Resource Selection in Heterogeneous Communication Environments using the Teleservice Descriptor

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Abstract: Automated processes in distributed communication environments require tools for unifying heterogeneous multimedia services. The Teleservice Descriptor is introduced for generic handling and integration of traditional and innovative forms of communication. The Intelligent Resource Selector applies this descriptor for dynamic selection of communication end points and combination of necessary converters for service interworking. The Intelligent Personal Communication Support System provides the test-bed for the implementation of the developed algorithms, applicable in CPE, TINA and IN solutions.

Keywords: Multimedia communication in distributed, heterogeneous networking and communication environments, Media Conversion, Quality of Service, Personal Communication Support, Personal Mobility.

1. Introduction

Future communication, as described in the Virtual Home Environment (VHE) concept [2] within the emerging Universal Mobile Telecommunication System (UMTS) standards [1], aims to deliver to deliver *"information any time, any place, in any form"*. Systems have been introduced to manage and to control the global reachability of people in order to maximise or to filter it – independent of their location, the used communication medium, and the applied human communication interaction (asynchronous or synchronous). Additionally, these systems are to provide access to asynchronous messages from everywhere and with any kind of terminal.

In this context, an overview of the *intelligent Personal Communication Support System* (iPCSS) has been presented at the previous workshop [26], supporting the three important aspects of Personal Communication Support, namely *Personal Mobility*, *Service Personalization*, and *Service Interoperability* in distributed multimedia environments. For the latter case, 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 term 'intelligence' refers to the capability of the iPCSS to make certain decisions within user-defined limits by itself, therefore relieving the user from pre-planning every possible situation in his communication environment.

The research is backed by practical implementations of the system, performed jointly by TU Berlin, GMD Research Center for Open Communication Systems (FOKUS), and Deutsche Telekom Berkom.

While the previous paper provided an overview of conversion capabilities and the complexity of the system, we focus now on the technical aspect of unifying access to heterogeneous multimedia services, comprising and integrating traditional and innovative forms of communication.

Section 2 analyses the respective requirements, while section 3 introduces the Teleservice Descriptor for generic handling of telecommunication services. Section 4 presents the Intelligent Resource Selector, applying this descriptor for the dynamic selection of communication end points and the combination of necessary information converters for service interworking. The concept and experiences of the implementation within the iPCSS are sketched in section 5. The outlook points to possible applications of the core system within a wide scale of scenarios, comprising CPE, TINA [7] and Intelligent Network (IN) [19] solutions.

2. Heterogeneous Multimedia Communication Facilities

Humans communicate with each other in many very different ways. Transport media as well as presentation media of the different ways of communication have individual properties and heterogeneous characteristics.

Electronic, digitized and computerized media handling has unified a lot of aspects in terms of transport and storage of communication data, however it has brought up completely different, incompatible solutions for each task, which are just recently going to be bridged.

A computerized communication system dedicated to a specific medium, such as a telephone system with digital switching, has been built to take care by default of all specific properties of this very form of communication.

In the next step, a system dedicated to bridge two forms of communication, such as a system dedicated to forward e-mail by voice telephone, can handle the specific properties of these two forms of communication in a predefined, pre-planned and well adjusted manner.

As our current research is focused on automated, intelligent decisions how to handle actual communication request most appropriate, and therefore to bridge any form of communication with any other, we face the problem to handle the full variety of individual characteristics for each event of communication.

For automated handling, the heterogeneity of communication has to be classified precisely, allowing the system to match components for various purposes within a huge construction kit. Elements required for the adaptation and conversion of communication media, such as connecting gateways, the selection, configuration and building of converter chains, have to be in the focus of such classification, providing a generic description of the semantic carried by each of the media used.

While our implementation test-bed uses a CPE/CPN environment, the underlying technology needs to be scalable for integration in future global communication systems, considering the recent developments in TINA [8] and Intelligent Networks (IN) [19].

3. Generic Approach: The Teleservice Descriptor (TSD)

The basics for global connectivity and ubiquitous computing are at first the hardware supporting all the necessary performance and the broadband networks for high speed multimedia services, and at second the software controlling all services. This software has to handle a huge set of telecommunication and information services, which makes it impossible to create a controlling software for each service. To design a system, which is able to handle the whole set of services and combine services to enable service interworking (e.g. a GSM user can be invited to an ATM-based videoconference) a unique description for all services is required.

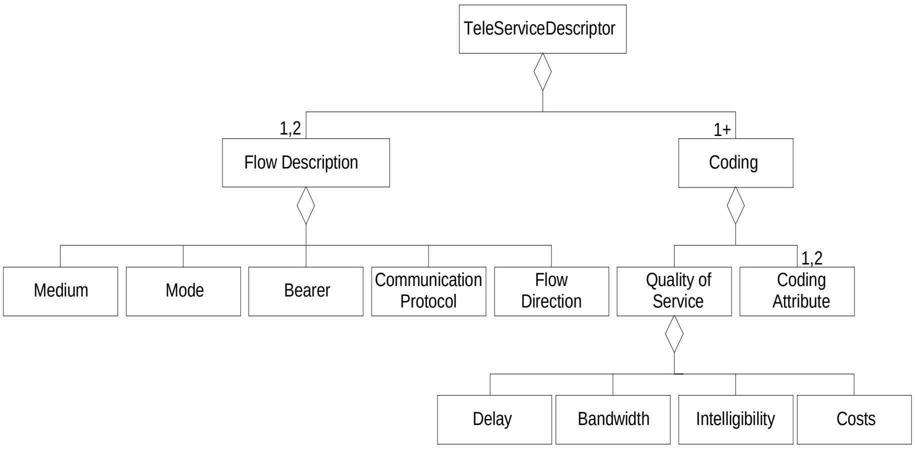


Fig. 1. Structure of the Teleservice Descriptor

This section describes the different parameters for such a generic description and suggests a complete set of attributes for a generic service descriptor. It leads to the structure presented in Figure 1.

To prevent misunderstanding with other meanings of “service”, we introduce the term *Teleservice*, describing the special meaning in the context of telecommunication.

attribute	open lists of possible values
Medium	image, video, speech, audio, video & audio, text, file
Mode	synchronous, asynchronous
Flow Direction	sink, source, sink-source
Bearer	ISDN, B-ISDN, ATM, Ethernet, FDDI
Communication Protocol	X.400, MMC, H.320, FTP, RFC822, MMM, HTTP, SNMP, G3, G4
Coding	GIF, JPEG, BMP, TIFF, G3, G4, XPM, BPM, PGM, PPM, PNM, XBM, XWD, MPEG1-Video, MPEG2-Video, AVI, MOV, FLIC, MJPEG, H.261, MPEG1-Video & Audio, MPEG2-Video & Audio, ADPCM, LPC, PCM, MLAW, ALAW, AU, WAV, VOC, SND, MIDI, S3M, 669, MPEG-Audio
Quality of Service	bandwidth, delay, costs, intelligibility

Table 1 Teleservice Descriptor Attributes

Telecommunication services enable users to communicate in different ways using these services. The specific characteristic of a dedicated Teleservice can be described with a set of attributes, which has been defined to describe the meaning of the term "service" within this document. These attributes are in detail "medium", "mode", "information flow", "bearer", "communication protocol", "coding", and "quality of service" (see examples in Table 1). Only the complete set of the attributes describes a Teleservice. The entries of *possible values* given in the table represent incomplete, open lists, which lists have to be updated day by day with new bearers, communication protocols, and codings.

Other approaches have been influenced by the different kinds of communication. In this context the term service has been used for any kind of information exchange. The meaning of service has been overloaded frequently. Different network technologies classify their services to improve the handling of terminology. Each approach uses different classifications and different terminologies (e.g. Intelligent Networks (IN) services may be split into basic or supplementary services, while Integrated Service Digital Network (ISDN) services can be split into bearer services, Teleservices or supplementary services). TINA-C aims to be applicable for all types of services, including simple bearer services, sophisticated multimedia services, management services, and operation services. The benefit is, that for each class of service a reference model has been provided [8].

Using the Teleservice description described in the following, it is not necessary to classify Teleservices or to describe the meaning of Teleservices in detail. The values fitting the introduced attributes have to describe the whole Teleservice properties. The attributes which are discussed subsequently have been defined by scrutinizing some existing telecommunication environments. Three main types of attribute groups have been derived – general attributes, transport/communication related attributes, and quality of service attributes.

3.1. General Attributes

At first, three Teleservice attributes will be introduced which are derived from information exchange of human beings. The attributes medium, mode, and information flow have no technical background. If somebody wants to describe only the communication between two human beings, without any technical equipment, these attributes would be sufficient to characterize the transmission aspect of the information exchange.

3.1.1.Medium

From the broad scope of meanings of the term "medium", comprising perception media, representation media, presentation media, storage media, transmission media, and information exchange media [17], this paper considers the aspects defined for computerized multimedia communication, in particular the technical media stimulating the human senses for information exchange, namely perception media, such as text, graphic, picture, speech, sound, and music.

For building the TSD, the defined values of the attribute *medium* are shown in Table 2. Some of the values refer to the same human sense, other senses are omitted. While video and still image both stimulate the visual sense, the impact for communication systems (data volume, semantic, cost) as well as the cognitive processes involved

values	short description
image	is a still image
video	is a motion picture
audio	is any kind of sound
speech	is a single human or computer generated (speech synthesis) voice
video & audio	is video with simultaneous audio
text	is text coded in any format
file	is not further interpreted, arbitrary data

Table 2 Values for the attribute Medium

are completely different. Audio and speech (as the audible representation of a natural language), as defined above, are useful distinguishments for the purpose of automatic handling these media within an intelligent communication environment, and so is the combined class of video&audio.

Of course, the list could be easily extended if experimental approaches to stimulate the other human senses like touch (Braille devices, data gloves), smell or taste should be integrated into the respective scenario.

On the other hand, communication may involve data not addressed towards the human senses but sent to a special user application (e.g. large tables of stock prices). Such data are covered by the value ‘file’. These data should not be altered or interpreted by intermediate communication systems.

Conversion

In the previous section, the term “conversion” was implicitly used. Now it should be discussed from a pragmatic point of view, which media could be converted into another and what the result of such a conversion could be expected. A short summary is given in Table 3. The media types in the left column represent the source media. On the top of the table the target medium is specified. The table shows the results of the conversion from source to target.

Not in all cases the semantic of the source media survive the conversion. It is then only possible to produce a message that an entity from the source media type was detected. An example is the conversion from image to speech. Despite research in image recognition, it is nearly impossible to convert from image to speech preserving the full semantic of the source image. A solution is to notify the receiver with a synthetically created speech message: “There is an image for you”, or “Image containing to faces”.

Some conversions are only possible by using more then one conversion steps, for instance speech to image. Speech can be recognized by special software packages, analyzing the language and later the spoken words. The type of the result may be ‘text’. Finally, we convert this text to image by pixel or postscript representations.

It is not possible in each case to convert without loss of semantic. When converting video&audio to audio, the video part is lost. While converting audio to video&audio, the video part of video&audio is blank or replaced by an still image.

All entries in Table 3 titled “trivial” are not difficult to convert, using state of the art conversion mechanisms. The column “file” is also easy to treat. Without any problems, it is possible to represent all media types as file.

	image	video	audio	speech	video & audio	text	file
image	trivial format conversion	still video	message	message	still video	message	save image as file
video	still picture – selected frame	trivial format conversion	message	message	silent video	message	save video as file
audio	visualization in different kinds	music notes on video	trivial format conversion	message	“black” video	message	save audio as file
speech	characters on image	characters on video	yes	trivial format conversion	“black” video	speech recognition	save speech as file
video & audio	combine video & audio to image	lost audio, or display of music notes	lost video	message	trivial format conversion	message	save video & audio as file
text	characters on image	characters on video	speech synthesis	speech synthesis	text scroll; speech synthesis	trivial format conversion	save text as file
file	message	message	message	message	message	message	trivial format conversion

Table 3 Possible Media Conversions

3.1.2.Mode

The mode of a Teleservice can be synchronous or asynchronous (Table 4).

values	short description
synchronous	both parties involved at a time
asynchronous	one party involved at a time

Table 4 Values for the Attribute Mode

Asynchronous Teleservices do not depend on any time conditions. The performance of such transmissions is influenced by best effort strategies, what means that the information arrives at the receiver as fast as possible. E.g. the internet Message Transfer Agents, a store and forward message handling system, works on these principles. An example for a connection oriented asynchronous Teleservice is a sophisticated automatic answering machine which forwards the recorded message to a certain telephone number.

Synchronous Teleservices are real-time dependent. A fixed time frame exists for transmitting a part of the information from the sender to the receiver (end-to-end delay). If the time frame is exceeded the synchronous communication will be broken. If the information reaches the receiver before the time frame is exceeded, the transfer is successful. A subclass of synchronous communication is isochronous communication, where the jitter is very low.

3.1.3.Flow Direction

Using this attribute (Table 5), the direction of the information exchange can be determined.

values	short description
sink	the Teleservice receives information
source	the Teleservice transmits information
sink/source	the Teleservice receives and transmits information

Table 5 Values for the Attribute Information Flow

The "flow direction" of a Teleservice can also be described as duplex or simplex, or as unidirectional and bi-directional. Unfortunately the values do not express anything about the fact which side of the connection receives and which sends information, which can be described with the terms source and sink. In case a Teleservice is described with the value "sink/source", it is based on a bi-directional (duplex) connection and both sides are transmitter and receiver at the same time. The values "sink" and "source" describe unidirectional (simplex) connections, and the additional information in which direction the information flows is given.

3.2. Transport and Communication Related Attributes

In contrast to the general attributes above, the transport and communication related attributes have a technical background. With these attributes, it is possible to describe the technical characteristic of a Teleservice in a generic way. Therefore, it was necessary to abstract from specific and proprietary parameterization of the underlying technologies. An approach for mapping a Teleservice to the parameterization of a physical resource leads to a system of dynamic resource configuration management, which is part of our research, but not covered by this paper.

3.2.1.Bearer (CPE-Bearer)

The "bearer" attribute describes the physical network technology on which the Teleservice will be transported to a service gateway which can be controlled by the intelligent communication environment (Table 6). These gateways enable the connection to different network technologies outside the Customer Premises Equipment (CPE) / Customer Premises Network (CPN). For instance, the connection between an old Public Switched Telephone Network (PSTN) and a CPE/CPN is only possible via service gateways. The service gateway can perform a bearer conversion (e.g. from ISDN to ATM). The knowledge about the underlying network technology is necessary to address the respective gateway.

possible values	short description
ATM	Asynchronous Transfer Mode (ITU-T I.361)
FDDI	Fibre Distributed Data Interface (ITU-T 3914x)
ISDN	Integrated Service Digital Network (ITU-T I.320)
B-ISDN	Broadband Integrated Service Digital Network (ITU-T I.321)
DQDB	Distributed Queue Dual Bus (IEEE 802.6)

Table 6 Possible Values for the Attribute Bearer [27]

Ethernet	normal 10Mbit Ethernet (IEEE 802.3)
GSM	Global System for Mobile Communication
DCS-1800	Digital Cellular System
PSTN	Public Switched Telephone Network

Table 6 Possible Values for the Attribute Bearer [27]

The starting point for this approach is the existence of distributed communication environments, which are based on distributed heterogeneous networks. In such an environment, the underlying network characteristic is transparent to the users. Different network technologies are interconnected. Solutions for interconnecting different kind of network technologies exist and have been tested for a long time. It is possible to address applications directly, independent of the underlying network. An example for addressing an application is File Transfer Protocol (FTP). Although the user addressing an application does not know where the host computer is located and what the kind of network it is, the information is transported through. It could be a TCP/IP connection over Ethernet or over ATM. For using services inside of the CPE/CPN the attribute bearer is useless, but for the description of services transmitted over service gateways (see above), the attribute "bearer" is required.

3.2.2.Communication protocol

The "communication protocol" (Table 7) is an attribute holding information about the protocol which is used between the application related entities of the communication end-points.

example value	short description
X.400	Message Handling System (ITU-T X.400)
RFC822-mail	Internet Mail (RFC 822)
SNMP	Simple Network Management Protocol (RFC 1270)
MMM	multimedia mail
H.261	video compression for p x 64 kBit/s (ITU-T H.261)
H.320	format for narrow-band visual telephone services (ITU-T H.320)
HTTP	Hypertext Transport Protocol
ISDN	Integrated Service Digital Network (ITU-T I.320)
FTP	File Transfer Protocol (RFC 765)
DAP	Directory Access Protocol (ITU-T X.500)

Table 7 Possible Values for the Attribute Communication Protocol [27]

In the context of the attribute "bearer" above the fact was discussed that in customer premises equipment it is possible to address user applications. To communicate with these applications it is necessary to define the communication protocol. On the basis of this protocol, the user applications can exchange information (e.g. a video conference is based on the H.320 standard).

The possible values for "context" have been designed as an open list, allowing the addition of new communication protocols to the list.

Depending on the usage of the TSD it might be necessary in some scenarios to define a further attribute "Transport protocol", covering such lower level protocols as

TCP/IP, X.25, IPv6, ISDN, RTTP, ZMODEM. However, as the systems developed within our projects employ middleware platforms like CORBA in distributed communication environments, these protocols are transparent.

3.2.3.Coding

The attribute “coding” (Table 8) describes the format the data is stored or transmitted in the system.

possible values	related medium
GIF, JPEG, BMP, TIFF, G3/G4 Fax	Image
MPEG1, MPEG2, AVI, MOV, FLIC	Video / Video & Audio
ADPMC, LPC, PCM, G.711, ALAW, MLAW	Audio / Speech
AU, WAV, VOC, SND, MIDI, S3M, MPEG	Audio
Binaries and other non-interpreted formats or raw data	File
ASCII, ISO 8859, EBCDIC	Text
HTML, SGML, LaTeX, PDF, PS, DOC, FM	File
ARJ, GZIP, ZIP, LHA, MIME, uuencode, Base 64	File

Table 8 Possible Values for the Attribute Coding [18, 27]

A format is a guideline how data have to be structured. It divides the data in control data (meta data) and usage data. The control data is mostly stored in a header and defines the areas of usage data. For the usage data the order of information and possible used compression algorithms are stored. Data streams without a header contain the control information between the usage information or lack any control information. In this case, the format must be well defined and fixed. These data formats could not only be stored in a file system, but appear also in a continuous data flow coming from a stream device like a video-camera. “Coding” is sorted by the different existing file types. Therefore the used names for the attributes come from the corresponding file type. In due to the endless number of existing codings this attribute should be designed as a growing list of supported codings.

3.3. Quality of Service Attributes

To fulfil the vision for future telecommunication environments to deliver “information in any time, any place, in any form”, an unlimited spectrum of telecommunication services will be offered by different service providers. The spectrum of conceivable services ranges from simple communication services up to complex distributed multimedia services. To enable the interworking of these services this document focuses on the third part of the slogan – “information in any form”. This requires to convert certain communication media into another media or at least into another format of the same medium, leading to a support of higher flexibility of terminals or applications.

Such conversions are currently done by stand-alone processes, realized in software or designed as hardware. Examples for conversion processes in this context are Text-to-Speech conversion, Optical Character Recognition, and Speech Recognition. Future telecommunication environments need to be able to combine such processes of conversion to enable service interworking in a generic way. For that reason, all the converters must have a unified interface for enabling arbitrary combinations of them.

Providing such conversions in an integrated framework with well defined interfaces, able to combine any conceivable combination of converters (e.g. fax -> image conversion -> Optical Character Recognition -> text conversion -> Text-to-Speech -> audio format conversion) leads into the problem of evaluating the quality of the outcome of each conversion in the conversion chain. The assessment of that quality enables the finding of a most appropriate converter chain, a most appropriate terminal, applicable for the requested service. This section deals with the problem of Quality of Service attributes which satisfy the demands discussed above. [7]

A number of Quality of Service attributes have been introduced in [26], some of them are discussed below. However, not all of them could be used for the design. For enabling an easy-to-handle algorithm which is able to compare two complete sets of Quality of Service attributes it is necessary to reduce the number of attributes. The attributes proposed for usage are “bandwidth”, “delay”, “cost” and “intelligibility”. Please note that the term QoS has been adopted from the networking context, but is used in a different way with other parameter sets here.

3.3.1.Bandwidth

The parameter “bandwidth” (Table 9) describes the required transmission resources.

possible values	short description
150 Mbit/sec	high speed connection - Constant Bitrate transmission
14400 baud	small-band modem connection - Constant Bitrate transmission
20 - 50 Mbit/sec	Variable Bitrate transmission

Table 9 Possible Values for the Attribute Bandwidth

The attribute contains information about the minimum bandwidth which is needed for the Teleservice. The bandwidth is the resulting data rate during the connection. It is suggested to use as values numbers in Mbit/s. There is also a need to set up connections with no dedicated bandwidth. These connections can be initialized with 0 Mbit/s as a special value, e.g. e-mail or G3-fax.

3.3.2.Delay

The term “delay” (Table 10) is used in this document synonymously to the term “end-to-end delay”. It describes the time the information exchange needs from the transmitter to the receiver (the receiver is not the communication endpoint, but the human being who uses the communication endpoint). An alternative name could be “global delay”.

possible value	short description
1 ms	describes a definite time value

Table 10 Possible Value for the Attribute Delay

“Delay” is composed of the three sub-types network transmission delay, computing delay, and buffering delay.

The network transmission delay is caused by the limited speed of signals and influenced by all factors which slow down the connection (e.g. overload, failure, and breakdowns). A computing delay results from any calculation process (e.g. conversion processes). Buffering is required in flow control related mechanism.

3.3.3.Cost

The parameter “cost” (Table 11) refers to all use of computational resources as well as to the transmission cost. In a distributed communication environment it is possible to abstract from the used network and to use different computational resources during a communication. Different converters and other service supporting resources could be used transparently to the user. For charging and billing each provider can define a certain amount of concrete resource which a user has to pay for the usage of it. To calculate how much a user has to pay for a concrete communication, every value has to be summed up to the total amount.

possible values	short description
US$ 0,03	a certain amount of a certain currency
3 units	a certain amount of a virtual currency

Table 11 Possible Values for the Attribute Cost

In the area of computing the term “cost” is also used to describe the required resources for a computing process. In face of that, the next attribute is modelled. It could be seen as a subclass of the attribute “cost”.

A problem arises when time dependent rates and flat rates have to be compared within the cost estimation in a QoS evaluation. A possible solution would be to evaluate the time dependent rates for average communication time.

Due to the various aspects to cover with the attribute, it is in some places used in its plural form “costs”.

3.3.4.Intelligibility

The parameter “Intelligibility” is the most important determiner for the correct transport of the semantic of the information during a Teleservice conversion process. Defined in Webster’s dictionary as “capability of being understood or comprehended”, it describes whether the human being perceiving the output of the conversion process is able to recognize its semantic correctly or not. The term is mostly used in the context of complex conversion, as text to speech, optical character recognition and speech recognition.

Concrete values for this attribute are difficult to determine (Table 12). Generally, such assessments are only possible by human beings. The assessments are explained in a colloquial way. Computer supported fax processing (i.e. the received fax will be converted into text and then into speech) is an example for a need of the determination of “intelligibility”. The problem using a computer is to asses the received fax, whether the semantic is lost or not. A possible solution for this specific problem is the usage of optical character recognition programs. If the number of recognized words is to small, the received fax is useless for the conversion into speech. The attribute “intelligibility” can be divides in various subordinated categories, such as

- Error Probability, which is the more technical version of the intelligibility
- Quality degradation due to (accumulated) lossy compression
- Quality degradation due to entropy reduction (color reduction, quantification, scaling, resampling).

possible values	short description
hard to decipher	value oriented on human beings
50%	semantic loss after conversion

Table 12 Possible Values for the Attribute Intelligibility

These categories deliver ways to measure and determine values for the intelligibility. Technical categories can evaluate bit error rates, mean square differences, noise levels, while on a language level e.g. the hit counts of spelling checkers determines the kind of the language as well as the usability of the outcome of the OCR.

3.3.5.The Attribute Quality of Service

For a first approach it is impossible to consider the whole complexity of possible Quality of Service attributes. A useful selection has been made above with bandwidth, delay, costs, and intelligibility (Table 13). This is a strong simplification, but it is useful for demonstrating a first functional model. All usage of resources is hereby covered by the parameter cost, and all errors, compression losses, degradation influence the intelligibility.

possible values	short description
bandwidth	required transmission resources
delay	temporal stoppage of the communication
cost	usage charge of any equipment / resources
intelligibility	capability of being understood or comprehended

Table 13 The Attribute Quality of Service

3.4. Summary

Employing the developed Teleservice Descriptor, it is possible to describe all Teleservices in a generic way. For the demonstration of this ability, six example cases of communication are shown in Table 14.

The first example represents the easiest case – the conventional ISDN telephony. The used “communication protocol” is only G.711, because the signalling before the connection is enabled via D-channel protocol Q.931 [27] is irrelevant. The “intelligibility” should be set to 100%, if only connections between ISDN telephones are desired (the process of digitizing the natural speech through the microphone in the ISDN-telephone is out of the scope of this study).

The asterisks in the table have the meaning of a wildcard. It is possible to use all possible values in the asterisk context, or the asterisked attribute is useless in the special context. For instance, for the Teleservice *chat* many chat protocols are conceivable and the Quality of Service attributes do not make any difference. The differences between the values of “cost” for *ISDN telephony*, *File Transfer* and *WWW via Cellular* are the semantic of the values. ISDN telephony means the costs per unit, *File Transfer* the costs per megabyte, and *WWW via Cellular* the costs per minute.

The intelligibility of the ISDN-based Video Conference is 70 percent. This means, that the quality reduction through the video compression is to high to keep the original contents.

Service Expl. Attributes	ISDN telephony	ASCII Chat	File Transfer	WWW via Cellular	Joined Editing of Documents	Video Conference
Medium	speech	text	file	*	*	video&audio
Mode	synchronous	synchronous	asynchronous	asynchronous	asynchronous	synchronous
Flow Direction	sink/source	sink/source	source (or sink)	source (and sink)	sink/source	sink/source
Bearer	ISDN	*	ATM	DCS-1800	*	ISDN
Communic. Protocol	ISDN	*	FTP	HTTP	CSCW	H.320
Coding	G.711	ASCII	file	ASCII	file	*
QoS-Param.						
Bandwidth	64kbit/s	*	25Mbit/s	9600baud/s	64kbit-2Mbit/s	128kbit/s
Delay	0	*	*	1 sec	*	0,3 sec
Cost	DM 0.12/unit	*	$15/Mb	DM1.80/min	$ 0/unit	DM 3.60/min
Intelligibility	100%	*	*	100%	100%	70%

Table 14 Examples for Teleservice Descriptor Usage

Based on concrete Teleservice as described above, it is now possible to describe terminal capabilities and conversion processes in a generic way for enabling intelligent selection algorithms. To give an outlook on further extensions, all discussed Quality of Service attributes should be step by step integrated into the Teleservice description. Beside this, it is necessary to design a model for creating the concrete values for a Teleservice automatically, in particular the Quality of Service attributes.

4. Automatic Resource Selection

This section is based on an approach for a *Teleservice Descriptor* developed above, describing each kind of Teleservice in a generic way. In an intelligent communication environment it is not sufficient to use such a description for services only. Beside the services, a generic *terminal description* and *converter description* is required for the construction of a selection algorithm to find the most appropriate terminal for a requested Teleservice at the user’s current location dynamically. The selection can be divided into several parts: selecting only terminals, or selecting multiple converters and one terminal to build a converter chain.

Within the selection process, the TSD is applied to various objects involved, as shown for a less complex case in Figure 2. The details will be explained within this section.

4.1. Representations of Physical Resources

The following analysis is based on the assumption that an end-user system is able to handle a Teleservice. Additionally it is necessary to assign Teleservice Descriptor

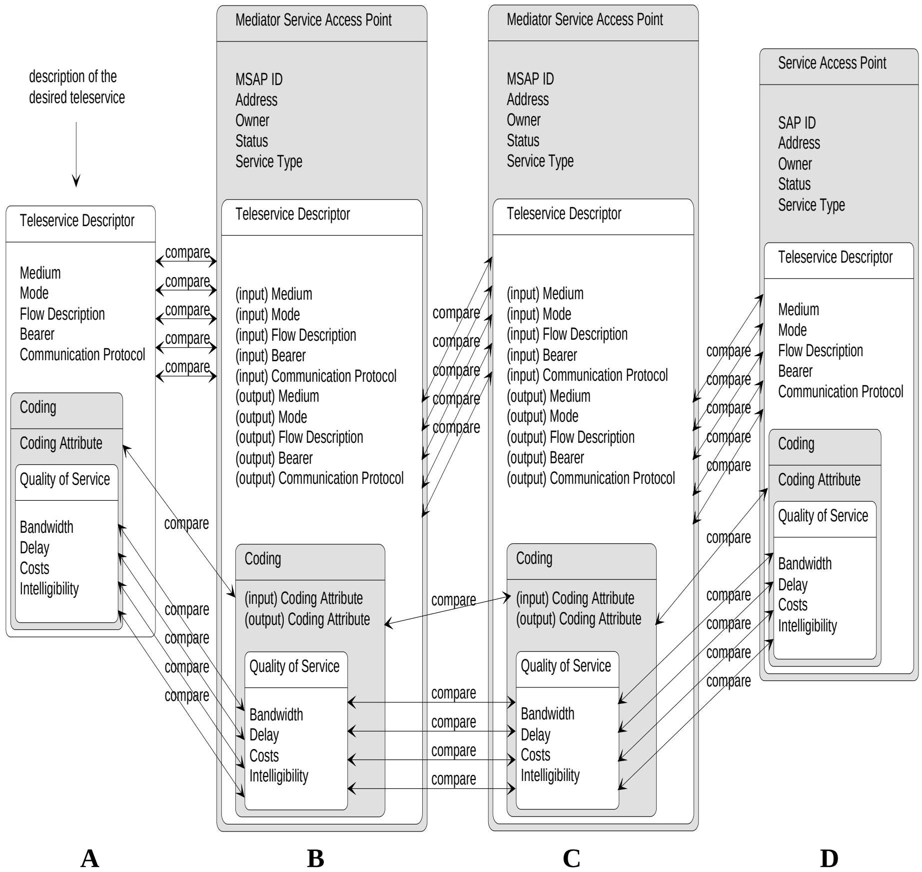


Fig. 2. Dynamic Resource Selection – Converter Chain containing TSD, MSAP, SAP

attributes to terminals and converters, so that the input and/or output of a terminal or converter could be described in a generic way.

Media conversion mechanisms can be done by converters implemented in software or designed as hardware. These converters need also to be described with the Teleservice Descriptor attributes. The concrete assignment of the attributes is different for each terminal. The result of the assignments is a generic representation for terminals and converters, which is also used for the selection mechanisms.

4.1.1.Service Access Point

A Service Access Point (SAP) is a logical representation for a physical communication endpoint which is able to handle a specific Teleservice. The underlying physical resource could be hardware (e.g. a telephone) or software (e.g. a software package for video conferencing). The Service Access Point describes the communication capabilities of this physical resource, i.e. which Teleservice the resource supports. This description is done by the complete set of Teleservice Descriptor attributes.

A complete set of TSD attributes is used. Additional attributes for a complete terminal description are needed (“SAP ID”, “Address”, “Owner”, “Status”, “Servicetype”). The complete Service Access Point model is shown in part D of Figure 2.

Due to physical resources which support more than one Teleservice at a time, it is conceivable that a Service Access Point has to contain more then one TSDs. This approach is out of the scope of this document and can be avoided by representing such a resource in the respective number of Service Access Points. The only exception is that a Service Access Point can contain as many Coding and QoS attributes as it supports different codings. The two attributes have to be seen as a n-tuple, because the QoS of a coding describes the quality degradation of the Teleservice during the processing by the terminal (e.g. the representation of a 24 bit image on an 8 bit screen). The n-tuple of the “Coding” attribute and the “Quality of Service” attribute is stored in the attribute “Coding”. Most of Service Access Points representing software support many codings (e.g. an image viewer supports many formats of image).

The attribute “SAP ID” guarantees a unique name for each Service Access Point for access / administration activities. In the attribute “Address” the physical address of the terminal is stored (i.e. an ISDN-telephone number, an IP-address, a hostname, or a port on a distinguished host). Sometimes it is useful to assign a Service Access Point to a certain user of the system or to assign groups of Service Access Points to an organizational unit for simplifying administration. The attribute “Owner” stores the information to which user a terminal is assigned to.

Another administration related attribute is “Servicetype”. An administrator can use it for storing a human readable description (e.g. “ISDN based video-conferencing”). The attribute “Status” mainly stores the information whether a resource is usable or not; values are “busy” (a terminal is currently working), “idle” (a terminal is currently unused), “up” (the terminal is not busy, but can nevertheless not be used – “it is coming up”), and “down” (an administrator has disabled the usage of a terminal).

4.1.2.Mediator Service Access Point

A Mediator Service Access Point (MSAP) is a logical representation for a physical service converter which is able to handle a specific Teleservice on its input, to convert this Teleservice into another Teleservice, and to pass the result to its output. The underlying physical resource could be hardware (e.g. a MPEG real-time encoder board) or software (e.g. an Optical Character Recognition package).

The MSAP (see the models in part B and C of Figure 2) describes the conversion capabilities of this physical resource. In opposite to the SAP described above, an MSAP contains an input and an output. Both are described by the TSD attributes Media, Mode, Information Flow, Bearer, and Communication Protocol, which are therefore required twice. ID, Address, Owner, Status and Service type are equivalent to the SAP.

The major difference to the SAP results from the fact that a converter in general reduces the Quality of Service and produces a new Teleservice on its output. This reduction is described with one “Quality of Service” attribute for an MSAP. Input and output do not have a separate “Qualities of Service” each, because the semantic of “Quality of Service” is different to the Service Access Point – it describes the Quality of Service related conversion behaviour of a MSAP. In this case, “Quality of Service” describes the quality reduction for two specific “Coding attributes” (input coding attribute, output coding attribute) through the converter and is ternary assigned to two "Coding Attributes" (for ternary associations see [13]).

The input coding attribute is converted to the output coding attribute with the Quality of Service of the MSAP. The triple of the two "Coding attributes" and the one "Quality of Service" attribute is stored in the attribute "Coding".

A Mediator Service Access Point allows to specify more the one "Coding" attribute like a Service Access Point for the same reasons than described in the previous section. Also an MSAP can support several codings and particular conversions. The additional attributes in an MSAP are the same than in a SAP.

4.1.3.Virtual Access Point

The Virtual Access Point (VAP) represents a service generic or service neutral communication end-point, to provide independence of any existing, real telecommunication service or device. A VAP has a fixed relationship to a specific organizational unit (e.g. an office, or a desktop in an open-plan office) and can be understood as a collection of communication capabilities, which are represented as Service Access Points. (Figure 3)

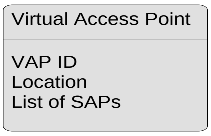


Fig. 3. Virtual Access Point

The creation of a Virtual Access Point is the result of configuration activities of an administrator. Its main target is to realize the mapping from a service generic communication address to a real physical terminal or mediator unit. Because the VAP processing is the last step in the address resolution it supplies a communication address. This address names the Service Access Point which is the most appropriate communication terminal for the requested Teleservice. In an intelligent communication environment the VAP is an elementary part to support the philosophy "Information any time, any place, in any form".

4.1.4.Intelligent Resource Selector

One of the most difficult problems is the dynamic resource selection. Resource selection is only possible when there exists a generic description for all kinds of resources (services, terminals, and converters), such as the TSD.

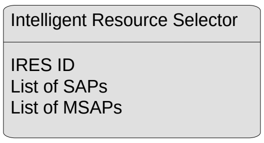


Fig. 4. Intelligent Resource Selector

The Intelligent Resource Selector (IReS) provides an algorithm for the dynamical finding of the most appropriate converter chain related to a requested Teleservice if no terminal can support it without conversion. The IReS is parameterized with

- the list of Service Access Points contained in the respective VAP,
- additional Service Access Points (terminal registration),
- forbidden Service Access Points (the user does not want to use),
- preferred Service Access Points (terminals the user prefers),
- and possibly with any other user preferences the Intelligent Resource Selector can take into account.

An Intelligent Resource Selector itself maintains a list of all available Mediator Service Access Points. (Figure 4).

4.2. Selection Processes

The *dynamic resource selection* is divided into two parts, the *single* and the *multiple resource selection* (Figure 5). The first is a selection between terminals described and represented as SAPs, whereas the latter works on SAPs and MSAPs to build converter chains.

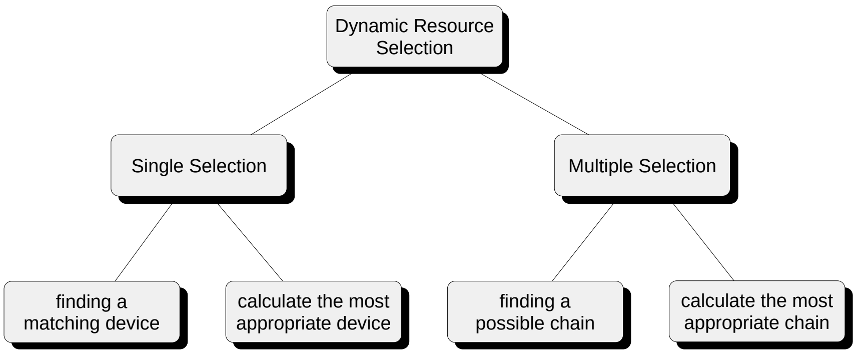


Fig. 5. Dynamic Resource Selection – Different Selection Processes

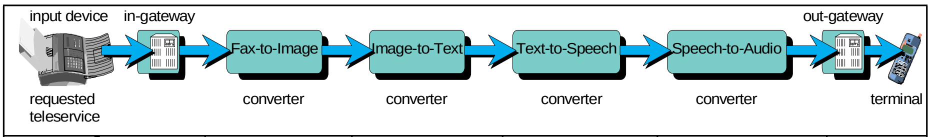
A converter chain (see example in Figure 6) consists of an in-gateway as the input interface, several converters, an optional out-gateway, and one terminal, representing the communication endpoint. A converter chain can contain as much converters as there are available. The converters connected in series have only to meet one condition: The Teleservice produced by the output of a connected converter has to match the Teleservice of the input of its successor.

The *single resource selection* can be further divided in *finding a single matching device* and *calculating the most appropriate device* (SAP). The most appropriate terminal for a Teleservice is that terminal which supports the desired Teleservice with the best QoS and satisfies all the preferences the user has been made.

The *multiple resource selection* can be further divided in *finding a possible chain* and *calculate the most appropriate chain*. The namely introduced selection processes are strongly different in calculating expenditure. *Calculate the most appropriate chain* is the selection process with the highest calculating expenditure.

<u>4.2.1.Finding a single Matching Device</u>

Finding a matching terminal is very simple. Every TSD in all of the SAPs (contained in the very Virtual Access Point the user was located) has to be compared with the Teleservice Descriptor in the parameterization of the process. The first Service



	requested TSD	Fax-to-Image		Image-to-Text		Text-to-Speech		Speech-to-Audio		delivered TSD
		in	out	in	out	in	out	in	out	
Medium	image	image	image	image	text	text	speech	speech	audio	audio
Mode	async.	async.	async.	async.	async.	async.	async.	async.	sync.	sync.
Flow Dir.	sink	sink	sink	sink	sink	sink	sink	sink	sink	sink
Bearer	Ethern.	Ethern.	Ethern.	Ethern.	Ethern.	Ethern.	Ethern.	Ethern.	ISDN	ISDN
C. Prot.	TCP	TCP	TCP	TCP	TCP	TCP	TCP	TCP	Q.931	Q.931
Coding	G3	G3	tiff	tiff	ASCII	ASCII	.au	.au	G.711	G.711

Fig. 6. Dynamic Resource Selection – Converter Chain with TSD mappings

Access Point which has the same TSD as the desired Teleservice is used as the result. Other Service Access Points which could also match the requested Teleservice will be ignored. The algorithm follows the “first fit”-strategy.

Two TSDs match if each pair of attributes has corresponding values. It means that the attributes “Medium”, “Mode”, “Flow Description”, “Bearer”, and “Communication Protocol” must be the same, while the QoS attributes “Bandwidth”, “Delay”, “Cost”, and “Intelligibility” in the SAP have to be the same or better values as the desired Teleservice (e.g. if a “bandwidth” of 5 Mbit/s is required a SAP with a “bandwidth” of 10 Mbit/s could be selected). The QoS attribute of the requested Teleservice is the minimum QoS for the available terminals.

4.2.2.Calculating the Most Appropriate Device

Calculating the most appropriate device is based on *finding a matching device*. All SAPs within the very Virtual Access Point are compared with the desired TSD. If there is more than one matching terminal, it depends on user predefined specifications which one has to be selected (terminal owner, preferred SAP etc.).

Based on the additional parameters and the requested Teleservice, the IReS chooses the most appropriate SAP. Therefore the QoS values of all possible SAPs are calculated. The QoS comparison is not trivial. The attributes “bandwidth”, “delay”, “costs”, and “intelligibility” have to be weighed for making a solution possible.

A preliminary evaluation model is the selection of the SAP which has

- the highest “Intelligibility”,
- the lowest “costs”,
- the shortest “delay”, and
- the bandwidth corresponding to the requested Teleservice.

The problem is to define the priority of attributes, which may also depend on user preferences. One user communicates images for publication and insists on the highest intelligibility, the other one is short of money and satisfied reading white noise.

A discussion of selection strategies can be found in [25].

4.2.3.Finding a Possible Converter Chain

The *multiple resource selection* is an enhancement of the *single resource selection*. Additional mediator units are involved in the selection process and the result of a *multiple resource selection* could be a combination of many mediator units and one terminal (forming a converter chain – see above). A multiple resource selection is only necessary in the case that no matching SAP was found in the *single resource selection*.

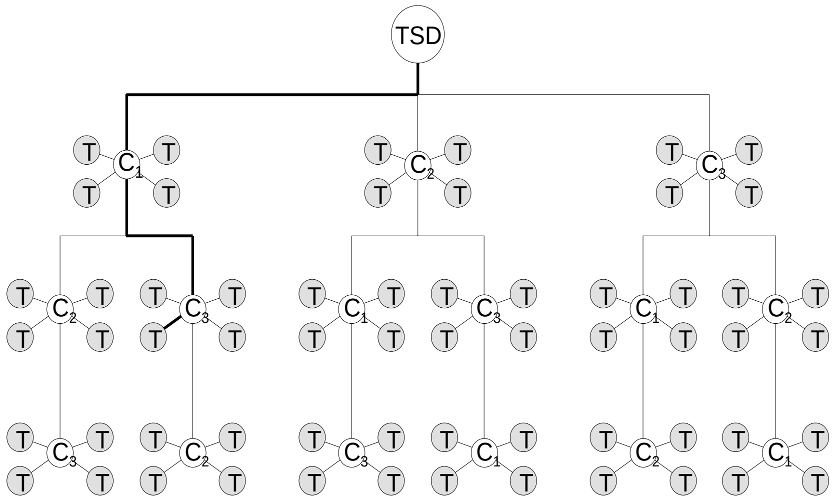


Fig. 7. Selection of possible Converter Chains (C={C_1 ... C_3} T={T_1 ... T_4})

Calculating a converter chain needs a complex algorithm. Each possible combination of converters with a final terminal must be evaluated. The theoretical space of search is tremendous. Figure 7 shows the possible space of search represented as a tree, gives us the impression how the number of possible combination grows with the number of available terminals and converters. The figure demonstrates a scenario with three converters and four terminals, leading into 60 possible converter chains, one of them emphasized.

Five converters and five terminals allow 600 combinations, and one hundred converters and terminals lead to over 500.000 theoretical possibilities. Realistic values for the number of terminals and converters are substantially higher, because all available software tools supporting a specific Teleservice have to be represented as a SAP, so that the number of possible converter chains could be millions.

The main task of the algorithm is therefore to reduce the space of search. Traversing of trees is a well-known method in the field of computer science [16]. Different procedures such as Backtracking or Branch-and-Bound are applicable. The chosen approach is based on a Backtracking-algorithm. This algorithm traverses a tree first down to a leave and tries then to find the next leave. For finding one possible chain (a valid path through the tree down to a leave) this is the best algorithm, because the number of temporal solutions and iterations is much smaller then in a Branch-and-Bound algorithm. The space of search is drastically reduced and the Backtrack can immediately stop if a possible chain was found.

The algorithm starts with passing the requested TSD to the Intelligent Resource Selector. It tries to combine one matching MSAP to the Teleservice Descriptor,

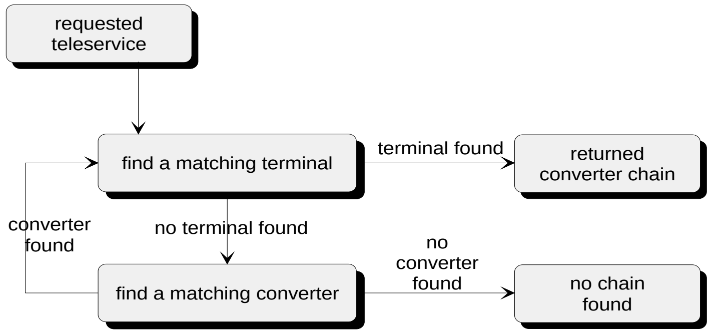


Fig. 8. Dynamic Resource Selection – Algorithm

employing the same matching criteria as in the *single resource selection*. During the comparison of MSAPs only a subset of all attributes is taken into account. Figure 2 shows the corresponding attributes during a converter chain calculation. If a matching MSAP is found, the algorithm tries then to find an appropriate SAP matching its output.

In the negative case the algorithm continues trying to combine the next MSAP to the last found, otherwise the found SAP is the end of a possible converter chain. The found chain can be returned to the IReS calling entity.

If all converters have already been tested and no terminal was able to add to the converter chain the calculation is unsuccessful, so that no connection can be set up. Figure 8 shows a general overview of the developed algorithm.

4.2.4.Calculating the most appropriate chain

With the algorithm introduced above it is possible to calculate a feasible converter chain. The algorithm stops if one solution was found. For calculating the most appropriate converter chain the same algorithmic approach could be used. Therefore we continue the calculation for finding all possible converter chains. The temporary solutions are stored and analyzed later. Due to its underlying Backtrack-algorithm the algorithm is able to find all possible converter chains without parsing the whole tree. Useless branches are detected early and will not be further analyzed.

The next step is now to calculate the QoS for every single temporary solution. The QoS of a Mediator Service Access Point has been introduced as a the QoS reduction through a converter. On this assumption, the algorithm can calculate the reduction of the QoS through a whole converter chain by combining the attributes of all the included components as an arithmetic procedure. An example is given in Figure 9.

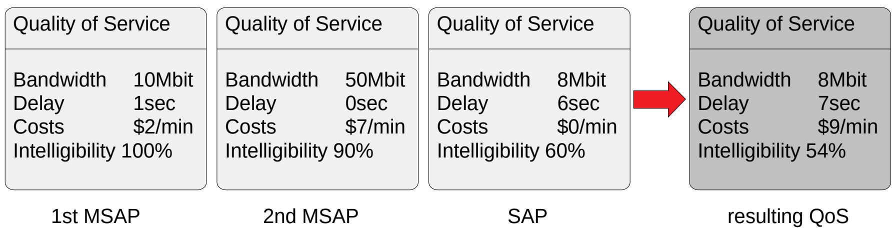


Fig. 9. Dynamic Resource Selection – Quality of Service Combining

A possible set of rules for calculating the overall QoS is given below, more details are discussed in [25].

- The overall value for “bandwidth” is the minimum “bandwidth” in the chain because an information flow is only as fast as at the slowest part on its way.
- The overall value for “delay” is the sum total of all delays in the chain.
- The overall value for “cost” is similar to “delay”, adding up all components.
- The overall value for the attribute “intelligibility” results from the product of the percentage values, as

$$QoS_{overall} = \frac{QoS_1}{100} \cdot \frac{QoS_2}{100} \cdot \ldots \cdot \frac{QoS_n}{100} \cdot 100$$

After all $QoS_{overall}$ are calculated for all converter chains the algorithm searches for the best one, considering the user preferences as described previously.

A possibility for optimization the whole selection process is to evaluate the Quality of Services “on the fly”. The resulting temporary $QoS_{overall}$ can be compared with the desired Teleservice Descriptor. If it falls below the requested one the calculation can be stopped, reducing the space of search more efficiently than the first one.

If a valid converter chain was found, the included converters have to be configured. This means, that streams have to be connected, the QoS parameters have to be controlled and the connection has to be managed up to the end of the session. The control of customer premises equipment is not trivial. Within our project this task is handled by the Resource Configurator and the Converter Framework’s Job and Stream Control, which are not covered by this paper.

5. Design and Implementation

In the first stages of this research project, the work in the iPCSS project was closely related to the complementary project of Personal Communication Support in TINA. During the ongoing work it was found that it would be more useful to focus on the aspects of media conversion within this project. Nevertheless, the reusability and possible integration into TINA was never lost from our perspective, and most design concepts of the current iPCSS consider this migration path from the beginning. The design is oriented on the Information Viewpoint and the Computational Viewpoint of the Reference Model for Open Distributed Processing (RM-ODP) [14]. In this paper only an abstract Computational Model (Figure 6) is given without all the performed decompositions of objects.

5.1. Computational Model

A Computational Model describes a system in terms of interacting Computational Objects (programming entities), see also the TINA Computational Modelling Concepts [9]. Computational objects used to have interfaces to communicate with other objects. There are operational interfaces and stream interfaces. A computational specification considers objects, the interfaces they support, and which interfaces they require at other objects.

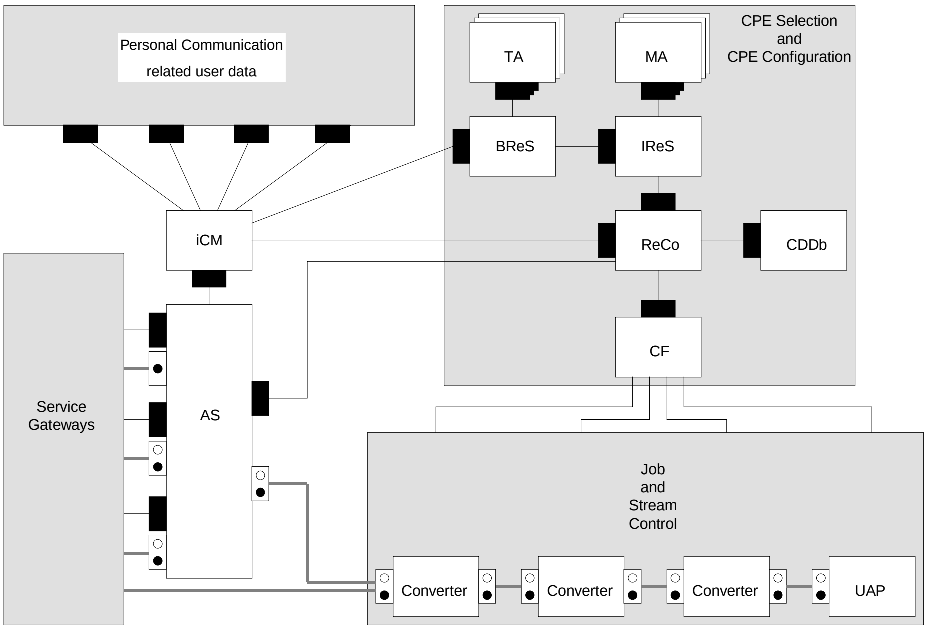


Fig. 10. Resource Selection within the computational model of the iPCSS (simplified)

The “Personal Communication related user data” CO is discussed in [24]. Recapitulating, the CO covers other COs, which contain information like user location, personal schedule, intelligent call logic, and terminal registration.

The Terminal Agent (TA) Computational Object models the SAP from section 4, representing a terminal of a user system. It maintains the capabilities of a specific terminal from the system perspective, to be considered in terminal selection activities done by the Basic Resource Selector. The TA contains information of the supported services using the Teleservice Description.

In the iPCSS Computational Model the description of converters is represented by the Mediator Agent (MA), modelling the MSAP from section 4. The Computational Object MA includes, conform to the TA, a Teleservice Descriptor for representing the supported service.

The Basic Resource Selector (BReS) is intended to maintain information about communication capabilities at certain locations. The BReS will maintain knowledge about a pool of resources, and therefore the BReS has to contain associations between locations (e. g. rooms or pico cells) and terminals, represented by the Terminal Agents (TA). The latter holds the terminal specific information, i. e. terminal state and capabilities referenced by the BReS.

A BReS dynamically selects a physical terminal depending on the requested service capabilities. Therefore it provides an intelligent selection algorithm to *find the most appropriate terminal*. Needed parameters for the selection are modelled in the TAs.

The result of the BReS activities will be one terminal ID. This information will be returned to the intelligent Communication Manager (iCM). The Local Context only pertains the user's current location to get terminal information appropriate to the requirements of a requested service.

The Intelligent Resource Selector (IReS) is an Service Supporting Object for the BReS. The Intelligent Resource Selector maintains knowledge about a pool of terminals/applications (TAs) and converters (MAs). Therefore the IReS has associations to Terminal (CO TA) and Mediator (CO MA). An IReS dynamically calculates the *most appropriate converter chain* depending on the requested Teleservice. The selection algorithm could be influenced by user preferences covered by the CO “Personal Communication related user data”.

The Resource Configurator (ReCo) is an Service Supporting Object for the Intelligent Resource Selector. It has the ability to configure converter chains and to control the stream binding of them. Therefore, an abstract MA/TA oriented connection graph (including the whole converter chain) is delivered to the ReCo, which has to be configured. The ReCo controls the configuration activities via the CO Converter Framework (CF). Only the CF has the knowledge and the ability to configure physical devices. The dedicated parametrization for devices is stored in the CO Converter Description Database (CDDb).

The intelligent Communication Manager (iCM) is the central component of the system. Triggered by the Active Store (which covers all the incoming gateways to the system) with a service request, it controls all the system behaviour. The functionality is defined like a state machine acting on dedicate system states.

In face of the distributed and object oriented approach the decision was made to use a CORBA conform platform for the implementation. The interfaces of the COs described in this paper are all specified with the Interface Definition Language (IDL).

Exemplarily, the interface definition of the Basic Resource Selector is given in Figure 11. The used ORB is ORBIX on Sun Workstations (Solaris 2.5). The used C++ compiler is SUNWspro 4.2.

```
interface I_BReS {
     I_TerminalIdList SelectTerminal
          (in I_Cid cid,
          in I_TSD requested_tsd,
          in I_TerminalIdList additional_tas,
          in I_TerminalIdList forbidden_tas,
          in I_TerminalIdList prefered_tas,
          in string options);
     I_TerminalIdList get_AllTaIds();
     I_CoIntRefList   get_AllTa();
     I_BReSLabel      get_BReSLabel();
     I_BReSDescr      get_BReSDescr();
     I_LocationId     get_LocationId();   };
```

Fig. 11. Example interface definition of the Basic Resource Selector

The runtime system comprises one entity of the Active Store, intelligent Communication Manager, intelligent Resource Selector, Resource Configurator, and Converter Framework for a service Request, respectively. The number of entities of Basic Resource Selectors, Terminal Agents, and Mediator Agents depends on the size of the represented communication scenario. Typical peculiarities including some offices with typical numbers of computers, telephones, and other communication devices, invoke several thousand entities of CORBA objects, as discussed in section 4.2.3.

The introduced systems is tested on computing resources and performance with the result, that a SUN Ultra 1 configured with 196 MB memory can handle several communication requests nearly real time. The only delay occurs during the starting process of any software, or the computing time of any asynchronous converter.

6. Summary and Outlook

This paper has presented the possibility of unified handling of telecommunication services by using the generic modelling of an Teleservice Descriptor, telecommunication devices, and service converters. Algorithms for finding appropriate terminals or converter chains for a communication request have been developed and implemented within the context of the iPCSS, representing a CORBA-based platform for the provision of full PCS capabilities, considering quality aspects for the automatic process.

The generic description, the algorithms developed, and the modular, scalable design of the iPCSS allows tailoring for various purposes and environments. While the testbed implementation is focused on the Customer Premises Equipment (CPE), the scalability in all directions, from global telecommunication architectures like TINA and IN (see below), down to a compact, individual solution, was a major aspect in the research [24]. The tool enabling such a wide range of scalability and independence from single/multiple host environments was the usage of a middleware platform hiding such properties, CORBA in our case.

Intelligent Networks (IN), successful in telecommunication worldwide [19], know the concept of Intelligent Peripherals and Service Nodes (IP/SN) for the dialogue with the user and for enhanced service platforms.

The iPCSS with its concept of the Active Store and the dynamic selection and configuration of individually tailored converter chains provides a powerful IP/SN [22, 23]. As it is already implemented on CORBA technology, the same migration strategies can apply as described for the TINA service nodes, as follows.

The Telecommunication Information Networking Architecture (TINA) represents a fundamental software architecture for Distributed Processing Environments (DPE), based on CORBA technologies, for rapid and flexible introduction of innovative services into information networking [7].

The CORBA based approach of the iPCSS and the design of the Computational Objects follow the ideas of the TINA Service Architecture [10] closely, with the purpose of allowing an integration of dedicated aspects of the iPCSS into TINA.

The emerging TINA Service Node concept, which provides an important step in evolution from IN based service environments toward TINA based service environments, follows the principal to model service control and service management TINA conform, but still provides access to the logic of IN based switches (via an IN Adaptation Unit) and TINA end-systems (via a TINA Access Session) [22].

Further information about our research can be obtained from "http://www.fokus.gmd.de/ice/".

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