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Abstract The design and the development of multichannel information systems require new approaches, mainly based on the definition of adaptive behavior with the goal of increasing the efficiency and effectiveness of solutions. In this paper, we show a simplified example of financial information system, where several services impose constraints. The approach we propose tries to solve these service limitations by means of an enriched definition of channel and new logical primitives. These are then used to define rating classes that will be the starting point of our adaptive strategies.

1 Introduction

The anytime/anywhere/anyone paradigm [9] requires a novel generation of applications [6], which dynamically modify their internal structure according to the change of context; moreover, specific application constraints can reduce the efficiency of the application, e.g., services requiring a transfer rate higher than available for mobile networks. These new challenges constitute the goals of the Italian MAIS FIRB project, started in 2002. Within the project three models have been defined, addressing the most important features of functions, users, and channels relevant in dynamic adaptation of multichannel information systems. In this paper, we present a model describing a generic distribution channel with the goal to identify its modifiable components. To better explain our model, we discuss its characteristics in the contest of a typical multichannel financial information system. Our descriptions allow us to define adaptive strategies on channel utilization to increase the efficiency and effectiveness of multichannel information system. The paper is organized as follows: Section 2 describes the requirements of the financial information system discussed in this work, and their constraints requiring adaptive capability; Section 3 describes a multichannel architecture through the definition of conceptual and logical dimensions. Section 4 presents an approach to identify the modifiable components of the information system by using rating classes; Section 5 illustrates the adaptive strategies we defined. Finally, Section 6 presents related work in the field of adaptive systems and Section 7 draws concluding remarks and presents future work.

2 Business requirements

We define a reduced set of requirements that a bank may have to build a multichannel information system to support its financial services. In particular, let us assume that a bank wants to integrate its traditional channels (branch counters and call centers) with new ones, mainly based on Internet and mobile communication, with the goal of increasing the number of customers. The bank users are grouped into *internal users*, i.e. bank employees accessing financial services through the information system and *external users*, who represent the bank's customers. The bank delivers a set of services; mainly divided into *information services*, which have the aim of informing the customer of the state of his stock dossier and assisting him in the use of services, and *operative services*, which enable him to carry out operations. Both information and operative services are delivered by means of a multichannel infrastructure described below.

2.1 Informative services

Various are the kinds of financial information services that a banking information system can deliver; for the sake of brevity, we consider only a reduced number of these services. The *stock quotation* is a typical informative service, which shows for a given stock its floatation throughout the exchange session. This information must be continuously updated by the information system and it is available to all customers. We also consider an advanced information service, for special customers only: the *enriched news*. It allows users to watch press conferences or interviews with the most important financial experts, and it is delivered by means of videos.

2.2 Operative services

Among operative services, we select the most typical examples to complete our business specification: *buying selling stocks;* the first operation allows the user to insert orders to purchase stocks available in one of the world markets. The user selects one of the stock dossiers he wants to add the share to and then chooses the stock he wishes to purchase. Once the share has been selected, the user sees the related information, and the application enables him to insert an order of purchase. In a similar way, it must be possible to insert sales orders for stocks held in a particular stock dossier. As in the previous operation, the user first chooses the stock dossier and then selects the share he wants to sell. Then, he visualizes the information related to it and he inserts the number of lots, price, and order duration.

2.3 Service constraints

Not all the previously described services can be delivered along all the possible channels foreseen in the bank information system, because some of them have constraints reducing the use of the anywhere/anyone/anytime paradigm. In this paper we discuss only three service constraints, representing typical requirements.

- **Bandwidth**. A typical service limitation is related to the speed of the channel through which the service must be delivered. The enriched news informative service, for example, sends streaming video requiring fast channels with a significant bandwidth.
- **Graphical support**. Another typical requirement refers to the capability of the end user device to support graphic images. Several services need to send their users graphic resources, for example in the stock quotation service.
- **Interaction mode**. bank customers can access the application by means of different devices, each one characterized with different input devices (e.g., keyboard, touch screen, or telephone keyboard). Different input devices need different interaction strategies between the application and the end user, for example, in the case of buying or selling of stocks.

3 multichannel architecture description

In parallel with the traditional decomposition of information systems in **application, logical and technological** models, we first show the channels from an application point of view and then we describe them by means of new logical dimensions we introduce with the aim to underline and extract the adaptable components of information systems. The technological model describes the objects, which compose the information system. The last step in the description of the multichannel architecture is the mapping between application channels and the objects composing them.

3.1 Application channel

Nowadays several application channels [12] exist to dispatch financial services, beyond the traditional branch counter. In particular we consider two categories of channels: Internet banking and telephone banking. Although other classifications of banking channels [3] have been proposed, we do not consider, in this paper, other important channels (e.g., ATM or business-to-business application channels), because we are more interested in the application of our approach to a typical multichannel architecture rather than giving an exhaustive example of a specific, but restricted application domain. In fact, the two application channels we add to the traditional branch counter channel can also be used in other application domains.

Branch counter. The branch counter is the oldest channel used by banks to interact with their customers. It is composed of a number of branches, placed in several regions where customers can go to carry out (informative or operative) services by interacting with a bank teller. Some special services may request the authentication of the customer, by means of his signature on the service request, or need the explicit authorization of a senior employee. The services are performed by using well-defined workflows. This channel is used in about 90% of banking information systems [12].

Internet banking The Internet banking channel requires that customers interact with the bank information system by means of an Internet connection. Customers access the bank application (typically a web site) through a login/password mechanism. After the authentication phase, they may carry out services according to their personal profile. On the basis of the different devices used to access the web application, we define three different banking channels: PC banking, TV banking, and mobile banking. The first is characterized by the use of a personal computer as an end user device, which allows customers to access multiple services simultaneously, thanks to the features of nowadays PCs. The TV banking channel is different with respect to the previous one because the end device is a TV set and not a PC. The connection with the Internet is obtained by means of a dedicated hardware component, named set top box, which is connected to the TV set and to a keyboard. The mobile Internet channel allows customers to access financial applications virtually anywhere, by means of PDAs or mobile phones through radio mobile networks. This interaction mode causes further constraints, because these devices have reduced graphic resolutions and processing power with respect to both PC and TV. Moreover, the underlying network technologies (e.g., GPRS) used to access applications are slower than the ones exploited in the previous two channels.

Telephone banking Telephone banking represents an alternative way to interact with financial systems; the most significant feature of this channel is the use of telephone technologies as a connection medium between users and banks. Telephone banking includes two channels: SMS and call centers. SMS (short message services) is a service offered mainly to mobile phones allowing the forwarding of short messages (maximum 160 characters) through a GSM network. This channel is used by several banks [2] to deliver short reports on financial markets or news. The relevance of this channel is explained by considering that in several countries, especially in Europe, the diffusion of mobile phones is much larger than personal computers. The call center is another channel used in the financial domain (see for example [5]). Customers dial a given telephone number and they can access the services by means of the voice and/or telephone keyboard. Customer authentication is required and it is carried out in a different way with respect to the other channels due the physical limitations of telephone devices.

3.2 Logical channel

Since we are mainly interested in the definition of adaptive strategies for information systems, we analyze the application by using an enriched, applicationindependent, notion of channel by adding some elements, which are not immediately associated with the traditional meaning of "channel". Thus, from the logical point of view, we consider a channel not only the network distributing the service, but we include also the *device* of application users, the *network interface* through which the device connects to the *network*, and *application protocols*. Figure 1 shows the UML specification of our channel elements. According to the UML schema, each channel instance is described through the composition of zero or more instances of the elements above mentioned.

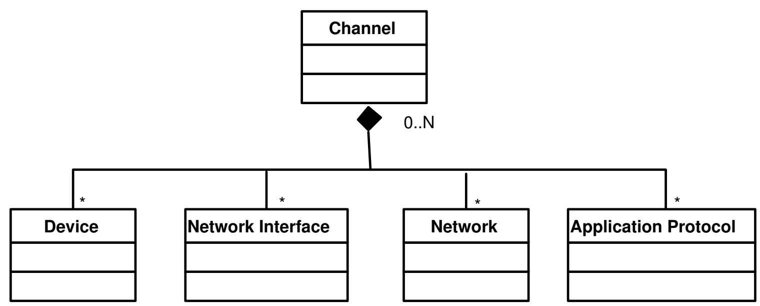

Figure 1. UML specification of logical channel elements

Each element, composing the channel, is characterized by a number of *attributes* (for example screen resolution of the device or network topology). In [13] we present the detailed channel model with all attributes. The choice of which attributes to select within the ones described in the complete model depends on the specific application domain; for example in financial information systems, the weight of the device used by customers is not relevant, while the screen resolution is. Each attribute is associated to a value, which can be numeric, as for example in the case of the device weight, or a set of numbers (possibly continuous), or a mathematical function, e.g., the graph function describing the network topology. Notice that our model can be augmented with new attributes by means of generic UML classes named *attributes*, inserted in the complete channel model; they are defined as a pair name-value. Within the financial application domain, we consider as relevant attributes describing a device, the *screen resolution* and the *number of colors*, which are relevant for example when the information system wants to send users graphical information, and the *audio support* describing the presence or absence of audio cards inside the device. Its presence is mandatory when customers want to use the video conference services described in Section 2.2. Another key attribute is the *input device* used by customers; this attribute is relevant in the definition of the best interaction methods. In fact, for example, an alphanumeric password is more complex to write using multi-mode numeric keyboard rather than with alphanumeric ones. The second channel component is the network interface representing the connection between devices and transmission media. Notice that a device can access different transmission media by means of different interfaces, for example, a PC can access the Internet via LAN through a network card or via PSTN by means of an analogical modem. In the financial context, we consider that the only relevant attribute is the maximum *transfer rate* achievable by the specific interface. The next component describing a channel is the network. It includes all physical structures, hardware components and protocols defining a network infrastructure. In this component, we include all protocols covering the first four levels of the ISO/OSI protocol stack. Within the bank information system, we identify two relevant attributes for the network: the *transfer rate* and the *security* level that the channel offers. The last channel element is the set of application protocols allowing users to interact with the information system. We identify two interesting attributes with respect to this component: the *security* support and the *standardization* of the application protocol.

3.3 Technological channel

The last step in the analysis of multichannel architectures is the description of the object composing the information system; the selected groups are then described by using the attributes defined before. We define two kinds of attributes; they can be either *observable* (e.g., device position), if a software layer allows only showing their values to the information system; or *controllable* (e.g., bandwidth or screen resolution), if it is possible to modify them. Thanks to the identification of these attributes we can identify adaptive parts of multichannel architectures, and define adaptive strategies to satisfy service constraints. It is important to underline that only in this phase it is possible to detect which attributes are observable or controllable; in fact these features are strictly dependent on the particular object selected. Devices considered for the financial information system are displayed in Table 1, where each row represents the description of a device, while columns represent the device instances and the component attributes. The italic values indicate dimensions, which are not only observable, but also controllable.

Device	**Screen resolution**	**Number of colors**	**Audio**	**Input device**
PC	*640 X 480 - 1024 X 768*	*True colors*	*Yes*	Alphanumeric keyboard
TV	*640 X 520*	*256 colors*	*Yes*	Alphanumeric keyboard
PDA	*320 X 240*	*16 colors*	*Yes*	Touch screen
Mobile phone	N.A.	N.A.	*Yes*	Numeric
Telephone	No	No	Yes	Numeric

Table 1. Description of device instances used in the application

In [13] a more formal specification of Table 1 is shown by using UML; all the devices selected in the information system and their attributes are associated through a part-of relationship. By means of the UML stereotype, it is possible to underline observable or controllable attributes. By analyzing Table 1 some aspects emerge: PC and PDA offer a wide level of controllability, in fact, the controllable attributes are the audio support, the screen resolution, and the number of colors, while the input device attribute is observable only. The less controllable device is the telephone because it has no observable attribute. In the same way as we did with devices, we identify the network interfaces used in our information system. Table 2a shows the result of this analysis. The PSTN interface is different from the Analogical Modem, because the first network interface is associated with the telephone, while the latter can be used only with a PC or a TV set. It is worth noting that no network interface provides controllable attributes. By analyzing the business requirements of the financial application, four different networks have been identified, as reported in Table 2b. From the table, it results that only the WIRED network offers controllability of attributes. In fact, we assume that there exists an agreement between the end user, the bank and some Internet providers, which allows augmenting the transfer rate by applying specific pricing policy. The security level is another controllable attribute thanks to the possibility to select different secure networks offered by Internet providers with different prices. Table 3 describes the application protocols used in the financial application. The first two rows describe two important Internet protocols allowing sending hypertext documents (HTTP) and defining a secure communication channel (SSL). This protocol is controllable because it is possible to modify the version of SSL to be used. SMS-AL is the application protocol used to deliver SMS messages. The last two application protocols describe a set of bank procedures, which are carried out in a branch counter between employees and customers (Employee-Customer application protocol), or between call center operators and customers (Call center-customer).

a)

Interface	**Transfer rate**
Network card	10 - 100 Mb/s
Analogical modem	28.8 - 56 Kb/s
GSM	9600 b/s
GPRS	N.A.
PSTN	2 x 4800 Hz

b)

Network	**Transfer rate**	**Security**
PSTN	2 x 4800 Hz	No
WIRED	*64 - 100 Mb/s*	*Yes*
GSM	9600 b/s	No
GPRS	22 kB/S (for Italian network only)	N.A.

Table 2. Description of network interface and network

Protocol	Standardization	Security
HTTP	Yes	No
SSL	Yes	*Yes*
SMS-AL	Yes	No
Employee customer	No	Yes
Call center customer	No	Yes

Table 3. List of application protocols used in the application

3.4 Channels in financial information systems

It is now possible to map the application channel described in Section 3.1 with one or more n-ples of physical objects previously defined.

Application channel	Device	Interface	Network	Protocol
Branch counter	Not used	Not used	Not used	Employee Customer
Internet banking	PC	Network card/ modem	WIRED	HTTP SSL
	TV	Modem	WIRED	HTTP SSL
	Mobile phone PDA	GPRS	GPRS	HTTP
Telephone banking	Mobile Phone	GSM	GSM	SMS-AL
	Telephone mobile phone	PSTN	PSTN	Call center Customer

Table 4. Description of conceptual channels

Table 4 shows the description of application channels in terms of instances of the elements describing a channel. Notice that three n-ples are associated to the Internet banking (one for each channel as defined in Section 3.1.2), and two to the Telephone banking.

4 Rating class

Often informative or operative services, for example the enriched news service shown in Section 2.1, impose additional requirements to one or more channel features, e.g., bandwidth. Typically, constraints are expressed in natural language and sometime limitations are expressed in generic terms; in Section 2.3, for example, we say that, to dispatch the enriched news service, the channel bandwidth has to be fast, but we do not specify what a fast channel is. To analyze service constraints, we introduce the concept of rating class, which associates qualitative values (e.g., fast or slow), expressed in service constraints, with some quantitative values related to the attributes defined in Section 3.2. Figure 2 shows the pseudo-code description of how we define rating classes associated to a given service constraint. Step 1 consists in the identification of attributes which might influence the channel features described in the service constraints. For example,

1 Identify attributes associated with channel features involved in the constraint
2 Associate channel features with a measure obtained by means of attributes composition
3 Define a measurement scale
4 Identify thresholds
5 Map defined thresholds to qualitative terms of constraints specification

Figure 2. Rating class definition

channel bandwidth, described in the first service constraint of Section 2.3, is influenced by attribute transfer rate both of the network interface and of the network. Step 2 considers the definition of a measure of the channel feature. For example, we define the measure of the channel bandwidth as the minimum value between the network bandwidth and network interface bandwidth. In this case, the measure we define is a quantitative one. In step 3, according to the obtained values, we define, at application level, a measurement scale. It can be one of the following types: ordinal, interval, ratio or absolute [4]. The measurement scale associated to the channel bandwidth is absolute, because the measure we define returns numeric values. Step 4 divides the range of the possible measure values in rating classes by means of thresholds and then, in the last step, we associate the qualitative values described in the service constraints with identified thresholds. By concluding the example of channel bandwidth, we define a threshold at 1 Mb/s and we consider a channel fast only if the channel bandwidth is at least 1 Mb/s. It is important to underline that the definition of thresholds strongly depends on the specific application domain and service; thus, for the advanced services in the information system presented in this paper, the channel bandwidth of 1 Mb/s is considered fast, while in other contexts it may be considered slow.

4.1 Rating classes for financial applications

According to constraints of Section 2.3, we define three different sets of rating classes, each one for a specific constraint. The first service constraint is associated to the bandwidth rating class described above, as an example. The second service constraint refers to the capability of end user devices to support graphics. Attributes related to this channel feature are the screen resolution and the number of colors which together define the measure of the graphic capability of devices. The next step in the creation of rating classes is the definition of measurement scale; which is composed by both the number of colors and screen resolution. According to step 4 of the pseudo code of Figure 2, we define two thresholds values both for number of colors and screen resolution (respectively T'_C=16 colors, T''_C=256 colors, and T'_R=320x240 pixel ,T''_R=640X480 pixel); the four values define the matrix shown in Figure 3. Consequently, we define three rating classes, and we say that a device **X** has a *High* graphic capability if its

	$\mathbf{X} < T'_R$	$T'_R >= \mathbf{X} <= T''_R$	$\mathbf{X} > T''_R$
$\mathbf{X} < T'_C$	Low	Medium	High
$T'_C >= \mathbf{X} <= T''_C$	Low	Medium	High
$\mathbf{X} > T''_C$	Low	Low	High

Figure 3. Rating class for graphic capability

values are included in the last column of Figure 3; if values are included in the first two cells of second column then the device has *Medium* graphic capability otherwise the device has a *Low* graphic capability. The last set of rating classes, defined in our application domain, is related to the modes on which services can receive data from application users. The only attribute related to this interaction mode is the input type. In this case, the measure of this channel feature is the value of the input device attribute. The measurement scale is ordinal, thanks to the introduction of the following ordered sequence shown from the highest to the lowest level: alphanumeric keyboard, touch screen and numeric keyboard. Thus, we can define three levels associated to the three values of the selected attributes. Finally, we can say that the interaction mode is *rich* if the device has an alphanumeric keyboard, *medium* if input devices are touch screens, and *low* otherwise. It is worth underlining that these thresholds are defined for our specific application context; probably more complex rating classes should be defined in other domains.

5 Adaptive strategy

When a user requests the execution of a service along one channel, the application has to verify if the service can be distributed through that channel. If there exist some service constraints, we define two adaptive solutions to allow the information system to execute the service along that channel. The adaptive solutions we define are: the *negotiation* and the *selection of alternative services*. Figure 4a shows a specification in terms of pseudo code of our adaptive strategy. First the system tests if the service S requested by a user along a channel C is executable, by invocation of the *"satisfiable"* procedure, which realizes our negotiation strategy (see Figure 4b). If some service constraints do not allow the application to dispatch S along C then the application selects all the alternative services of S. For each alternative service the application evaluates if it is executable. If no alternative service can be executed then the user's request cannot be satisfied. It is worth noting that the adaptive algorithm we presented is devoted to solve the channel constraints only, because it is based on the description of the channel features. In complex information systems service constraints include certainly channel requirements, as the ones shown in section 2.3, but they also include user and function requirements. These requirements sets are considered, in the MAIS project, in the context and function models. All ser-

```
1 Let S = service requested by user
2 Let C= channel along which the user
                    requests the service
3 IF satisfiable(S,C)== TRUE
4      BEGIN
5        Execute(S,C)
6        Exit
7      END IF
8 ELSE
9    S'=AlternativeServices(S)
10   FOR EACH Service Si in S'
11   BEGIN
12     IF satisfiable(Si,C)== TRUE
13       BEGIN
14        Execute(Si,C)
15        Exit
16       END IF
17   END FOR
18  Return Service_Not_Executable
18 END
```

(a) Specification of adaptive strategies

```
1 PROCEDURE satisfiable
2 INPUT: Service S, Channel C
3 OUTPUT:  Boolean Result
4 BEGIN
5 Let L= constraints(S)
6  FOR EACH Li in L
7   BEGIN
8     IF Satisfy(C,Li)==FALSE
9      BEGIN
10       Let A=attributes(Li)
11       FOR EACH Ai in A
12       BEGIN
13         IF Controllable(Ai,C)
14           BEGIN
15             update(A)
16             IF Satisfy(C,Li)==TRUE
17                   GO TO LINE 22
18           END IF
19      ENF FOR
20      RETURN FALSE //there exists at least one
                         constraints not satisfiable
21    END IF
22   END FOR
23   RETURN TRUE //The service is executable
24 END PROCEDURE
```

(b) Description of negotiation algorithm

Figure 4. Adaptive and negotiation strategies

vice constraints are then evaluated together. Figure 4b shows the negotiation strategy. The *"satisfiable"* procedure creates the set L of constraints associated with the service S; then, for each constraint L_i the procedure tests if the channel C satisfies L_i (line 8), that is, if the value of attributes describing L_i for C is included in the appropriate rating class. If the channel does not satisfy L_i, then for each attribute associated with L_i the application tests if it is controllable for C and, if so, the application updates its values and tests again if L_i is satisfied. If the last test is successful, then L_i is satisfied and the application verifies another constraint associated with S. Otherwise, if, for any reason, L_i cannot be satisfied the service is not executable. Finally, if all the constraints associated with S are satisfied then S is executable. To explain the use of our adaptive strategies, let us consider the constraints described in Section 2.3 again. Let us assume that a user requests a video along a wired network; the application executes the *"satisfiable"*procedure shown in Figure 4a. The application detects that there is only one constraint associated with the service (line 5). If the actual channel bandwidth is slow, then the information system identifies the attributes related to the constraint (line 10). The A set is composed by two attributes: the transfer rate of the network interface and the transfer rate of the network. By analyzing Table 2a, it results that no network interface allows the modification of its transfer rate. Conversely, the WIRED network is controllable (as result from Table 2b), thus the application tries to modify the network transfer rate. Notice that this strategy is effective only if the transfer rate of the network interface associated with the channel is equal or grater than 1Mb/s. If for any reason, the modification of the network transfer rate does not satisfy the service constraint, the executable procedure returns the logical value FALSE, then, according to Figure 4a, the application defines the S' set of alternative services and it tries to execute them, for example, one of the possible alternative services is to dispatch only the audio part of the video.

6 Related work

The design of multichannel information systems is a field largely studied from different points of view. In the field of the development of multi-device sites several approaches have been proposed. The transcoding technique [14] defines languages and tools which can detect and remove unimportant portions of the contents. Such contents adaptation is exploited for either an individual element or a set of consecutive elements in a Web document, and results in better presentation to the client device. This technique is also used by commercial tools as Oracle Portal-to-go or Volantis Mariner. Another interesting project is the Ninja project [11], which has the goal to create new web services applications providing accessibility to services from a wide range of devices.

In the description of multichannel architectures, we refer to the UWA [10] context model and the CC/PP profiles [8]. The UWA project defines a set of methodologies, notations, and tools to support the design and fast prototyping of complex, multi-device, ubiquitous web applications. In this domain, the description of the device and the network through which the web application is delivered are relevant constraints. In UWA, the context model is the reification of certain properties describing the environment of the application and some aspects of the application itself. It includes the physical context model describing some of what we consider as the channel attributes; differently from our approach, in UWA the physical context is observable only and cannot be modified. The composite capability and preference profiles (CC/PP) is one of the future standard proposed by the w3c consortium. A CC/PP profile is a description of device capability and user preferences that can be used to guide the adaptation of content presented to that device. This approach can be interesting to describe device attributes but, as in UWA, there is no possibility to change their values. An ample discussion about the future of the mobile information systems and their new challenges can be found in [7].

7 Concluding remarks

This paper presents an approach to identify the modifiable components of a multichannel financial information system with the aim to satisfy specific service constraints by adaptive strategies. The identification of modifiable components is obtained by an enriched definition of channel and its description in terms of controllable and observable attributes. Service constraints are translated into rating classes linking qualitative expressions to quantitative values. The adaptive strategies shown in this paper are only our first attempt to define an adaptive information system. Several are the future directions of our research. We are now studying more complex negotiation strategies and new adaptive strategies to select the best distribution channel for a given service according to both technical and business requirements. Another interesting aspect to investigate is the possibility to automatically define the rating classes by means of a domain ontology, which allows the application to modify thresholds according to the modifications of the application context.

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