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Author(s):	Jörg Riesmeier, Marco Eichelberg (OFFIS), Jonas Punys, Vytenis Punys (KTU), Didier Lemoine (ETIAM), Nándor Balogh (CORP)
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EXECUTIVE SUMMARY

SAMTA (Open Scaleable Architecture for Multimedia Telemedicine Application) is an European Union funded research project focused on the medical field of cardiology in Central and Eastern European countries. However, the project results presented in this document in the form of guidelines and recommendations are also applicable for many rural areas in the European Union. The intention of this document is mainly to provide the basis used for and the experiences gained with the introduction of telemedical services in clinical environments of Central and Eastern European countries. For a full description of the technical results we refer to the corresponding project deliverables [1-9] and the coming final report.

The project started with an extensive analysis of user needs. Based on the results of the interviews with the physicians at the clinical validation sites in Hungary and Lithuania the services of our general tele-medicine model could be classified according to their necessity. It turned out that tele-expertise and tele-distribution are absolutely necessary whereas tele-staff-meeting, tele-diagnosis and tele-processing are services of potential future interest.¹ Therefore, we concentrated on the two most important services in the following.

The title of this project already emphasizes the importance of openness and scalability when developing software. This is especially true for medical products where the average lifetime of a system is much longer than in most other fields of application. As a consequence we have built a general architecture which allows to replace particular components or to extend the model without destroying the basic structure. This is essentially done by using standards for the different protocols as well as for the data formats. The big advantage for the medical user is a stable user interface of the application, i. e. he does not have to learn how to operate the software each time an underlying component has to be replaced due to technological development. In general, a scaleable architecture improves the safety of investment for telemedicine users when faced with an uncertain future regarding the availability and cost of network infrastructures.

Though high-speed connections will probably be available in many European countries in the next few years the communication infrastructure is nowadays mainly based on analogue and digital telephone lines. Higher level protocols like DICOM (Digital Imaging and Communications in Medicine), the de-facto standard for exchanging medical images, are typically used with local area networks, e. g. inside a hospital. When expanding the use for external communication via unreliable narrow-band networks the protocols have to be extended or other arrangements have to be made. Especially for DICOM networks we have developed a number of recommendations.

Independent of any protocol extension the amount of data should be reduced significantly before transmission because of limited bandwidth. This can be done by carefully selecting the information (especially images) which really needs to be transferred to the remote site. The other approach is to compress the images and related information using special algorithms. We have investigated both and can, therefore, recommend different solutions depending on the requirements.

To evaluate the compression schemes investigated and developed during this project in a clinical environment we have performed a compression study. The physicians from the validation sites had to capture, select and compress images with different algorithms and

¹ The telemedical services mentioned here are explained in section 2.2 of this document.

parameters. Then they had to write a diagnosis to the compressed and uncompressed images following a specific protocol.

The telemedicine application developed during this project has been extensively tested in clinical practice, locally and also for some transmission experiments between clinical partners. Based on the physician's and technician's experiences we can now specify the hardware and software requirements as well as the obstacles one should be prepared for when introducing a telemedicine product into clinical environments.

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1. INTRODUCTION

SAMTA (Open Scaleable Architecture for Multimedia Telemedicine Applications) is an European Union (EU) funded research project within the INCO-COPERNICUS programme (Project Number PL961144). According to its objectives the project is focused on the medical field of cardiology in Central and Eastern European countries but the results are also applicable for many rural areas in the EU. SAMTA has developed an open scaleable architecture for multimedia telemedicine applications allowing system designers to choose features which make appropriate use of available network bandwidth. Such a scaleable architecture improves the safety of investment for telemedicine users when faced with an uncertain future regarding the availability and cost of network infrastructures.

This document is a contribution to workpackage WP11 “SAMTA Guidelines and Contribution to the European Standardisation Bodies (CEN)”. It takes input from all other deliverables produced during project’s lifetime and summarizes the results in a form suitable for wide dissemination. It provides guidelines to developers of open scaleable telemedicine applications in the use of services, structured data transmission, standards and compression techniques. Of course, a project like SAMTA with a limited scope cannot solve the issue of “narrow-band telemedicine” in general. However, some ideas presented in the following could also be applied for other fields of application besides tele-cardiology advice request.

This document starts with an analysis of the user needs and the identification of services following from that. Based on these requirements an open scaleable architecture is developed making use of structured data transmission and standardized protocols. Since this project is focused on Eastern Europe where the telecommunication infrastructure still needs to be improved a number of extensions for narrow-band networks are proposed. After describing the innovative image compression techniques developed within this project and analyzing the use of lossy compression in clinical environments the clinical trials performed in the Hungarian and Lithuanian validation sites are evaluated. Finally, the chapter “Lessons learned” summarizes the experiences gained during the development and use of the SAMTA application.

1.1 Glossary

The following terms and abbreviations are listed and described here in order to facilitate the reading of this document:

- **ASCII:** American Standard Code for Information Interchange, a code for representing characters as numbers, with each letter assigned a number from 0 to 127. Most computers use ASCII codes to represent text, which makes it possible to transfer data from one computer to another.
- **ATM:** Asynchronous Transfer Mode, a network technology based on transferring data in cells or packets of a fixed (small) size. Current implementations of ATM support data transfer rates of 25 to 622 Mbit/s.
- **AVI:** Audio Video Interleave, a format developed by Microsoft Corporation for storing video and audio information.
- **CORBA:** Common Object Request Broker Architecture, an architecture that enables pieces of programs, called objects, to communicate with one another regardless of what programming language they were written in or what operating system they are running on.

- **dBASE:** A popular database management system originally produced by Ashton Tate Corporation. The dBASE format for storing data has become a de-facto standard, and is supported by nearly all database management and spreadsheet systems.
- **DICOM:** Digital Imaging and Communications in Medicine, de-facto standard for medical image communication defining data structures and services.
- **HISA:** Healthcare Information System Architecture, a European pre-standard where the first part describes a healthcare middleware layer for information systems.
- **ISDN:** Integrated Services Digital Network, an international communications standard for sending voice, video, and data over digital telephone lines or normal telephone wires. ISDN supports data transfer rates of 64 kbit/s per channel.
- **Java:** A high-level programming language developed by Sun Microsystems. Compiled Java code can run on most computers because Java interpreters and runtime environments, known as Java Virtual Machines, exist for most operating systems.
- **JBIG:** Joint Bi-level Image experts Group, a standard for the lossless compression of bi-level images (only black and white).
- **JPEG:** Joint Photographic Experts Group, mainly known as a lossy compression technique for color images. Although it can reduce files sizes to about 5% of their normal size, some detail is lost in the compression. Above that there is also a lossless JPEG compression which is quite different from the lossy one.
- **MJPEG:** Motion JPEG extends the “JPEG” standard by supporting videos. Each frame in the video is stored with the JPEG format.
- **MPEG:** Moving Picture Experts Group, a working group of ISO (International Organization for Standardization). The term also refers to the family of digital video compression standards and file formats developed by the group.
- **OSI:** Open System Interconnection, an ISO standard for worldwide communications that defines a networking framework for implementing protocols in seven layers. Control is passed from one layer to the next, starting at the application layer in one station, proceeding to the bottom layer, over the channel to the next station and back up the hierarchy. OSI is also referred to as the OSI Reference Model or just the OSI Model.
- **PAL:** Phase Alternating Line, the dominant television standard in Europe.
- **Patient:** the patient, present or not during the session, anonymous or not, that is under examination during a telemedicine session, whatever the service is.
- **P-Platform:** the set of technical / medical / networks devices available in the telemedicine room located in the clinical site in charge of the “Patient”.
- **Prepared data:** for being used during a telemedicine service, some process may be performed on data before transmitting them from the “P-Station” to the “R-Station” (making them anonymous, etc.).
- **P-Station:** the station that is used during a telemedicine service. This station (PC, UNIX workstation, etc.) is able to retrieve from the local information sources (removable media, intranet, LAN) all necessary Patient information that may be transmitted to the R-Station. The P-Station is part of the “P-Platform”.
- **P-User:** the user of the “P-Platform”, whoever he is: referring physician, nurse or more generally the medical staff locally in charge of the patient, or the “Patient” himself.

- **ROI:** Region Of Interest, a region in the image the attention of the observer should be drawn to.
- **R-Platform:** the set of technical / medical / networks devices available in the telemedicine room located in the remote site concerned by the Patient during the telemedicine session.
- **R-Station:** the station that is used during a telemedicine service. This station (PC, UNIX workstation, etc.) is able to received all necessary Patient information that may be transmitted from the “P-Station”. The R-Station is part of the “R-Platform”.
- **R-User:** the user of the “R-Platform”, whoever he is: referred physician, nurse or more generally the medical staff remotely located and concerned by the patient case during the telemedicine session.
- **SSH:** Developed by SSH Communications Security Ltd., Secure Shell is a program to log into another computer over a network, to execute commands in a remote machine, and to move files from one machine to another. It provides strong authentication and secure communications over insecure channels.
- **TCP/IP:** Transmission Control Protocol / Internet Protocol, one of the main protocols in TCP/IP networks. Whereas the IP protocol deals only with packets, TCP enables two hosts to establish a connection and exchange streams of data. TCP guarantees delivery of data and also guarantees that packets will be delivered in the same order in which they were sent.
- **TLS:** “SSL” has been submitted as a draft standard to the Internet Engineering Task Force (IETF), as the Transport Layer Security (TLS) protocol.
- **UML:** Unified Modeling Language, a general-purpose notational language for specifying and visualizing complex software, especially large, object-oriented projects. UML builds on previous notational methods such as Booch, OMT, and OOSE.

2. USER REQUIREMENTS

2.1 Analysis of user needs

The extensive analysis of user needs has been performed at the beginning of the SAMTA project. The results have been presented in the corresponding deliverable D02.1 “Recommendations for open scaleable telemedicine services” [1]. Therefore, only the key concepts are highlighted and the guidelines are given below.

According to our experience the effective way to ensure the openness and the scaleability of the tele-medical system (and especially the stability of the user interface) is to apply the structured approach from the very beginning.

After defining the scope of the application based on the medicine domain the services might be classified in different cross-sections:

- application layers² (medical, technical and physical),
- implementation order (necessary services, services of potential future interest and other services).

The telemedicine service model (general scenario) has to cover all necessary services and services of potential future interest at all application layers.

For example the model in cardiac imaging was supposed to have the following stages (necessary services: tele-expertise and tele-distribution; services of potential future interest: tele-staff-meeting, tele-diagnosis, tele-processing):

- Preparation – answering some questions in advance,
- Connection establishment (directly expressed for on-line sessions),
- General comments on the problem (a question, a topic for discussion),
- Request for data / Priorities for data (this phase might be unnecessary sometimes),
- Medical data transmission,
- Sequential reply / Interaction,
- Input to form a common opinion,
- Conclusion.

This model should be developed.

Most of considered services usually are essential:

- medical (e. g. patient registration, information overview and browsing, data processing, annotation and reporting, etc.),
- technical (e. g. authentication, data security, data transmission, integration with information systems, logging, etc.) and
- physical (networking connections and protocols used).

However, we would recommend to give more attention to *some* of them.

The scaleability of application across the defined network scale has to be ensured. In the SAMTA case it was from “off-line, very low bandwidth” and “on-line, very low bandwidth” up to “on-line, very high bandwidth”. Therefore, some services should be prepared to be used adaptively. These are:

² Application layers are explained in more detail in the section 3.1.

- medical services: data package preparation, data package transmission, cooperative work;
- technical services: dynamical selection of data compression (e. g. use computer resources intensively to compress data and to save transmission time over very low bandwidth network; data compression might not be used in case of very high bandwidth network when transmission time is negligible).

To support adaptivity a special technical service should be introduced for tracking the data exchange speed and evaluating which medical services are available in what extent. Essentially, the network exchange protocol is recommended to remain the same for the whole network scale.

Another important field is the medical data security. There are special data protection / security constraints in medicine, generally depending on the category of the medical staff (i. e. nurse, technician, physician, consultant, system administrator, etc.) and personalities (e. g. a physician in charge of a patient versus a physician of the same department or a physician in general, etc.). The possibility to define and to follow such rules of data protection and security (read / append / modify) has to be foreseen.

Data anonymization is an additional constraint during the telemedicine session. Typically the R-user is supposed not to be interested in the personal details of a patient or a case under a telemedicine procedure. Therefore patient information has to be anonymised when presented for the R-user – i. e. skipped or altered in such a way that the necessary information from the medical point of view is retained.

2.2 Service identification

2.2.1 Introduction

From diagnosis to treatment, from learning to training, one may imagine all kinds of services whose only link is the medical domain. In the present paragraph, the main concern is more to cover the whole spectrum of possibilities than to go too deeply into details. Thus, the retained divisions may be discussed, it should not have an impact on the content of this document while no major class of telemedicine services has been forgotten. A more detailed description can be found in the corresponding deliverable [1].

2.2.2 Classification

Service	Description
<i>Tele-acquisition</i>	The patient may play an active role in data acquisition phase (blood tension, stethoscope, ...) and transmit them on-line or off-line to his doctor (generalist or specialist).

<i>Tele-monitoring</i>	A diagnosis device sends measures on-line (EEG ³ , ECG ⁴ , blood tension, ...) to a remote device displaying relevant information enabling the medical staff (technician, nurse, etc.) to be warned when needed. The patient plays a passive role.
<i>Tele-diagnosis</i>	A referring physician does a diagnosis remotely while a medical professional (technician, nurse, etc.) manipulates on the patient a diagnosis device transmitting measures (EEG, ECG, blood tension, ...) on-line.
<i>Tele-expertise</i>	A referred specialist helps remotely a colleague establishing a diagnosis or specifying a treatment strategy.
<i>Tele-processing</i>	A remote application performs data processing and sends back the results, under the visual control of an expert.
<i>Tele-surgery</i>	A surgeon performs remotely a surgical act using robotics, assisted by a surgeon present in the operating room able to intervene if required.
<i>Tele-staff-meeting</i>	A meeting of medical professionals (nurses, physicians) located at at least two remote sites having in charge the same patients all along the therapy process and discussing diagnosis or treatment strategies.
<i>Tele-teaching</i>	A course is given by a professor to students located in one or several sites, using video-conference facilities and an application dedicated to the medical domain.
<i>Tele-access to databases, protocols, ...</i>	An access to dedicated databases, guidelines, etc. is given in order to retrieve desired information available from a remote server. It may help concluding a diagnosis, defining a treatment strategy, using a new protocol, etc.
<i>Tele-distribution</i>	A set of medical information is sent by telecommunications to a remote site (outside the local network) without medical feedback.

2.2.3 Data generated and conveyed

In the following paragraph, “off-line” and “on-line” terms qualify the availability and the production of the information packages. Different packages may have more or less the same content but nevertheless must be considered as different data packages. It depends on when data is produced with reference to the telemedicine session.

The presentation of the different information packages identified in this chapter aims to be exhaustive. One does understand that each telemedicine service as defined above does not necessarily include all of these packages.

³ Electroencephalogram

⁴ Electrocardiogram

Off-line Predated Patient Data [OF-PPD]

Off-line Predated Patient Data consist of an heterogeneous package of multimedia information concerning the Patient, acquired and retrieved before the telemedicine session, whatever it is. This heterogeneous information comes from administrative information systems (Hospital and Department Information Systems), patient examinations (anatomical, functional and other investigation devices) and the medical history of the patient.

In an ideal case, this information may be pushed or retrieved from the local network. In many cases a digitization phase should be needed since most relevant information is still stored as paper or film documents. It is dedicated to serve as background information that will be formatted and augmented by additional information by the P-User to present the patient's case to the R-User.

This information, once prepared, is always transmitted from the P-Station to the R-Station.

On-line Patient Investigation Data [ON-PIVD]

On-line Patient Investigation Data consist of investigation information (produced by an investigation device for diagnosis purpose) concerning the Patient, acquired and transmitted on-line during the telemedicine session, whatever it is. This information may come from different investigation sources (image, functional signal or other investigation device).

This information, prepared or not is always transmitted on-line from the P-Station to the R-Station.

On-line Patient Intervention Data [ON-PITD]

On-line Patient Intervention Data consist of intervention information (produced by an intervention device – surgery / endoscopy / radiology) on the Patient, acquired and transmitted on-line during the telemedicine session, whatever it is. This information may come from different treatment sources:

- camera (P-Station ↔ R-Station)
- surgical device feedback (P-Station ↔ R-Station)
- surgical device control (R-Station ↔ P-Station)

On-line Video-Conference Data [ON-VCD]

On-line Video-Conference Data are at least audio / video information generated during the telemedicine session. This information may be augmented by application data enabling to send commands to the audio/video devices: switch on/off, selection of the current microphone / camera, orientation and focus, etc.

Service Application Data [SAD]

Service Application Data are dedicated to the session. They are divided into three parts:

- Off-line Service Application P-Data
- On-line Service Application Data
- Off-line Service Application R-Data

Off-line Service Application P-Data [OF-SAPD]

Off-line Service Application P-Data are generated off-line by the P-User in order to prepare a session, using the dedicated application. They are built using the Predated Patient Data (background patient information). It consists in the relevant information that shall help the P-User to present the Patient's case to the R-User: oral comments, links on data, ROIs on images. The result is an information package that may be digested by the remote application to help the R-User to have a quick overview of the case.

On-line Service Application Data [ON-SAD]

On-line Service Application Data are generated through application user interfaces and exchanged by application on-line during the session. It may be understood as an on-line extension of Off-line Service Application Data since the information generated is of same order.

Off-line Service Application R-Data [OF-SARD]

Off-line Service Application R-Data are generated off-line by the R-User in order to conclude a session, using the dedicated application. The information generated is of same order of Off-line Service Application Data.

2.3 Communication of data streams in telemedicine services

2.3.1 Introduction

A telemedicine service cannot simply be stamped as on-line or off-line service. Only a few of them are fully on-line or off-line services: a full on-line service means that the whole information exchanged between the two sites whatever it is (images, texts, video-conference data streams, etc.) is done during the session.

2.4 Scope of the present study

2.4.1 Introduction

The main objective of this workpackage is to evaluate how the current standards existing or emergent in different domains such as Multimedia & Information Technology, Computer Sciences in Healthcare fit the requirements in terms of interoperability of the different types of services in the emergent Telemedicine domain. Trying to make an exhaustive assessment is out of the scope of this study. The retained approach is to try making some trials on a few services selected in the restrained domain (though large enough) of cardiology.

2.4.2 Subset of services retained in the present study

As stated in section 1 of this chapter, the following services were retained in the present study:

- Tele-expertise
- Tele-distribution

2.4.3 Specification of the data generated and conveyed

Data Stream Service	OF-PPD ⁵	ON-PIVD ⁶	ON-VCD ⁷	OF-SAPD ⁸	ON-SAD ⁹	OF-SARD ¹⁰
<i>Tele-expertise</i>	Off-/In-session	–	In-session	Off-/In-session	In-session	Off-/In-session
<i>Tele-distribution</i>	Off-session	In-session	–	–	–	–

⁵ Off-line Predated Patient Data.

⁶ On-line Patient Investigation Data.

⁷ On-line Video-Conference Data.

⁸ Off-line Service Application P-Data.

⁹ On-line Service Application Data.

¹⁰ Off-line Service Application R-Data.

3. ARCHITECTURE AND PROTOCOLS

3.1 Open scalable architecture

3.1.1 Introduction

Based on the analysis of user needs and the identification of services described in the previous chapter we have built a general application architecture fulfilling the requirements of openness and scalability. In the following we will only describe the basic principle of our approach, the complete description can be found in deliverable D02.1 “Recommendations for open scalable telemedicine services” [1]. The work has also been published in the proceedings of some medical informatics conferences, e. g. [10].

The main problem of large software systems is that they grow gradually over the years. It is very seldom that they are developed completely in one part. This is especially true for the medical field. Therefore, it often happens that new applications or functionalities have to be integrated into an existing system. But the architecture of the whole system cannot be changed every time. A stable architecture based on openness and scalability is required.

Openness combines a variety of aspects, but requires always the independence from any particular system. This is done by the intensive use of existing standards guaranteeing interoperability. Scalability means that the global behavior of a system is not affected by the substitution of one of its components or the integration of a new component, while the global efficiency in terms of quality of services and number of available services may be modified. In summary openness is together with scalability a guarantor for a long lifetime of a system and should therefore be mandatory when developing software architecture.

3.1.2 Approach

The basic idea of our concept is to differentiate three main levels of abstraction: reference model, architecture and implementation. We consider architecture as a specialization of the reference model and the implementation as a specialization of the architecture. The separation of reference model and architecture is very useful to compare different systems with different architectures (even from different domains) under the same reference model (see OSI model [15]).

Furthermore we recommend to use multiple views describing different aspects to express an architecture. HISA (Healthcare Information System Architecture) [16] combines this concept with different levels of abstraction. It introduces, therefore, a so-called specification framework in pyramid form where the two axes are level of abstraction (strategic, conceptual, logical and physical) and view (enterprise, structural, functional, engineering and technological). So each combination (given by the coordinates of the two axes) forms another view with another level of abstraction, though not every combination has to be examined.

To organize a system based on network communication we recommend to introduce a layered structure similar to OSI. One of the basic principles of layered structures is the hiding of information, i. e. the functionality of upper layers mainly consists of the functionality of one or more lower layers. In this vertical communication the upper one is the service user and the lower one the service provider, i. e. the upper service “uses” the lower service. But there are also horizontal communications between services of the same kind within the same layer.

For the SAMTA architecture we propose three different layers (similar to those used in HISA): Medical Services Layer, Technical Services Layer and Physical Services Layer. The medical services are those offered to the user (typically a physician). Each service corresponds to one or more operations in the real world. Recurrent operations and work flows can be combined to profiles or scenarios, e. g. “second opinion”. The technical services result from the requirements of the medical services. They offer basic operations used by several medical services. Most of them are generic and not specific to the medical field. The physical services provide the structures, protocols and services used by the technical services. They are very close to the supported hardware (e. g. network structure) and form an interface between the application and the environment (hardware and software).

Figure 3.1 shows a combination of the introduced concept of different levels of abstraction (horizontal axis) with the proposed layered structure (vertical axis):

	Reference Model	Architecture	Implementation	
Medical Services	RM	AM	IM	Complexity ↑ ← Abstraction
Technical Services	RT	AT	IT	
Physical Services	RP	AP	IP	

Figure 3.1: Architectural model

3.1.3 Tools

The available technologies for architectural purposes can be divided into two groups: development or design tools and methods to integrate new services or applications into a heterogeneous environment. The first group consists of a variety of (mostly graphical) CASE (Computer Aided Software Engineering) tools supporting the developing progress. We strongly recommend to use a general-purpose notational language like UML [17], which is predestined for specifying and visualizing complex software, especially large, object-oriented systems.

The integration work could be done by common solutions for middleware layers and distributed objects like CORBA [18] which provides techniques to build platform independent software interfaces and communicate with remote objects. The great advantage is that it is even possible to build interfaces for existing applications regardless what programming language has been used.

3.2 Structured data transmission

3.2.1 Introduction

As the title of the project (Open Scaleable Architecture for Multimedia Telemedicine Applications) indicates we are focusing more on multimedia issues, although the medical community have not solved well the conventional verbal (free text / words, numbers or structured text based, voice) medical electronic telecommunications yet.

We know in medicine that “an image worth 1000 words” and in cardiology, that we are focusing on during our project, an image sequence (selected clips) of the pumping heart may worth even more. However, most of the decisions of clinicians are based on written (signed)

text-based reports coming from colleagues – including reports from imaging diagnostic service centres.

The communication of medical images cannot be separated from the communication of patient related data (e. g. cath-lab reports, ultrasound reports, discharge reports). In fact usually doctors starting with these (patient identification and demographic data), including the alphanumeric description of the findings on the image. The image supports their opinions or dilemmas as the basis of those findings. The whole history of the paper-based and electronic patient record keeping, results reporting and hospital discharge letters reflects the problem of information entry and presentation in textual form.

How to structure data, how much coding versus free text? According to our experiences clinicians need some text based and/or graphical comments and/or annotations together with the images / clips, as usually they need more specialised expertise to understand an image / clip (that they might see more easily now using information technology), than to understand a verbal (written or spoken) text about their meaning. Even the diagnostic experts of the same image diagnostic discipline (e. g. ultrasonographers, angiographers) need some description about related predated and preprocedure clinical data, the circumstances how images were taken, about their procedure products (images / clips), about their statements or conclusions relating to images (in case of result reporting) or about their questions (in case of consultancy or second opinion).

A more detailed description can be found in the corresponding deliverable D03.1 “Recommendations for medical structured data transmission in CEC/NIS¹¹ countries” [2]. The work has also been published in the proceedings of some medical informatics conferences, e. g. [11].

3.2.2 Structured data formats

A multitude of data formats for the transmission of such “structured data” exist, including industry standards (e. g. in Hungary “tagged” ASCII, MS Word DOC, dBASE texts and memos, etc., are mostly used today), open standards for structured text (e. g. SGML [29], HTML [31]) and specialised “medical” standards (EDIFACT [30] in Europe, HL7 [37] in the United States, and DICOM [13] worldwide). We analysed the suitability of existing standards and promising newcomers like XML [32] and SMIL [33] for structured multimedia data transmission for the requirements of cardiology in the CEC/NIS countries.

Our experience is, that the freedom of clinicians in describing their opinion and suggestions make the situation colorful even in one hospital, not to mention countywide, countrywide or international situation. In general, reporting clinicians may be totally *free to use* any format for the report. Similarly they may be free to use whatever terms they choose.

There are many reasons for the use of *structured reporting*. The structuring introduces a systematization, which contributes to the quality and completeness of the interpretation. The use of *codes* allows a homogenous understanding of information items and facilitates computer processing of the report for many purposes. However, structured reporting must be used carefully. Semiological descriptions are sometimes hard to codify. If badly used, structured reporting may be counter-productive, by severely limiting the reporting clinicians power of expression. In some cases, the report sent to the requester may include a structured interpretation. In other cases, it may only be a tool to record the interpretation for use within the department, this structured interpretation being translated into a conventional textual report to be sent to the Requester.

¹¹ Central European Countries / Newly Independent States

It seems that there is *no universal solution for classification and coding*. In both Hungary and Lithuania International Classification of Diseases (ICD-10) [38] coding is mandatory for reimbursement and practically this is the only mandatory structured system there. It is not detailed enough for clinical use at specialist (tertiary) centres. SNOMED [36] – although it is a multi-axis scheme that clinically detailed and satisfying- used mainly by the pathologists, as it is not totally match cardiologist's classification. Clinical based REED codes are widely used in England. It started as a disease-coding scheme, but the latest version practically tries to describe the whole electronic patient record. The American College of Cardiology (ACC) carried out (concerning cardiology) the most effort on content standardization for the purpose of computerization. They have published several datasets including heart catheterization / angiography but not for ultrasound yet.

3.2.4 Approach

In spite of these severe difficulties in SAMTA project *we described*:

- *The logical structure or CONTENT* (data fields and their sequences) for the selected two types of Cardiac Diagnostic Service Centres (ultrasound and angio), the structured clinical datasets to be used there during our demonstration in telemedicine.
- *The physical structure or FORMAT* conventions and standards might be used for the above content during tele-working.

We have concluded that if you want to do tele-reporting XML, SMIL and/or DICOM Structured Report [14] are good solutions, but for tele-consultancy use DICOM Structured Report, as it became a standard recently (that is why we have no experience implementing it).

3.3 Standardized protocols (review of encoding syntaxes)

3.3.1 Introduction

The scope of this review is restrained to the telemedicine services defined in 2.4.2. The characterization of the data is focused on their use in the frame of these services and should not be generalised.

3.3.2 Data bundling

In both tele-expertise and tele-distribution services, a special attention must be paid to the way the data are linked and presented by the P-User (or P-Station in automatic procedures) to the R-User (R-Station). In asynchronous phases of a telemedicine sessions (preventing the P-User and the R-User to discuss and to explain one to each other how to deal with the information received) the information exchanged between the two applications may appear huge and complex. The data characterization helps describing each data stream that may be considered as multimedia information packages transferred during or off the session. The way this information is organized is in some way as important as the information itself because it helps understanding the clinical context of the whole multimedia message. For instance, some audio comments should be listened to while looking at this particular image or the textual report concerning an examination from which the image was selected, etc. Some standards are currently under study by the healthcare community to evaluate the promising possibilities offered:

- SGML (Standard Generalized Markup Language) [29]
- HTML (Hyper Text Markup Language) [31]

- XML (Extensible Markup Language) [32]
- SMIL (Synchronized Multimedia Integration Language) [33]
- DOM (Document Object Model) [34,35]

At date, XML is already adopted by the healthcare community providing a powerful, flexible format for expressing data and ensuring a basic level of interoperability between applications that manipulate structured information independently of the underlying semantics.

3.4 Review of Transmission Protocols

3.4.1 Introduction

The scope of the review of transmission protocols is focused only on the services identified in chapter 2 of the present document as the services that should be tested in SAMTA.

Quality of Service (QoS) Considerations

Two aspects should be taken under consideration:

1. QoS concerning the network availability and the adequacy with the network service offered.
2. QoS concerning security aspects:
 - Encryption
 - Medical information access control
 - Tractability

Regulations

Because telemedicine is an emergent technology, health national policies in Europe (inside European Community and Eastern Europe) have not yet adapted all the required regulation enabling a full usage of telemedicine. Concerning tele-expertise and tele-distribution in the frame of SAMTA trials, the following attitude was recommended:

- ensuring the confidentiality of the patient information conveyed on the network;
- keeping a trace of the information exchanged:
 - information transmitted;
 - information received;

Since SAMTA is not focused on data protection the integration of security by means of technical facilities is very limited. Other projects might take it more into account – especially when required by legal regulations in the participating countries.

3.4.2 Services requirements

The table in section 2.4.1 gives information on the required services to perform tele-expertise and tele-distribution services. While tele-distribution is essentially performed out of any emergency context, time in tele-expertise practice may sometimes be much more important; a case may be urgent even if it is not a question of seconds. Anyway, the limits of the retained or available technology to set up such services should be identified (bandwidth required / available, service on-line / off-line, etc.).

Point-to-point connection

A point-to-point connection allows to easily set up a cooperative session. Tele-expertise may necessitate a cooperative phase, depending on the medical case. The acceptability of the cooperative application by the two physicians highly depends on the quality of the service offered. The available bandwidth has a direct impact on this degree of quality. It could be divided into two data streams: ON-VCD and ON-SAD. Since the users may communicate by telephone while using the application, the highest priority should be given to ON-SAD data streams and ON-VCD should be allowed only if it does not decrease the quality of the cooperative session.

From N-ISDN (< 1 Mbit/s) to B-ISDN (#N Mbit/s) the ratio (bandwidth required / price) as well as the technology locally available are two major parameters to specify the level of the application. However, the core of the application including the cooperative feature built upon TCP/IP should not be modified (scaleable oriented architecture).

Internet

Internet combines advantages and disadvantages due to the recent emergence of this telecommunication technology, yesterday restricted to the academic research. This technology could be a good candidate for exchanging data before or after a SAMTA session including a cooperative session. A good point in favor of such a solution is that one does not need to set up an expensive infrastructure to use it. However, some limitation exists and must be taken into account:

- when data are sent by e-mail, there is no guarantee that they will be received or received in time (< 24 hours).
- at the reception side the data are stored locally by the internet provider. The memory size available is itself limited (# 1 MBytes)

It is possible to plan cooperative sessions on the Web but it is more reasonable to keep it in mind as a solution for future evolution than as a solution for today. The main issue is that an Internet provider does not always provide a permanent internet address to each customer but a temporary one each time the customer is connected (same problem as in telephony). It is necessary to interrogate a third server from both sides to establish a temporary point to point connection (as an example, the MS Windows application NetMeeting implementing the T.120 [25] protocol uses the so-called "ils" servers enabling to connect to remote stations). Once this is done, the problem of bandwidth usually limited by the telephony technology prevents for thinking of such a solution for cooperative sessions.

3.5 Review of Cooperative Protocols

3.5.1 Introduction

Cooperative protocols exist but are not well adapted to fulfill the specific requirements of telemedicine session. There is no attempt to extend DICOM for developing cooperative applications using still / dynamic medical images. The ITU-T T.120 suite which consist of a series of recommendations is not able to ensure interoperability between applications because it is more a family of protocols stacks than a standard. And even so, it is not directly applicable to the medical field (not white board oriented, the video may be used to see the correspondent as well as to display dynamic medical images coming from the video output of an investigation device, e. g. ultrasound device, etc.).

At a lower level, some standards allow to develop cooperative applications above IP. The UNIX operating systems (COSE, Common Open Software Environment) acknowledges ToolTalk as standard (available on most UNIX systems). However, ToolTalk is not a solution for PC platforms (e. g. MS Windows).

Java is the most general solution since it offers the facilities to develop cooperative solutions (the Listener mechanism).

3.5.2 Off-line stages

Cooperative may be off-line, enabling the P-User to present a patient's case, using the facilities of cooperative feature of the application. The asynchronous mechanism should allow to store in a file the application interactive events. This file may be sent by one User to the other who can "re-play" the presentation (ON-SAD converted as OF-SAPD before the session or OF-SARD after the session). One major issue is to be able to ensure the synchronization of the events (displaying an image while speaking) when the hardware does not allow the development of "real" real-time applications.

3.5.3 On-line stages

The cooperative application should be symmetric because a master/slave approach is not well accepted by the users. The required bandwidth is approximately 0.5 Mbit/s for ON-SAD streams (see RETAIN deliverables, TEN-IBC B1012-3012).

3.6 Adequacy (telemedicine service vs. encoding protocols vs. compression standards vs. available bandwidth)

3.6.1 Introduction

The two services implemented in SAMTA project were tele-distribution and tele-expertise. Tele-distribution is a very simple application from a functional point of view. It may be manual or automatic (adding automatic routing facilities). Using a Web technology, the limitation is mainly due to the memory space available on the internet provider server. Anyway, in all cases, the compression issue is of major importance. The tele-distribution service may be specified in terms of characterization and amount of information to transmit. The choice of the most adapted compression algorithm depends on these specifications.

3.6.2 Comparision

The tele-expertise level of service may be scaleable. However, it is not a continuous phenomena. The following table describes the possible evolution of the application:

Data Stream Services	OF-PPD¹²	ON-PIVD¹³	ON-VCD¹⁴	OF-SAPD¹⁵	ON-SAD¹⁶	OF-SARD¹⁷
<i>Tele-expertise</i>	<ul style="list-style-type: none"> - no dynamic images - dynamic images with lossy compression - dynamic images with lossless comp. 	-	<ul style="list-style-type: none"> - low quality video only - low quality audio/video¹⁸ - high quality video - high quality audio/video 	no limitation	<ul style="list-style-type: none"> - not possible - possible 	no limitation
<i>Tele-distribution</i>	<ul style="list-style-type: none"> - no dynamic images - dynamic images with lossy compr. - dynamic images with lossless compression 	<ul style="list-style-type: none"> - dynamic images with lossy compression - dynamic images with lossless compression 	-	-	-	-

The trials that have been performed in the scope of SAMTA project helped determining the constraints (minimum bandwidth required, loss rate, etc.) corresponding to each level of quality of service (higher from bottom to top in each case).

¹² Off-line Predated Patient Data.

¹³ On-line Patient Investigation Data.

¹⁴ On-line Video-Conference Data.

¹⁵ Off-line Service Application P-Data.

¹⁶ On-line Service Application Data.

¹⁷ Off-line Service Application R-Data.

¹⁸ If it is not possible to use another telephone line.

3.7 Extensions for narrow-band networks

3.7.1 Introduction

DICOM (Digital Imaging and Communications in Medicine) [13] is today's de-facto standard for exchanging medical images between devices from different vendors. Current acquisition devices produce large amounts of image data which causes also the average size of DICOM data sets to increase more and more. Since the goal of this project is to define a scaleable architecture for telemedicine applications with a special focus on narrow-band networks DICOM's suitability for such purposes has been examined and possible extensions to the standard have been proposed in deliverable D06.1 "Recommendations for an extension of MEDICOM/DICOM for narrow-band networks" [5]. The work has also been published in the proceedings of some medical informatics conferences, e. g. [12].

3.7.2 Current situation

The DICOM standard itself does not define physical requirements for the underlying network. Nothing is said about the bandwidth or stability of network connections. The DICOM protocol just requires a reliable transport connection (e. g. TCP/IP [19]) between the two communication partners. The standard already supports various compression algorithms to reduce the size of large images, but compression was not defined under special consideration of narrow-band networks. Therefore, it makes sense to investigate whether there are any potential enhancements that could improve this situation. In particular, objects with large amounts of non-pixel data promise good results, because this textual information remains completely uncompressed in the current version of the standard. New DICOM objects containing only non-pixel data are e. g. Structured Reporting, Softcopy Presentation States and Waveforms.

In telemedical applications typically a report and only a few (key) images which are diagnostically relevant are transferred on-line. To leave out unnecessary images is, of course, the most effective compression technique, especially when the network bandwidth is very limited. DICOM allows to store and reference different elements in the new Structured Reporting objects and, therefore, enables the exchange in a standardized manner.

3.7.3 Recommendations

We have extracted a short list of implementable recommendations from the experimental results performed within the corresponding workpackage. In our opinion the following six extensions promise best improvements with justifiable effort:

1. A transparent "compression layer" should be integrated into the protocol stack to reduce the total amount of data transferred via the narrow-band network. Especially DICOM objects with large non-pixel portions would profit from it. Currently SSH [20,21] would be a good "ready-to-use" solution because the integration of a compression algorithm is already specified with the Z-lib [39] support. In long term TLS [22] should be used instead because of its flexibility and standardization.
2. At present image data represent the biggest part of DICOM data sets. New image compression schemes introduced into DICOM in an open way would facilitate the effective use of available network bandwidth. Possible candidates would be segmentation as a pre-processing technique for any further compression, and other innovative schemes

like wavelet compression, MPEG [27,28], etc. Parts of new JPEG2000 [26] compression schemes will most probably be integrated into DICOM.

3. Currently DICOM specifies no compression for overlay plane data at all. We propose to introduce a JBIG [23] compression similar to the JPEG [24] compression of pixel data which is already specified in the standard. Of course, the improvements achieved by this extension strongly depend on the use of overlay planes in “real-world” DICOM objects.
4. In cases not only images are exchanged image and context information should be separated and a (structured) report referencing only the relevant (key) images should be transferred. This reflects the fact that in most cases only a small number of acquired images is really necessary for the diagnosis. The emerging DICOM Structured Reporting (SR) provides such facilities besides others. Since there are no experiences with SR in practice up to now nobody knows whether this approach will be successful.
5. Especially for the use of unstable network connections and the transmission of very large DICOM objects (e. g. multi-frame) we recommend to introduce a “re-get” functionality as part of an extended storage and query/retrieve service. After a break-down the transmission of the last object would not need to be restarted but could be resumed with the last not completely transferred data packet instead.
6. Finally, the compression ratio of the algorithms used and the effort put into compression (e. g. none, only on transport layer, additional measures like JBIG or a re-ordering of data elements) should be adaptable automatically. This could be done by introducing a means of monitoring the current overall time needed for compression, transmission and decompression. In particular for connections with changing bandwidths it is important that the available bandwidth is used as good as possible.

Most of these recommendations do not necessarily require an extension of the DICOM data structures or network services. Number 1, 5 and 6 can be integrated transparently by extending the underlying network protocols. Number 4 requires the support of the involved applications but can be implemented with the current DICOM structures.

Other more sophisticated extensions as described in deliverable D06.1 could be added or used instead. The choice from the list of extensions depends on the particular situation and the effort one would spend to improve the use of the existing conditions.

4. IMAGE COMPRESSION AND ANALYSIS

4.1 Innovative image compression techniques

An image compression should be used in order to save data transmission time over low and very low bandwidth networks. However, the most popular image compression schemes have already been defined in DICOM (lossless and lossy JPEG [24]). They are not sufficient in the sense of compression ratio achieved at the selected image quality for all cases.

Two ways and the corresponding algorithms have been suggested to improve the situation (see deliverable D04.1 “Innovative medical image compression techniques” [3]). They are very similar to the approach that is going to be used in the upcoming standard JPEG2000 [26].

- The compression ratio of almost any image compression scheme (lossless or lossy) could be improved by factor 1.5-2 if an image segmentation is applied before the compression. Most of diagnostic medical images contain two sort of information: diagnostic and overlaid (patient name, examination date and time, etc.). For example the removal of overlaid information from secondary captured B-mode ultrasound image enables to improve compression ratio approximately twice, as the useful field of view covers about 40-60% of the image. This technique is compliant with existing image compression schemes.
- Higher compression ratio (approximately 2-2.5 times if compared with JPEG) could be achieved if an alternative image compression scheme based on wavelet transform (instead of DCT, discrete cosine transform, in the case of JPEG) is applied.
- There is no universal wavelet transform which could suit for all possible classes of images. We would like to recommend to use the image content complexity measure as a starting criteria for selecting an appropriate wavelet class.
- According to the experimental results for compression of angiographic and ultrasound medical images [3] we recommend to use Odegard, Villa or Antonini wavelets. Being bi-orthogonal and symmetrical, they considerably outperform well-known Daubechies wavelets (which are orthogonal but not symmetric) in this particular application area.

4.2 Lossy compression in clinical environments

It is very difficult to set-up a single protocol for ultrasound compression evaluation. Problems are varied from point-to-point ultrasound machine adjustments (gain, compress / reject, pre-processing, e. g. density correction linear or gaussoid, post-processing) varied by patients. Wall thickness determination depends on e. g. how the transducer is held.

In cardiology it is more difficult to know and capture the really important sequences in advance, “on the fly”. So after having the longer (6 sec) sequence, that includes the problem, it is useful (for the transmission) to cut the acquired sequence to those 1-2 sec loop only, that exactly shows the essence. This cutting we can call “clinical compression”, after what we can use technical compressions (and in case of ultrasound maybe starting with image segmentation first).

The most essential steps of our compression study using SAMTA application:

1. *Clinical* compression in SAMTA application: cut the most important part of the loop.
2. Preparation for *technical* compression (e. g. adjust quality factor for lossy JPEG).

3. Making lossy JPEG compression during “prepare to send” procedure.
4. Using the “image segmentation” features of SAMTA reduces the image size (geometrically) by 30% on average.

During the compression study the medical users at the validation sites performed these three or four steps for a number of ultrasound and angiography images (they have captured and selected before). Then they had to write a diagnosis to the uncompressed images as well as to the compressed images (using a given form). The latter was performed twice each time with different file names. Finally, the cross reference name table telling the physicians the relationship between the different image sets have been sent to them asking for their general opinion about compression (in free text form). The detailed compression protocol and a description on the set of test images used during the compression study are described in deliverable D10.1 “Recommendations on the use of lossy compression in clinical environments” [9].

Results from the experiments in Hungary: Average transfer times during our compression study (64 kbit/s leased lines, 10 simultaneous users/line).

File size (Kbyte)	P-Site	R-Site	Distance (km)	Time (minutes)
278	Sote Heart Clinic	Sote Heart Clinic	0	0.2
278	Sote Heart Clinic	Koranyi Heart Center	10	5.8
254	Koranyi Heart Center	Sote Heart Clinic	10	3.8
650	Sote Heart Clinic	Balatonfured Heart Hosp.	150	3.0
750	Balatonfured Heart Hosp.	Sote Heart Clinic	150	3.6

Concerning the amount of data for loops, and the low bandwidth of telecommunication channels in Central European countries, we have to use off-line preprocessing, incorporating lossy compression techniques (4:1-12:1 for angiography and 6:1-18:1 for ultrasound). This amount of lossy compression does not significantly affect the diagnostic power of the reviewers.

5. EVALUATION OF CLINICAL TRIALS

The above listed guidelines have been used as a basis for application software development. The clinical trials of two telemedicine services (tele-expertise and tele-distribution) have been performed using the software and appropriate PC hardware.

The key point of the PC configuration devoted to multimedia telemedicine applications is the random access memory (RAM). A special attention should be paid in the case of movies that are supposed to be altered or edited on the individual frame basis. The RAM should be sufficient to hold the whole sequences of frames to display (playback) them at real-time rate. For instance to play back full-frame (PAL resolution, 768×576 pixels) color (24 bits/pixel) movie with 1 or 2 seconds duration at 25 frames/sec rate one should use the Windows'95/98 PC with at least 48 or 80 Mbytes of RAM accordingly.

5.1 Hungarian demonstrator

5.1.1 Introduction

As we have described in the general architecture definition of SAMTA we will downscale the wide clinical scenario possibilities to tele-distribution (the majority of which multimedia result reporting) and to tele-expertise / tele-consultation of annotated, lossy compressed images / clips attached to verbal data in ultrasonographic and in angiographic diagnostic centres in cardiology at our demonstration sites, using narrow band telecommunication channels. This later means that diagnostic quality clips will usually be sent over the Wide Area computer Network (WAN) before the tele-consulting process and they will be replayed on both P- and R-site during tele-consultancy.

On the other hand in case of urgent consultancy, a just acceptable (lossy compressed) image sequence can be sent in 4 minutes (on average) from P-site to R-site on a 64 kbit/s, multi-used line, assuming the line is alive and our SAMTA application is running on both sides.

However, these Diagnostic Service Centres are not islands in healthcare. They are part of hospital Local Area Network (LAN, where patient demographic and preprocedure data already recorded), they communicate with their in-house departments (request / report), sometimes they do procedures for external request and part of their result reports are usually included in the general hospital discharge letter that is sent to the requesting party (another hospital, general practitioner, etc.). The image loops themselves are in different formats on different modalities. We have experienced, that in angiography, image sequences are available in digital, DICOM format either on CD ROM or on the network (Ethernet or ATM).

5.1.2 Frame grabbing

In ultrasound however we either have no digital storage of images in the scanner machine or they are in proprietary hardware, using proprietary formats. So we frame grabbed the image sequences for ultrasound from the machine's SVHS output port using PC Card. The frame grabbing process however is not easy and not easy to automate it. There are organizational and technical issues.

In our countries doctors make the ultrasound scanning. The doctor handles the scanner and the US machine's keyboard and trackball. A technician handling a computer equipped with

frame grabber card and grabbing software. The doctor indicates the start of grabbing (usually the beginning of a hart cycle) and the technician either see the end of heart cycles or programming the grabber software to grab 2-6 seconds.

5.1.3 Technical approach

We usually grabbed MJPEG AVI file 25 frames/second full PAL frames in 24 bits color depth (the latter is too much, but we had no option to decrease it). We were not accepting less quality than the regularly used SVHS tape. The US machine itself has memory to hold frames for about 2 loops. Our experiences showed that if we play back the loop from this internal memory of the US machine (rather than from the scanner directly) while we are digitizing from the SVHS output port, we have got less frame drops.

The problem with AVI files is that they are hardware dependent. It was not possible to play back (or cut) the captured files without the capture card inserted (that is on different than the capture machine). Later we have found a 3-rd party software only codec to decompress them, but it was still not very convenient solution. Because of the frame drops and of the hardware dependencies of AVI files we considered direct MPEG2 [28] capture. In spite of good quality and sizes there were 3 major problems with this solution: it is expensive, it is not integrated (capture, software only playback and especially editing) and it is not easy to integrate into our a telemedicine application.

5.1.4 Experiences

Our experience is that data preparation process (verbal, textual and image data capture) before the tele-working session should be relatively easy and as automated as possible to reach the real usage of any telemedicine system.

Alphanumeric and image import or capture, playback, cut, segmentation, compress store and send process should be used within one, integrated environment, and our SAMTA application meet this criteria. Beyond exact editing possibilities (criticized above) we can import alphanumeric (textual) data from our databases or files.

A more detailed description can be found in the corresponding deliverable D08.1 "Evaluation of the Hungary demonstrator" [7].

5.2 Lithuanian demonstrator

The selected "store and forward" approach using DICOM data exchange appeared to be successful and scaleable over wide range of network technologies (from 4.8-16.8 kbit/s dial-up analog modem connection up to 100 M bit/s fast Ethernet LAN). The performance of telemedicine services on a higher network data rates (starting from 1 Mbit/s) was acceptable.

There are some organizational suggestions in case of lower data exchange rates (especially not exceeding 64 kbit/s):

- It is recommended to use lossy compression in order to reduce transmission time. And we recommend to send only the most important (separate) frames lossless compressed, if necessary.
- In order to increase reliability and speed of a modem connection it is recommended to connect to the nearest Internet service provider (ISP) and use DICOM data exchange over encrypted virtual channel, instead of making a long-distance call.

- If tele-distribution service should be provided over low bandwidth and dial-up connections, the intermediate telemedicine server should be used. However, such a solution is not fully DICOM compatible (though it is based solely on DICOM exchange) in the sense of impossible confirmation about the success of data transfer from the final destination to the original sender.

A more detailed description can be found in the corresponding deliverable D09.1 “Evaluation of the Lithuania demonstrator” [8].

6. LESSONS LEARNED

In the following we summarize the experiences gained during the SAMTA project. We hope that other projects or developers in the field of telemedicine applications might profit from it.

6.1 General remarks

International projects

- Many Central and Eastern European countries are developing very fast in terms of improving their competence in medical informatics, IT infrastructure and networks of excellence. SAMTA partners reflect the current situation in Europe: Hungary lies in a start-up position, i. e. between EU project partners (France and Germany) and other Eastern European partners (Lithuania) in terms of medical and technical equipment, communication infrastructure, etc.
- The main purpose of such international projects is to exchange knowledge and experience among the participating partners / countries (usually health care is focused on a national basis). In this special case the cooperation is also useful to close the technological gap between Eastern and Western Europe (i. e. knowledge transfer). Of course a project of 2-3 years cannot close the gap completely but it supports the Eastern European countries to catch up significantly faster.

Medicine

- Physicians tend to be quite busy. This shortage of time prevents things which are technically possible or at least makes them more difficult to achieve in clinical practice (e. g. most medical users are not willing to test many versions of an application). Therefore, it is a good idea to have medical staff who feel responsible for the project and take enough time for it.
- Doctors are used to examine reality (e. g. a patient's health status) but not to imagine possible future developments. Planning and discussing about things that do not yet exist is more difficult for them than analyzing reality. Therefore, early prototypes of the application should be prepared to support the discussions.

Informatics

- Both technical requirements and the state of the art change rather quickly in computer science. It is not possible to perform an application related research project over a period of 2-3 years without anticipating and reacting on changes in the technical background during the project duration. This adds to the inevitable uncertainties of planning research which are present in all fields of science.
- One way of handling technical uncertainties is the consequent reliance on standards in all technical fields where the project does not intend to go beyond the current state of the art (i. e. which are not in the core of the scientific interest of the project). Since standards are typically used unchanged over a period of at least 3-5 years even in computer science, they help to stabilize the technical framework in which the research is carried out.

6.2 Workpackage specific remarks

WP01: Project Management

- E-mail, phone calls, etc. cannot replace personal discussions (i. e. face-to-face). The regular project meetings with participation from all partners have definitely improved cooperation between the project participants.
- Cultural and language barriers should not be underestimated. Different languages, different approaches to work, different technical infrastructure as well as large physical distance (long travel times) increase the necessary effort for project management and make communication more complex.
- It has shown to be important to keep close contact to the responsible project officer at the European Commission. Project management needs to guarantee a capability for short term reactions and a certain amount of flexibility toward requests from the Commission. Sufficient project management personnel resources for communication with the Commission need to be included in the project plan.

WP02: Analysis of user needs and appropriate services in telemedicine

- Telemedicine is a very general term which is often used inappropriately because not precise enough. An objective sign of the advent of telemedicine in the daily medical practice should be once people will speak about tele-distribution, tele-expertise, tele-processing, etc. (or equivalents terms).
- When analyzing the telemedicine services, it appears clearly that in the future, every domain, every specialty, every practice of medicine should be concerned in some way by one or several tele-services. For medical specialties which strongly depend on the evaluation of data like images, signals or lab results such as Radiology, Cardiology or Pathology, the use of tele-services is foreseeable. For other specialties such as Surgery or Psychology usage scenarios may be different. Nevertheless we think that these specialties can also profit from tele-services in one or another form.

WP03: Analysis of structured data transmission standards for CEC/NIS usage in cardiology

- Medicine is not completely standardized. For example, in many institutions doctors are free to express themselves regarding content and form when creating reports. It is a good opportunity to introduce structured reports and/or codes in the scope of a telemedicine project.
- Because of different medical schools, institution profiles (e. g. more or less research oriented), uncertainty and personal preferences, etc. it is not easy to agree on a common structure or coding.
- XML / SMIL and DICOM Structured Report are both too new to decide what is better for cardiac reporting. The latter has been approved just before the end of this project and for both solutions there are almost no implementations and/or test data up to now.

WP04: Analysis and development of innovative medical image compression techniques

- Image compression algorithms are applied usually to the whole image pixel array. However, medical imaging devices usually generate images consisting mainly of two kinds of information: diagnostic (useful field of view) and overlaid ones.
- Removal of overlaid information enables to improve compression ratio approximately twice, as the useful field of view usually covers about 40-60 % of the image. This result was achieved by combining the application of image processing techniques (histogram analysis, mathematical morphology, image masking).
- Applying different classes of wavelets to medical image compression we noticed that some classes of them suit considerably better than others (e. g. Odegard, Villa or Antonini wavelets for angiographic and ultrasound images). The image content complexity measure has been introduced to set the relationship between image complexity and wavelet class in the transform.
- These ideas closely correlate with the new image compression standard JPEG2000 (appearing in November 2000), which is supposed to allow the segmentation of the image and the application of special wavelet classes. These classes can automatically be chosen on the base of the image complexity criteria.

WP05: Portable MEDICOM/DICOM toolkit development

- Although the format of DICOM datasets as well as the communication protocols are quite complex and not straightforward for a non-specialist, it is possible to provide him with efficient tools enabling him to implement DICOM services, to read, create or display DICOM images.
- There are many commercial and free DICOM toolkits available, some of them only suited for research purposes and not for commercial products. Nevertheless they usually have to be adapted to be easy to use or to integrate into an existing environment.

WP06: Development of MEDICOM/DICOM extensions for narrow-band networks

- DICOM (especially the network services and compression schemes) was not defined under special consideration of narrow-band / unreliable networks, but with only a few changes it works sufficiently (e. g. by introducing a transparent compression layer).
- Though the contribution of non-pixel data is very small compared to the large amounts of pixel data it makes sense to investigate new possibilities to reduce the overall size of DICOM datasets.
- Developing new (special) image compression schemes for DICOM is not too useful since the DICOM committee prefers for good reason to use existing (JPEG lossy, JPEG lossles, JPEG-LS) or upcoming standards (JPEG2000) wherever possible. There is also a development going on to introduce MPEG for cine-runs / movies into DICOM.

WP07: Application Integration

The following comments apply to software development in general. It should be stressed, though, that attention to these principles from the beginning of a project make 'life easier' in later phases even if development concerns research / prototype software not intended for immediate commercial use.

- To make integration of separate pieces of software easier it is desirable to define and to document the linking interfaces at the earliest possible stage.
- Software modules supposed to be integrated into applications should return error codes but never crash or terminate the program. If a module crashes / aborts the application is also terminated without having a possibility to understand the reason for the error. If the module displays error messages, has a user interface or generates log files there should be an easy method to adapt the message text (e. g. translate them into different languages).
- Integration becomes more difficult if developers of the module, and people integrating the application software use different tools for the development of software (e. g. the binary format of DLLs, Dynamic Link Libraries, generated by Borland C++ and Microsoft Visual C++ compilers are incompatible).

WP08/09: Setup and validation of Hungary / Lithuania demonstrator

- Telemedicine usage is more than just technology: Organizational issues are sometimes more important with regard to the time required for a telemedical consultation than network transmission speed.
- The total time for a telemedical consultation is very dependent on:
 - preprocessing (software and hardware tools, integration of them, storage etc.);
 - network topologies (network load / traffic shaping is obviously also important beyond the network bandwidth).
- DICOM data exchange appeared to be successful and scaleable over wide range of network technologies (from 4.8-16.8 kbit/s dial-up analog modem connection up to 100 Mbit/s Fast Ethernet LAN). For lower data exchange rates (especially not exceeding 64 kbit/s) it is preferable:
 - to use lossy compression in order to reduce transmission time;
 - to send only the most important (separate) frames lossless compressed, if necessary;
 - to connect to the nearest Internet service provider (ISP) and use DICOM data exchange over an encrypted virtual channel, instead of making a long-distance call;
 - to use the intermediate telemedicine server if tele-distribution service should be provided over low bandwidth and dial-up connections. However, such a solution is not fully DICOM compatible though it is based solely on DICOM exchange. It is impossible to get confirmation about the success of data transfer from the final destination to the original sender.
- Data protection does not yet seem to be an issue in Hungary and Lithuania – neither encryption nor anonymization were features demanded by the medical project users in Hungary / Lithuania. Nevertheless the legal regulations will most probably change in the future as the Central and Eastern European countries are developing fast and come closer to Western Europe. Then a multi-national telemedicine project like SAMTA would have to think about data protection and security more intensively – this might be a good starting point for future projects with a different focus.

WP10: Analysis of lossy compression techniques in medical imaging

- Image capture and preprocessing (editing, compression etc.) is a difficult, timely process that should be eased by an integrated, easy to use environment.

- It is not easy to implement image compression techniques when new, major changes are coming (JPEG2000, MPEG2 capture and codecs etc.).
- One major problem with image evaluation is that patients are not the same (they are not equally suited for examination with echo or angio techniques because of different body weight, etc.)
- When evaluating the quality of compressed images the physicians should only be able to see the pure medical image and not the text information which is typically “burned in”. Otherwise they may judge the compression ratio according to the quality of the text characters and not of the medical image.

WP11: SAMTA Guidelines & Contribution to the European Standardisation Bodies

- There is a strong trend towards the use of standardized general-purpose image compression algorithms in medical image processing (e. g. JPEG2000). This indicates a consolidation of the multitude of competing algorithms especially in the Wavelet domain discussed in literature in the past. Research in the field of telemedical applications has to recognize this trend.
- Standardization takes a long time, e. g. five years of development time for a new standard is not unusual. Therefore, developers might be tempted to choose a “second best” proprietary solution for a problem or to use a draft of a standard currently being developed (if available) which is often not compatible with the final version. This statement, however, does not hold true only for the medical or image processing domain. A good example for a similar trend in information technology is the ISO C++ standardization effort and the multitude of products which implement earlier, incompatible drafts of the this standard.

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