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EXECUTIVE SUMMARY

This document is a contribution to the workpackage WP02 "Analysis of user needs and appropriate services in telemedicine" whose main objective is to produce a deliverable "Recommendations for open scaleable telemedicine services". This ambitious title must be taken with caution: while trying to be general enough when it was possible, these recommendations mainly concern the medical field of cardiology and only a limited part of telemedicine services. The role of such a document is to be part of the inputs in the conception designed of the prototype application of SAMTA project.

The document is divided in three main parts :

- *Services identification and network scaleability* : this contribution is focused on services that will be proposed in the scope of SAMTA project. A general scheme of a telemedicine session is proposed and the user's requirements at each stage are analyzed : the functionalities that should be proposed and the characterization of the data that should be processed
- *Protocols identification and proposal* : this contribution is focused on an enlarged protocol point of view that is :
 - Encoding protocols ;
 - Transmission protocols ;
 - Cooperative protocols ;

A definition of every telemedicine service in a general point of view is proposed and, for each identified service, the characterization of the data streams to convey between the two stations implied in the session is done. Then, the analysis is focused on the two services retained in the scope of the first implementation of SAMTA application.

- *Architecture Recommendations* : this contribution takes inputs from part 1 and 2 and proposes some architecture recommendations for scaleable telemedicine services. Three different levels of complexity to classify the services are identified (medical, technical and physical). At each level, a analysis grid may be applied according to the level of abstraction (implementation, architecture and reference level).

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0. INTRODUCTION

This document is a contribution to the workpackage WP02 "Analysis of user needs and appropriate services in telemedicine" whose main objective is to produce a deliverable "Recommendations for open scaleable telemedicine services". This ambitious title must be taken with caution: while trying to be general enough when it was possible, these recommendations mainly concern the medical field of cardiology and only a limited part of telemedicine services.

The document is divided in three main parts :

Services identification and network scalability : this contribution is focused on services that will be proposed in the scope of SAMTA project ;

Protocols identification and proposal : this contribution is focused on an enlarged protocol point of view that is :

- Encoding protocols ;
- Transmission protocols ;
- Cooperative protocols ;

Architecture Recommendations : this contribution takes inputs from part 1 and 2 and proposes some architecture recommendations for scaleable telemedicine services.

0.1 Glossary

- **Application 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. The scalability may be measured in terms of modularity, extendibility and genericity.
- **Network Scalability** : means that a system may adapt its global efficiency in terms of quality of services and number of available services according to the service available at the network layer (bandwidth available, communication protocol, etc.).
- **Patient** : the patient, present or not during the session, anonymous or not, subject of care motivating the telemedicine session.
- **Patient Telemedicine Folder** : the relevant information pertaining to the telemedicine session extracted from the patient folder and, sometimes, enhanced in order to clearly present the purpose of the session.
- **Prepared data** : for being used during a telemedicine service, some process may be performed on data before transmitting it from the P-Station to the R-Station (making it anonymous, etc.).
- **P-Platform** : the set of technical / medical / networks devices available in the telemedicine room located in the clinical site in charge of the Patient.

- **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.
- **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.

1. SERVICES IDENTIFICATION AND NETWORK SCALEABILITY

This part of the document describes potential needs of users and potentially required application functionality. It was prepared by combining the experience of wide range of telemedicine applications : from off-line low speed networking¹ to on-line high and very high speed² networking.

Analysing the potential needs of the users special attention was paid to ensure the network scaleability and the stability of the user interface.

The requirements defined might appear redundant after the validation phase of the SAMTA project (the SAMTA work-packages WP08 and WP09) or even before it (and therefore not implemented). On the other hand, some more services might be required during the trials.

This part of the document is itself organised according to the following topics :

- definition of the classes of telemedicine services for cardiology ;
 - general model for the analysis of telemedicine services ;
- user needs for telemedicine services at the Medical Services Layer³ ;
- user needs for telemedicine services at the Technical Services Layer³ ;
 - user needs for telemedicine services at the Physical Services Layer³.

1.1 Referenced Documents

- [1.1] CEN TC251 prENV 12265 : Medical Informatics - Electronic healthcare record architecture.
[1.2] CENTC251 N98-119, FWD Electronic HealthCare Record Communication, Part 1, Extended Architecture, 1st December 1998, PT26 WGI. <http://www>.

1.2 The role and the place of telemedicine services

Tele-medicine services scale, given in part 2 of this deliverable (see "Typology of emergent telemedicine services"), describes the variety of possible telemedicine applications. The exhaustive analysis of all listed services is out of the scope of the SAMTA project, which is focused on cardiology in general and cardiological imaging in particular. As the latter includes some kinds of radiological techniques, it is possible to extend the cardiology application domain with diagnostic radiology.

Therefore from the Multimedia Tele-Medicine Application point of view three priority groups of telemedicine services can be defined and analysed later on :

Necessary services :

¹ Image Processing & Multimedia lab., KTU, was involved in the PECO'92 project "Information technologies for Cardiology and Radiology in Lithuania and Eastern European Countries". As the result it was developed and installed several PC-based workstations, communicating between each other over dial-up telephone lines.

² OFFIS (University of Oldenburg) and ETIAM (formerly with University of Rennes) were involved in TEN-IBC project "RETAIN: Radiological Examination Transfer on ATM Integrated Network". Radiological telemedicine sessions took place between Germany, France, Spain and Portugal over mixed ISDN and ATM network.

³ See architecture description model defined in part 3 "Architecture recommendations" of the deliverable.

- Tele-expertise or tele-consultation
- Tele-distribution of medical results

Services of potentially future interest :

- Tele-staff-meeting
- Tele-diagnosis
- Tele-processing

Other services (tele-acquisition, tele-monitoring, tele-surgery, etc.).

The general aim of telemedicine in this scope is to effectively obtain some extra knowledge in a special situation of health care (the cardiology in particular), in which a certain problem is faced. The process of obtaining such knowledge can have the form of :

- advice – in technological terms it can be described as a single reply for a single question.
- discussion – a process of consequent questions and answers.

1.3 Tele-medicine service model

In general the request-response scenario is supposed to be used for all the scale of the network throughputs. The telemedicine session in general may be divided into the following stages, listed according the scheme (see Figure 1) :

Preparation answer to some questions in advance, e. g. :

- A broadcast call for assistance or application to a certain centre/specialist ?
- Off-line or on-line ?
- Date and time constraints
- Data worth to be prepared in advance (including data preparation process itself)

Session initialization (directly expressed for on-line sessions) :

General comment on the problem (a question, a topic for discussion)

- Computer text
- Structured report
- Multimedia (voice/video) comment
- Short medical record, including the list of medical data (illustrations) available for comments
- Basic characteristics of the above mentioned data should be presented, e. g. : ID, type, origin of the data, clinical background, relative date of acquisition, amount of data together with automatically evaluated time of transmission
- Supposed to be prepared before the tele-working session and transmitted during the "connection establishment" phase.

Request for data / Priorities for data

- This phase may be unnecessary sometimes
The response (R-user⁴) is supposed to rank the data in order to transmit the most valuable first
- Additional questions (in any form) can be formulated in order to go more deeply into details

Medical data transmission

- In general this step would be used in both directions of tele-working

⁴ See terminology description given in part 0.1 "Glossary".

- e. g. DICOM data sets, 1D bio-signals, data overlays (objects marked on the data : ROIs, labels, etc.), comments (plain text, structured report, multimedia annotation, etc.)

Sequential reply / Interaction

The kind of interaction (e. g. tele-cursor, audio-conference, video-conference, etc.) depends on the network throughput between the P-station and the R-station⁵

Input to form a common opinion

- An opinion of each person involved in current tele-working session should be reflected

Conclusion

- Structured report prepared by all the medical staff involved in the tele-working session

⁵ See terminology description given in part 0.1 "Glossary".

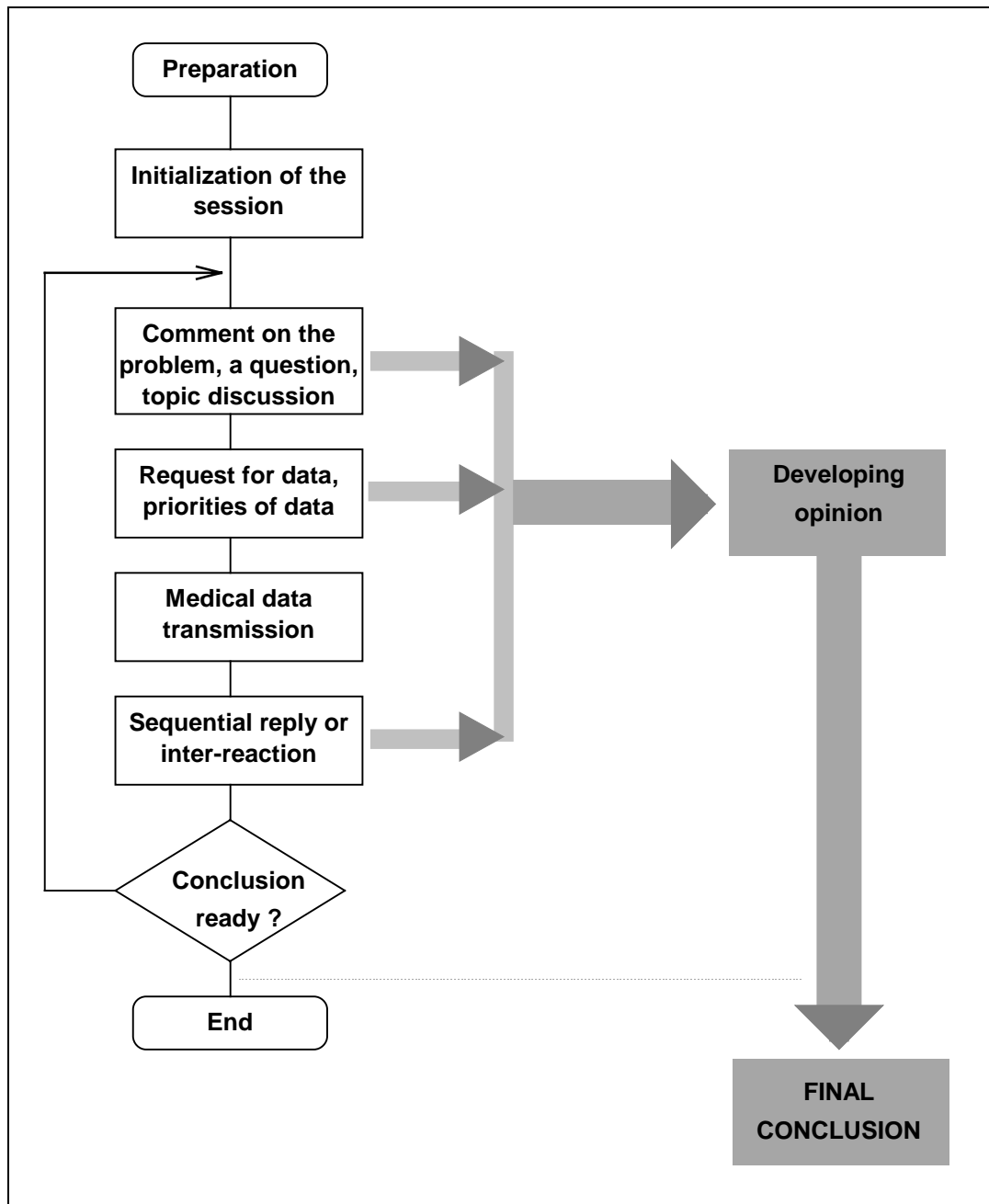


Figure 1: Tele-medicine service model

1.4 Medical services layer

User (typically a physician) needs are described within the Medical services layer. The services which are under the scope of the SAMTA project and these of potentially future interest will be listed and described below.

1.4.1 Patient registration, information overview and browsing

This complex of services is devoted for the manipulations with the patient folder (representing "history" of the patient) :

- presentation of the contents (index) of the folder ;

- selective review of records (e. g. everyday observations, prescriptions, examination reports, etc.) of the folder ;
- addition of new records to the folder ;
- selection of records of the folder that could be exported in order to prepare the data for a telemedicine session.

The services listed should follow special data security constraints, generally depending on the category of the medical staff, i. e. nurse, technician, physician, consultant, system administrator, etc.

1.4.2 Medical information acquisition

Generally this service can be described as acquisition of either mono-dimensional or multi-dimensional functional signals from the patient. As there is a huge variety of such signals, only some examples are given below :

1D signals - represents time series typically:

- directly acquired bio-signals, e. g. ECG, EEG ;
- indirectly measured kidney, thyroid function, respiration curve, etc.

2D signals:

- X-ray images, nuclear medicine images ;

multidimensional signals:

- time series of 2D signals, e. g. angiographic images, echocardiographic images, etc.
- volume representing CT and MRI scans (image series).

This kind of medical information in general will be further referenced as patient signal-data. The process of the patient signal-data acquisition itself can be formally defined as "the process which results in the discrete signal representation in a P-station or/and R-station".

1.4.3 Patient signal-data review and processing

The service should include :

- basic functions for signal-data review (i. e. replay / step-by-step replay / rewind / cine of a time series ; image grey-scale manipulation, so called windowing ; etc.)
- a kind of plug-in technology for data processing functions.

The plug-in technology implies a possibility for developing and using new data processing functions that may be requested by the users (distance measurements using calibration, data automatic detection, etc.) .

1.4.4 Medical data annotation and reporting

The annotation can be performed upon a record of patient telemedicine folder or patient signal-data. It can be divided into two categories :

- marking of objects (ROIs, labels, etc.) on a certain patient signal-data ;

- annotating a record / a set of selected records of patient folder, the whole patient signal-data or/and selected objects on this signal-data.

The annotation itself can be represented in various forms :

- Plain ASCII text
- Structured report
- Multimedia (voice) annotation

1.4.5 Data package preparation

There is no sense, while preparing a telemedicine session to transfer the whole patient folder from the P-User to the R-User. On the contrary, the relevant information pertaining to the session should be extracted from the patient folder and, sometimes, enhanced in order to clearly present the purpose of the session. This data package is called " patient telemedicine folder " or " view " (Cf. " View Record Item Complex " in [1.1] and " Selected Component Complex " in [2.2])

The service should include the possibility to enter the patient folder browsing mode and to select necessary records of the folder and include them along with corresponding signal-data into the data package under preparation.

Finally the data package will contain several kinds of information :

- the index (table of contents), containing the characteristics of the data (e. g. ID, type, origin of the data, clinical background, date, etc.) ;
- selected records of patient folder ;
- selected signal-data along with a suggested sequence and parameters for data processing ;
- a set of annotations (general, patient folder record oriented, signal-data oriented).

1.4.6 Data package transmission and Cooperative work

The initial stage of it can be generally implemented in two ways :

- broadcasting about the need for assistance
- applying to a certain selected centre or specialist.

The other stages will follow the general model defined above. Depending on the network throughput between the P-station and the R-station (from lower to higher) the following kinds of cooperative work can be defined (the properties are inherited going down the scale) :

- off-line review / replay / re-processing of received data and optional human communication over conventional facilities (i. e. telephone) ;
- off-line review / replay / re-processing of received data, conforming the timing constraints (e.g. displaying dynamic images in real acquisition time) ;
- quasi-on-line review / replay / re-processing of received data, conforming the timing constraints ;
- synchronized on-line review / replay / re-processing of received data (i. e. tele-cursor) ;
- audio-conference ;
- video-conference.

1.4.7 Profiles / scenarios

Special combinations of above described services may be arranged into typical telemedicine procedures for various fields of medicine. Though the construction of such scenarios is out of the scope of the SAMTA project, the possibility to have them should not be forgotten.

1.5 Technical services layer

The technical services layer presents the further exploration of the medical services layer. Some of them are essential and will be listed only. Others need additional exploration and will be characterized accordingly.

1.5.1 Essential services

- Authentication, data security
- Data transmission
- Data / image / sound acquisition and presentation
- Text processing, printing services
- Integration into information systems (i. e. PACS, RIS, HIS, database services, data archive operations)
- Data compression, error control and correction

1.5.2 Additional data security aspects

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 responsibilities (e. g. a physician in charge of a patient vs. a physician of the same department or a physician in general, etc.). So the possibility to define and to follow such rules of data protection and security (read / append / modify) has to be foreseen.

1.5.3 Data anonymisation

In some cases, the R-user is supposed not to be interested in the personal details of a patient or a case under a telemedicine procedure. Therefore personal information has to be anonymized when presented for the R-user – i. e. skipped or altered in such a way the necessary information from the medical point of view is retained. The P-user should be presented with full information. In any case, the telemedicine application must be conformed to the local policies.

There may be an exception of this rule in case the R-user was in charge of the patient or the case under the telemedicine procedure. In any case, the decision to remove or not personal information from the data is under the P-user responsibility.

1.5.4 Dynamical usage of data compression

As it is very difficult to predict data rates, processing and transmission times, an adaptive solution is proposed to use data compression or not for on-line tele-working.

A kind of "ping" procedure has to be used to evaluate timing characteristics for the tele-working session (both end-user sides, whole data route). Compression should be used if

$$T_{compression @ P} + T_{transmission compressed} + T_{decompression @ R} \ll T_{transmission uncompressed}$$

These timing characteristics depend on the equipment, which usually will be under continuous improvement, so the "ping" procedure should be carried for almost every session of tele-working. For time and economical reasons "ping" procedure should use a typical subset of data used for current tele-working session (not a special test data). The subset of data should be transmitted in both compressed and uncompressed forms to obtain all timing values.

1.5.5 Application synchronization

Special attention should be paid to synchronization of data processing by means of processing parameters in order to present the data adequately for both P-user and R-user.

1.6 Physical services layer

Most services of the physical layer are essential. Only some of them need additional exploration and will be characterised accordingly.

1.6.1 Network "scale"

Scale Mark	Characteristics	Comments
Net0	Off-line, very low bandwidth	Dial-up telephone lines, max. 56kbps Data transmission in advance desirable, as the time for data on-request transmission is too high
Net1	On-line, very low bandwidth	Leased-lines, max. 56kbps Some synchronization. Data transmission in advance desirable, as the time for data on-request transmission is too high
Net2	On-line, low bandwidth	Synchronization, tele-cursor. The data on-request transmission time is appropriate.
Net3	On-line, high bandwidth	Real time audio, synchronization, tele-cursor
Net4	On-line, very high bandwidth	Real time video-conferencing

Remark **The properties of the network are inherited going up the scale.**

1.7 Low level aspects

As the scalability of services requires scalability of protocols, the TCP/IP is supposed to be used for all on-line connections (e. g. from modem to ATM).

The off-line telemedicine can use the TCP/IP, if it follows scheme with intermediate telemedicine server and data transmission by means of E-mail envelopes.

2. PROTOCOLS IDENTIFICATION AND PROPOSAL

2.1 Introduction

This part of the document – ” Protocols identification and proposal ” takes inputs from the previous part. It is itself organized according to 5 main topics :

1. brief typology of emergent telemedicine services and specification of the data and data streams pertaining to them ;
2. delineation of the boundaries of the study according to the domain of interest specified in §1 : ” Services identification and network scalability ” ;
3. review of encoding syntaxes well adapted to encapsulate the data identified in §1 ” Services identification and network scalability ” ;
4. review of transmission protocols well adapted to convey the encapsulated data identified in §1 ” Services identification and network scalability ” ;
5. review of cooperative protocols for on-line / off-line cooperation between remote applications.

2.2 Referenced Documents

- [2.1] SGML, Standard Generalized Markup Language, ISO 8879:1986
<http://www.iso.ch>
- [2.2] HTML 4.0 Specification W3C Recommendation, revised on 24-Apr-1998
<http://www.w3.org/TR/1998/REC-html40-19980424>
- [2.3] Extensible Markup Language (XML) 1.0, W3C Recommendation 10-February-1998
<http://www.w3.org/TR/1998/REC-xml-19980210>
- [2.4] Synchronized Multimedia Integration Language (SMIL) 1.0 Specification W3C Recommendation 15-June-1998
<http://www.w3.org/TR/1998/REC-smil-19980615>
- [2.5] Document Object Model (DOM) Level 1 Specification Version 1.0 W3C Recommendation 1 October, 1998
<http://www.w3.org/TR/1998/REC-DOM-Level-1-19981001>
- [2.6] <http://www.imtc.org/t120.htm>
- [2.7] <http://www.imtc.org/i/h320.htm>
- [2.8] EC/DG-XIII/TEN-IBC B3012 RETAIN Deliverables (1997)

2.3 Typology of Emergent Telemedicine Services

2.3.1 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.

2.3.2 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, ECG, 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 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 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.

2.3.3 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.

2.3.3.1 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 may come from different sources :

- administrative / patient information
 - HIS (Hospital Information System)
 - DIS (Department Information System)
- patient examinations (anatomic and functional)
 - image source (still and dynamic images)
 - functional signal
 - other investigation device
 - biology
- medical history of the patient
 - examination / treatment / surgical reports
- academic information
 - digital atlas
- other information sources

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.

Data Description	Source	Size	Existing encoding de facto standards
Textual Information	(Patient administrative information, reports, etc.) : <ul style="list-style-type: none"> • HIS (hospital network) • RIS (PACS, hospital network) • diagnosis / clinical workstation (PACS, hospital network) 	< 1 MBytes	RTF, html
Oral Information	(mono/stereo audio recordings of reports, etc.) : diagnosis / clinical workstation (PACS, hospital network)	(8 kBytes \Rightarrow 86 kBytes) * recording time (in sec)	CCITT A-Law CCITT u-Law Creative ADPCM GSM IMA ADPCM PCM etc.
Images (still or dynamic images)	<ul style="list-style-type: none"> • local film scanner / digitizer (local network) • images sources (PACS, hospital network) 	# N MBytes	DICOM video standards
Functional signals	<ul style="list-style-type: none"> • EEG, ECG, EMG sources : local network • video tape • digital media 	# N MBytes	video standards

2.3.3.2 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 source (dynamic images)
- functional signal
- other investigation device

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

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
Dynamic Images	(ultrasound images, endoscopy images, etc.) : diagnosis devices	# N Mbit/s	video standards
Audio signal	(electronic stethoscope, etc.) : series / parallel port of the P-Station	< 2 Mbit/s	?
Functional signals	<ul style="list-style-type: none"> • EEG, ECG, EMG sources : local network / series / parallel port of the P-Station • video tape 	< 1 Mbit/s	video standards

2.3.3.3 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)

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
Video connection	(video camera, endoscopy source, etc.)	0.5 Mbit/s < . < N Mbit/s depends on : lossy/lossless compression compression rate ROI extraction on images	video standards
Functional signals	EEG, ECG, EMG sources : series / parallel port of the P-Station	< 1 Mbit/s	video standards
Surgical device commands	joystick, game /series / parallel port of the P-Station (RS232 / RS422)	# 1 Mbit/s	?

2.3.3.4 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.

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
Video connection	camera	0.5 Mbit/s < . < N Mbit/s depends on : lossy/lossless compression compression rate ROI extraction on images	video standards
Audio connection	microphone	< 2 Mbit/s	CCITT A-Law CCITT u-Law Creative ADPCM GSM IMA ADPCM PCM etc.
Microphone / camera devices commands	application from both sides	< 0.5 Mbit/s	

2.3.3.5 Service Application Data [SAD]

Service Application Data are dedicated to the session. They are devised in three parts :

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

2.3.3.6 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 is all relevant information that shall help the P-User to present the Patient's case to the R-User : oral comments, links on data, ROI's 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.

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
textual information / links on available multimedia information	P-User application	# N MBytes	RTF, HTML, XML, DOM, SMIL, etc.
oral comment	P-User application & microphone	# N MBytes	CCITT A-Law CCITT u-Law Creative ADPCM GSM IMA ADPCM PCM etc.
application information	P-User application	# N MBytes	

2.3.3.7 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.

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
application information (image selection, annotations, windowing, drawings, many user-interface facilities, ...)	P-User application	< 0.5 Mbit/s	Common Open Software Environment (COSE)

2.3.3.8 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.

Data Description	Source	Size and/or Bandwidth Required	Existing encoding standards
textual information / links on available multimedia information	P-User application	# N MBytes	RTF, HTML, XML, DOM, SMIL, etc.
oral comment	P-User application & microphone	# N MBytes	CCITT A-Law CCITT u-Law Creative ADPCM GSM IMA ADPCM PCM etc.
application information	P-User application	# N MBytes	COSE

2.4 Communication of Data streams in telemedicine services

2.4.1 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.

Most of telemedicine services may be divided in several stages, according to the way information exchanges are performed. In the following table, the way each data stream may be conveyed between the P-User and the R-User telemedicine platforms is analyzed: the transfer may be done during the session (In-session), beforehand or afterwards (Off-session).

Data Stream Service	OF-PPD⁶	ON-PIVD⁷	ON-PITD⁸	ON-VCD⁹	OF-SAPD¹⁰	ON-SAD¹¹	OF-SARD¹²
Tele-acquisition	Off-session	In-session	–	In-session	Off-/On-line	In-session	Off-/In-session
Tele-monitoring	–	In-session	–	–	–	–	–
Tele-diagnosis	In-session	In-session	–	In-session	In-session	–	In-session

⁶ Off-line Predated Patient Data.

⁷ On-line Patient Investigation Data.

⁸ On-line Patient Intervention Data.

⁹ On-line Video-Conference Data.

¹⁰ Off-line Service Application P-Data.

¹¹ On-line Service Application Data.

¹² Off-line Service Application R-Data.

<i>Tele-expertise</i>	Off-/In-session	-	-	In-session	Off-/In-session	In-session	Off-/In-session
<i>Tele-processing</i>	Off-session	-	-	-	Off-line	-	Off-line
<i>Tele-surgery</i>	Off-/In-session	-	In-session	In-session	In-session	-	In-session
<i>Tele-staff-meeting</i>	Off-/In-session	-	-	In-session	In-session	In-session	In-session
<i>Tele-teaching</i>	Off-/In-session	-	-	In-session	-	-	-
<i>Tele-access</i>	-	-	-	-	Off-/In-session	-	In-session
<i>Tele-distribution</i>	Off-session	Off-session	In-session	-	-	-	-

2.5 Scope of the Present Study

2.5.1 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.

2.5.2 Subset of services retained in the present study

As stated in Part 1 of this document, the following services are retained in the present study :

- Tele-expertise
- Tele-distribution

With a lower priority, some other services with a potential future interest should be considered :

- Tele-staff-meeting
- Tele-processing

Finally, in a larger extent, two other services could be developed :

- Tele-diagnosis
- Tele-teaching

Only the two first services are detailed in the present document. The others give an idea of the evolution in terms of user needs that may help taking some decision for the architecture of the application.

2.5.3 Specification of the data generated and conveyed

Data Stream Service	OF-PPD ¹³	ON-PIVD ¹⁴	ON-VCD ¹⁵	OF-SAPD ¹⁶	ON-SAD ¹⁷	OF-SARD ¹⁸
<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	–	–	–	–

2.6 Review of Encoding syntaxes

2.6.1 Introduction

The scope of this review is restrained to the telemedicine services defined in [\[MISSING_REFERENCE\]](#). The characterization of the data is focused on their use in the frame of these services and should not be generalized.

2.6.2 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 listen 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. The following lines give a short description of such works.

¹³ Off-line Predated Patient Data.

¹⁴ On-line Patient Investigation Data.

¹⁵ On-line Video-Conference Data.

¹⁶ Off-line Service Application P-Data.

¹⁷ On-line Service Application Data.

¹⁸ Off-line Service Application R-Data.

2.6.2.1 SGML

The Standard Generalized Markup Language [2.1] is a well established international standard (ISO 8879-1986). SGML is a meta-language (that is, a means of formally describing a language, in this case, a markup language) that defines the rules of creating a document grammar. The grammar created for a kind of document is a Document Type Definition (DTD). SGML does not specify document structure or tag semantic but the way to create them.

In SGML, kinds of tags (or markups or encoding) are especially used :

- Procedural markup, which deals with the layout and aspect of the data (e. g. `` for **bold** character) ;
- Descriptive Markup or Semantic markup, which give a sense, a structure to data.

Furthermore, SGML does not address the transport of documents among applications.

2.6.2.2 HTML

HTML [2.2] is an application of SGML for the layout of documents on the WWW and now considered as a universal method for displaying data.

HTML has a specific Document Type Definition (DTD), which defines procedural markups (e. g. ``, `<i>`, `<H1>`...), some descriptive markups (`<HEAD>`, `<BODY>`...) and a hypertext markup `<A>`.

Although visual and user interface standards are a necessary layer, they are insufficient for representing access medium to text and pictures. It is not a standard for intelligent search, data exchange, adaptive presentation and personalization, and does not provide facilities to represent data so that software can better search, move, display and otherwise manipulate information currently hidden in contextual obscurity. HTML cannot fulfill these needs because it is a format that describes how a Web page should look, rather than how presenting data.

In short, while HTML provides rich facilities for displaying, it does not provide any standards-based way to manage data.

2.6.2.3 XML

XML (Extensible Markup Language) [2.3] is a simplified subset of SGML, that is optimized for delivery over the Web ; it is defined by the World Wide Web Consortium (W3C), ensuring that structured data will be uniform and independent of applications or vendors. XML provides a universal method for describing data.

XML provides a data standard that can encode the content, semantics, and schemata for a range of cases, from simple to complex. XML can encode the representation for the following :

- an ordinary document ;
- a structured record, such as an appointment record or purchase order ;

- an object with data and methods (e. g. the persistent form of a Java object or ActiveX control) ;
- a data record, such as the result set of a query ;
- meta-content about a Web site (such as CDF) ;
- graphical presentation (such as an application user interface) ;
- standard schema entities and types ;
- all the links between information data (with XML Linking Language, i. e. XLink) and people over the Web.

As a universal standard for the expression of data, XML offers many advantages to organizations, software developers, Web sites, and ultimately to end-users.

XML provides a powerful, flexible format for expressing data, whether as a wire format for sending data between client and server, a transfer format for sharing data between applications, or a persistent storage format on disk. Because structured data in XML can include a self-describing schema (i. e. StyleSheets that can be designed with XSL), XML promises interoperability between applications that manipulate structured data independent of the underlying semantics.

For end-users, XML promises to provide a much richer set of Web applications for browsing, communication, and collaboration. The growing use of XML will improve Web-browsing applications for viewing, filtering, and manipulating information.

XML has a family of companion standards, propositions or recommendations like CSS2, DOM, XLink, SMIL, DCD, RDF, Namespaces,... (Cf. www.w3c.org) proposed to display and layout XML documents, structure and give normalized access to them, create hypermedia links, create multimedia presentation, ...

2.6.2.4 SMIL

SMIL (Synchronized Multimedia Integration Language) [2.4] allows integrating a set of independent multimedia objects into a synchronized multimedia presentation. Using SMIL, presentations such as a slide show synchronized with audio comments or a video synchronized with a text stream can be described.

A typical SMIL presentation has the following characteristics :

- the presentation is composed of several components that are accessible via a URL, e. g. files stored on a Web server ;
- the components have different media types, such as audio, video, image or text ;
- the begin and end times of different components have to be synchronized with events in other components. For example, in a slide show, a particular slide is displayed when the narrator in the audio starts talking about it ;
- the user can control the presentation by using control buttons known from video-recorders, such as stop, fast-forward and rewind.

Additional functions are " random access ", i. e. the presentation can be started anywhere, and " slow motion ", i. e. the presentation is played slower than at its original speed.

The user can follow hyper-links embedded in the presentation.

SMIL has been designed so that it is easy to author simple presentations with a text editor. The key to success for HTML was that attractive hypertext content could be created without requiring a sophisticated authoring tool. SMIL achieves the same for synchronized hypermedia.

SMIL documents are XML documents as defined by the XML 1.0 specification.

2.6.2.5 DOM

The Document Object Model (DOM) [2.5] is a platform- and language-neutral interface that will allow programs and scripts to dynamically access and update the content, structure and style of documents. The document can be further processed and the results of that processing can be incorporated back into the presented page.

The Document Object Model (DOM) is composed of the Requirements, Core, XML and HTML parts. Level one (Core) provides a common API for software developers and web script authors to access and manipulate parsed HTML and XML content inside conforming products. The XML and HTML parts extend the Level one Core specification to describe objects and methods specific respectively to XML and HTML documents. All markup as well as any document type declarations are made available. DOM Level one is intentionally limited in scope to methods to represent and manipulate document structure and content.

A standard API for controlling how documents are rendered via stylesheets, validated against a DTD, accessed by given users, etc. will be specified in a subsequent revision level of the DOM.

2.7 Review of Transmission Protocols

2.7.1 Introduction

The scope of the review of transmission protocols is focused only on the services identified in Part 1 of the present document as the services that should be tested in SAMTA.

2.7.1.1 Quality of Service Considerations (QoS)

Two aspects should be 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

2.7.1.2 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 could be retained :

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

Ech partner involved in SAMTA experimentation should make assurance with health authorities in his own country that provided that the two above rules are respected, no regulation violation should be denounced.

2.7.2 Services requirements

The table in §0 gives information on the required services to perform tele-expertise and tele-distribution services. While tele-distribution is essentially performed out of any context of emergency, 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.).

2.7.2.1 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 devised in 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).

2.7.2.2 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). Even if the application is able to split the big files in several files of acceptable memory size to send them in several e-mails, with the reverse procedure at reception, this local temporary storage may prevent for ensuring the exchange of medical files if no precaution is taken :
 - necessity to regularly retrieve e-mails from the internet provider server to the teleradiology station ;
 - necessity to negotiate a larger temporary storage with the provider.

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. Once this is done, the problem of bandwidth usually limited by the telephony technology prevents for thinking of such a solution for cooperative sessions.

2.8 Review of Cooperative Protocols

2.8.1 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) acknowledges ToolTalk as standard (available on most UNIX systems). However, ToolTalk is not a solution for PC platforms (Windows and NT).

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

2.8.2 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.

2.8.3 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 Mb/s for ON-SAD streams (see RETAIN Deliverables).

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

2.9.1 Introduction

The two services that must be implemented in SAMTA project are 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.

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-PPD¹⁹	ON-PIVD²⁰	ON-VCD²¹	OF-SAPD²²	ON-SAD²³	OF-SARD²⁴
<i>Tele-expertise</i>	<ul style="list-style-type: none"> - no dynamic images - dynamic images with lossy compression - dynamic images with lossless compression 	-	<ul style="list-style-type: none"> - low quality video only - low quality audio/video²⁵ - 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 compression - dynamic images with lossless compression 	<ul style="list-style-type: none"> - dynamic images with lossy compression - dynamic images with lossless compression 	-	-	-	-

The trials that will be performed in the scope of SAMTA project should help 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).

¹⁹ Off-line Predated Patient Data.

²⁰ On-line Patient Investigation Data.

²¹ On-line Video-Conference Data.

²² Off-line Service Application P-Data.

²³ On-line Service Application Data.

²⁴ Off-line Service Application R-Data.

²⁵ If it is not possible to use another telephone line.

3. ARCHITECTURE RECOMMENDATIONS

3.1 Introduction

This part of the document describes general architecture recommendations for telemedicine applications. The main objective is to define a reference model flexible enough to cover (almost) all aspects of telemedicine applications. The application developed within SAMTA project will be a demonstration for this concept.

The main part of this document is itself organized according to the following topics :

- explanation of important terms
- basic idea of architecture model
- identification of telemedicine services
- introduction of layered structure
- definition of communication between these layers
- considerations about scalability and openness
- integration into existing systems
- identification of available technologies

3.2 Terminology

There is no question : architecture is important for every large software project. But if you ask people what software architecture actually is you will obtain a variety of answers describing more or less the same concept. The reason is that there is no standard, universally-accepted definition of this term.

Considering this we don't even try to give a final definition. A rather long list categorized in textbook, classic, bibliographic and visitor definitions can be found in [3.1]. Nevertheless a very short and precise one shall be cited : " An Architecture, as we intend to use the term, consists of (a) a partitioning strategy and (b) a coordination strategy. The partitioning strategy leads to dividing the entire system in discrete, non-overlapping parts or components. The coordination strategy leads to explicitly defined interfaces between those parts. "

HISA (Healthcare Information System Architecture) [3.2] an European Prestandard for the field of medical information systems also deals with this topic. Even though there is no direct relationship to the field of telemedicine, we will use some of HISA's terms and concepts for this work.

In the following we try to give a short summary on architecture and related terms :

The architecture of a system deals with the orderly arrangement of its individual parts. It describes the overall structure consisting of clearly identifiable components and their objectives, scope and interactions with the rest of the system. The goal of such decomposition is to control the complexity of a large system to some extent and to make reliable and cost-effective the various phases of its life-cycle (planning, design, development, maintenance).

Each component can be fully described by its external behaviour because it hides the internal details by the use of data encapsulation and accurately specified interfaces ("black boxes"). As an advantage a component can be substituted, removed or added without affecting the rest of the system. Due to their independence they allow distributed development and testing. Furthermore the re-use of software components plays nowadays – in times of rapid prototyping and componentware – an important role. Other aspects of this modular concept like scalability and openness are described later in this document (see 0 and 0).

Whereas the architecture is very close to the actual implementation and developing process of a system the reference model as a further abstraction gives a more conceptual overview. The reference model is totally independent from any actual application. It combines a class of architectures and allows them therefore to be compared, i. e. the individual components of different systems with different architectures are arranged according to the abstract components of their superior reference model. The OSI network model [3.3] with its seven layers is a good example for this concept.

The implementation as the final step describes "only" one possible transformation into a real piece of software which fulfills the given requirements. For this reason the implementation is fully out of the scope of these architectural considerations.

3.3 Motivation

The great importance of an architectural concept for a software project like SAMTA lies in the nature of its life-cycle. Large systems – especially in the medical field – are running for a very long time from their start up. Since the (external) conditions and requirements often change during their lifetime it is very important that they can be adapted appropriately. For economic reasons as much as possible should be re-used for the system's next generation. But this requires an architecture which is consistent between system versions. It should be possible to extend or substitute individual components without changing the basic structure of the whole system. A well-designed architecture is therefore a guarantor for a long life of large systems because it supports the evolution from their start up.

Architecture is not only a discipline of design but also a representation of design. Modern CASE (Computer Aided Software Engineering) tools support the graphical development of software architecture. The output of such programs can be used to document the progress and the final results. These documents can help people outside the development to understand the principles on which the architecture is based. Especially in the medical field there is often a commitment to document each working step for the purposes of verification.

3.4 Scope

The main objective of this document is to define a general (rather abstract) reference model for telemedicine applications. Furthermore some recommendations for the development of the SAMTA demonstrators (concerning WP07 – Application Integration, see 0) will be given. But it is fully out of the scope of this document to describe their implementations or any other implementation specific detail.

3.5 Referenced Documents

- [3.1] Software Architecture, Software Engineering Institute, Carnegie Mellon University :
http://www.sei.cmu.edu/architecture/sw_architecture.html
- [3.2] HISA – Healthcare Information System Architecture Part 1 / Healthcare Middleware Layer, CEN/TC 251, Final Draft 2, prENV 12967-1 :1997, March 1997 :
<http://www.ehto.be/ikb/standards/centc251/hisa/index.html>
- [3.3] OSI – Open Systems Interconnection, International Organization for Standardization (ISO) :
<http://www.iso.ch/cate/3510001.html>
- [3.4] Software Architecture Technology Guide :
<http://www-ast.tds-gn.lmco.com/arch/guide.html>
- [3.5] DICOM – Digital Imaging and Communications in Medicine, National Electrical Manufacturers Association (NEMA), Washington :
<ftp://ftp.nema.org/medical/dicom>
- [3.6] UML – Unified Modeling Language :
<http://www.rational.com/uml/resources.html>
http://www.omg.org/library/schedule/Technology_Adoptions.htm#tbl_UML_Specification
- [3.7] CORBA – Common Object Request Broker Architecture, Object Management Group (OMG) :
<http://www.omg.org>
<http://www.corba.org>
- [3.8] Java, Sun Microsystems :
<http://www.javasoft.com>

3.6 Architecture

3.6.1 Basic idea

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 [3.3]).

Furthermore we recommend to use multiple views describing different aspects to express an architecture. HISA [3.2] 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.

3.6.2 Services

Analysis of user needs and appropriate services in telemedicine is the title of the workpackage related to this document. As a result of this analysis the required services have been identified in §1. From technological point of view these services are on a very high level, but from enterprise view they are already to specific. Our approach is to introduce – analogous to HISA – three different levels of complexity to classify the services and to hide the technical details where they are not needed.

3.6.2.1 Medical Services

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 ”.

There are many different ways to categorize the medical services. One possibility is to divide them into three groups depending on the activity status : (user) active, (user) passive and cooperative (work). A more technological one distinguishes the services on their requirements to the network capabilities : on-/off-line, low to high bandwidth, synchronous/asynchronous. Another one depends on the priority of implementation : necessary services, services of potentially future interest and other services.

From user’s point of view these are the most important services, because he doesn’t want to know how they function he only wants to use them.

3.6.2.2 Technical Services

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. HISA distinguishes therefore between Healthcare Common Services and Generic Common Services.

One possibility is to divide the technical services into five functional groups : network transmission, local services (e. g. printing), security aspects, compression and human interaction (e. g. CSCW). Not all of them are necessary for a basic telemedicine application, but they have to be taken into account.

3.6.2.3 Physical Services

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).

3.6.3 Layered Structure

There are many different methods to structure a system. A very common one is the layered structure used by OSI [3.3].

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.

Besides the tabular representation of layered structure the circular one – symbolizing the rings of an onion – is also very common.

3.6.3.1 Three main layers

The introduction of three different levels of complexity to classify the services leads automatically to a three layered structure as the following table shows.

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

The horizontal axis of this matrix forms the level of abstraction (increasing from right to left) and the vertical axis represents the level of complexity (increasing bottom-up). Therefore each service layer can be described at different levels of abstraction and each high-level service can be subdivided into its low-level services.

This structure (at least the vertical direction) follows HISA which introduces three layers with different degrees of abstraction. The original HISA terms are : Healthcare Application Layer, Healthcare Middleware Layer and Healthcare Bitways Layer. Though HISA only covers the field of information systems the underlying concepts are generally enough to be used for SAMTA. The corresponding terms for SAMTA are : Medical Services Layer, Technical Services Layer and Physical Services Layer. These three main layers are itself divided into several sub layers with an internal hierarchy.

3.6.3.2 Additional layers

There are many ways to refine this layered structure. As mentioned above a special combination of medical services might be arranged to recurrent operations, so-called profiles or scenarios. They could possibly form a fourth layer on top of the Medical Services Layer.

On the other end of this structure a level zero (below the Physical Services Layer) could be introduced to integrate the aspects of different transmission media into this model. For example modem and (analogous) telephony use a normal (analogous) telephone line while ISDN (including digital telephony) uses a digital one. But one level down both use the same twisted-pair cable.

Another approach would be to subdivide the three main layers into several sub layers. In fact the Physical Services Layer corresponds to the lower six layers of the OSI model.

3.6.3.3 *Other low-level aspects*

Some services require or strongly depend on specific properties of the underlying network.

Important aspects are :

- Network structure
 - LAN : Ethernet, Fast Ethernet, FDDI, ATM
 - WAN : Modem, ISDN (HDLC or PPP), ISDN with Multilink PPP, Frame Relay, ATM
 - dial-up vs. leased-line, point-to-point vs. routed, store-and-forward vs. on-line
- Bandwidth & Quality of Service
 - narrow-/broadband
 - guaranteed bandwidth, packet size/loss, real-time
 - availability, stability
 - communication costs

3.6.4 *Inter-layer communication*

The main communication direction is – due to the layered structure of this architecture – a vertical one. Services from upper layers use the functionality from lower layers. If these layers are direct neighbours we call it a direct communication. Although this should be the only communication form in layered structures there are also indirect communication relationships between other layers. Most of the functionality in the OSI model exists in all communication systems, although two or three OSI layers may be incorporated into one. The main reason is efficiency.

Additionally we propose to introduce an information and communication model as it is used in DICOM (Digital Imaging and Communications in Medicine) [3.5]. Such a model is predestined to demonstrate relationships between the individual components of a system and to real-world objects.

3.6.5 *Scaleability*

Scaleability 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. The scaleability may be measured in terms of modularity, extendibility and genericity.

That means in a more detailed form :

- modularity : components can be substituted without affecting the rest of the system (same external behaviour) or even removed ; that facilitates migration.
- extendibility : new components can be integrated and can interoperate in the whole system (external behaviour is compatible) to extend the capabilities of an existing system.
- genericity : standard components support a fundamental set of common needs, whereas additional components support local needs ; that promotes openness and modularity.

Scaleability of services requires scaleability of protocols as a prerequisite. This is for example the main reason to recommend TCP/IP protocol stacks on slow connections like modem where the overhead could be avoided but at the costs of scaleability to higher bandwidth transmission technologies.

3.6.6 Openness

Openness combines a variety of aspects. First of all it means the independence from any actual system. This is mostly done by the intensive use of existing standards, not only to guarantee interoperability between different systems but also to be independent from any proprietary solution provided by a certain manufacturer (safety of investment).

Openness also means the extensibility of a system. The functionality of a system should be easily adapted to the local needs of a certain environment. Future developments should be integrated without changing the whole concept. This aspect partly overlaps with the properties of scalability and portability (the ability to implement an application on different platforms).

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.

3.6.7 Application integration

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. Therefore it often happens that new applications or functionalities have to be integrated into an existing system. But the architecture of the whole system can't be changed every time. A stable architecture is required.

Another scenario is that there are existing applications that should be combined and perhaps extended by new functionality to build a new application. In this case there is a chance for designing a completely new architecture which considers the individual applications as components of a whole system.

The application integration in SAMTA project is part of the workpackage WP07. It will mainly base on the results of this deliverable.

3.6.8 Available technologies

Protocols for encoding, transmission and cooperative work have already been analysed in Part 2 of this document. The available technologies for architectural purposes can be divided into two groups : development or design tools and methods to integrate new services or application into a heterogenous environment.

The first group consists of a variety of (mostly graphical) CASE tools supporting the developing progress. We do not demand to use such a tool, but we strongly recommend to use a general-purpose notational language like UML (Unified Modeling Language) [3.6], which is predestined for specifying and visualizing complex software, especially large, object-oriented systems.

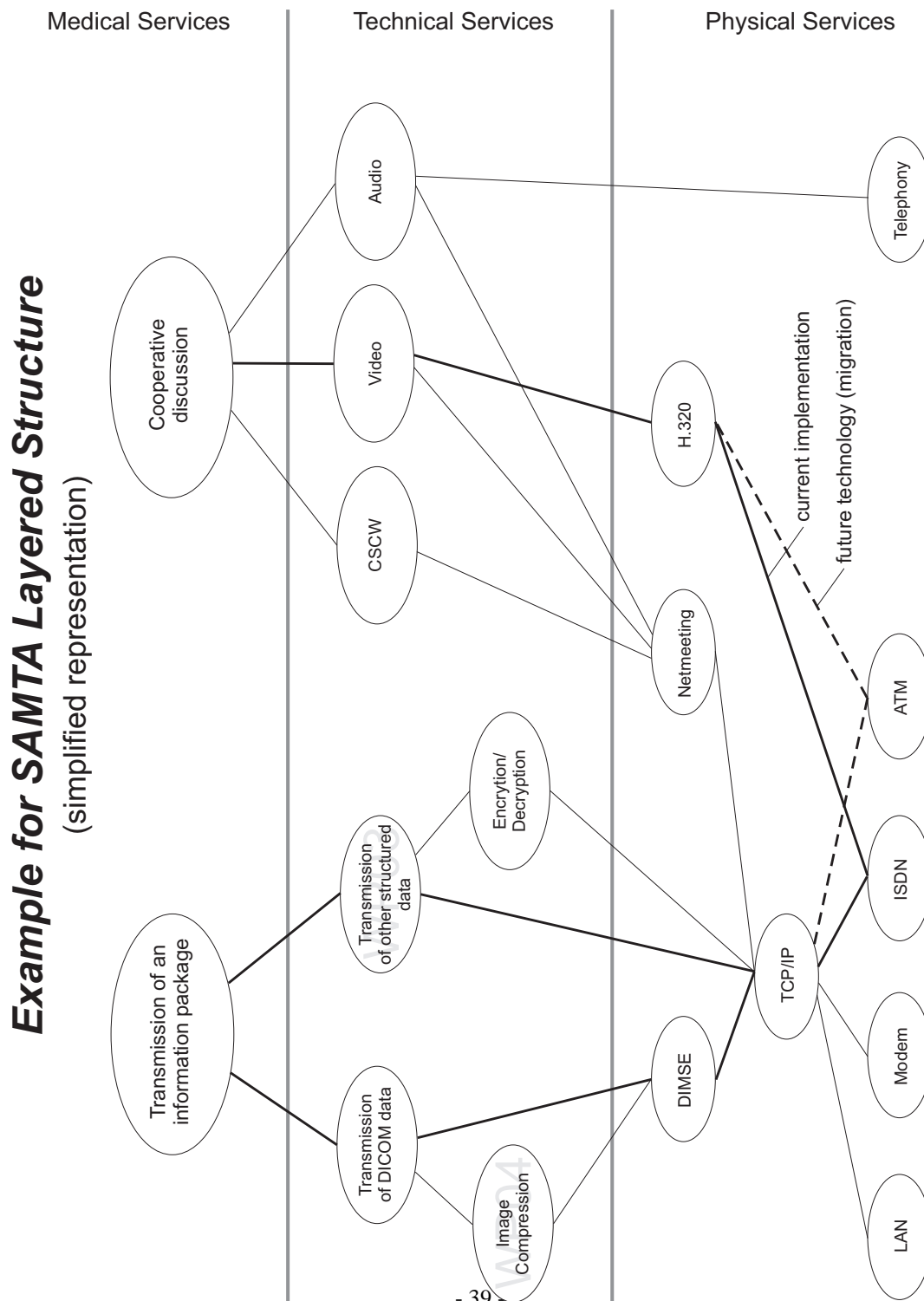
The integration work could be done by common solutions for middleware layers and distributed objects like CORBA (Common Object Request Broker Architecture) [3.7] or Java [3.8] which provide techniques to build platform independent software interfaces and communicate with remote objects. The great advantage is that it is even possible to build interfaces for existing applications regardless what programming language has been used.

Other more web-based approaches could use browser plug-ins and special MIME (Multipurpose Internet Mail Extensions) types to exchange information between different systems. This solution is very common in the fast growing internet market since it promises to achieve results with minimum effort.

Appendix A : Example for SAMTA Layered Structure

The following figure is a demonstration for the architecture model developed in this document. It shows two medical services broken down to their underlying services. The thick lines (linking two services) represent a choice of services that could be used for implementation. The dashed lines should demonstrate a possible migration to new technologies (here from ISDN to ATM) without affecting the higher level services.

The interfaces between the three main layers are more part of the abstract reference model than of the implementation, i. e. there is no need for a formal specification.



BIBLIOGRAPHY

- [1.1] CEN TC251 prENV 12265 : Medical Informatics - Electronic healthcare record architecture.
- [1.2] CENTC251 N98-119, FWD Electronic HealthCare Record Communication, Part 1, Extended Architecture, 1st December 1998, PT26 WGI. <http://www>.
- [2.1] SGML, Standard Generalized Markup Language, ISO 8879:1986
<http://www.iso.ch>
- [2.2] HTML 4.0 Specification W3C Recommendation, revised on 24-Apr-1998
<http://www.w3.org/TR/1998/REC-html40-19980424>
- [2.3] Extensible Markup Language (XML) 1.0, W3C Recommendation 10-February-1998
<http://www.w3.org/TR/1998/REC-xml-19980210>
- [2.4] Synchronized Multimedia Integration Language (SMIL) 1.0 Specification W3C Recommendation 15-June-1998
<http://www.w3.org/TR/1998/REC-smil-19980615>
- [2.5] Document Object Model (DOM) Level 1 Specification Version 1.0 W3C Recommendation 1 October, 1998
<http://www.w3.org/TR/1998/REC-DOM-Level-1-19981001>
- [2.6] <http://www.imtc.org/t120.htm>
- [2.7] <http://www.imtc.org/i/h320.htm>
- [2.8] EC/DG-XIII/TEN-IBC B3012 RETAIN Deliverables (1997)
- [3.1] Software Architecture, Software Engineering Institute, Carnegie Mellon University:
http://www.sei.cmu.edu/architecture/sw_architecture.html
- [3.2] HISA – Healthcare Information System Architecture Part 1 / Healthcare Middleware Layer, CEN/TC 251, Final Draft 2, prENV 12967-1 :1997, March 1997:
<http://www.ehto.be/ikb/standards/centc251/hisa/index.html>
- [3.3] OSI – Open Systems Interconnection, International Organization for Standardization (ISO):
<http://www.iso.ch/cate/3510001.html>
- [3.4] Software Architecture Technology Guide:
<http://www-ast.tds-gn.lmco.com/arch/guide.html>

- [3.5] DICOM – Digital Imaging and Communications in Medicine, National Electrical Manufacturers Association (NEMA), Washington:
<ftp://ftp.nema.org/medical/dicom>
- [3.6] UML – Unified Modeling Language:
<http://www.rational.com/uml/resources.html>
http://www.omg.org/library/schedule/Technology_Adoptions.htm#tbl_UML_Specification
- [3.7] CORBA – Common Object Request Broker Architecture, Object Management Group (OMG):
<http://www.omg.org>
<http://www.corba.org>
- [3.8] Java, Sun Microsystems:
<http://www.javasoft.com>