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Towards automated composition of convergent services: A survey

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ABSTRACT

A convergent service is defined as a service that exploits the convergence of communication networks and at the same time takes advantage of features of the Web. Nowadays, building up a convergent service is not trivial, because although there are significant approaches that aim to automate the service composition at different levels in the Web and Telecom domains, selecting the most appropriate approach for specific case studies is complex due to the big amount of involved information and the lack of technical considerations. Thus, in this paper, we identify the relevant phases for convergent service composition and explore the existing approaches and their associated technologies for automating each phase. For each technology, the maturity and results are analysed, as well as the elements that must be considered prior to their application in real scenarios. Furthermore, we provide research directions related to the convergent service composition phases.

1. Introduction

The telecommunication and computer network industries are facing a great shift from atomic services (*e.g.*, voice and email) towards much more dynamic, convergent services, such as unified social networking and integrated video conferencing. Under this premise, telco and computer network operators need to transform themselves from simple operators into services aggregators carrying the duty of providing services that bring together numerous applications from a variety of sources [1].

The term "convergent" has been used widely in telecommunication and computer networks with two meanings: to describe the fusion of fixed and mobile services [2], or as a synonymous of the Next Generation Network (NGN) that is a packet-based network able to transport all type of information and services, like voice, data, and video, integrating traditional telephony networks and Internet [3]. In this paper, we use the term "convergent" as efficient coexistence of services available on the Telecom (*e.g.*, voice and video calls with reverse charging offered by telco operators like Orange and Movistar) and Web (*e.g.*, services of maps and RSS feeds offered by big Internet players like Google and Yahoo) domains to provide more services to the user.

Telecom services can be created by using Services Creation Environments (SCE) [4] and Mashup Development Environments (MDE) [5,6] that allow the users (*e.g.*, programmers and administrators of telco and/or computer networks) to combine the functionalities of heterogeneous services using drag-and-drop and wire tools for composing new services. Such a way of carrying out service composition is valid as long as the number of traditional communication services is low and the reliability of services is high enough ($>$ 99%) so they do not change continually [7].

In the case of the convergent service composition, that involve atomic services from the Web and Telecom domains, such services may change their interfaces, become available or unavailable, and their number may also grow to unmanageable sizes. Both the dynamic nature of services offered by the Web and the sheer amount of relevant services that may be available on it for a given task hinder greatly the use of approaches offering semi-automated service composition (*i.e.*, composition based on MDEs and SCEs). If time is a crucial factor, semi-automated service composition may become inefficient, which raises the need of approaches able to perform fully-automated service composition.

Automation is defined as the delegation of tasks to machine or computer systems, thus reducing procedural load and freeing

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Table 1
Works selected for reviewing.

Work	Phase	Origin	Domain	Automation	Semantic	Result
[23]	Creation	Both	Convergent	Medium		Prototype
[24]	Creation, execution	Both	Convergent	Medium	✓	Prototype
[25]	Creation	Academic	Convergent	Medium		Prototype
[26]	Creation, execution	Both	Convergent	Medium		Prototype
[27]	Creation, execution	Both	Convergent	Medium	✓	Prototype
[28]	Adaptation, execution	Academic	Convergent	High	✓	Prototype
[29]	Adaptation, execution	Academic	Convergent	High	✓	Prototype
[30]	Creation, execution	Academic	Convergent	Medium	✓	Prototype
[31]	Creation, execution	Academic	Convergent	Medium	✓	Prototype
[32]	Creation, execution	Both	Convergent	Medium	✓	Model
[33]	Creation, execution	Industry	Convergent	Medium	✓	Prototype
[34]	Creation, execution	Academic	Convergent	Medium		Model
[35]	Creation, execution	Academic	n/a	High	✓	Prototype
[36]	Creation, execution	Academic	n/a	High	✓	Prototype

operators from vigilance over routine and tedious tasks [8]. Several approaches have appeared to fully automate the composition of services available in the Web from both academia [9–14] and industry [15,16]. Similarly, some research has revolved around fully automation of communication service composition, coming mainly from European Projects [17,18]. Considering the evolution of service composition in the Telecom and Web domains, we raise the first research question addressed in this paper: *Which is the level of automation that has been achieved to date from previous service composition approaches?*

In addition to the aforementioned automation, it is important to consider that the service composition carried out in the Telecom fundamentally different of the conducted in the Web, which means that some technical issues must be contemplated when combining services from both domains [19,20]. Moreover, several other characteristics pertaining to specific application domains, like user preferences, response time, adaptability, and scalability must be taken into account. This is because the fact that convergent service composition often involves the challenge of merging two areas of knowledge with their respective concepts, technologies, and architectures. For this reason, a systematic way of analysing the strengths and weaknesses of each existing solution for a particular application domain is needed. In this way, we raise the second research question addressed in this paper: *which elements must be considered for applying automated services composition in different specific domains?*

Convergent service composition is also a complex process that often involves several elaborated steps or phases, from processing the input to selection of services to its execution. As these phases often focus on one or more aspects of the service composition process, it is needed to classify them. In this way, we raise the third research question addressed in this paper: *which are the phases for convergent service composition and the approaches useful in each one of them?*

The above raised research questions indicate that building up a convergent service is not trivial, because although there are significant approaches that aim to automate the service composition at different levels in the Web, telco networks, and computer networks, selecting the most appropriate approach(es) for specific case studies is complex due to the big amount of involved information and the lack of technical considerations. Thus, in this paper, we identify the relevant phases for convergent service composition and explore the existing approaches and their associated technologies for automating each phase. For each technology, the maturity and results are analysed, as well as the elements that must be considered prior to their application in real scenarios. Furthermore, we provide research directions in the convergent service composition phases.

The research conducted to answer the raised questions led to the following contributions:

- Identify the relevant phases for convergent service composition.
- Explore and analyse the existing approaches and their associated technologies for automating each phase.
- Provide research directions in each one of convergent service composition phases.

The remainder of this paper is organised as follows. In Section 2, we present the methodology followed to build up this survey. In Section 3, we review foundations about service composition. In Section 4, we introduce the phases for convergent service composition. In Sections 5–7, we describe and discuss each phase and its associated approaches. In Section 8, we present research directions. Finally, in Section 9, we provide some conclusions that help to select approaches for convergent service composition.

2. Methodology

To solve the research questions, we follow the next steps [21]: (*i*) formalize the service composition process by defining different phases, (*ii*) classify the existing approaches under the umbrella of requirements and criteria for their application in convergent composition; and (*iii*) define the guidelines for employing diverse approaches and their technologies in convergent service composition.

In this paper, we carry out a comparative literature review [22], aiming to identify the existing approaches in service composition in recent years through the lens of its applicability in convergent composition of services. In order to select the works presenting the approaches useful for our study, we introduced search keywords on three electronic databases: ACM, IEEE, and Science Direct. As convergent composition is a relatively new field, we do not expect to find many publications using the exact keyword. Therefore, we used the following keyword phrases: “convergent service composition”, “automatic service composition”, “automated service composition”, “Telecom 2.0 service composition”, and “mashup composition”. We found 250 works. Afterwards, we looked through the titles of such works to eliminate those not related to the field; for the rest, we browsed the abstracts to estimate their relevance and whether they have experimental results. We selected both recent works from recognized conferences and relevant ones from high impact journals. As a result, 65 works were selected for a full-text review.

Tables 1 and 2 present, in no order of relevance, the works selected for reviewing. These works are analysed according to: the phase (*i.e.*, adaptation, creation, execution, and generation), the origin of the proposed (*i.e.*, academy, industry, and from both in alliance), the domain (*i.e.*, Web, Telecom, and convergent—deals with methods for convergent composition), the level of automation provided to users (*i.e.*, high, medium, low; when users participate little in the process or needs to know little about technical issues, higher is the automation), the use of semantic in any of the phases above mentioned, and the result of the work (*i.e.*, prototype, model, product, and standard). The detail of the literature review as well as the rest of