Reliability Engineering and System Safety 145 (2016) 74–82

Contents lists available at ScienceDirect

Reliability Engineering and System Safety

journal homepage: www.elsevier.com/locate/ress

Comparative analysis of standby systems with unreliable server and switching failure

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ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form
2 August 2015
Accepted 7 September 2015
Available online 15 September 2015

Keywords:
Switching failure
Unreliable server
General repair
Availability

ABSTRACT

The purpose of this paper is to study the steady-state availability of a repairable system with standby switching failure. The repairable system configuration includes the primary and standby components, where an unreliable server is responsible to repair or monitor the failed ones. The time-to-failure and time-to-repair of the components follow exponential and general distribution, respectively. The server subjects to active breakdown when it is repairing. The time-to-breakdown of the server is also assumed to be exponentially distributed. When the primary components fail, the standby components replace the primary components successfully with probability $1-q$. The repair time of the failed components and the repair time of the breakdown server are generally distributed. Further, we frame a practical model with three different repairable system configurations. We use supplementary variable method and integro-differential equations to obtain the steady-state availability of these three different repairable system configurations. Finally, we compare the cost/benefit ratio among the three configurations given the distribution parameters, and to the cost of the primary and standby components.

1. Introduction

System reliability or availability is essential issues to measure the performance of a repairable system, such as in power plants, manufacturing systems, industrial systems and telecommunication industrial systems. In a repairable system, the standby components will replace the primary components when the primary components break down. It is always possible to fail during the switching from the failed primary components to the standby components. As well in realistic environments the server is possible to break down when it is repairing. Therefore, considering an unreliable server in a repairable system is also practical and imperative. In this paper, a possible application of our model is in a network standby system with considering an unreliable server and switching failure. Since the quality telecom service is the key for companies to survive. The standby system can be an effective scheme to improve the reliability of the network service.

In earlier studies of the series systems with repairable components/units, we can draw attention to the research of Gaikowsky et al. [3] and Wang and Pearn [15]. They have analyzed a series system with the warm standby and cold standby components respectively, and the component's repair time is assumed to be exponentially distributed. Then Wang et al. [17] and Wang and Kuo [14] investigated three different series models with the cold standby and mixed standby components. They have given a systematic methodology to obtain the steady-state availability and the mean time to system failure. The general repair time for components in the series system was developed by Wang et al. [18] who applied the supplementary variable technique and the recursive method to develop the steady-state availability. Recently, Ozaki and Kara [11] used the state transition analysis and the supplementary variable method to study 1-for-2 shared protection systems including general repair time distributions to derive Mean Time to First Failure (MTTFF).

For the concept of the standby switching failures, Lewis [8] first brought it up in the reliability with the standby system. Then Ke et al. [6] provided a Laplace transform method for developing the system probability and analyzed the statistical inference for the availability of the repairable system with standby switching failures and reboot delay. Wang et al. [16] continued to study the steady-state availability and mean time to failure of four different repairable systems with the warm standby components and analyzed the costs and benefits, where time-to-failure/repair of the components is assumed to be exponentially distributed. Hsu et al. [4] then investigated the profit analysis of the machine repair problem with switching failure and reboot delay, where they used the probabilistic global search Lausanne (PGSL) method to derive the joint optimal parameter values to maximize the profit and satisfy the availability constraint. Furthermore, Sadjadi and

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http://dx.doi.org/10.1016/j.ress.2015.09.001
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Soltani [12] explained the redundancy allocation problems in series-parallel systems with the choice of redundancy strategy where the components' time to failure follows an Erlang distribution. The switching from the cold standby components to the active components is imperfect.

Some examples for the possible failure of the server stations can be found in the work of Wang and Cao [13] who have presented the repairable retrial queues with the unreliable servers and used supplementary variables method to derive the availability, failure frequency and reliability function of the servers. Further, Li et al. [9] have investigated BMAP/G/1 retrial queue system with server subject to active breakdown (the server fails when he is repairing). They applied the RG-factorization method to obtain the stationary availability, failure frequency and queue length. In addition, Ke and Huang [7] investigated the system performance for the randomized vacation M/G/1 queueing system with an unreliable server and a delayed repair by supplementary variable technique.

For recent research on the reliability and the availability in the repairable system, we can see Huang et al. [5] applying Monte Carlo simulation to analyze the reliability of the warm standby redundancy configurations. Also, Liu et al. [10] has studied the system reliability in a cold standby repairable system with working vacations and vacation interruptions, where a matrix-analytic method is applied to derive the several important performance measures. Then Ardakan and Hamadani [1] investigated the reliability of the series-parallel systems with mixed redundancy strategy including the active and cold-standby components. They used genetic algorithm (GA) to obtain the optimization of redundancy allocation problem (RAP). Furthermore, Feizollahi et al. [2] exploited the linear mixed integer programming and provided the exact solution methods to derive the system reliability of the series-parallel systems with cold standby redundancy strategy.

The most existing literature of the series system has focused on unreliable server with repair time exponentially distributed. Little attention has been given to a repairable system with an unreliable server with repair time generally distributed. Therefore, it motivates us to investigate a repairable system with standby components and an unreliable server with repair time generally distributed. This paper is organized as follows: in Section 2, we describe a practical model with three different series systems with different assumptions. In Section 3, we investigate the integro-differential equations formulas for three different configurations by using the supplementary variable method to derive the steady-state availability. In Section 4, we provide numerical analysis of cost/benefit ratio among the three configurations.

2. Model

A practical model related to telecommunication industry is presented for illustrative purposes. We consider a network system which provides the network service and is managed by the DSLAM (Digital Subscriber Line Access Multiplexer). The DSLAM is a network switch located in the telephone company and collects network data from CPE (Customer Premises Equipment) and forwards them to the internet. There are multiple NICs (network interface cards) on DSLAM to aggregate and transmit network data or signal. NICs are treated as components here. Through NICs, DSLAM connects the customer's end (CPE) to the internet. The high availability of the network system can be provided by deploying a recovery system called APS (Automatic Protection Switching) on DSLAM. APS is responsible to detect and monitor the failure of NICs and proceed replacement. We define two kinds of NICs: primary NICs (active NICs), and standby NICs (backup NICs). When the primary NICs breakdown (loss of signal or loss of frame), the APS allows the standby NICs to take over system operations and assume its traffic load. However, the switch over from a failed primary NIC to a standby NIC may fail due to hardware or software issues. Moreover, the failed NICs can be fixed through the remote server. The remote server can be considered as the Snmp server, Telnet server, etc. Once a NIC is repaired, it is as good as new. In addition, the remote server may function wrongly or fail sometimes (active breakdown). It can also be fixed. Once the remote server is repaired, it can function again. A diagram of this network standby system is shown in Fig. 1.

Initially, the primary NICs and the standby NICs are working on the DSLAM. Both of the primary NICs and standby NICs can be considered to be repairable. The primary NICs fail independently of the state of the standby NICs and vice versa. Let the time-to-failure of the primary NICs and the time-to-failure of the standby NICs be exponentially distributed with parameter λ and α, respectively. The APS on DSLAM detects the failed primary NICs

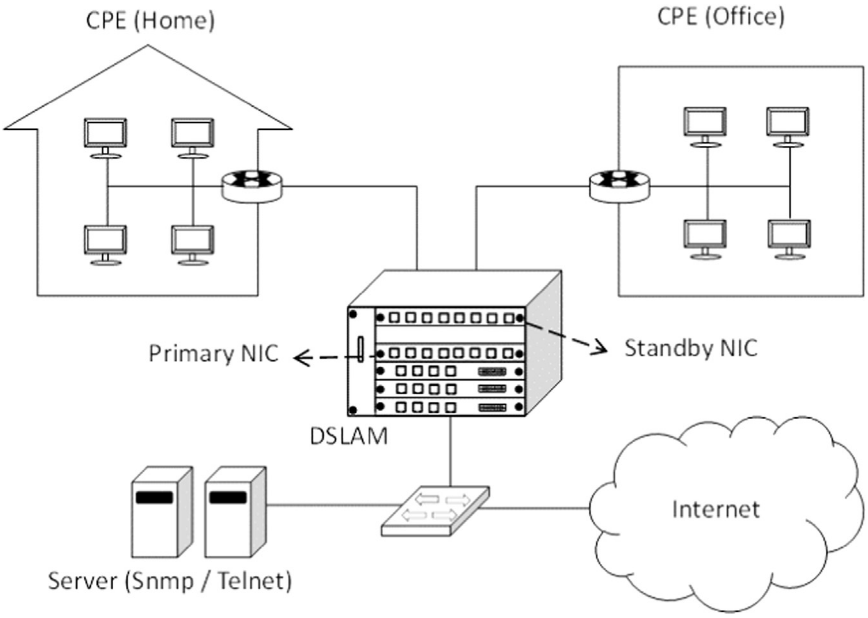

Fig. 1. DSLAM topology diagram.