Colored Petri Nets Based Fault Diagnosis in Service Oriented Architecture

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ABSTRACT

Diagnosing faults in a service-oriented architecture (SOA) is a difficult task due to limited accessibility of software services. Probabilistic approaches of diagnostic faults may be insufficient due to the black-box nature of services. In SOA, software services may be obtained by different service providers and get composed at run-time. This is the reason why there are diagnosis faults at execution time, and is a costly affair. The authors have demonstrated a Color Petri Nets (CPN)-based approach to model different faults that may occur at execution time. Some heuristics are proposed to diagnose faults from the CPN modeling. CPN behavioral properties have also been used for fault diagnosis. The model may be helpful for dependability enhancement of an SOA-based systems.

KEYWORDS

Colored Petri Nets, CPN, Fault Diagnosis, Fault, Petri Nets, Service Oriented Architecture, Service, SOA

1. INTRODUCTION

Service Oriented Architecture (SOA) utilizes the implementation of business processes as a composition of interacting services (Mendling, 2006). Due to dynamic and heterogeneous nature of SOA, guarantee of failure free system is a cumbersome task. Faults may occur at any stages of SOA based system (SBS) and if not handled correctly their effect may propagate into the whole system and eventually brings the system into failure. Nature of fault generation and its impact is different in different cases. Even a single fault can behave differently in the changed circumstances. Manual identification of faults at execution time is impractical and cumbersome. So, a clear understanding of faults and their propagation effects are very important in order to propose some fault diagnosis and repair strategy. The main property of SOA is to dynamically discover services from different service providers and their composition at run-time in order to construct the software system. This transparency makes the SOA effective but also brings the possibility of various faults at a dynamic time. The study of different types of faults that may occur at a dynamic time is very necessary. In the present work, we focus only on the modeling of dynamic faults in SOA that may occur at execution time.

Petri Net is a basic modeling tool of parallel and distributed systems. It was originated from Carl Adam Petri’s dissertation in 1962 for the purpose of describing chemical processes (Murata, 1989).

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Nowadays, Petri Net is grasping the popularity in modeling the concurrent, parallel and dynamic systems. A normal Petri Net would not be able to model in different cases like while a node only holds the same kind of items or tokens. The time-related dependency of the system also cannot be shown by simple Petri Net. Thus, there are many extensions of Petri Nets such as Colored Petri Nets (CPN) (Jensen, 2015), Timed Petri Nets (TPN) (Popova-Zeugmann, 2013), Stochastic Petri Nets (Haas, 2002), Labeled Petri Nets (Murata, 1989), Partially Observed Petri Nets (POPNs) (Yin, et al., 2018), state-charts (Wodtke & Weikum, 1997), hierarchical state machines (Yannakakis, 2000) etc.

Fault modeling is more effective in terms of time and cost if it is represented in a formal manner. Petri Net is one of the several mathematical modeling languages of DESs, now gaining popularity in modeling and control of DESs due to their graphical representation and advantages in designing distributed, parallel and concurrent systems (Tong, et al., 2016; Ma, et al., 2015). Since SOA is also a distributed, parallel and concurrent system, fault diagnosis system of SBS can be modeled using Petri Nets representing abnormal events in a place or a transition as a fault location. There are many studies using Petri Nets but only a few studies are available that discuss faults in SBS. Most of the researchers have emphasized on modeling of service composition and dependency analysis rather than how faults can be diagnosed in the SBS.

In this paper, we adopt CPN to model the dynamic faults in SBS. Different types of dynamic faults, along with their sub-types, are covered under discussion. A case study has been taken to demonstrate various fault scenario in SBS. Some heuristics are proposed for the automated identification of dynamic faults from the CPN model. Different CPN properties are also used for the fault modeling. This approach enhances the understanding of dynamic faults in the aspect of SOA and will be helpful in the proposition of newer fault recovery mechanisms.

In the conventional techniques, it requires prior knowledge of faults or a special structure, which may not be realistic in practice. To deal with this problem, in this work, SBS faults are modeled as abnormal events that can occur on any transition or place mapped to the CPN that enhances the understandability and assists in testing and fault recovery process. The idea is to model different activities of SBS through CPN and find out the possibility of faults in different scenarios. In addition, the purpose of this paper is to help the researchers and practitioners to get the information about the major scenarios of temporal faults, service unavailability faults and service composition faults along with their diagnosis techniques. Moreover, the additional objective of the paper is to check the behavioral characteristics of the CPN whether they are helpful to the fault diagnosis or not.

This paper is organized as follows. Section 2 presents a brief related work of the fault diagnosis systems of the SOA using Petri Nets. Section 3 describes Petri Nets and Color Petri Nets. Section 4 describes some preliminary definitions used in the study. Section 5 delivers a brief discussion about fault diagnosis in SBS. Section 6 shows the modeling SOA activities into CPN. Section 7 presents the proposed fault diagnosis approach of SBS. Some of the behavioral properties of CPN to detect SOA faults are discussed in Section 8. Experimental analysis of our proposed model is given in Section 9. Finally, Section 10 concludes the paper.

2. RELATED WORK

In this section, some existing contributions in the field of fault handling of SBS are discussed. In the literature, several studies on fault handling of DESs have considered different extensions of Petri Nets such as Colored Petri Nets (CPN) (Li, 2010; Nie, et al., 2013; Kumar & Gupta, 2016), Timed Petri Nets (TPN) (Wang et al., 2015; Taleb et al., 2018), Timed Colored Petri Nets (TPN) (Boukredera & Bernard, 2012). Stochastic Petri Nets (Lefebvre and Leclercq 2011), Labeled Petri Nets (Fanti et al., 2013; Francesco et al., 2015), Partially Observed Petri Nets (POPNs) (Yin, et al., 2018; Liu et al., 2018; Lefebvre, et al., 2013), etc. Among them, some of the relevant contributions concentrated on the state-of-the-art of fault diagnosis of SBS using Petri Nets are briefly described in the following paragraphs.
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