QUALITY OF SERVICE AGGREGATION IN E-BUSINESS APPLICATIONS

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Abstract: In e-business applications, enterprises build their processes to achieve their business goals. One of the architectural models of e-business applications is a service-based approach. This approach consists in orchestrating the e-services offered by one or several enterprises partners in order to build the desired business processes. It is important for the enterprises to ensure client satisfaction in order to be more attractive and more competitive. Quality of Service has a significant impact on client satisfaction. Therefore, clients need e-business applications with high Quality of Service to be satisfied. In this context, we propose in this paper an approach that allows clients to measure the satisfaction degree of the services orchestration. This approach takes into account client's preferences on QoS attributes and their related dependencies in the measurement of the satisfaction degree. We treat two examples of services orchestration and show how does the measured satisfaction allow the client to choose the best one.

1 INTRODUCTION

Electronic business or e-business can be defined as the use of the technology of the Web to do business. There is a variety of e-business models. Among them, we found the Business to Client (B2C) and Business to Business to Client (B2B2C) (Qi and Huang, 2005). Enterprises based on these models put much importance to *client's satisfaction* in the development of their e-business applications. For this purpose, enterprises have to provide e-business applications with high Quality of Service (QoS) to be more competitive and to reach client's satisfaction. QoS has a significant impact on client's satisfaction and it is closely related to this latter. In this paper, we propose a method to measure client's satisfaction related to QoS of the e-business application. We are interesting in e-business applications supported through orchestrated e-services.

When developing their e-business applications, enterprises aim to respect client's *QoS expectations* specified on the services orchestration. QoS expectations are defined by the upper and lower bounds of the QoS levels that the services orchestration must meet to guarantee client's satisfaction. The upper QoS level's bound is denoted *desired QoS level* (Parasuraman et al., 1994), and represents the QoS level that satisfy the best the client. Whereas, the lower QoS level's bound is denoted *adequate QoS level* (Parasuraman et al., 1994), and represents the minimum QoS level that satisfy the client. We denote also the measured QoS level at run-time and on client's side by *the perceived QoS level* (Parasuraman et al., 1994). However, during services' life cycle, perceived QoS attributes values of the services may change. This leads to a variation of the perceived QoS level of the services orchestration into the range of QoS expectations. Besides, the client's satisfaction of the e-business application supported through this services orchestration will be impacted. Therefore, clients exploiting the e-business application need to know how much they are satisfied in terms of QoS.

Various works dealing with evaluation of services orchestration's QoS attributes exist in the literature (Cardoso et al., 2002; Jaeger et al., 2005; Rosenberg, 2009). Currently, none approach supports different QoS attributes simultaneously in order to provide a high level information about the QoS of the overall services orchestration. The satisfaction degree of services orchestration is a such high level information, which facilitates the interpretation of QoS attributes values of the services orchestration.

To measure the satisfaction degree of services orchestrations, we will use a Multi-Criteria Decision Making (MCDM) method that takes only client's preferences on the QoS attributes as inputs, neces-

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sary to construct the QoS aggregation model. Moreover, we consider that there are dependencies between clients' preferences over QoS attributes. Therefore, we use an aggregation operator, which is able to support preferential dependencies. The method we choose is the MACBETH method (Costa et al., 2005) extended to the 2-additive Choquet Integral (Clivillé et al., 2007; Mayag et al., 2010).

The remainder of this paper is organized as follows. Section 2 discusses related work. In Section 3, we present our approach for the measurement of services orchestration satisfaction degree. Section 4 details a use case of the satisfaction degree measure, while Section 5 concludes the paper.

2 RELATED WORK

In this Section, we compare our approach to the existing ones in 2.1, and we overview related works on QoS evaluation for services orchestrations in 2.2.

2.1 QoS Aggregation Efforts

(Menascé, 2003) presents an automatic QoS controller for e-commerce sites. The QoS controller monitors the site's workload and determine the best configuration that meet the site's QoS requirements. It executes an algorithm that takes into account the observed workload, the desired QoS levels, to determine configuration parameters. The algorithm tries to find the configuration parameters that maximise a QoS metric defined as:

$$QoS = \sum_{i=1}^{n} w_k \times f_k(\Delta_k)$$

where n is the number of QoS attributes being aggregated, w_k is a relative importance weight assigned to QoS attribute k ($\sum_{i=1}^{n} w_k = 1$), Δ_k is a relative deviation of the QoS attribute k defined in a way that the relative deviation is positive when the QoS attribute exceeds its requirement and negative otherwise, and $f_k()$ is an increased function of Δ_k. The authors assume that the relative weights (w_k) are assigned by site management. In our mind, assigning directly weights to QoS attribute is not a trivial task, especially when we have several QoS attributes. In our approach, we need only decision maker preferences to determine aggregation model parameters. Moreover, the authors use linear transformation to normalize Δ_k (i.e., to have a value in the interval [0,1]). The better the normalized value is (tends to 1), the better the QoS requirement is met. Therefore, the normalized value represents the satisfactory value to the related QoS attribute. Using linear transformation is not very accurate to model the real satisfaction of the client. For example, the model of the availability's satisfaction can be a curve. In our approach (see Section 3), we do not use linear transformation to normalize QoS attributes but we compute normalized values based on informations given by the client (see Figure 6).

In (Szydlo and Zielinski, 2008), authors present a method for adaptive quality control of services orchestrations. The goal of the method is to satisfy client requirements and to preserve his budget by changing SLA during execution. The method is based on a QoS controller that monitors deviation of perceived QoS attributes values from the agreed in the SLA, and on this basis, services to be invoked are selected. The client choose a set of SLAs he is interested in, and the system selects the SLA with the best fitness function and price. The fitness function is defined as a weighted mean of QoS attributes values. Authors uses the Analytical Hierarchy Process (AHP) (Forman and Selly, 2001) method to build the aggregation model. However, the AHP method does not take into account dependencies between preferences on QoS attributes since it is based on the weighted mean operator.

(Herssens et al., 2008) presents an approach for services selection. The approach is based on a QoS model that enables users to express their requirements and providers to represent their services' QoS. The model also allows to represent priorities (preferences) and dependencies between QoS attributes. The selection mechanism relies on a MCDM method that takes into account relationships and dependencies between QoS attributes. The MCDM used is the Choquet Integral. However, authors assume that the service provider specifies the dependencies and their effects (i.e., positive or negative) that can exist between QoS attributes. In general, dependencies between QoS attributes are due to the techniques used to improve one or several QoS attributes. In other words, depending on the technique used, the improvement of a QoS attribute can affect other QoS attributes in a positive or negative way. However, we can obtain the desired QoS (that fit the best the expectations) by using appropriate techniques. In our approach, we assume that dependencies exist between client's preferences over the set of QoS attributes and not between QoS attributes variables. Authors also use linear transformation to normalize QoS attributes. As we discussed above, this assume that the satisfaction of the client is linear which is not necessarily the case. Our approach takes only client's preferences as inputs and allows to generate normalized QoS attributes values and aggregation operator parameters.

In our previous work (Fakhfakh et al., 2011), we have used Measuring Attractiveness by a Categorical-Based Evaluation TecHnique (MACBETH) method (Costa et al., 2005) based on the weighted mean operator to aggregate QoS attributes values. The MACBETH method allows us to express QoS attributes in the same scale and determine the weights of the weighted mean operator. The advantage of MACBETH method is that its inputs are only restricted to the informations provided by the client (i.e., preferences and their intensity over QoS attributes) and does not make any other assumption. We used this kind of method because we consider that the satisfaction is client specific (i.e., varies from one client to another) and depends on client preferences. However, the major limitation of the MACBETH method is that it assumes that client's preferences on QoS attributes are independent. For example, let us consider three QoS attributes : response time, reliability and availability. One client may express that he prefers more the availability than the response time when the reliability is good. However, he prefers more the response time than the availability when the reliability is bad. These kinds of information is not supported by MCDM methods based on a weighted mean operator due to its independence assumption. For this purpose, we use a MCDM method based on the Choquet Integral operator.

In this paper, we will use an extension of the MACBETH method to the 2-additive Choquet Integral (Cliville et al., 2007; Mayag et al., 2010) that permits to take into account dependencies between client's preferences.

2.2 QoS Evaluation for Services Orchestrations Approaches

Various approaches have been proposed to compute each QoS attribute value independently for services orchestration (e.g., giving response time values for all services composing the orchestration, how to compute the response time of the overall orchestration ?). These approaches can be classified in two categories: *probabilistic model-based approaches* (Gallotti et al., 2008)(Sato and Trivedi, 2007)(Cortellessa and Grassi, 2007)(Zhong and Qi, 2006) and *workflow pattern-based approaches* (Jaeger et al., 2005) (Rosenberg, 2009)(Cardoso et al., 2002) (Coppolino et al., 2007). The first category of approaches allowing to compute QoS attributes values of services orchestration is based on probabilistic models. It consists in transforming the services orchestration model into a probabilistic model (e.g., Continuous Time Markov Chain (CTMC) model (Gallotti et al., 2008)(Sato and Trivedi, 2007) or Discrete Time Markov Chain (DTMC) (Cortellessa and Grassi, 2007) or Stochastic Petri Nets (SPN)(Zhong and Qi, 2006)). Then, the probabilistic model is annotated with QoS attributes values. Finally, these approaches use tools like PRISM (Gallotti et al., 2008) or SPNP (Zhong and Qi, 2006) to compute each QoS attribute value of services orchestration. The major drawback of these approaches is that they only support reliability and/or response time (see Table 1).

The second category consists in defining aggregation rules of QoS attributes for each pair of workflow patterns (van der Aalst et al., 2003). A pair of workflow pattern is composed of "one split pattern" (e.g., AND-split) and "one join (synchronisation) pattern" (e.g., XOR-join) except the *sequence* and the *loop* patterns, which are individually considered. The advantage of workflow pattern-based approaches is that they support larger set of QoS attributes (see Table 1). Moreover, they are extensible: *(i)* more workflow patterns could be added and *(ii)* new QoS attributes could be integrated. For that reason, in our approach, we will exploit a workflow pattern-based approach.

However, when changes affect positively or negatively some QoS attributes values, it becomes difficult to estimate how much the whole orchestration fits client's expectations and satisfaction ; especially when we have several QoS attributes. Thus, it would be useful to have a high-level information. We define this information as the services orchestration satisfaction degree. This could be done by aggregating the QoS attributes values to provide a sole aggregated value that measures the satisfaction degree of the services orchestration. To this end, we propose to use a MCDM method.

3 AGGREGATION PROPOSAL

In this section, we introduce our proposal for aggregating QoS attributes values in order to provide a measure of the satisfaction degree of services orchestration according to client's QoS expectations. We operationalize *the satisfaction degree* as the score out of 1 that represents how much the perceived QoS level, for the overall services orchestration, respects QoS expectations (i.e., client satisfaction). It takes the value of 0 if the perceived QoS level is less than or equal to the adequate QoS level, and the value of 1 if the perceived QoS level is greater than or equal to the desired QoS level. As we said above, QoS expectations are defined by means of desired and adequate QoS levels. We define a QoS level as a vector of QoS attributes values denoted $(q_1,\ldots,q_n)$, where

Table 1: Aggregation Categories vs Supported QoS Attributes.

Category	Research work	Supported QoS attributes
Probabilistic model-based approaches	(Gallotti et al., 2008)	Execution time, reliability
	(Cortellessa and Grassi, 2007)	Reliability
	(Sato and Trivedi, 2007)	Response time, reliability
	(Zhong and Qi, 2006)	Reliability
Workflow pattern-based approaches	(Jaeger et al., 2005)	Throughput, response time, cost, availability, reputation, security
	(Rosenberg, 2009)	Throughput, response time, cost, availability, reputation, security , scalability, accuracy, robustness
	(Cardoso et al., 2002)	Response time, cost, reliability, fidelity
	(Coppolino et al., 2007)	Reliability

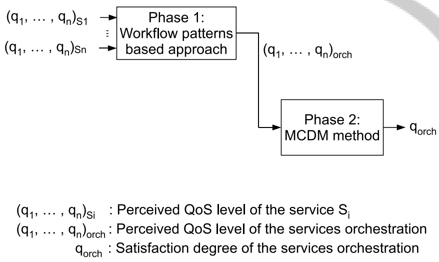


Figure 1: Principe of the Aggregation Approach.

$q_{j,1\leq j\leq n}$ is the j^{th} QoS attribute value. Therefore, the desired QoS level is a vector of the desired QoS attributes values, while the adequate QoS level is a vector of the adequate QoS attributes values. If the client knows the services involved in the services orchestration, he may define his individual QoS expectations on each service. In this case, QoS expectations on the services orchestration can be computed by applying a workflow pattern-based aggregation approach.

Our approach is composed of two phases (see Figure 1): in the first phase, we use workflow patterns aggregation rules, while in the second phase we use a MCDM method based on the 2-additive Choquet Integral. At execution time, each service S_i has a perceived QoS level $(q_1,...,q_n)_{Si}$ (obtained from perceived QoS attributes values). Given these perceived QoS levels of all orchestrated services, they are firstly aggregated in phase 1 using workflow patterns aggregation rules. This results in one perceived QoS level of the services orchestration $(q_1,...,q_n)_{orch}$ (see Figure 1). Then, the QoS attributes values of this perceived QoS level will be aggregated in phase 2 using a MCDM method. This provides us a sole and consolidated value, which is the satisfaction degree of the services orchestration. Before detailing these two phases, we present a car insurance e-business application supported through a services orchestration described in Figure 2. We will use this B2C services orchestration model to illustrate our approach hereafter.

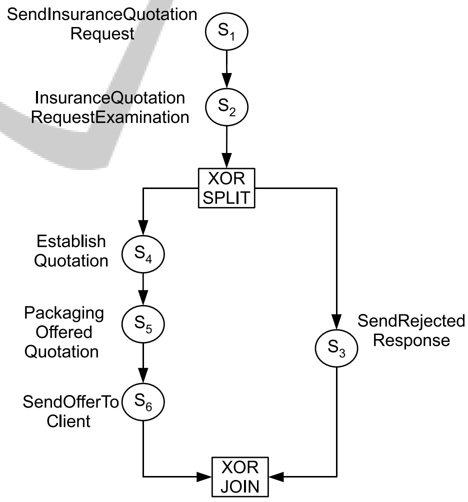


Figure 2: B2C Services Orchestration.

The process starts by asking some informations to the user (user age, driving license, car type and model, etc.). Such informations are firstly analysed for a decision: either the quotation request is accepted, either

Table 2: Aggregation Rules (Rosenberg, 2009)(Cardoso et al., 2002).

	Response Time	Reliability	Availability
Sequence	$\sum_{i=1}^{n} q_{rt}(s_i)$	$\prod_{i=1}^{n} q_{rel}(s_i)$	$\prod_{i=1}^{n} q_{av}(s_i)$
Loop	$q_{rt}(s_i) * c$	$q_{rel}(s_i)^c$	$q_{av}(s_i)^c$
AND-AND	$\max(q_{rt}(s_1), \ldots, q_{rt}(s_n))$	$\prod_{i=1}^{n} q_{rel}(s_i)$	$\prod_{i=1}^{n} q_{av}(s_i)$
XOR-XOR	$\sum_{i=1}^{n} p_i.q_{rt}(s_i)$	$\sum_{i=1}^{n} p_i.q_{rel}(s_i)$	$\sum_{i=1}^{n} p_i.q_{av}(s_i)$

[a] c denote the number of occurring loops
[b] p_i the probabilities of the outgoing branches for XOR-XOR

it is immediately rejected. When accepted, a quotation is established taken into account user informations provided. Then, a commercial offer is packaged comprising the car insurance quotation and some commercial and promotional offers (life insurance, house insurance, etc.). The commercial offer is sent to the user.

Hereafter, we assume that QoS expectations (i.e., desired and adequate QoS levels) and measurements (i.e., perceived QoS attributes values) are respectively given by the client and a monitoring system (QoS attributes measurement is out of the scope of this paper).

3.1 Phase 1: Aggregation based on Workflow Patterns Rules

In the first phase (see Figure 1), we use aggregation rules based on workflow patterns (see section 2.2) to compute each QoS attribute value of the services orchestration. This consists in applying step-by-step rules in order to aggregate QoS attributes values. The applied rules are those corresponding to the pairs of workflow patterns used in the services orchestration model. Beginning from the most nested pair of workflow pattern, the orchestration model is parsed and aggregation rules for each QoS attribute in the perceived QoS level are progressively applied. This terminates when the whole services orchestration is reduced to a single node (Figure 3). The resulted QoS attributes values of the resulting node compose the perceived QoS level of the services orchestration. This approach is relevant for each QoS attribute that has aggregation rules for the pairs of workflow patterns. We will detail this phase through the illustrative example of the services orchestration described in Figure 2.

For simplification purpose, we will consider a restricted set of three QoS attributes values: *response time* (q_{rt}), *reliability* (q_{rel}) and *availability* (q_{av}). The aggregation rules for each pair of workflow patterns and for each QoS attribute are summarized in Table 2.

The first step consists in checking the most nested workflow pattern which is the sequence pattern between S_4, S_5 and S_6 in Figure 3a. Then, we apply the respective aggregation rule from Table 2. The QoS attributes values computation of this composition pattern gives :

$$q_{rt}(S_{4,5,6}) = q_{rt}(S_4) + q_{rt}(S_5) + q_{rt}(S_6)$$
$$q_{rel}(S_{4,5,6}) = q_{rel}(S_4).q_{rel}(S_5).q_{rel}(S_6)$$
$$q_{av}(S_{4,5,6}) = q_{av}(S_4).q_{av}(S_5).q_{av}(S_6)$$

Thus, the orchestration model is reduced to that given in Figure 3b. Then, taking into account the reduced orchestration model, the next workflow pattern to be considered is the sequence pattern of S_3 and $S_{4,5,6}$. The QoS attributes values computation of this composition pattern gives :

$$q_{rt}(S_{3,4,5,6}) = p_1.q_{rt}(S_{4,5,6}) + p_2.q_{rt}(S_3)$$
$$q_{rel}(S_{3,4,5,6}) = p_1.q_{rel}(S_{4,5,6}) + p_2.q_{rel}(S_3)$$
$$q_{av}(S_{3,4,5,6}) = p_1.q_{av}(S_{4,5,6}) + p_2.q_{av}(S_3)$$

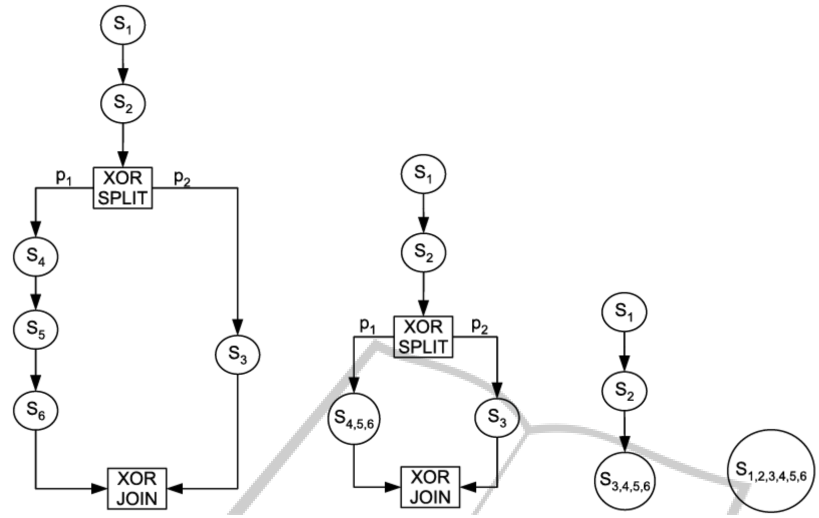
The obtained orchestration model from this step is composed of three nodes structured in sequence (Figure 3c). By aggregating QoS attributes values of these three nodes in sequence, we obtain:

$$q_{rt}(S_{1,2,3,4,5,6}) = q_{rt}(S_1) + q_{rt}(S_2) + q_{rt}(S_{3,4,5,6})$$
$$q_{rel}(S_{1,2,3,4,5,6}) = q_{rel}(S_1).q_{rel}(S_2).q_{rel}(S_{3,4,5,6})$$
$$q_{av}(S_{1,2,3,4,5,6}) = q_{av}(S_1).q_{av}(S_2).q_{av}(S_{3,4,5,6})$$

This resulting values are those that compose the perceived QoS level of the whole services orchestration $(q_{rt}, q_{rel}, q_{av})_{orch}$ and will be the input of the phase 2 (Figure 1).

3.2 Phase 2: Aggregation using the 2-Additive Choquet Integral

The goal of this phase is to aggregate different values in the perceived QoS level of the services orchestration (i.e., $(q_{rt}, q_{rel}, q_{av})_{orch}$) in order to obtain a measure of the satisfaction degree of the services orchestration (q_{orch}) (see Figure 1). This measure allows us



(a) Step 1. (b) Step 2. (c) Step 3. (d) Step 4.

Figure 3: Workflow Pattern-Based Aggregation Steps.

Table 3: Example of QoS Levels Illustrating Dependencies.

	Response Time	Reliability	Availability
A	0.7	0.8	0.9
B	0.8	0.75	0.9
C	0.8	0.75	0.5
D	0.7	0.8	0.5

to detect positive or negative deviations that affect the perceived QoS level of the services orchestration from one execution to another. It is also useful to compare several services orchestrations having the same business goal.

As we discussed above (see Section 2.1), the weighted mean operator considers that the client's preferences on the QoS attributes are independent. However, they could be some dependencies between them. As an example, let us consider four QoS levels denoted A, B, C and D presented in Table 3. One client may express that he prefers the reliability to the response time when the availability is good (i.e., he prefers A to B). On the other hand, the same client may say that he prefers the response time to the reliability when the availability is bad (i.e., he prefers C to D). These two expressions of preference leads to the following inequalities:

$$q_{orch}((0.7, 0.8, 0.9)) > q_{orch}((0.8, 0.75, 0.9))$$
$$q_{orch}((0.7, 0.8, 0.5)) < q_{orch}((0.8, 0.75, 0.5))$$

These preferences cannot be modelled by a weighted mean operator. Indeed, the first inequality implies that reliability is more important than response time, whereas the second inequality implies exactly the opposite. This means that the importance between the reliability and the response time depends on the satisfaction of the availability. This case is an example of preferential dependencies between criteria and is not supported by the weighted mean operator (see (Grabisch and Labreuche, 2005; Grabisch and Labreuche, 2008) for more details about criteria dependencies).

For this reason, we have choose the 2-additive Choquet Integral, which takes into account preferential dependencies between criteria.

The 2-additive Choquet Integral operator is defined by the following aggregation formula:

$$q_{orch} = \sum_{i=1}^{n} \nu_i . q_i - \frac{1}{2} \sum_{j=1}^{n} I_{ij} . |q_i - q_j| \tag{1}$$

and involves 2 types of parameters :

- Shapley parameters ν_i, which are the weights of each QoS attribute, with $\sum_{i=1}^{n} \nu_i = 1$,
- Interaction parameters I_{ij} that quantify mutual interaction between criteria i and j, with $I_{ij} \in [-1, 1]$ and $\left(\nu_i - \frac{1}{2}\sum_{j=1}^{n} |I_{ij}|\right) \geq 0 \ \forall i \in [1, n] \ \mathit{and} \ j \neq i$. These parameters ($I_{ij}$) may be:
  - positive, which implies that there is a contradiction between the pairs of criteria. So the aggregated value of QoS attributes (q_{orch}) decreases,
  - negative, which implies that there is a positive synergy between the pairs of criteria. Thus, the aggregated value of QoS attributes (q_{orch}) increases,

– null, which implies that the pairs of criteria are independent. Therefore, the 2-additive Choquet Integral becomes equivalent to the weighted mean operator.

We use an extension of the MACBETH method (Costa et al., 2005) to construct the model of the 2-additive Choquet Integral (Cliville et al., 2007; Mayag et al., 2010), as it takes as inputs only client's preferences. It is based on pairwise comparison of situations made by the decision maker, who is the client in our case. The MACBETH method comprises four main steps (Figure 4). As MACBETH method is based on the weighted mean operator, only the two latter steps differ since the aggregation operator and its related parameters are different.

3.2.1 Context Definition Step

The first step consists in identifying the criteria that the comparison will be based on. In our context, criteria are QoS attributes (e.g., response time, reliability, availability). Secondly, situations that will be compared are defined. In our case, situations are represented by QoS levels (i.e., vectors of QoS attributes values).

If we consider the example of the e-business process cited above, the situations to be compared are the perceived QoS level of the overall services orchestration $(q_{rt}, q_{rel}, q_{av})_{orch}$ (i.e., resulting from workflow patterns aggregation rules) in addition to the desired and adequate QoS levels of the overall services orchestration. The desired and adequate QoS levels are called reference situations in MACBETH method. They are denoted respectively as *good* situation and *neutral* situation. After normalization, these two situations correspond respectively to the situations $(1,1,1)$ and $(0,0,0)$, for which the associated satisfaction degrees are respectively 1 and 0. So, the client (the decision maker) has to compare the following situations:

$$\begin{aligned} S_{orch}^{good} &= (q_{rt}^{good}, q_{rel}^{good}, q_{av}^{good}) \\ S_{orch}^{perceived} &= (q_{rt}, q_{rel}, q_{av})_{orch} \\ S_{orch}^{neutral} &= (q_{rt}^{neutral}, q_{rel}^{neutral}, q_{av}^{neutral}) \end{aligned}$$

Note that if we have more situations (e.g., previous services orchestration executions), we can include them in the definition context. This provides more accurate models of QoS attributes normalization (see Section 3.2.2).

Table 4: Preferences and Preference Strengths for Response Time.

q_{rt}	Good	$S^{perceived}$	Neutral
Good	No	h_1 [a]	P
$S^{perceived}$		No	h_2
Neutral			No

[a] 0=null, 1=very weak, 2=weak, 3=moderate, 4=strong, 5=very strong, 6=extreme

3.2.2 The QoS Attributes Normalization Step

In this step, the goal is to normalize QoS attributes values. We do not use linear transformations to normalize them, but we preferably exploit informations provided by the client. For that purpose, the client (decision maker) uses his expertise to judge given situations and fulfill the matrix of judgements like the one given in Table 4. Firstly, he is asked for each QoS attribute about his preferences between pairs of situations (including the two reference situations). If the client prefers situation S^i to S^j for a QoS attribute k, this is noted as follows:

$$S^i \succ S^j$$

and means that for the normalized QoS attributes values $q_k^i > q_k^j$. This is mapped in Table 4 into the classification of the situations by their order of preference depending on the values of the QoS attribute k.

Secondly, the client expresses his strengths of preference about the difference of attractiveness between the same situations. The strengths of preference are characterized with seven levels in the MACBETH method: *0=null, 1=very weak, 2=weak, 3=moderate, 4=strong, 5=very strong, 6=extreme* (see Table 4). If the client is not able to give his strengths of preference but only his preferences, this is noted as *positive* or more shortly P. For a QoS attribute k, the client prefers the situation S^i to S^j with a difference of attractiveness characterized by a strength $h_m \in \{0, ..., 6\}$ i.e.,

$$S^i \succ^{\mathbf{h_m}} S^j$$

This is equivalent to :

$$q_k^i - q_k^j = \mathbf{h_m}.\alpha \tag{2}$$

where α is a coefficient necessary to meet the condition q_k^i and $q_k^j \in [0,1]$.

When all the strengths of preference between situations are provided and the matrix of judgements is fulfilled (e.g., see Table 4), a system of equations can be extracted. Each strength of preference expressed on pair of situations gives an equation under the form of equation 2. By solving this system of equations,

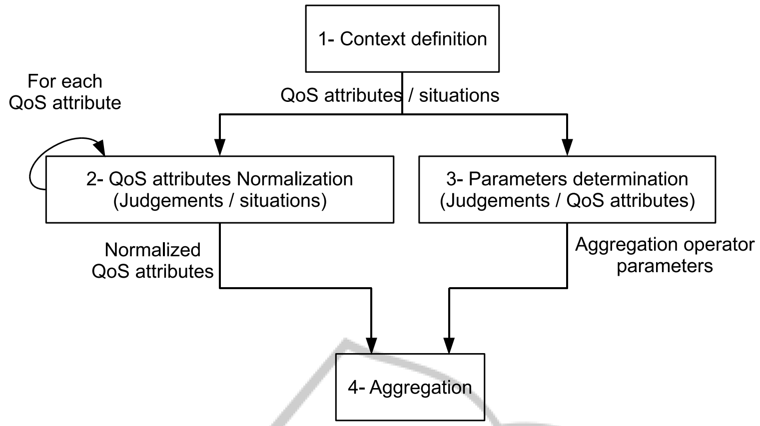


Figure 4: The Main Steps of MACBETH Method.

the normalized QoS attributes values are quantified in the interval [0,1].

Example: for the strengths of preferences expressed in Table 4 for the response time, the system of equations is the following:

$$(q_{rt}^{good} = 1);\ q_{rt}^{good} - q_{rt} = 1 - q_{rt} = h_1.\alpha$$
$$(q_{rt}^{neutral} = 0);\ q_{rt} - q_{rt}^{neutral} = q_{rt} - 0 = h_2.\alpha$$

In the above system, the unknown variables are q_{rt} and α, as $h_1, h_2 \in \{0,...,6\}$ and are given by the client. So, the system of equations can be solved and the normalized response time of the perceived QoS level can be computed. Note that the same procedure is established for each QoS attribute (i.e., reliability and availability).

3.2.3 Model Parameters' Determination Step

In this step, we have to determine the parameters of the 2-additive Choquet Integral, which are ν_i and I_{ij} (See formula 1). In the case of three QoS attributes $(q_{rt}, q_{rel}, q_{av})$ or more simply (q_1, q_2, q_3), the 2-additive Choquet Integral takes the form:

$$q_{orch} = \nu_1 q_1 + \nu_2 q_2 + \nu_3 q_3 - \frac{1}{2} I_{12}|q_1 - q_2| - \frac{1}{2} I_{13}|q_1 - q_3| - \frac{1}{2} I_{23}|q_2 - q_3| \quad (3)$$

Once the strengths of preferences are given (e.g., see Table 5), a system of equations can be extracted. Then, the parameters of the aggregation operator can be computed by solving the system of equations. We restrict the client to only fulfill the first diagonal of the matrix as we consider providing all the strengths of preferences over all the combinations of pairs of situations is more complex and a hard task.

For example, the system of equations extracted from Table 5 is:

$$q_{orch}^{(0,1,1)} - q_{orch}^{(1,1,0)} = h_1.\alpha = -\nu_1 + \nu_3 - 0.5I_{12} + 0.5I_{23}$$
$$q_{orch}^{(1,1,0)} - q_{orch}^{(0,1,0)} = h_2.\alpha = \nu_1 + 0.5I_{12} - 0.5I_{13}$$
$$q_{orch}^{(0,1,0)} - q_{orch}^{(1,0,1)} = h_3.\alpha = -\nu_1 + \nu_2 - \nu_3$$
$$q_{orch}^{(1,0,1)} - q_{orch}^{(0,0,1)} = h_4.\alpha = \nu_1 - 0.5I_{12} + 0.5I_{13}$$
$$q_{orch}^{(0,0,1)} - q_{orch}^{(1,0,0)} = h_5.\alpha = -\nu_1 + \nu_3 + 0.5I_{12} - 0.5I_{23}$$
$$q_{orch}^{(1,0,0)} - q_{orch}^{(0,0,0)} = h_6.\alpha = \nu_1 - 0.5I_{12} - 0.5I_{13}$$
$$\nu_1 + \nu_2 + \nu_3 = 1$$

The system can be put in a matrix form. Therefore, it is resolvable only and only if the matrix is non-singular.

The client can verify if the computed weights (ν_i) and the interaction parameters (I_{ij}) corresponds to his preferences. This can be done by computing the satisfaction degrees of the binary situations and verifying if they are conform with his preferences. Otherwise, he can modify his strengths of preferences for best translation of his preferences.

3.2.4 Aggregation Step

The QoS attributes values being normalized in Section 3.2.2 and the Choquet Integral parameters being computed in Section 3.2.3, we can now aggregate the perceived QoS level of the services orchestration by applying formula (3). The resulting value from the aggregation represents the satisfaction degree of the client from QoS point of view.

In the next section, we present a use case of the satisfaction degree following this approach.

Table 5: Client's Judgements for Choquet Integral's Parameters Determination.

	$(0,1,1)$	$(1,1,0)$	$(0,1,0)$	$(1,0,1)$	$(0,0,1)$	$(1,0,0)$	$(0,0,0)$
$(0,1,1)$	No	h_1	P	P	P	P	P
$(1,1,0)$		No	h_2	P	P	P	P
$(0,1,0)$			No	h_3	P	P	P
$(1,0,1)$				No	h_4	P	P
$(0,0,1)$					No	h_5	P
$(1,0,0)$						No	h_6

4 USE CASE

E-business applications is a growing area and we can found several e-business applications in the market relating to the same business goal. We have presented in the previous section a B2C services orchestration allowing the client to request for an insurance-car quotation. Let us consider another services orchestration satisfying the same business goal, but differs slightly. The second services orchestration follows the model of B2B2C applications as it involves many enterprises (see Figure 5). These enterprises collaborate together in order to provide to the client the best offer. This services orchestration is roughly the same as the already presented above (see Figure 2) but differs when the quotation request is accepted. In this latter case, the quotation request is sent to two car-insurance subcontractors and partners (enterprise B and C in Figure 5), each of them establishing a quotation. Note that the enterprises B and C do not have the same process to establish quotations. When all quotation proposals are received by enterprise A, they are submitted for analyse and comparison. Then, a commercial offer is packaged comprising the best insurance quotation and some commercial and promotional offers as already discussed in Section 3. Finally, the commercial offer is sent to the client.

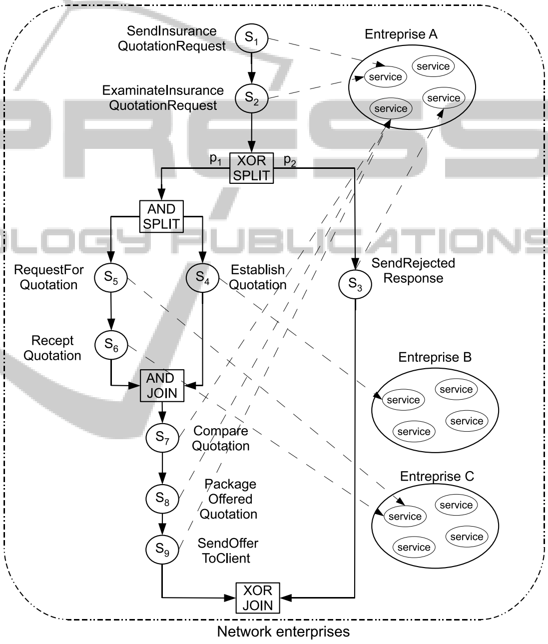


Figure 5: B2B2C services orchestration.

We will now compute the satisfaction degree of each services orchestration using the provided informations from the same client. This allows the client to discriminate the two e-business applications and choose the best one from his QoS point of view. Let us consider that the client's QoS expectations of these e-business applications are:

$$S^{good} = desired\ QoS\ level = (60,1,1)$$
$$S^{neutral} = adequate\ QoS\ level = (120,0.7,0.6)$$

We will not detail the workflow pattern-based aggregation phase but we give directly the perceived QoS levels of the two services orchestration. We denote the perceived QoS level of the first e-business application (B2C) as S^1, while the perceived QoS level of the second e-business application (B2B2C) is denoted as S^2 :

$$S^1 = (q^1_{rt}, q^1_{rel}, q^1_{av}) = (78,0.8,0.95)$$
$$S^2 = (q^2_{rt}, q^2_{rel}, q^2_{av}) = (95,0.9,0.9)$$

Given these four situations $S^{good}, S^{neutral}, S^1, S^2$, the client has to compare them and express his strengths of preferences over the difference of attractiveness between them for each QoS attribute (we omitted details due to lack of space).

This allows us to normalize QoS attributes values of each situation. The normalized QoS levels of situations S^1 and S^2 are as follows:

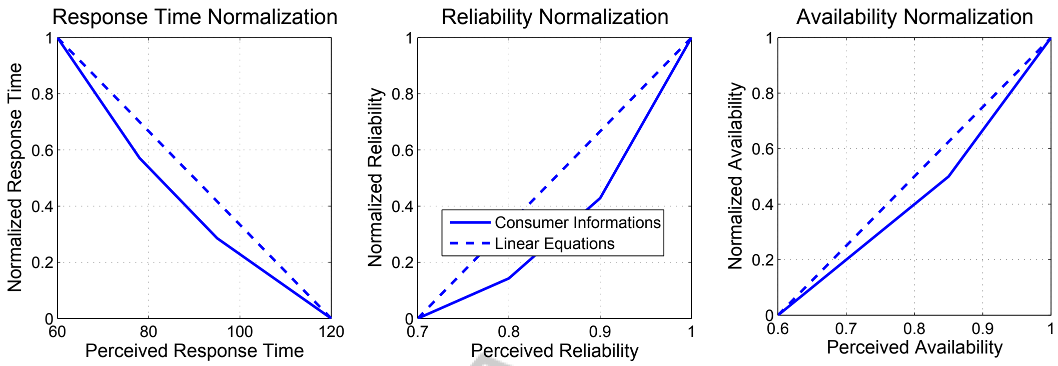


Figure 6: QoS Attributes Normalization.

$$Normalized\ S^1 = (\frac{4}{7}, \frac{1}{7}, \frac{1}{2})$$

$$Normalized\ S^2 = (\frac{2}{7}, \frac{3}{7}, \frac{2}{3})$$

As we discussed above, we do not use linear equations to normalize QoS attributes but we are based only on client's informations (i.e., preferences and strengths of preferences on QoS attributes). The use of linear equations takes only into account the satisfactory value (i.e., the best QoS attribute value) and the unsatisfactory value (i.e., the lower QoS attribute value) and assume that the client's satisfaction is linear between them. This assumption is not very accurate. Figure 6 shows that the client's satisfaction based on his provided informations can be non-linear (curve in continuous line). We consider that this method models the best the client's satisfaction.

QoS attributes values being normalized, we have to compute the parameters ν_i and I_{ij} to build the QoS aggregation model based on the 2-additive Choquet Integral. To this end, the client has to compare fictive situations and expresses his strengths of preferences on the difference of the attractiveness between them. This leads to the following computed parameters:

$$\nu_1 = 0.125,\ \nu_2 = 0.55,\ \nu_3 = 0.325$$

$$I_{12} = 0.1,\ I_{13} = 0.05,\ I_{23} = 0.2$$

By applying the formula 3 at the normalized situations S^1 and S^2, we get the following satisfactions degree:

$$q_{orch}(S^1) = 0.2535,\ q_{orch}(S^2) = 0.4476$$

According to these measured satisfaction degrees, it is clear that the client is more satisfied with the second e-business application (B2B2C) despite the fact that its services orchestration model contains more services. This is explained by the fact that this client has put much more importance at the reliability than the response time ($\nu_2 > \nu_1$).

5 CONCLUSIONS

This paper presents an approach that measures the satisfaction degree of services orchestrations related to the client's QoS expectations. The approach newly combines workflow patterns aggregations rules and the 2-additive Choquet Integral. We have shown how does the measured satisfaction degree allow the client to discriminate several e-business applications having the same business goal. This permits to the client to choose the best satisfactory e-business application from his QoS point of view. Moreover, for one e-business application, this approach allows us to detect the deviation of its perceived QoS level by comparing the measured satisfaction degree with that resulting from the previous e-business application's executions.

The presented approach exploits the services' perceived QoS levels that are all obtained along the executed/runtimed services orchestration. Thus, the satisfaction degree is obtained when the execution terminates. Our future work aims to evaluate the satisfaction degree of the services orchestration throughout its execution and predicts the deviation of perceived QoS level inside QoS expectations range. Whenever we detect potential deviation, we will try to recover it by dynamically adapting/modifying the services orchestration.

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