACS/HIS/RIS systems.

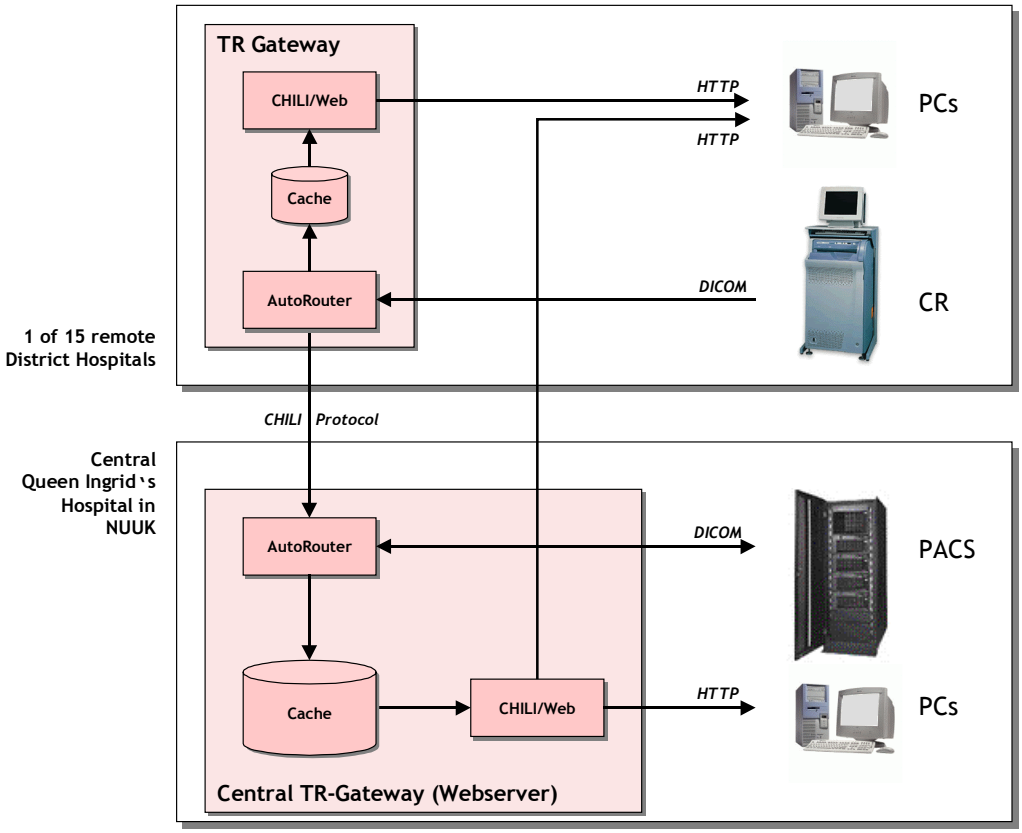

Fig. 1. (Simplified) data flow and architecture of the central and remote TR-Gateways

3.2 External Teleradiology Gateways

The external gateways (at the remote district hospitals) have several tasks. They store the locally produced images in a local cache (PostgreSQL database). If transmission to the central gateway is interrupted, the external gateways continue the interrupted transfer automatically when the network is up again. Previously transmitted images are not transmitted again. All images of a DICOM association are kept together. Furthermore, the gateway has a built-in webserver which provides all stored images to the local network in the district hospital. A Java applet is provided by the CHILI webserver which enables local PC users to display and manipulate the images. No specific software is necessary on the client PCs of the users, except support for the Java runtime environment which is also provided by the webserver [7].

If the disks of the gateway reach a certain limit of usage capacity, images are removed from the disks automatically. Specific criteria, such as the age of the study or last access can be defined. Only the image files are removed. All meta data in the database regarding the patient and report data are kept. If the user accesses a study which no longer has the image files on the local disk, these are loaded from the central teleradiology gateway in Nuuk. Even if the image files have been removed they are automatically retrieved from the central PACS via DICOM Query/Retrieve [7]. Finally, the user in the district hospital will receive and view the images in his local

environment. Associated reports can also be displayed in the Java applet of the webserver. They are fetched online from the central HIS.

3.3 Workflow

When a new study arrives at a teleradiology gateway, it retrieves the meta information of other existing studies of the same patient from the central teleradiology gateway. The image data is not transferred at this stage - only the meta data. The image data is fetched the moment a user selects the study in the database.

Because the transfer of a study can take some time, the system indicates which images are online and which are nearline. The user is informed about a request which might take several minutes and receives a message as soon as the requested study is online. This mechanism allows the authorised medical staff to access all images of a patient, no matter where in Greenland the image study has been produced.

3.4 The Central Teleradiology Gateway

The teleradiology gateway in the central hospital has the same functionality as the external gateways. With its built-in webserver it provides all images to the entire hospital. Users can access the images directly through the database interface of the webserver or through the electronic patient record which provides links to the specific image study in the context of the current patient and case.

3.5 User Authentication

User authentication is an important aspect of such a system. A central directory service (e-directory; Novell Inc.) is used by all information systems for this purpose. Local emergency accounts have been created in the event that the central e-directory is not available (e.g. network interruptions caused by heavy snow storms). Furthermore, a so-called ticket system is used to implement “single-sign-on”. This means that a ticket is passed from the HIS to the webserver which grants temporary access to a specific set of images.

3.6 System Hardware and Operating System

Special attention had to be given to fault-tolerance and easy replacement of defective parts of the hardware. Intel-based 19” rack servers (ProLiant Series, HP) with the operating system SuSE Linux Enterprise Server (SLES, Novell Inc.) have been selected for the teleradiology gateways. They are all equipped with two mirrored disks (Raid-1) and redundant power supplies. All systems are protected by an uninterruptible power supply (UPS) to protect the computers from power failures. The host performs an automatic shutdown when the UPS reports a power failure and boots automatically once the power is returned.

The disks of the gateways are mirrored with Raid-1 technology. The operation of the system is not affected if one of the two disks fails. The latter can easily be replaced by a new one by non-experts. An entire pre-configured backup system is provided in the central hospital in the event of more severe hardware breakdowns.

3.7 Measures against software and data loss

Appropriate measures have been implemented for the easy restoration of the software configuration. Mondo Rescue is used to create one or more bootable rescue CD images based on the server’s filesystem [8]. In the event of catastrophic data loss, even users with little IT background are able to restore the entire system. Changes in the configuration after the last Mondo backup are saved at several locations.

Application data, such as medical images and reports, are temporarily unavailable if a teleradiology gateway has to be re-established after a complete breakdown. But as soon as new data is created in the district hospital, the system automatically receives all meta information of existing studies of the same patient from the central teleradiology gateway, resp. the PACS/RIS behind (see section 3.3), for the user to access and display them. Another way to view older image studies is to access the central CHILI webserver directly.

4. Results

The requirements of the project have been met by a transparent DICOM communication over slow and unreliable network links. All images of a DICOM association are kept together by means of different transmission strategies and recovery procedures. Only those images which have not yet been transmitted are sent again. This protects the system against network interruptions and data loss.

All authorised users have access to all images and reports created in the entire teleradiology network of Greenland. The teleradiology solution is seamlessly integrated into the PACS/RIS systems and the user can access and display images from the context of the electronic patient record or directly via the image webserver. Single-sign-on and ticket mechanisms prevent that the user has to log into each information system separately.

Several measures in the architecture, in the hardware setup and in backup and recovery mechanisms ensure a robust system which can be recovered easily even after a severe failure.

5. Conclusion

It is possible to establish reliable blackbox solutions to transmit images and reports over unreliable networks over long distances, thus supporting medical care for people in inaccessible regions.

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