Instrumentation and measurement of multi-channel services systems

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Abstract: This paper focuses on the mediation between Interactive e-Services (IeS) and channels used during human-organisation interactions. This mediation consists in a succession of service adaptations, changing from an abstract structure to a concrete one. Our contribution is mainly devoted to aspects concerning the Quality of Service (QoS), particularly about instrumentation and measurement issues, and it provides clues to answer the question “How can multi-channel services be adequately monitored and controlled?”.

Keywords: multi-channel; context-sensitive; pervasive computing; Quality of Service; QoS; instrumentation; measurement.


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1 Introduction

With the rapid development of telecommunication technologies, offering convergence (through IP protocols) and universal roaming for wireless networks, from GSM/UMTS to WiFi, and those of the mobile communicating devices (PDAs, Origami, etc.), new models of organisation and infrastructure for services and usages can be envisioned.
and must be carefully designed and evaluated in a usage and application directed approach.

Our research focuses on the mediation between Interactive e-Services (IeS) and channels used during an interaction between a human being and an organisation. This mediation consists in a succession of service adaptations from an abstract structure toward a concrete one, deliverable to a user. These adaptations are closely linked to different contexts both coming from the user and the organisation context. The user context (which will be explained later in this paper) can be seen such as defined by Dey et al. (2001). The organisation context concerns the rules but also the strategies (marketing aspects) used by that organisation.

Our contribution is mainly devoted to aspects concerning the QoS. This means that we are investigating the different manners to deliver services to the user with suitable QoS. The question of instrumentation and measurement is an important issue for us. We consider it is valuable to understand how multi-channel services can be adequately monitored and controlled. That is why we decided to develop a tool able to catch several traces of the key elements during interaction sessions. Analysing those traces could help us to determine whether the QoS is adequate. Thus, we could intervene to modify the system adequately. Here, the notion of QoS is subjective, and another question that naturally ensues is “How can we define and measure the quality of a service component provided through multimodal/multi-channel interface or via mobile devices?”.

In scientific literature, there is no rule (i.e., like those given by Nielsen and Tahir (2001) concerning the web pages characteristics) to decide if the quality of a service is sufficient or not. In our paper, we will try to answer both questions. We will begin with the second one, because the possible answers to this question will be useful to answer the first one.

This paper is structured as follows. First, Section 2 will introduce our multi-channel services approach. Then, in Section 3, we will deal with the quality of service in interactive e-services. Section 4 will be a presentation of a technical solution we have built aimed at managing the mediation between IeS and channels and that we called Ubi-Learn. This includes the presentation of experimental results concerning the QoS of customer telephone interactions in the context of a multi-channel service system. Finally, we close with the main conclusions and suggestions for future research.

2 Our multi-channel services approach

For some years now, we have been witnessing a strong growth of services provided through multiple channels. As we said before, this is linked with the proliferation of ‘virtual channels’, such as the internet, telephone, mobile devices, etc. In this section, we present our multi-channel services approach and we explain the possible connections between services and channels.

In Direct Marketing (DM) area, for instance, customers have been used to the multi-channel approach for a long time. Indeed, remote sales through phone or mail are an old practice. In other domains, some researchers employed the word ‘channel’ to talk about communication between humans, or between human and organisations, etc. For instance, the overall service provided by many remote sales organisations such as 3 Suisses International, which includes several service components offered through virtual channels (e.g., the web, phone and mobile phones), in parallel with or as an alternative to physical facilities. According to several researchers, a channel of service
delivery can be defined as the means of communication through which a service is delivered to (or reaches) the customer. Virtual channels can be defined as the means of communication using advanced telecommunications, information, and multimedia technologies. Nowadays, the trend for multi-channel environments is growing (Sousa and Voss, 2006). This report gives arguments showing that new technologies afford an increasing number of virtual channels of service delivery.

We hold another vision of a channel. For us, an interaction channel with an organisation is the union of:

- a means of routing (of information/of documents, of tangible goods, of services, etc.) toward a specific location (fixed, mobile), with specific features (delay, temporality, quality of services–availability, faithfulness, costs, etc.)
- an interaction device with the user (customer, citizen, learner, etc.) with some «modals» properties (using of natural language or not, direct action, etc.), some temporal properties, and some «affordance» (semiotic and metaphoric aspect, guidelines, etc.).

The organisation could be a Direct Marketing company, an educational centre, etc. And this organisation would give the set of IeS available to the customers, employees, partners, learners, etc., i.e., all users who could be interested in those IeS. In addition, we note that this evolutionary definition allowed us to build a bridge between two communities: Direct Marketing (DM) and Human Computer Interaction (HCI). Thus, all channels, virtual or physical, can be mapped to this definition.

2.1 Toward a channel modelling

In Chevrin (2006), we presented our taxonomy of mediation between the channels used during a personalised interaction with a user and IeS. We consider mediation as the management of the link between the channels and the IeS during the interaction.

Figure 1 shows the four main notions we need to qualify mediation: network, user’s device, person and interaction.

On the right side of Figure 1, we can see that a channel is composed of both a network and a user’s device:

- Networks and access protocols have some norms and constraints. It is part (1) on Figure 1. Naturally, this part of the channel is subject to strong constraints of QoS, according to the user’s task. Lots of works deal with this subject. Concerning that point, we were inspired from the Multi-channel Adaptive Information System (MAIS) (MAIS, 2006) project.
- In the user’s device part (Interaction Device (ID), part (2) on Figure 1), the quality must be determined during the interaction, according to the contexts. This quality consists in determining if the ID’s characteristics are sufficient to manage the IeS while keeping both the intention of the author and the ergonomic aspects in mind.

On the left side of Figure 1, we can see that a personalised interaction is composed of both a person and an interaction:
• The interaction mechanism knowledge: semiotic aspect, ergonomics, HCI design, conversational aspect with the grounding (Chevrin et al., 2006), adequacy to the tasks/medias, etc. (see part (3) on Figure 1). This part is used to detect intrinsic characteristics of a channel, thus we can find the link between the needs of the IeS and the author’s intention.

• All the information related to the user (profile, etc.). The data linked to him or her will be provided, in part, by the Customer Relationship Management (CRM) systems (see part (4) on Figure 1). (Chevrin et al., 2005b). This can allow us to determine the user’s need.

Those explanations helped us to propose the channel definition given in the previous section. The next section is dedicated to the IeS issues and the links with QoS.

**Figure 1** The four main elements of our mediation taxonomy

![Diagram of mediation taxonomy]

2.2 Interactive e-Services (IeS) issues

Our needs concerning the description of IeS invocation and composition are slightly different from the main works about web services. This is due to our different needs of dynamicity. With standard web services (WSDL and UDDI), the goal is to discover (at run time) an IeS on the fly, for a particular need (rent a car, for example) with the possibility to delegate the service to a brokering service. But the workflow is static and the model is done at design time. In the case of the Ubi-Learn project (that will be presented in Section 4), we don’t really need to discover new IeS on the fly, because the external IeS (delivered by a third party) are known at design time (Chevrin et al., 2005a).

New technologies and ways of using those technologies are affording new ‘communication’ opportunities in several areas. For example, in business, we can see the growing of e-Commerce then m-Commerce for mobile, then u-Commerce for ubiquitous, and soon p-Commerce for pervasive. Of course, there are different economic models and according to the economical model, the IeS proposed by the organisation will be different both from design and business process levels. The same report can be done in e-Learning (Chevrin et al., 2006). The MultiModal Interaction (MMI) W3C group has been working a lot on the different issues and interests of multimodal interactions. Those works show a strong link between the modality(ies) used and the user activity (task). Our IeS approach is, among other things, well-founded by our overall (multi-channel) vision of an interaction between a user and an organisation that offers several IeS (sets of tasks). Even if the web services technology can be used (not necessarily, though), for the realisation of the IeS, it is necessary to distinguish them from classic web services.
The goal of our IeS approach, with a complex mediation, is to allow the re-use of IeS in a great number of devices settings (channel or channel coupling) for different targets (people, audience (De Troyer, 2001)) and for different organisations (generics). Following the example of the W3C, we are convinced that there is a strong dependence between the medium (modality for the W3C and also the channel for us) used during the interaction and the organisation and the making-up of the IeS deliver to the user. Our theoretical framework (Chevrin, 2006) defines more precisely what a channel is and proposes some relevant properties that allow us to characterise communicational devices (channel or set of channels).

One recurrent problem that we must provide an answer for, is the management of the continuity of interaction. In HCI, it is called seamless interaction. This property is really important in DM. Indeed, a break down during an interaction between an organisation and a customer is often harmful for the organisation (loss of customer confidence, loss of sales, etc.) (Chevrin et al., 2005a, 2005b). With our approach (that will be presented in Section 4), this property of ‘no break down’ is really taken into account with three distinct points:

- the restoring of both the break down and the loss toward the customer
- the recovery of the interaction at the break down time (memory of all the actions done before the break down, such as the IeS finished, the data exchanged, etc.)
- the channel used for the interaction restoring is not necessarily the same as the one used before the break down (considering the different parameters).

Moreover, our approach must follow the three next directions:

- The IeS will have to be suited into the mediation layer because they need to be context-aware and adapted to the communication channels. Nevertheless, it is important that this adaptation be made from descriptions supplied by the IeS (auto-supplying, same as introspection). It would be also interesting if the IeS presented some properties that could allow us to alter, from outside, several elements modifying its behaviour from the customer point of view.
- It is also useful to take into account the potential of the organisation to support the self-service adaptable (My-Organisation) by the customer himself.
- The IeS must keep a minimal quality to be delivered to the user. In particular, the author intention must be respected, and the channel must be adapted to deliver it.

Those works about IeS are still in progress. One of our main goals is to place some QoS parameters inside the different IeS. Then, when an IeS will be called, a first test of QoS will be done from the IeS itself (such as the possible channels target).

In the next section, we show that IeS management (composition, adaptation, etc.) is closely linked to the channel used during the interaction.

### 2.3 The inter-dependence between IeS management and channels

We consider that the dependence between IeS (tasks/activities) and channel is a key parameter to take into account for the QoS management. The channel used will influence the IeS management, adaptation and presentation to the end user. In the same way, according to the IeS, the different channels available for the user will be used differently.
For example, if a video must be displayed, the system will suggest to the user, if possible, to switch for a while, from his or her cellular phone (without enough capabilities) to his or her web browser, in order to refer to this document better.

In Chevrin et al. (2006) we have shown several scenarios where the composition of different eS is conditioned by the nature of the channel and their interaction styles (direct manipulation vs. speech dialogue). Indeed, from our previous evaluation of the first prototypes combining different interaction channels (Derycke et al., 2003; Chevrin et al., 2005a, 2005b), we have discovered that the concurrent accesses to several eS conducted to different interleaving of the eS primitives, depending on the channel in use. The fragmentation of the source document (for example, a form) must be adapted to the channel characteristics and to the interaction elements (such as widgets, vocal forms, etc.). Moreover, we agree that the learner should be able to choose the channel that she or he wants and to carry out the service that she or he wants. Obviously, this is only possible if the service is available for the selected channel.

3 QoS and Interactive e-Services

For a long time, there have been interactions between people and organisations using telecommunication networks. For example, traditional distance learning organisations use telecommunication networks to support distant learners activities: tutoring, counselling are mostly done by telephone in a one to one relationship, etc. Many examples can be given in other domains, like e-Commerce, e-Health, e-Governance, etc.

The evolution and the emergence of new technologies has led to new uses and obviously, new opportunities to interact with users. There are two relevant examples of those opportunities:

- Mobile commerce (m-Commerce), which appeared a few years ago with the emergence of small devices, such as cellular phones, PDAs, etc. Even if designers and programmers must take into account the technical characteristics of this kind of devices in order to adapt their content, m-Commerce goes beyond the web pages miniaturisation and the services offered are not necessarily the same as those suggested in e-Commerce.

- The same observation can be made about mobile Learning, which is not only an adaptation of e-Learning systems to access through wireless network, but increases the accessibility (from the learner’s location) and the ‘reachability’ (to the learner’s location). Several research projects (Attewell, 2005; McLean, 2003) have shown that in spite of the current limitation of the mobile devices put in the users’ hands (i.e., a basic cellular phone), it is possible to consider new learning activities, less focused on rich document interactions, but more communication oriented, which can be compared to Computer Supported Collaborative Learning (CSCL) mode of education.

In addition, in the last years, a new concept has appeared: the Ubiquitous or Pervasive Computing also called Ambient Intelligence. The next two sections deal with that concept and are followed by the description of our vision for QoS management and the discussion of related works in QoS measurement and management.
3.1 Pervasive computing or ambient intelligence

The concept of Ambient Intelligence (AmI) or pervasive computing was developed by the ISTAG advisory group to the European Commission’s DG Information Society and the Media. According to ISTAG (2001), Ambient Intelligence (AmI) is “a stable yet evolving vision”. AmI is not the solution for social problems, it represents a new paradigm for how people can work and live together.

The concept of AmI is a vision in which humans are surrounded by computing and networking technology embedded in their surroundings. AmI puts the emphasis on user-friendliness, efficient and distributed services support, user empowerment, and support for human interactions. This vision assumes a shift away from PCs to a variety of devices which are unobtrusively embedded in our environment and which are accessed via intelligent interfaces. In order for AmI to become a reality, a number of key technologies are required:

- unobtrusive hardware (miniaturisation, nano-technology, smart devices, sensors, etc.)
- a seamless mobile/fixed web-based communication infrastructure (interoperability, wired and wireless networks, etc.)
- dynamic and massively distributed device networks
- natural feeling human interfaces (intelligent agents, multi-modal interfaces, models of context awareness, etc.)
- dependability and security (self-testing and self-repairing software, privacy ensuring technology, etc.)

The IST Advisory Group (ISTAG, 2001) has already given some relevant scenarios of pervasive computing in different areas. Here, we provide a simple scenario in e-Learning. This allows us to illustrate some QoS issues in a multi-channel situation.

“A teacher has made contents for a distance learning promotion course. This document is available on a learning platform, accessible by both students and teachers, and is composed by a video accompanied with some reports. Different channels (such as web browser, PDA, phone, etc.) are supported by the platform.”

We consider QoS measurement to be a difficult task. In a multi-channel interaction, this task is even more difficult because of the lack of references or rules. In that scenario, we can show that the author intention can be important to determine the QoS of a service. For example, if the teacher considers the video to be a central point of the course, students will have to use a channel able to broadcast that video. Obviously, there are some other parameters, which could be used to measure the QoS. We will see some of them in the rest of the document. Here, with this simple scenario, we just wanted to show that the QoS measurement is a large and difficult issue.

3.2 Context-aware adaptation for pervasive computing

Studies about pervasive computing put the users’ tasks at the central point (Banavar et al., 2000), and we think that it is still valid today.
In this section, we want to focus our argumentation on the context-aware computing issues. In fact, there is no consensus about the definition of context in the context-aware computing research field (Abowd and Mynatt, 2000). Several searchers have suggested definitions of context, such as Dey et al.

“any information that can be used to characterise the situation of entities (i.e., whether a person, place or object) that are considered relevant to the interaction between a user and an application, including the user and the application themselves. Context is typically the location, identity and state of people, groups and computational and physical objects,” (Dey et al., 2001)

or in Chalmers et al. (2004) and Brezillon (2003), where a distinction is made between relevant and irrelevant contexts:

“You can distinguish relevant context from that which is not at any step of a decision-making process or a performing task. Irrelevant context is called external knowledge. Relevant contextual knowledge depends on the agent, the current situation, and the decision at hand.”

Here, context and knowledge are strongly linked, and each interaction situation has its own relevant context.

Recent works, such as Henricksen (2003), aim to better formalise context. All those researches about AmI, pervasive, ubiquitous or context-aware deal with four questions:

- capturing the contextual variables
- normalising and exchanging them, perhaps through shared models based on ontology
- using dedicated software architectures to take into account the context evolving elements, like events broadcasted to the concerned applications
- better formalise the rules for decision about the adaptation of the services or documents to the context.

We remember from the previous works on context-aware computing that there is a real need for better models of contexts and models of adaptation of services which are context-sensitive.

3.3 QoS of an IeS

The QoS of an IeS can take place at different levels of interaction. We have found several levels in the life cycle of an IeS, which are relevant to control the quality of these IeS in our framework. Obviously, the following list is not exhaustive:

- The specification of the IeS must be abstracted in order to be mapped (adapted) to the different channels. For IeS delivered by an outsider, we cannot be sure that the specifications will be abstract enough; that is the reason why we are working on a proxy which filters the IeS, and adapts it in a compliant way. Here, one of the main difficulties is to keep the author’s intention. Nevertheless, the users’ needs must be taken into account. In our scenario, if the learner has previously seen the video and would just like to remember one part of it, he or she can use a device which has a poorer QoS, even if the author’s intention is not respected.
Concerning the concrete IeS interface for the user, it is necessary to follow heuristics, such as those proposed by Nielsen and Tahir (2001) for the web. Nevertheless, this kind of heuristics does not exist yet in the concerned channels, such as phones with audio interactions, PDAs, etc. That is why we added traces to our system (see Section 4.3) in order to find our own heuristics, or at least try to improve the interaction quality according to the context.

The intention of the IeS author must be respected during the different levels of adaptation. If we consider the scenario previously discussed, a teacher makes an IeS composed by a video together with explanations: if a learner accesses this IeS through a small device, which is not able to play the video, the intention of the author is not respected, because for him or her, the video and documents cannot be separated, and a single picture, for example is not enough to replace that video. In addition, the user’s intention should also be taken into account.

Figure 2 summarises our vision of the QoS management. We consider that the QoS could often be subjective information. Mapping QoS taxonomy (a lot of works deal with that subject, and our aim is not to propose another one) and both author’s intentions and user’s needs will be helpful to detect if an IeS can be proposed for a particular user or not. Thus, the context of the interaction will be fundamental to make such a choice. In fact, an IeS could be identified as ‘available to the end user’ according to the mapping between some QoS parameter and both the author’s intention and the end user’s need. An aspect of our works consists in trying to perform the general quality of the interaction (high level of the IeS), proposing to manage composition of the different IeS according to the context, and particularly according to the channels used during the interaction.

3.4 Related works in QoS measurement and management

The QoS and related issues have been the subject of many researches and modelling efforts across several communities for a few years. In our case of study, it is relevant to get acquainted with the progresses of the web and web service community (e.g., Ran, 2003), the network and internet communities (e.g., Crawley et al., 1998) and also the
middleware community (e.g., Zinky et al., 1999). In spite of the differences between those communities, they have the same objective concerning quality. According to Marchetti et al. there are two major issues:

“(i) to identify the relevant measurable characteristics affecting the quality of the services provided by a given “object” (e.g., a web-service, a network infrastructure, a middleware platform) and (ii) to define means (e.g., architectures, paradigms, components, and protocols) to implement an ‘object’ whose values of its measurable characteristics satisfy some quantitative constraints.” (Marchetti et al., 2004)

Those authors name the measurable characteristics of objects QoS parameters (Frolung and Koistinen, 1998).

For example, concerning the web-service community, works identify QoS parameters for better characterising services (Marchetti et al., 2004). Zeng et al. (2003) propose a methodology enabling the evaluation of the QoS of a composite service. In relation to the works of Ran (2003), they suggest to extend service discovery on the basis of QoS-related information. The main issue is the difficulty to obtain, define, and evaluate several of the QoS parameters, such as availability, performance, and so on. That is reinforced by the fact that we work in an end-to-end manner since the channels used to let a service and users interact are sometimes beyond the control of the provider. A solution will be to have services labelled by providers with sets of QoS parameters. However, this solution is limited because of the user’s perception to the QoS, such as provider, network or device availabilities, are not under provider control. van Moorsel (2001) proposes approaches to reduce those issues. Several contributions of MAIS (2006) discuss those works.

In a communication, Marchetti et al. present their own solution based on a ‘Quality Model’:

“The quality model consists of (i) a system model defining objects and actors, and of (ii) a set of roles and rules enabling the association of quality information to objects. Quality information is expressed using quality parameters and quality sets.” (Marchetti et al., 2004)

This system is based on the Service Oriented Architecture (SOA) with an extension to a channels representation. These works have in several points, the same orientation as we have.

In fact, the MAIS project (MAIS, 2006) is largely oriented by QoS issues. Some of the works developed in that project have been used as a starting point of our research. More details on the subject (relation between MAIS project and our works) are available in Chevrin (2006).

4 The Ubi-Learn project

In this section we will describe both the conceptual and practical solution we have built aimed at managing the mediation between IeS and channels and that we called Ubi-Learn. Then, we will present how we see the QoS management in our infrastructure.
4.1 Overview

Our Ubi-Learn project aims to support more mobile and flexible learning processes by integrating recent progresses and development of software engineering, pervasive computing and context-aware computing domains of research. We have started the design and implementation of this new infrastructure for the intermediation between the learners, with fixed or mobile locations, accessing a system through various devices and value-added networks, and a collection of learning services, which can be extensible, depending on the context. The problem of the intermediation is complex, due to the number of settings that can be encountered, and to the needs of flexibility and dynamic adaptations. This implies that some decisions about the composition (of medium, channels, services, etc.) must be taken at run-time and not at design-time. Our technological infrastructure is designed with those constraints, and provides capabilities to be extended in order to support new communications channels or new user devices in the future.

4.1.1 Software architecture

Figure 3 shows the mediation between IeS delivered by the organisation and the user via the use of different channels (multi-channel interaction) synchronously or asynchronously. This entails issues, such as ruptures in an interaction when a user switches channels, etc. This mediation is context-sensitive. We considered the Context (4) as the context-aware defined by Dey et al. (2001). The other type of context is the organisation policies (3), which concern the different rules and policies of the organisation. Those two contexts (3) and (4) are achieved by a Collection of Context Services (CCS). Those services could be delivered by an outsider, as Liberty Alliance in (3). This context management is the key of the adaptation of the IeS delivered to the users. The management of such pervasive e-Services (Chevrin et al., 2005b) is based on the transformation chain that we have implemented with a Multi-Agents System (MAS) middleware presented in Figure 4 and described in more detail in Section 4.1.3.

Figure 3  Simplified view of our software architecture (Ubi-Learn) (see online version for colours)

In the area of pervasive e-Services (our IeS), we claim that a good management of the mediation entails two major issues. First, using two contexts (3) and (4) in Figure 3 enables both adapting and composing of the different IeS for a good presentation to the user. Secondly, from our previous evaluation of early prototypes (Chevrin at al., 2005b), combining different interaction channels, we discovered that the concurrent accesses to
several IeS led to different interleavings of the IeS primitives, depending on the channel in use. The user’s entry point of Ubi-Learn is an Application Server where our Java application is run, which delivers various types of pages (displayed or spoken). One goal of Ubi-Learn was to build an application able to deal with multiple channels and we considered the following ones: telephone, Web browser and Personal Digital Assistant (PDA). To interact with our prototype through a telephone, a converter (named C1 in Figure 3) is needed to translate the VoiceXML pages generated into speech and also to interpret what the users say into data sent to the application. The same kind of converter is needed for PDA (named C2 in Figure 3), but Web browsers can access the Application Server as long as the latter is able to deliver native Web pages. If we go from that extreme to the other, there are the pervasive services, which require a front end to be implemented; that front end’s action is to call Web Services and produce XML flows on the fly.

4.1.2 Collaboration between the main entities of Ubi-Learn

The entry of the system is a java servlet called DirectoryServlet which is linked to the MAS system through the Proxy Agent. This Agent creates and runs a majority of the Agents, except Display, Session and User Agents. An example of the link between the MAS and a servlet is given in Gandon (2006).

The number of Display Agents is the same as the number of users’ requests and the number of User Agents is the same as the number of connected users. CRM Agent accesses to the different organisation rules. This agent knows rules such as if user’s birthday 20% discount or if student’s mark lower than 10/20, then give him two extra exercises. Those rules depend on the organisation business type. Rules Agent contacts the service to be run according to the services already ran and finished, and static or dynamic rules. The Display Agent is able to transform an XML flow in a Markup Language flow such as XHTML, VoiceXML, etc. understandable by the diverse User Devices. Finally, each service is represented by an agent. When the service is called for the first time, its agent sends a XML flow to the Interface Agent and warns the Session Agent whether the service is actually finished (this allows the break down into the interaction management; see Chevrin (2006) for details).

4.1.3 The mediation middleware

Figure 4 shows that a mediation uses several levels: the IeS Composition, the Channel prediction, the QoS, the format that we call the Quality of Interaction (QoI) by analogy with the QoS, and finally the persistence of data. Those different levels influence the mediation and obviously, the composition and the adaptation of the IeS, but also the capacity to choose the best channel for a particular IeS or composition of IeS. It is important to notice that, in Figure 4, all agents performing the actions are represented as a single agent whereas, to implement one agent of the figure, there could be a hierarchy of concrete Jade agents (Jade, 2006) (e.g., a factory, a manager, etc.). Now we describe more technically the different levels which take part in a mediation into our middleware.

The first level we describe is the composition of IeS (see Figure 4). It consists in determining the temporal composition (i.e., the orchestration) of the IeS depending on the context. The composition of IeS is performed by an appropriate agent in the MAS, called the RA (see Figure 4). When a user accesses Ubi-Learn through a telephone channel,
the RA will decide not to access the e-Service which enables to skim through the catalogue, although this e-Service is accessible through a Web channel. In our prototype, the orchestration rules are static and thus difficult to enrich. We are still working on another evolution of the prototype including a flexible workflow manager based on previous works (Hadjouni et al., 2005). Moreover, several relevant researches are carried out in this area. For example, Blake’s works (Blake, 2004) on a workflow based on software agents for business orchestration. Other works as Maamar et al. (2005) study web services orchestration with software agents.

The second level, the ‘Channel determination’, means that the context influences the channel used for the customer-organisation interaction. For example, simple rules of an organisation could force the use of a fax, to validate the customer order (e.g., in a travel agency). To manage that, the UA and the CRMA (see Figure 4) are used to request the different contexts to predict the channels available to carry out an e-Service. Both marketing and communication rules (coming from organisation policies) which predict the right channels could be more complex and are based on our theoretical framework on the communicational features of the channels (we also achieved a taxonomy formalising a mediation, explained in Chevrin et al. (2005a)). For the time being, this feature is achieved by UA and the CRMA, but we intend to design dedicated agents for it. The use of two contexts (respectively used by the UA and the CRMA in Figure 4) can lead to incompatibilities between them. So, a major question is: how to bring a ‘cross-fertilisation’ between context-aware and policies of the organisation? This complex and open problem is not discussed in this paper.

The third level, ‘Adaptation to QoS’ is closely linked to the ‘Channel determination’ level. For example, a customer using a 3G mobile phone will be able to receive high-quality videos whereas a GSM telephone user will only get a low-quality or no video at all. In this area, there are some researches with some relations to our approach. The MAIS project (MAIS, 2006) addresses a large effort on the QoS. This project is also particularly oriented to networks and studies adaptivity on each layer in the information systems, from the application to the networks and devices. Several layers of adaptivity are considered and particularly the needs of multi-channel information systems and the systems for the disabled users are addressed.

The fourth level, ‘Format’ indicates the data presentation to the user according to the channel used. In other words, Format is the manner in which the data from the IeS
are formatted to be displayed or spoken to the customer. Thus, the IeS are adaptable to the channels used. Indeed, every e-Service is represented by an EA (see Figure 4), which produces an XML flow and an appropriate agent called the IA aims to transcribe it into the relevant language (XHTML for a Web browser, WML for a PDA and VoiceXML for a telephone). To perform that, the agent uses XSL transformations. Some researches are achieved in this area, such as the recent project AMACONT (Hinz and Zoltan, 2004), and also in the Web Application area, relatively close to our approach from the IeS adaptation point of view. In this project, the authors suggest a step by step electronic document generation via a pipeline such as the Cocoon framework (http://cocoon.apache.org/fr) in the Apache suite. Nevertheless, their notion of device does not take into account the nature of the different networks. Another recent project, Thales (http://www.thalesgroup.com/home/home/), offers this kind of adaptation with the Human-System Interaction Container (HIC) (Lard et al., 2004).

The fifth level of the prototype is the ‘Interaction persistence’ (see Figure 4). This is a kind of layer which manages interaction ruptures; two kinds of ruptures are to be considered: the unintended ones (e.g. due to a communication breakdown) and the intended ones (e.g., a user naturally finishes using the application, but not all the interaction). This level is achieved by the Session Agent SA (see Figure 4) and implements an ‘enhanced’ session management which integrates multiple communications through different channels.

For example, if a customer is using Ubi-Learn through a telephone and a rupture occurs during the interaction, he would be able to re-access Ubi-Learn from his or her computer via a Web channel and then be re-identified; and he or she would recover everything he or she was doing.

Figure 5 shows the UML Collaboration diagram of Ubi-Learn, and the links between several major Agents of the MAS system. Some comments have been added on Figure 5, in order to make its reading easier. To summarise the global running of the middleware let us imagine that a customer accesses the Application Server through several channels. This server sends the user request to the PA. This agent creates a SA specific both to the user and the channel and it is responsible for the persistence of each mediation. Then, the request passes through UA (manages the user preferences, roles, etc.) and CRMA (manages the organisation policies). Those agents take the contexts into account. Afterwards, the RA achieves a particular composition of the IeS according to the channels in use. The RA sends a request to the appropriate EA, and the latter sends an XML flow (representing an abstract representation of the e-SI) to the IA, which sends the Markup Language flow (XHTML, WML or VoiceXML) to the PA. Then the data is sent back to the Application Server. And the latter transmits the Markup Language flow to the right channel. In the next section, we will look further into the part of the QoS management.

4.2 Management and measurement

In this section we will present what we mean by QoS and how we propose to manage it through our infrastructure. There are several distinct kinds of QoS. They can be related to the networks, to the cost (money, time, etc.), ergonomics, etc. Whatever they are, we have to manage them for multi-channel, context-sensitive interactions.
Figure 5  UML collaboration diagram of Ubi-Learn
In this way, we consider that there are several distinct ways to manage QoS. Here we present three of them. First, as already stated, the IeS itself must contain some parameters of QoS (such as the channels where it is possible to carry it out, the author’s intention, etc.). Then, an adaptation level could be spread out in the mediation middleware. In that case, there are two possibilities:

- We create a special adaptation level dedicated to the QoS management. It’s the last step of the IeS adaptation. If it is possible, this level tries to adapt the IeS and the channels used else the system gives back to the user a message that explains why it is not possible to access this IeS.

- Each adaptation level has its own QoS measurement system.

Finally, we must be able to modify the system to improve the QoS of the IeS if it is possible, or give some recommendations to the user. To achieve that, we must set up a system able to register the different interactions between the user and the system. This idea to save some traces raises several problems. The most serious of them is to decide if instruments should be inside or outside the system. We have already done several experiments on this part, and we present one of them in the next section.

4.3 Experimental results

A part of the Ubi-Learn project is dedicated to the instrumentation and the measurement of interactions performed in multi-channel services systems. One of those channels is the telephone. Experimental results presented in this section are mainly dedicated to that channel. Text To Speech (TTS) synthesis and Automatic Speech Recognition (ASR) used in this project are considered as services. Measuring the quality of this kind of service is not trivial. If it’s interesting to propose a natural dialogue between users and machines, based on ASR and TTS, it is much more interesting to have tools that check the effectiveness and the usability of the used equipments and interfaces.

Concerning that last point, the observations of all scientific communities remain the same: there are very few corpus and tools provided to observe the use of multi-channel systems. It is necessary to find new ways to model, conceive and carry out information processing systems able to provide logs (at a low level but also for a higher degree of complexity) situated in time and space. It will also be very relevant to capture information about the use contexts (state of the networks, level of the user’s stress, ambient noise level, light brightness, etc.), in order to be able to reproduce those situations, later, if one wants to understand what occurred at runtime.

The process we implemented in order to record conversations between the users and our vocal server was external to the system itself. It recorded conversations but also surrounding noises. This first step showed that what the system believed to hear was not necessarily what the users uttered. Typically, with the question ‘How old are you?’ it happened that the machine recorded ‘33’ in the database, whereas the true answer pronounced by the user was ‘23’. The human tutor, in quiet listening can note this anomaly down and listen to the recorded sentence again to make up his or her opinion.

The audio corpus represents 4888 seconds, that is to say 1 hour and 35 minutes of speech. On average, each conversation lasts 213 seconds (standard deviation of 90). The shortest dialogue lasts 132 seconds, and the longest lasts 574 seconds. Those durations were automatically calculated by the machine which noted down the
beginning and the end of each conversation. After the results obtained during this first experiment, we can say that the VoiceXML language (VoiceXML) did not have, in an internal way, a mechanism which gave the possibility to follow the interactions with the users connected on the Interactive Voice Response (IVR). Until version 2.0 of VoiceXML (Rouillard, 2004), it was not possible to carry out a real trace of what the users had actually pronounced during their dialogue with the system. But it was possible to consult the variable supposed to recover the value corresponding to vocal grammar elements. In other words, it was not possible, up to now, to record automatically what the user really pronounced at runtime.

Since the relatively recent version of VoiceXML 2.1, which is yet only a ‘working draft’ of the W3C, it is technically possible to record what the user pronounces during the vocal interaction. For that, it is necessary to initialise the recordutterance attribute of the \(<property>\) tag with the value ‘true’. One can then obtain the following data thanks to certain application variables (see Table 1):

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Variables of the application, available in VoiceXML 2.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>application.lastresult$.confidence</td>
<td>Confidence level (between 0.0 and 1.0). A value of ‘0.0’ indicates a low confidence and ‘1.0’ a high confidence</td>
</tr>
<tr>
<td>application.lastresult$.inputmode</td>
<td>Input mode used (‘dtmf’ or ‘voice’)</td>
</tr>
<tr>
<td>application.lastresult$.recording</td>
<td>Vocal data corresponding to that the user said</td>
</tr>
<tr>
<td>application.lastresult$.recordingduration</td>
<td>Duration (in msec) of the last voice recognition</td>
</tr>
<tr>
<td>application.lastresult$.recordingsize</td>
<td>Size (in bytes) of the last voice recognition</td>
</tr>
<tr>
<td>application.lastresult$.utterance</td>
<td>The utterance recognised for this interpretation</td>
</tr>
</tbody>
</table>

We used this specificity (available in our laboratory IVR-vocal server) to develop a recording mechanism of the possible man-machine interactions in VoiceXML (voice and telephone keyboard). Thanks to this instrumentation, it is possible to collect traces which reflect the use of an application. During each interaction, the related piece of information is recorded in a database. We have developed tools allowing experimenters (not necessarily data processing specialists) to analyse the collected data. From this graphical user interface, an ‘expert’ of the domain (a pedagogical engineer, for instance) can listen to the vocal recording (.wav) corresponding to the user’s answer and compare it to what the machine believed it had understood during the interaction.

We tested this process with a multimodal e-Commerce application using speech recognition and voice synthesis, providing the visualisation of the products pictures, and also allowing the use of telephone keyboard DTMF (Dual-Tone Multi-Frequency), and the possibility to click on web page hyperlinks. For example, on the first row of Figure 6, we can see that when the task was about choosing a cloth size, the machine believed to recognise the answer ‘large’ from the user voice interaction.

By clicking on the file (.wav) of that very row, the expert can check that the user has really pronounced this word or sentence, and can correct the information if necessary. The good/bad understanding statistics (of the machine) are updated during each interaction. This allows to measure and check the interface quality of service.
5 Conclusion

In this paper, we have presented our approach concerning the measurement of the quality of services in systems supporting multi-channel services. We showed that the interdependence between IeS management and channels is very important in order to provide relevant solutions according to contexts, tasks, user profiles, network traffic, etc.

With the e-Learning example developed in this paper, it’s easy to understand that the quality of the service is not just a network/infrastructure quality issue. Indeed, in multi-channel architectures, we have to face the possibility that the same information can be given across different and heterogeneous networks and devices.

We have worked for many years on that issue concerning the quality of service and proposed a mediation middleware. This framework, based on a multi-agent system, takes into account, at the same time, rules and organisation policies, profiles and user’s roles together with IeS capabilities.

Some interesting results about the instrumentation and the measurement of multi-channels systems let us realise that if we want to fathom the quality of a service, we have to reproduce the context of the interaction (with the same elements as those captured during the interaction). We particularly worked on the possibility to record telephone conversations while a machine and a human are talking to each other. In these circumstances, we provided tools for users that make it easier to assess whether the service was valuable. We believe that, in pervasive computing situations, particularly, it will provide robust and rich information that could be used to improve the quality of multi-channel services.

Now, we want to improve our system of trace capture. Currently, we catch traces with suitable systems and the data obtained are not organised according to a dedicated formalisation. So, first, we want to make a generic system allowing to catch different useful traces (vocal, textual, etc.). This system will help us to determine if the quality of the interaction proposed to the end user is convenient or not. And secondly, we work on a specification of traces in order to map the information logging on a formal model of traces. This system of trace-logging will also allow us to carry out a study on the use of our system (using of mobile device, etc.).

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References


Notes
1Here, we mean both usability and ergonomic rules.
2Other names have been given, e.g. dimension, attributes, etc. (Frolung and Koistinen, 1998).
3http://www.projectliberty.org/
4Dual-tone multi-frequency.

Website