SUMMARY OF A LITERATURE REVIEW IN SCALABILITY OF QoS-AWARE SERVICE COMPOSITION

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Abstract — Dynamic Service composition is a process by which a service-based application can compose itself, based on multiple requirements like functional specifications, QoS requirements, and cost constraints. Mechanisms to discover and evaluate potential services, while optimizing QoS, is a NP-hard problem. Hence, most solutions focus on obtaining a good selection of services that meets the QoS constraints of an application. One would expect that, in such a scenario, the problem of scalability of dynamic service composition would be well understood. Nevertheless, this paper shows that authors have no consistent way to characterize the scalability of their solutions, and so consider only a limited number of scaling characteristics. This review aimed at establishing the evidence that the route for designing and evaluating the scalability of dynamic QoS-aware service composition mechanisms has been lacking systematic guidance, and has been informed by a very limited set of criteria. For such, we analyzed 47 papers, from 2004 to 2018.

I. STUDY DESCRIPTION

This template, We followed the guidelines of Kitchenham[1] for systematic literature reviews in Software Engineering.

A. RESEARCH QUESTIONS

Our study intended to answer the following questions:

[RQ1:] How are authors on QoS-based dynamic service composition evaluating the scalability of their solutions?

[RQ2:] What are the scaling dimensions (and their value ranges) being considered by researchers in this area to characterize the scalability of their solutions?

[RQ3:] What are the metrics being considered by researchers to characterize the scalability of their solutions?

B. DATA SOURCES AND SEARCH STRATEGY

In software engineering, electronic databases are normally considered sufficient [2][3]. Hence, we used the following search engines: IEEE Explore, ACM Digital Library, Science Direct, Engineering Village (which searches INSPEC as well as EI Compendex), ISI Web of Knowledge, Google Scholar, and CiteSeer. We searched all the data sources, using a combination of the following keywords (and variations): quality of service (QoS, QoS-aware, QoS-enabled), web service composition (WSC, Service Composition, Service-based, Service-Oriented, Service-based Architecture, Service oriented Architecture, Service-selection) and dynamic (Adaptive, Adaptation, Self-adaptive, Self-optimizing, Self-healing, Self-managing). The search strings formed by these keywords were adapted for each search engine.

C. STUDY SELECTION

Papers were selected for the analysis based on the following inclusion and exclusion criteria: [Inclusion] Conference papers, journal articles, workshop papers and technical reports. [Exclusion] Criteria E1-E7 helped to filter out misclassified results, or results that were only tangentially related to the topic. Criteria E8-E11, applied after full text screening, aim at selecting papers whose techniques can be compared against each other. Criteria is presented with a summarised rationale when judged necessary.

[E1:] Papers unrelated to dynamic service selection; [E2:] Papers that were completely domain-specific. Rationale: we seek to identify attributes and metrics relevant to the problem of dynamic composition in general; [E3:] Papers with journal extensions (latter included); [E4:] Papers prior the Web Service standard (year 2000); [E5:] Papers not published in English; [E6:] Duplicate references; [E7:] Papers unobtainable from databases or authors; [E8:] Papers dealing exclusively with technical improvements to the underlying infrastructure (e.g., SOAP, WSDL, BPEL, DAML-S, OWL-S), with no mention of QoS. Rationale: these technologies do not address the problem of matching services based on QoS.

[E9:] Papers without a mechanism for QoS evaluation. Rationale: necessary for selecting services for the workflow. Using cost as the only determiner is insufficient; [E10:] Papers with no mention of workflow or its abstract services. Rationale: service-based applications are composed in a workflow, which gives rises to its end to end QoS. Mechanisms that do not consider a workflow or its tasks structure are outside our scope; [E11:] Papers with no mention of candidate services for an abstract service. Rationale.
Our problem involves choosing the right service from many candidates. Papers that did not address this were not within scope. In order to apply criteria E8-E11, we unified the vocabulary used by the papers, defining (i) an abstract service the functional specification of a certain task (sometimes referred to as a task or service class or abstract service in the application workflow); and (ii) a candidate service as an implementation of an abstract service (also referred to as service candidate or concrete service). Each candidate service has a QoS that it advertises through its SLA. Following the application of all exclusion criteria, 47 papers were selected for analysis (listed in Appendix 1).

D. Data Extraction
The following data was extracted from each article:

- Title, authors, publication venue and year;
- Scalability claimed for the solution?
- Claim based on evaluation?
- Approach used for evaluation of scalability.
- Metrics considered for characterizing scalability.
- QoS characteristic considered for service composition and their constraints (when specified).
- Scaling dimensions considered for evaluation of scalability and their range of values (when specified).
- Technique for composition of services.
- Optimization/utility function for composing services.

E. Threats to Validity
The study had the following threats to validity:

Construct validity: Our study aimed at understanding how the scalability of QoS-based dynamic service composition was being evaluated. One concern is related to the appropriateness of measures to answer our research questions. We believe the measures collected are sufficient to provide a fair characterization of the state-of-the-art of scalability analysis according to Duboc et al.’s [4].

Internal validity: Main threats are incomplete and/or wrong selection of primary studies and individual researchers’ bias. These threats were mitigated by following a pre-defined protocol, carrying out several dry runs individually, and consolidating the differences collaboratively. The selection of primary studies and data extraction was performed individually by three researchers, with another researcher serving as a third-party control. Values inferred from graphs in papers are approximate, due to their low resolution. Hence, while values are internally consistent, they are not necessarily exact. External validity: Our scope covered only academic data sources, automatically precluding any commercial solution, not indexed by these sources. Also, our exclusion criteria excludes domain-specific papers and papers relating to improvements in SOAP, WSDL, OWL, etc.

II. SUMMARY OF THE RESULTS
After Answers to our research questions follows. We emphasize that we do not evaluate the scalability of each solution. Rather, we survey the research landscape for techniques that have been used to claim their scalability.

[RQ1.] How are authors on QoS-based dynamic service composition evaluating the scalability of their solutions?

Scalability is the ability of a system to maintain the satisfaction of its quality goals to levels that are acceptable to its stakeholders when characteristics of the application domain and the system design vary over expected operational ranges [4]. Therefore, any analysis of an ordinary software quality in the presence of the variation of characteristics of the application domain and system design is, in fact, a scalability analysis [5]. We have observed that, out of 47 papers, 41 present some form of scalability analysis or claims. Some are explicit, as in paper [P2] which has a section entitled "QoS MOS Scalability, where authors analyse execution time with respect to the number of concrete services and abstract medical services. A similar section is presented in paper[P39], where authors evaluate the execution time of the algorithm with respect to the number of concrete services, abstract services and QoS constraints for a service composition. Other works present varied analyses without an explicit mention of the term “scalability”. This is the case of the paper [P10], which test for the percentage of optimal solutions found given an increasing number of services to combine.

The remaining 6 papers ([P22], [P25], [P26], [P28], [P38], [P40]) provide only working examples of their solutions, without accounting for variation. For example, paper [P24] shows the utility values for 8 abstract service and 40 candidate services. Only one paper [P28] does not give any numeric example at all. Our review also shows that papers which presented claim of scalability or of software quality (without consideration for variation), based their claims on some sort of evaluation: 33 papers use simulations, while the remaining 14 have used testing or a working example.

[RQ2.] What are the scaling dimensions (and their value ranges) being considered by researchers in the area of QoS based dynamic service composition to characterize the scalability of their solutions?

Our review showed that papers considered a large variety of scaling dimensions, pertaining both to the application domain and system design. Nearly all papers considered the workflow size and the number of candidate services (39 and 41 papers respectively) in their analysis. Other 19 application domain scaling dimensions have been mentioned, such as the number of QoS attributes, the number of requests per day, the amount of data transmission between services, the number of breach of services, among others. With the exception of the number of QoS, which were mentioned by three papers, all others were listed by at most one paper.

It is interesting to note that authors can be very specific with respect to the scaling dimensions. Paper [P14], for example, differentiates between the number of QoS attributes and the number of user QoS constraints, meaning that though there may be many QoS attributes that are measured, there might be only a few that the user is concerned about. In these cases, the search space can be shrunk dramatically.

Value ranges considered in the evaluations vary even more greatly. Take for example, the workflow size, which varied from 5 to 10000, considering all papers. Nevertheless, each paper evaluated its own range. For example, paper [P2]...
considered the range [5 - 16], while paper [P15] tested for [10 - 100]. Only one work evaluated workflows with more than 100 services, this was paper [P4].

Regarding the number of candidate services per abstract service, the range considered across the papers varied from 1 to 10000. As with the workflow size, different papers considered different ranges. With respect to the system design, 16 dimensions have been mentioned; some using a numeric scale.

Paper [P1], for example, varied the number of ants in an ant colony optimization (ACO) algorithm along the values 3, 6 and 7. Paper [P3] varied the max non-improving generations (MMIG), a design variable determining the termination condition, from 1000 to 5000. Others represented thresholds, such as the threshold for a statistical model of volatility in [P16]. Finally, some dimensions represented design choices, such as the choice of building tree algorithm in [P12] and the configuration mode in [P6], which varied among global dynamic, local dynamic and static.

[P9] and [P7], used a greater number of QoS, 9 and 10 respectively. Six papers did not specify the QoS considered. [P6] and [P8] considered different ranges. With respect to the technique for dynamic services composition. In the papers, 27 different techniques and 7 optimization/utility functions were used. From the optimization functions,

simple additive weighting was the most popular (29 papers). The QoS considered for the composition also varied: 23 different qualities were mentioned. Most solutions adopted execution time (40 papers), followed by cost (29 papers), availability (28 papers) and reliability (27 papers). Some others were: throughput, popularity/reputation, success rate, composability, maintainability, eco-impact and quality of the documentation. The number of QoS also varied. Most papers, 40 out of 47, used between 2 and 6 QoS. Only two, [P9] and [P7], used a greater number of QoS, 9 and 10 respectively. Six papers did not specify the QoS considered.

Nevertheless, these evaluations vary greatly. With respect to the scaling dimensions, there is a general agreement that the workflow size and the number of candidate services should be considered. Some works also agree on the number of QoS as an important scaling dimension. However, for all other application domain quantities, each paper has its particular concern. As for the scaling dimensions belonging to the system design, there is no consensus on variables. This is only natural, as each study has its own approach for service composition. The variables ranges of values also vary widely. With respect to commonly used variables, such as the workflow size and the number of candidate services, the variation in ranges were of orders of magnitude. Regarding the metrics used to measure the scalability of solutions, most agreed that execution time was an important concern, followed by success/failure rates, utility and costs. The study also revealed many other, less popular, metrics. Furthermore, each work assessed their own combination of metrics.

All these differences in the scalability are by no means surprising, as in the literature review we could also observe the variety of techniques used for service composition. The fact that there is no single set of metrics and scaling dimensions that fit the scalability analysis of all QoS-based dynamic composition papers is consistent with our view of scalability [4].

The problem with this observation, however, is that authors working on dynamic service composition might be at a loss when planning a scalability evaluation of their solutions, or when wishing to compare the scalability of their approach with others in the literature. What these authors are missing is a systematic mechanism for the selection of metrics and scaling dimensions for their scalability analyses. Such a mechanism must be able to identify with respect to a particular solution, aspects of the application domain and system design that may affect its scalability, and which software qualities might be affected by these characteristics. Using ad-hoc approaches entails the risk of overlooking relevant variables for the analysis.

III. DISCUSSION OF THE RESULTS

The results above confirm that scalability is indeed a concern for QoS-based service dynamic composition. Most authors attempt to justify their (explicit or not) scalability claims with evaluations of software qualities given some variation in the application domain and system design.

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APPENDIX A
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