The Active Store providing Quality Enhanced Unified Messaging

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Abstract

A variety of concepts for service integration and corresponding service platforms emerged in the last two years which aim on the one hand for the interworking and integration of classical telecommunications and data communications services, such as telephony, voicemail, fax, e-mail, paging, etc. and on the other hand for universal service access from a variety of end user systems, including both fixed and mobile terminals.

Unified Messaging as a branch of Personal Communication Support enhances control over reachability in telecommunication. Conversion technologies of communication media applying QoS evaluation allow to focus on the semantic of the information instead on carriage. An ODP system design and a CORBA-based prototype implementation provide the first step for a unified messaging system. This system can be integrated into other communication networks, e.g. as an IN service node or as a backbone service in an Extranet environment. This paper focuses on storage handling within the existing implementation and describes the quality enhancement in detail.

Keywords: *Unified Messaging, Service Node, Intelligent Peripheral, IN, Extranet, Communication Media, Universal Message Store, Media Conversion, QoS, Service Integration, Customer Service Control, Personal Mobility, Personal Communication*

1 Introduction

The concept of Unified Messaging has recently emerged from the research of Personal Communication Support (PCS) [1]. Reaching industrial relevance, it addresses the task of overcoming the multiple-mailbox approach of today's communication scenarios, with separated facilities for e-mail, voice storage, fax reception, etc. This coincides with the vision for future communication, to deliver *information any time, any place, in any form*, as it is described in the Virtual Home Environment (VHE) concept [5] within the emerging Universal Mobile Telecommunication System (UMTS) standards [4].

These concepts consider that global reachability is today realized by mobile equipment, so now the user wants to manage and to control this accessibility in order to maximize or to filter it – independent of his location, the used communication service medium, and the applied human communication interaction. Additionally, he wants to have access to his asynchronous message store from everywhere and in any form (i.e. using the available equipment). In this context the concept of PCS [7] provides people with a new dimension in communication. In general, the concept allows users to establish their own personalized communication environment by addressing three important aspects, namely:

- *Personal Mobility*, which denotes the mobility of the user in fixed and wireless networks, allowing the him to make use of communication capabilities available at different locations, i.e. at *any place and any time*;

- *Service Personalization*, including personalized call/reachability management, which allows the user to configure his communication environment and control his reachability according to his specific individual needs, i.e. *if, when, where, and for whom* he will be reachable, possibly supported by concepts of content screening.
- *Service Interoperability* in distributed multimedia environments between different types of communication services and terminals, allowing users to maximize their reachability. In this context, capabilities are required that enable dynamic/intelligent content handling and conversion of different media types and media formats in order to deliver information in *any form*.

The research is backed by the practical implementation of a prototype; the *intelligent Personal Communication Support System* (iPCSS). This system is developed jointly by TU Berlin and GMD Research Center for Open Communication Systems (FOKUS). In the project history, we already had practical implementation of PCS communication handling in 1995. Within the following year we presented a system employing fixed, 'pre-wired' media conversion for service interoperability, converting fax, e-mail, and voice into each other. This approach has found positive acknowledgement by industrial implementations [2] in 1997.

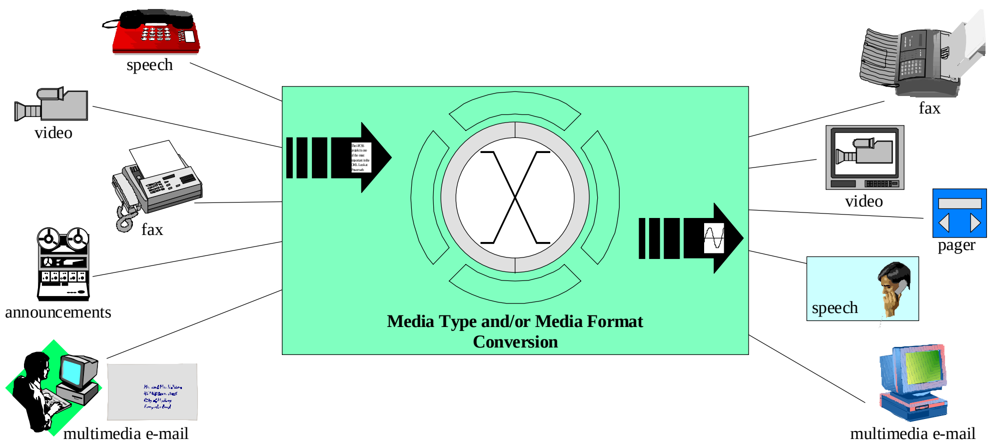

Figure 1: Media conversion prioritized in the iPCSS

Our focus in 1997/98 was to overcome the static, predefined character of the fixed converter implementations. Therefore, we implemented a system considering a set of user preferences for the dynamic selection of appropriate media converters, applying the evaluation of the quality of the conversion outcome for the final selection of the most appropriate chain of converters.

While related papers have described the conversion technology and configuration aspects [9,10], this one focuses on the perspective of the user receiving asynchronous and synchronous messages. Accessing these messages, he sees the storage facility and experiences the quality control, because the system avoids incomprehensible conversions of messages.

In this paper, we shortly discuss the theoretical aspect of sophisticated handling of communication media in the following section. In section 3, the latest implementation of the iPCSS is introduced as a practical example, with special considerations of storage and quality control. Section 4 describes, how the experiences of the experimental iPCSS will be used to develop a Unified Messaging System.

2 Media Handling

Each communication employs media, which can be abstracted on various levels. We distinguish transmission channels on a physical or a logical level, human perception systems, and several abstractions of presentation spaces, such electrical/air waves (physical level), 'audio' (low level), or 'speech' and 'sound' (higher level). Computerized multimedia already allows the integration of various lower level data (audio, video, text) into a single technical system. Consequently, this paper considers the integration of higher level presentation spaces by providing methods of converting such media as speech, text, image, etc. into each other.

2.1 Media Conversion

A media converter may be defined as a system entity, which input is information I_1 with the semantic S_1, carried by a specific medium M_1, using a specific form (or format) F_1. We obtain information I_2 as output in another Medium M_2 in format F_2, carrying a semantic S_2 (Figure 2).

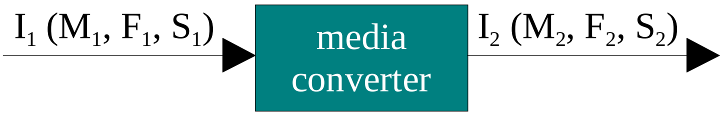

Figure 2: Media converter system

The quality of conversion can be measured by comparing the input and output semantic, S_1 and S_2, which should be preferred to be as close as possible, or having a predefined reduction.

Evaluating technical realizations of media converters we soon recognize that it is impossible to find commercial solutions for converting media (M_1, M_2) for every interesting combination of formats or technical representations (F_1, F_2). Therefore, the found solution supports different formats (F_1',F_2') and has to be accompanied with format converters (F_1, F_1') and (F_2', F_2). Consequently, we can distinguish two major classes of conversion *Media type conversion* and *Media format conversion*.

A deeper excursus into theoretical modeling of media conversion can be found in [9].

For specifying the model in more detail it is now necessary to consider the kinds of intended conversions. For this purpose, we need to consider that all information is intended to be perceived by human beings. However, this information could be generated by other humans as well as by technical systems.

An example, covering some complex media conversions, is the delivery of a fax message by telephone, after converting the fax image to text (Optical Character Recognition, OCR), filtering the text for speech purposes, converting the text to speech (Text to Speech, TTS), adapting the resulting audio format (e.g. µ-law to a-law), and delivering the audio stream via an ISDN line to the public phone system, to the plain old telephone of the recipient, or to a mobile phone (GSM-800, GSM-1800, or GSM0-1900). This example also illustrates the concept of *chaining* of converters.

2.2 Quality Evaluation

Brute force conversion of media would not be very satisfying for the user, as he often may realize that the chosen message was not suitable for the kind of media conversion applied.

A system can call itself intelligent only if it provides support for the user in the selection of the most appropriate media conversion and delivery method. A respective resource selection and configuration mechanism is described in the following section. Such a mechanism depends on comparable quality criteria for the conversion process as well as for the suitability of the message itself.

In the current implementation, a selection of important QoS parameters has been made from a variety of possibilities, which cover most detailed aspects. These parameters are:

- *Intelligibility*, covering problems of media synthesis, error probabilities, compression losses, channel noise, semantic reductions, and spell-check hit rates; given in percent (0...100%),
- *Bandwidth*, covering data volume and bit-rate; given in Mbit/s,
- *Delay*; given in seconds, and *Jitter*, given in milliseconds,

- *Cost*, covering aspects of tariffing and resource consumption (transmission and computation); given in countable units.

Quoting the example from the previous subsection, the intelligibility of the fax message could be measured at various stages. First, the noise level of the image can be determined (number of isolated pixels). After the OCR, the spell-check ratings for various languages can be compared, determining the required specific language and the worth of a following TTS conversion in general.

2.3 Generic Interfaces for Service Interoperability

A precondition for the provision of systems integrating heterogeneous legacy services is the unification of interfaces at various levels. Figure 3 provides an approach for process generic interfaces for heterogeneous external services and internal (core) components.

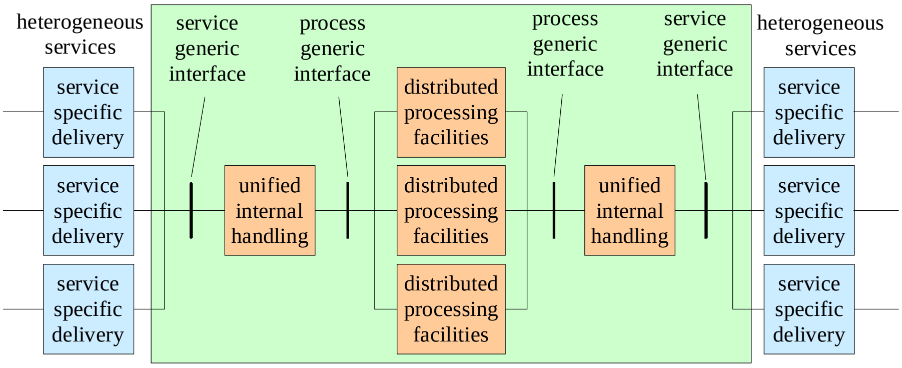

Figure 3: Generic interfaces for heterogeneous external services and internal components

Within a complex implementation, the components for the core system might be based on a heterogeneous, distributed processing environment. While each single component is represented by a certain object class (with a certain amount of instances of this class), different levels of generic object data and generic object interfaces have to be specified. In practical terms, the distributed processing facilities might be various core system objects on different hosts, connected by various network technologies, running different operating systems on different hardware platforms. The abstraction of these technical conditions is provided by a Middleware, such as CORBA.

Unifying heterogeneous external services, which are in our case different telecommunication and data communications services, require a service generic interface towards the core system. Across the system boundaries, the components realizing the bridge from the service specific to the service generic layer are called Service Gateways.

3 Intelligent Personal Communication Support

This section will provide an overview of the iPCSS development and implementation.

3.1 PCS Environment

The principles of Personal Communication Support, as described in the introduction, are already realized within a multiple stage mapping process of communication requests (e.g., calls). If such a communication request is detected, the first stage evaluates the personal preferences of the called user. This can result in actions such as call acceptance, call rejection, call forwarding to another user, etc. Second, the called (or forwarded) user is assigned to his current location, derived from schedule, manual, or automatic registration. Third, the location is examined for the communication capabilities available at this very vicinity. Next, the most appropriate conversion strategy is examined and a presenting terminal is selected. Finally, the selected chain of converters and the terminal are configured

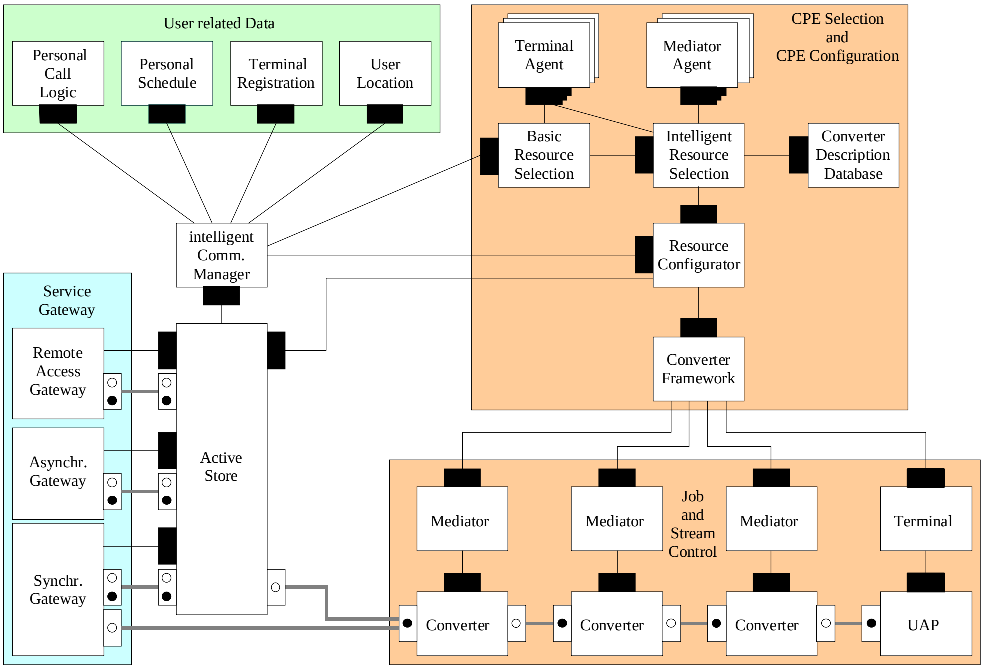

Figure 4: Computational Viewpoint of the iPCSS

for the processing of the communication request. Details of this process, except the media handling, can be found in [7].

For means of system development, the complexity of the problem and the heterogeneous hardware and software platforms to support require the application of sophisticated design methods, e.g. the Reference Model of Open Distributed Processing (RM-ODP) [12]. After an ODP compliant system design, the iPCSS prototype has been implemented on top of a CORBA-based Middleware.

3.2 System Design

From the five viewpoints of the RM-ODP the computational viewpoint of the iPCSS is provided in Figure 4. The computational objects are displayed with their *usage* interfaces. The interfaces for *management* and *monitoring* purpose are not shown within this figure.

Service Gateways connect the system to the whole world of communication outside, synchronous as well as asynchronous. They realize the access to legacy services (phone, fax, e-mail) and future tele-communication and data communication services (multimedia conferences, joint document editing, etc.).

Remote Access Gateways allow the user to access the information managed by the Active Store re-mote from nearly any kind of terminal. These special types of gateways are realized e.g. as Java applets (access via the WWW), as Agency (access with Mobile Agents), and as telephony gateway (access controlled by touch-tones or interactive voice response). Other forms of remote access are possible, such as fax polling or automated e-mail response.

A central component of the system is the Active Store (AS). Beside storing messages for the iPCSS users, it notifies the system of incoming communication requests and initiates the proper handling by questioning the intelligent Communication Manager (iCM) for immediate delivery. While the AS is responsible for the mediation between service specific gateways and the core system, the iCM repre-sents the central call processing unit of the iPCSS.

The personal preferences of a user, his current location, as well as information about the communi-cation terminals available at this very location, are provided by a set of modular user related profiles. The Personal Call Logic (PCL) provides rules and actions for call forwarding, prioritizing, screening, and specifically required conversions. The objects User Location (ULoc), Terminal Registration

(TReg), and Personal Schedule (PSch) describe the various aspects of reachability of a user, namely pre-planned regular locations or absences; manual or automatic registration at previously known locations or terminals.

The system related profiles for the internal and service generic representation of devices are logically represented by *Terminal Agent*s (TA) and *Mediator Agents* (MA), the latter representing conversion capabilities. The *Converter Description Database* (CDDb) contains the more technical information about the specific configuration parameters of each individual converter and terminal.

The *Basic Resource Selector* (BReS) preprocesses the information collected by the iCM. Its main tasks are to prepare the appropriate lists of terminals and mediators and the information of the user's preferences which are relevant for the selection process. Each instance of this object class has the knowledge of the communication capabilities of a certain location. This information is handed over to the *Intelligent Resource Selector* (IReS), which performs the actual selection process. It evaluates all possible converter chains for the incoming communication medium in relation to the terminal types available to and allowed by the user.

The *Resource Configurator* (ReCo) invokes the automatic configuration of the selected converter chain. This object transforms the service generic description employed in the selection process into a technical list of parameterization information suitable for the Converter Framework (CF). The latter object controls the whole configuration process as well as each single converter process and the stream binding between paired active converters. The CF automatically adapts the (possibly) different stream interfaces of the employed converters and mediates between different bearer networks if necessary. A sophisticated *Job and Stream Control* monitors the execution of all involved processes. The resource selection and configuration process represented by these objects is the key component providing the adaptivness of this architectural concept.

3.2.1 iPCSS Media Handling

The system is not only able to convert one communication medium into another using dedicated methods, it is also able to evaluate the assumed outcome of such a conversions and to dynamically propose the most appropriate way of conversion and delivery, based on the reachability of the user as well as the technical quality and the semantics of the communication content.

The differentiation of converter and terminal specific information into a service generic part (Terminal Agent, Mediator Agent) and a service specific part (CDDb) provides a concept of easy integration of conversion and filtering tools of third party providers, such as TTS, OCR, and Automatic Speech Recognition. Additionally, it allows further enhancements beyond the technical quality of the message for the evaluation of content semantics, ranging from simple keyword recognition to multimedia content evaluation.

3.2.2 Example Scenario

As an example, the case concluding the subsection 2.1 'Media Conversion' should be discussed. An incoming fax communication is handled by the Asynchronous Service Gateway "Fax". The recipient was recognized by his individual fax number, the sender is derived from the fax protocol, and the fax image is moved into the Active Store. The AS notifies the iCM, which requests the evaluation of the user's preferences (PCL) and applies the user's registration data in the ongoing call processing (TReg and ULoc). In the PCL, the user has categorized faxes from this sender as highly important. While the user is not registered at a specific terminal, the User Location delivers the sighting of the user's Active Badge [11] in the institute's library.

BReS and IReS are instructed to select the most appropriate terminal and converter for immediate delivery. Because there is no fax machine installed in the institute's library but only a telephone, the IReS evaluates a proper conversion strategy to read the text contained in the fax message to the telephone. ReCo and CF are provided with the selected converter chain and perform the configuration of the mediator processes. In this case the chain contains an image/text converter (OCR), text filter, text to speech converter (TTS), audio format conversion, terminated with a gateway for outgoing phone calls. After all these converters have been successfully installed and executed, the stream binding to the AS is established and monitored by the Job and Stream Control. Finally, the telephone in the library rings, and our happy user receives the so important fax message in spoken form.

Alternatively, if the received message has been defined less important, it stays within the Active Store. When triggered by remote access, the most appropriate way of delivery is selected as described above.

Following this short system overview, the aspects of the Active Store and the Quality ensurance should be discussed in the following.

3.3 Active Store

As the Active Store is in focus of this paper, it should be discussed in detail below. The store needs to provide facilities

- to preserve multimedia messages,
- to assign these messages to specific users known to the system,
- to communicate with a variety of service gateways accepting the messages,
- to trigger the further processing and evaluation within the system it is embedded in, and
- to retrieve messages in original form and as input for media conversion, both for delivery to local and remote terminals.

The concept of a Global Store has already been discussed in the context of multimedia e-mail [3]. Messages are stored in a central location and the messages are identified by a world-wide unique reference. The communication data is delivered just when explicitly requested.

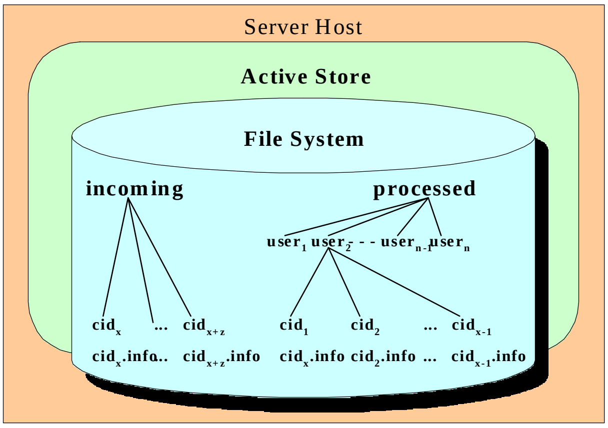

Figure 5: Structure of the Active Store

Within the context of this project the term Active Store (AS) is used to describe a system which is service generic and serves for all kinds of communication service gateways, including asynchronous communication services as well as synchronous communication services and remote access services.

The AS receives communication data, stores them structured and user related, moves them from one folder to another folder in the store, delivers them to other components of the iPCSS, e.g. to converter units, and finally erases communication related data.

Furthermore, the AS distinguishes communication data and the meta information about them by assigning a unique identification. Additionally, it provides access to the information in the store by various commonly available TCP/IP based communication protocols such as FTP and HTTP. As it is shown in Figure 5, the physical part of the Active Store is a part of the local file system of the server host, which is the workstation the Active Store process runs on.

3.3.1 Design of the Store

Since a communication request is always addressed to a person or to a group of persons, the communication information has to be stored retaining the relation between a message and the regarding person. Finally, a communication request is always related to at least one, called here a user. So, the store contains at least one folder for each user. Additionally, it has got an incoming folder, where messages and information are temporarily stored during evaluation.

The folders of the users contain all data related to already processed communication requests. To simplify the naming of the files, the communication identifier (cid_x) which will be created by the Active Store is also used as file name. A communication request produces always two files in the store; one file for the message (cid_x) and one file for the meta information (cid_x.info).

3.3.2 Message Identity and Multithreading

The service gateways are service specific but user generic. Each of them provide exactly one specific communication service (e.g. telephony service), but that for all users. They can process messages for multiple users at the same time. Consequently, it is possible that more than one communication request is initiated by the gateway at the same time. Even if a communication service gateway could ensure that a user gets his messages sequentially, it can not ensure to process all messages for all users sequentially. A service gateway needs the ability to process multiple messages for different users at the same time. The AS itself is multithreaded, therefore it is able to fulfil all services provided to multiple gateways at the same time.

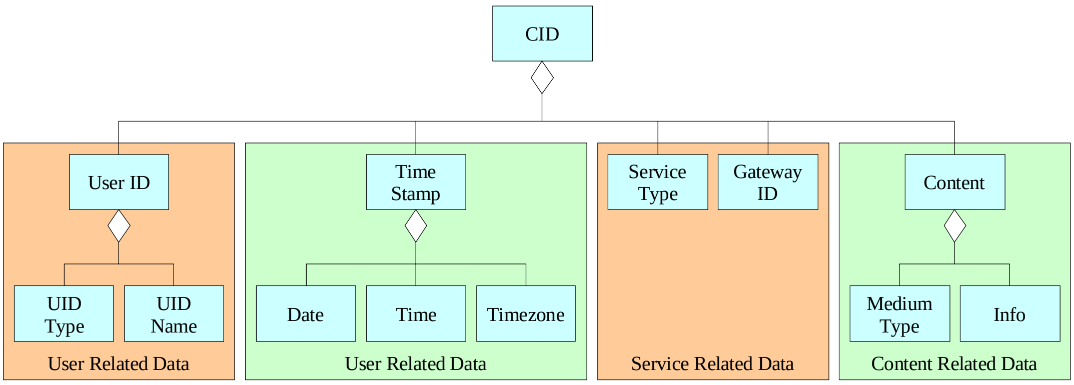

Figure 6: Communication ID information record

A communication request uniquely labeled with a communication ID, is initiated by the sender at a certain time in order to reach a specific address which depends on the used service (e.g. it is a phone number using the telephony service). This address generally regards to a person or a group. The message may be encoded and it is received by a service gateway. A communication request produces user related data, time related data, service related data, and content related data. Based on these categories, the CID (Figure 6) is structured as follows:

- *User Related Data* contain information about the sender of the message and the recipient. Therefore, the CID contains two instances of the structure User ID. This structure categorizes the type of the UID (e.g. phone number, e-mail address, etc.) and indicates the name itself.
- *Time Related Data* contain the structure Time Stamp, comprising two instances, for the time of creation as well as the time of receipt. The duration of delivery can be derived from the difference. A third time stamp might determine the expiration.

- *Service Related Data* distinguish the Service Type (e.g. telephony, e-mail, fax) and the Gateway ID.
- *Content Related Data* contain the Content field, holding information about the Medium Type of the message (e.g. text, image, video and/or audio, and speech), and possible textual descriptions of the content (Info).

3.3.3 Accessing the Store

The AS provides certain computational interfaces to the Service Gateways and the Resource Configurator. Three interfaces have been defined for service access, one for each type of the Service Gateways. This is done because the AS behavior does not differ in handling miscellaneous asynchronous communication services, but it differs in processing synchronous or remote access services. The AS assists system access to store communication data with a special computational interface to the Resource Configurator. Additionally, the stream interface for accessing messages inside the store employs protocols like FTP, HTTP, and IIOP, providing the advantage that the real implementation of the bulk data store is easily exchangeable.

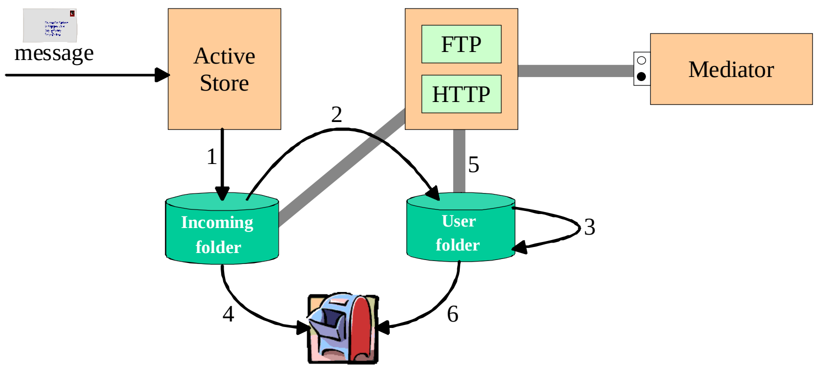

Figure 7: Data Life Cycle inside the Active Store

Figure 7 illustrates the life cycle of communication data inside the AS. (1) The first event in the life cycle of communication data is the temporary storage into the incoming folder. (2) If the communication request can be assigned to a specific user, the data are moved into the folder of this user. (3) The communication data can be moved from the folder of a user into a folder of another user, e.g. when the first user has forced this forwarding by configurations in the Personal Call Logic. (4) Otherwise, they may stay in the incoming folder or may be deleted. (5) If the communication request can be fulfilled successfully, the data are processed by mediator units, retrieved by HTTP, FTP, or IIOP. (6) The last event in the life cycle of communication data is the user forced removal.

3.3.4 Message reception

For synchronous messages, the task of the AS is only to initiate the evaluation of the user configuration. Its main purpose is the handling of asynchronous messages, is explained as follows. The service-specific Asynchronous Service Gateways employ the assigned computational interface to the AS. The main task of a service gateway is to receive the message, extract all possible information to be filled into a specific data structure, the Communication Request Information Record (CRIR), and to deliver it to the Active Store prior the message content.

The CRIR describes the initiator of the communication request, the addressee of the communication request, the protocols which enable the transmission of data, and the detailed physical resources of data transmission with. It employs the generic Teleservice Descriptor (TSD), which is discussed in detail in [10].

After a message is received by the service gateway it runs through four main stages (cf. Figure 8):

1. *process message:* The service gateway receives an incoming message which may be coded in a certain format. In the first step it has to be decoded or preliminary converted. The resulting data are scanned in order to obtain necessary information to process the communication request. The more attributes (such as legibility of a fax) are determined, the better the probability will be to deliver the message in a desired quality. Second, an information Object *Yellow Pages (YP)* is called for mapping physical addresses (phone numbers, personal fax numbers, e-mail addresses) to iPCSS-*User ID*s.
2. *assign CRIR:* In this stage the CRIR is filled with all data derived in the previous stage. If any attributes could not be determined, the corresponding fields are set to a well defined default value.
3. *inform core communication system:* In this stage the core system has to be informed about the new message. So, the Active Store is called and the CRIR is passed to the AS. The latter initiates the evaluation of the request by informing the iCM, and returns a *Communication ID* (described above).
4. *send data:* In the last step the data are transmitted to the Active Store, employing the previously received CID.

Now, the AS can establish an immediate connection to the user's terminal, if he has labeled this type of messages for prompt delivery, or store it for later browsing.

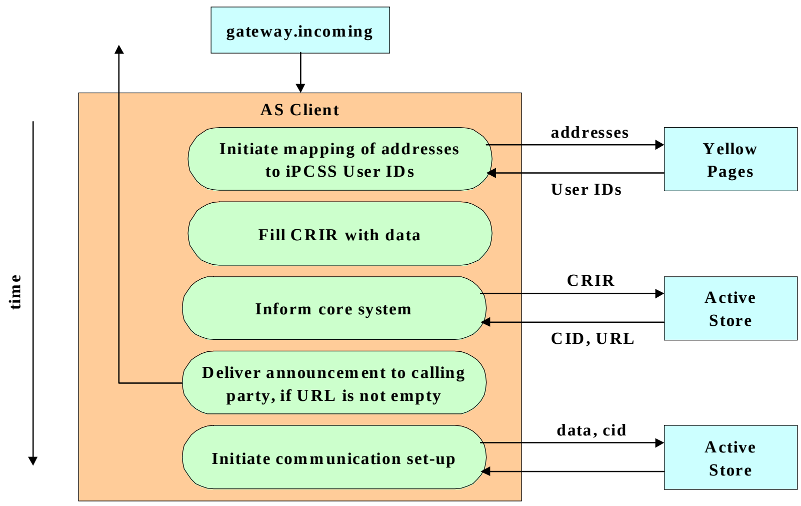

Figure 8: Active Store: Gateway Client Communication

3.4 Quality enhanced data access

The most significant feature of our system is its ability to generate chains for necessary conversions dynamically, on the fly. A precondition for this dynamic process is the evaluation of the usability of the outcome of the conversion process. Therefore, a powerful process of quality evaluation has been developed.

As discussed previously, a message has been stored in the Active Store, or a synchronous communication request is pending. All cases, the immediate message delivery, the remote access to stored messages, and the stream connection of synchronous communication is now evaluated by the resource selecting components for deliverablity to matching terminals. If no terminal matches the requested medium, the conversion is configured. Details of the selection of converters and the search algorithm for building valid converter chains, which are performed by the IReS, have been discussed in [10]. This paper focuses on the quality evaluation of a list of pre-selected chains. Figure 9 shows an example scenario from a technical point of view.

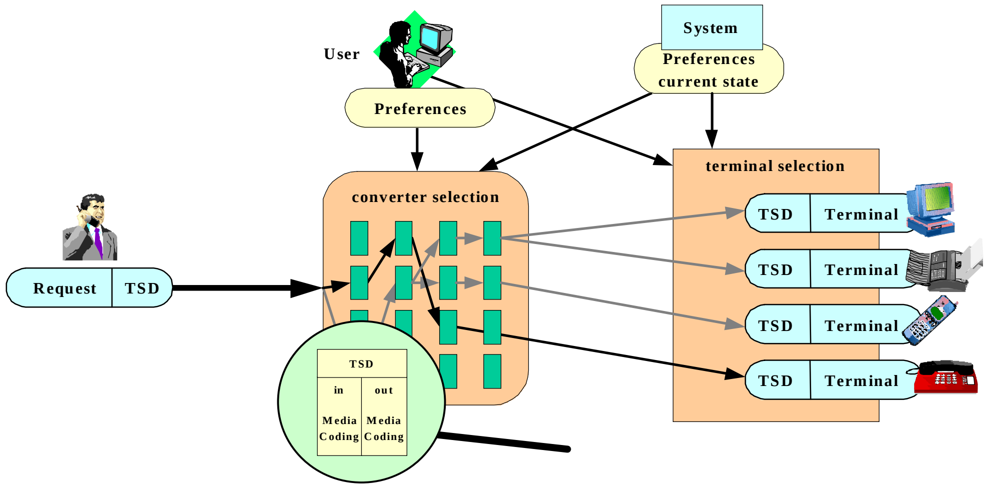

Figure 9: Basic selection process within the Intelligent Resource Selector

A single converter chain is described by a list of TSDs. The IReS checks the TSD parameters (e.g. Coding, Media) and creates technically valid chains considering primary preferences (preferred, forbidden terminals) and system states (idle, busy converter units). A list of such TSD-chains is the base for the following quality evaluation.

In order to optimize the evaluation algorithm, the chains are now checked for TSD parameters which are easy to compare without further knowledge, e.g. for keeping within the bandwidth boundaries. The remaining chains are kept on a stack. Each valid list is now mapped with the entries in the CDDb for the quality parameters of each converter involved. As a result, each converter chain is represented by their respective chain of concatenated QoS parameters (Figure 10). A three step evaluation process follows.

In the first step the incoming media parameters are compared with the current input state to check the capability of the converter. The real output state is calculated from the current state and the restrictions defined in the output media parameters.

The second step, shown in Figure 10, evaluates the QoS-parameters costs, delay, jitter, and intelligibility for a whole chain. For each of these parameters, a specialized concatenation function has to be employed. The costs and the delay are summed up. The final jitter is calculated as the maximum of all jitter parameters (similar to the bandwidth above). The intelligibility, which is represented as a percentage value, is calculated as the overall product of the individual values. The resulting description of the chain itself is now mapped to the quality of the incoming medium, which might already have quality deteriorations. The result is the overall quality of the chain described by spent costs, overall delay, maximum jitter, and the remaining intelligibility.

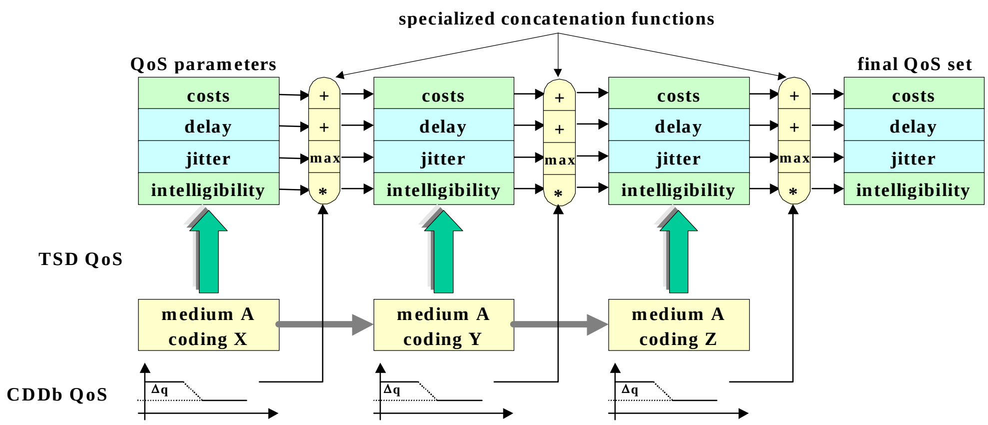

Figure 10: Evaluation process: QoS calculation

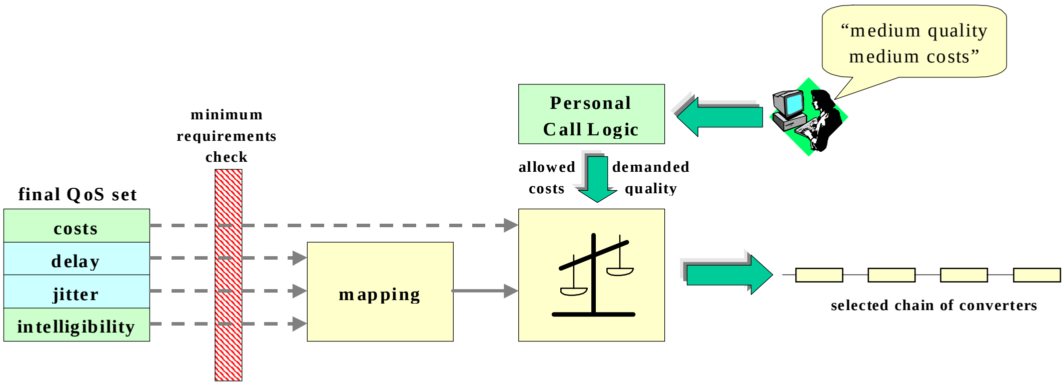

Figure 11: Evaluation process: Final decision

The third step is shown in Figure 11. The minimum requirements are checked. This concerns delay, jitter, and intelligibility. If the values are out of the usable range, the chain is rejected. Following, delay, jitter, and intelligibility are mapped to a single quality value. Both of these actions depend on the current connection mode (synchronous or asynchronous). That means for example that jitter and delay are less important in the asynchronous mode. The result is a description by the two parameters costs and quality, for each chain.

Figure 12 (left) shows a diagram with converter chains marked in by their costs/quality-ratio. The curve connects all chains with the highest quality for the respective value of the costs. The curve is growing monotonously, because a chain causing higher cost for the same or lower quality is considered as useless, these chains are rejected. On the other hand, the increase of costs in coincidence with the increase of quality is the expected behavior.

The remaining task is now to decide which chain on the curve should be taken. Therefore the chain must be judged with the given preferences, allowed costs and demanded quality.

The major aim of the given preferences pursued by the user is always a reduction of the arising costs. If the cost factor is less important, the user would always choose the best quality. With the limitation of the costs, the user defines implicitly an upper boundary for the demanded quality. Conversely, it could be possible to demand a particular quality which reduces the costs too. To keep the complexity of adjustment by the user in comprehensive limits, such preferences are not used.

If only one directive (allowed costs or demanded quality) is given, the decision is less complex. The chain closest to the respective limit is chosen. If the limit can not be met at all, the closest chain is taken. This guarantees that one chain is always selected, even if it is slightly out of the limit.

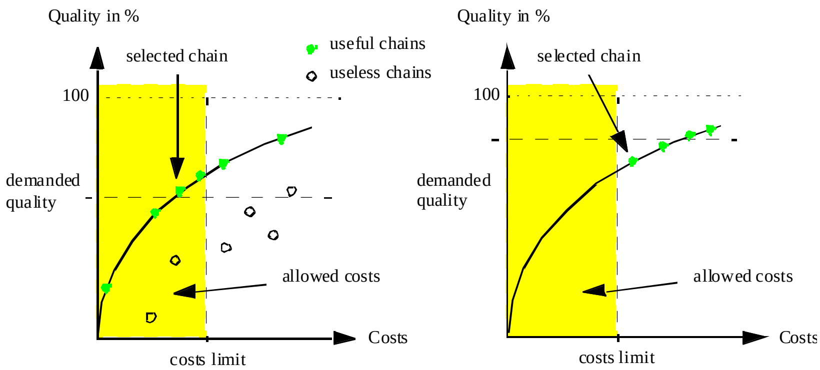

Figure 12: Selection by costs and quality preferences

The decision is more complex if both preferences are given (Figure 12). If the costs limit can be met, the chain with the closest quality is chosen. If the allowed costs are exceeded, a compromise between the allowed costs and the demanded quality has to be found. For that, the difference between the given preferences and the achieved parameters is calculated. The chain with the smallest difference is chosen.

Finally, the quality evaluator creates the return list. If at least one chain meets the minimum requirements, the result of QoS-evaluation explained above is always one selected chain. If no chain is found, an empty list is created and returned.

4 An iPCSS based Unified Messaging System

The design process and our practical experiences with the prototype implementation of the iPCSS have proven, that it is possible to design and to build a distributed system beyond the capabilities of traditional message handling systems. The success of the iPCSS and the positive acceptance of the emerging technology of Unified Messaging have motivated us to continue our work. The target vision of the evolution of the iPCSS is the development of an extended Unified Messaging System (UMS). The term *extended* emphasizes the task to overcome the multiple-mailbox approach of today's communication scenarios. Taking into account the Unified Messaging products available today, our UMS is enriched with remarkable innovations, e.g. a complete service interworking, customer service control, content screening/handling, fully manageable system architecture, different subscription models, flexible charging and billing policies, multi-level security for the system and for the customers, and a modular and freely scalable system.

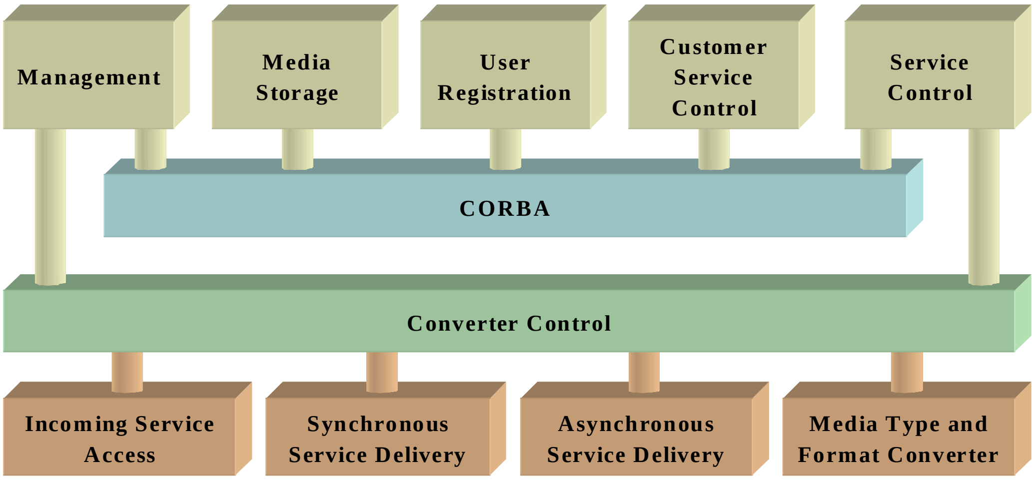

Figure 13: UMS subsystems

Since the beginning of 1998, we are redesigning the iPCSS [16]. The new UMS consists of a certain number of subsystems, which represent re-compositions of the iPCSS computational objects. Each subsystem incorporates modules, while each module provides information to or performs tasks for other modules or other subsystems respectively. The functionality of each subsystem can be dynamically enhanced by the integration of new modules. The outcome is a system, which is scalable for multiple applications, from a single host black box system for small enterprises or private customers, as integrated service in the backbone of Internet/Extranet providers, up to a Service Node [13] of an IN platform [14].

At the current stage of the redesign we have identified the following subsystems:

- The *Media Type and Format Converter Subsystem* features various converters for specific media format and media type conversions, such as TTS, OCR, and speech recognition.
- The *Incoming Service Access Subsystem* comprises service gateways dedicated to specific communication services, which should be integrated into the UMS. These gateways are able to trigger the service control subsystem (see below) in order to obtain information on the subsequent service processing (e.g. if an email should be filtered, converted, etc. or not).

- The *Synchronous Service Delivery Subsystem* comprises service gateways dedicated to specific communication services via which already converted information should be delivered to the end user. The gateways are triggered and controlled via the converter control subsystem on behalf of the service control subsystem.
- The *Asynchronous Service Delivery Subsystem* enables users to obtain universal access to stored information, i.e. messages. Since this access should be possible from various end systems a set of GUIs and Gateways has to be provided. The gateways are triggered and controlled via the converter control subsystem on behalf of the remote access control unit which is part of the asynchronous service delivery subsystem.
- The *Converter Control Subsystem* controls the media type and media format converter subsystem based on the information obtained from the *service control* or *service delivery* subsystems. Concerning the selection and appropriate configuration of converters it may use predefined converter chains or dynamically established converter chains.
- The *Service Control Subsystem* comprises the service control logic (i.e. call handling rules) and information objects related to users, terminals, etc.
- The *Customer Service Control Subsystem* allows users to modify their preferences for service control. Since this access should be possible from various end systems a set of GUIs and Gateways has to be provided, which are similar to the ones used in the asynchronous service delivery system.
- The *User Registration Subsystem* allows the usage of automatic location techniques, e.g. infrared tracking [11], GSM allocation, GPS positioning [15], etc. Additionally, manual and scheduled registration mechanisms will be provided within this subsystem.
- The *Media Storage Subsystem* provides persistent storage capabilities for multimedia information related to the services integrated in the UMS.
- The *Management Subsystem* is responsible for the manifold system management activities. This covers all functional management areas – fault, configuration, accounting, performance, and security.

5 Conclusions

This paper has presented an overview of the iPCSS, representing a CORBA-based PCS-platform for the provision of Unified Messaging capabilities as a usage example of automatically configurable technology of media conversion and handling, enhancing reachability of its users. This technology has been evaluated from the theoretical viewpoint, and tested in a prototype implementation.

One of the key components of a messaging system is a store able to temporarily manage multimedia communication data. As we have shown in this paper, such a store should, beyond preserving messages, become an active part. Our approach extends the common global store concept, leading to a system component capable of an autonomous handling of all communication related data. The iPCSS users profit from the processing their received messages concerning user predefined rules and quality of service preferences. This user centered approach goes far beyond the unified messaging systems available today.

The last section of this paper provided a short outlook of the future activities based on sound experiences and the industrial acceptance of the iPCSS. The described Unified Messaging System will employ the active store and quality of service concepts from its predecessor. Additionally, it integrates a system management, advanced strategies for accounting and billing, and different subscription models for its users. A UMS whitepaper for will be available soon at [16].

Acronyms

AS	Active Store
CORBA	Common Object Request Broker Architecture
CPE	Customer Premises Equipment
CPM	Customer Profile Management
DCT	Discrete Cosine Transform
DPE	Distributed Processing Environment
GPS	Global Positioning System
GUI	Graphical User Interface
iCM	Intelligent Communication Manager
IIOP	Internet Inter-ORB Protocol
IN	Intelligent Network
IP	Intelligent Peripheral
iPCSS	intelligent Personal Communication Support System
INAP	Intelligent Network Application Protocol
ISDN	Integrated Services Digital Network
JSCM	Job and Stream Control Management
LAN	Local Area Network
MA	Mediator Agent
OCR	Optical Character Recognition
ODP	Open Distributed Processing
PABX	Private Automatic Branch Exchange
PCL	Personal Call Logic
PCS	Personal Communication Support
POTS	Plain Old Telephone Service
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RM-ODP	Reference Model of Open Distributed Processing
TA	Terminal Agent
TSD	Teleservice Descriptor
TTS	Text-To-Speech conversion
UMS	Unified Messaging System
UMTS	Universal Mobile Telecommunication System
UPT	Universal Personal Telecommunication
VHE	Virtual Home Environment
WWW	World Wide Web

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