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# A Study of Petri Nets, Markov Chains and Queueing Theory as Mathematical Modelling Languages Aiming at the Simulation of Enterprise Application Integration Solutions: a first step

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**Abstract**

Enterprise Application Integration (EAI) is a research field that seeks to develop methodologies, techniques and tools to design and development integration solutions. The software ecosystem of companies is comprised of several applications, usually obtained from third parties or developed internally and custom-made for their business processes. Interest in EAI has arisen due to the need to integrate different applications composing the software ecosystem to allow business processes to evolve in response to the constant demands of the business market. The main challenge facing companies in this context is that most of their applications are not designed considering integration with other applications. The development of integration solutions is not a simple task. Guaraná technology provides a domain-specific language that allows for the design of conceptual models to represent integration solutions. This paper reports on a study of Petri Nets, Markov Chains and Queueing Theory, aiming to construct simulation models from conceptual models of integration solutions modeled with Guaraná. We map the building blocks Slot and Task of Guaraná to their corresponding elements in the mathematical modelling languages studied.



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## 1. Introduction

Business processes often need a set of applications operating together in order to carry out their services. The inclusion of new services into the company's software ecosystem is a difficult task. It has to find ways to incorporate new and different functionalities capable of interacting in a synchronized fashion with existent applications, due to the fact that most applications are not designed to be integrated with others. Enterprise Application Integration (EAI) was developed to solve this problem, by enabling numerous applications not designed to work together to share information and functionalities, providing an immediate solution for this need. Hohpe and Woolf (2003) reported a large set of patterns that could be used to develop integration solutions, depending on the most adequate type of solution for a particular integration problem[1].

Integration solutions are softwares whose main function is to synchronize data among different applications or reuse functionalities. Integration solutions are implanted into the software ecosystem as a new application that offers its users a high-level vision of the integrated applications with which they can interact[2]. Integration solution development consists of design, implementation, execution and monitoring stages. In order to facilitate the understanding of an integration solution's structure and operation, conceptual models are built to represent it in the design phase. There are a number of technologies to build that models, based on a messaging system style, which are appropriate to heterogeneous ecosystems and are ideal for environments that require flexibility[1]. These technologies also allow for the construction of conceptual models with a high level of abstraction, using an easy to understand graphic interface. Of the open source technologies, we can highlight: Spring Integration[3], Apache Camel[4], Mule ESB[5] and Guaraná[6]. Each of these offers a domain-specific language (DSL) to design conceptual models following the Pipes and Filters architectural pattern, in which larger processes are divided into smaller independent services (Filters), which are usually desynchronized by channels (Pipes)[1]. This study utilizes the Guaraná DSL.

Integration solution implementation can be an expensive and time-intensive process, which has encouraged studies that use integration solution simulation approaches. When developing an integration solution, it is important to meet all the demands of the ecosystem in which it will be included or the solution will run the risk of becoming vulnerable to performance issues[7,8,9].

In this paper, we aim to show that it is possible to translate a conceptual model based on Pipes and Filters developed in Guaraná to mathematic models capable of simulation in specific simulation tools. It is thus necessary to create the simulation model based on the conceptual model, which is capable of being processed by a simulator by way of equivalence between elements of the Guaraná model and the translated model. These elements are translated to three different models based on: Petri Nets[10], Markov Chains[11] and Queueing Theory[12]. The simulation of conceptual models is an important contribution in that it can enable the identification of conditions under which an integration solution could fail, while still in the design phase, thus reducing risks and costs involved in its construction.

The notion of simulation refers to the precise representation of all characteristics present in a real system. Simulation is an important ally when facing problems that are highly complex, often impossible to solve analytically or even by actual experimentation, which may be considered expensive. In addition, it allows an improved understanding of the real system and its evolution over time. The main objective of this study is to step forward in the simulation of enterprise application integration solutions.

This paper is organized as follows: Section 2 briefly reports some previous related works from the literature; Section 3 outlines the basic concepts used in the elaboration of conceptual models of integration solutions using Guaraná technologies, presenting the three approaches, Petri Nets, Markov Chains and Queueing Theory, as the objects of the study; Section 4 presents the translation of the elements from a simple model developed in Guaraná to simulation models using the three chosen approaches, as well as the mathematical formalism that serves as a foundation in each approach; finally, Section 5 presents final considerations and perspectives for future work.

## 2. Related work

Some works in the literature have shown different applications of Petri Nets, Markov Chains and Queueing Theory, but few of these have been in the context of EAI. However, it has been established that integration solutions can be characterized as discrete-event systems, which possess well-established simulation techniques[13]. Although we were