CHEMICAL ENGINEERING TRANSACTIONS

VOL. 33, 2013

Guest Editors: Enrico Zio, Piero Baraldi

ISBN 978-88-95608-24-2; **ISSN** 1974-9791

A publication of

AIDIC

The Italian Association of Chemical Engineering
Online at: www.aidic.it/cet

DOI: 10.3303/CET1333086

Network Service Reliability Analysis Model

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This paper proposes a network system reliability analysis method based on service. The significance of the network services becomes increasingly prominent in many fields like communication and aviation industry. More and more services depend on network transmission. Thus, the dependability and the reliability of network system are paid more and more attention. The reliability of network is related to several factors, such as hardware equipment, software services, human factors and so on. Most previous papers pay more attention on the hardware equipment factors than the others. The reliability of network is measured by if the equipment is normal running. Sometimes the hardware equipment is in normal operation, but some users may think that the network service is unavailable due to the network congestion, software errors or man-made mistakes which have no effect on the calculation of the reliability. There is a gap between the state of service execution in terms of reliability and what the network reliability data suggests. This paper attempts to propose a network service reliability analysis method based on service to bridge the gap. The paper satisfies these needs in the following ways:(1) we analyses various factors affecting reliability of the network system; (2) we establish the reliability block diagram of service operating process and calculate the reliability of the equipment by the diagram (3) we analyze a case utilizing the model in (2). This method will not overestimate the availability of network system. It enhances the previous study by utilizing the analysis based on service. With this method the gap between the service experience of users in term of reliability and the result reliability of the method will be bridged.

1. Introduction

Network has become an important part in our daily life. Communication network is closely linked with our life and work. With kinds of mobile terminal's increasing, it creates huge demand for network. Business, education, public services and government agencies all require steady and reliable network. The reliability of communication network is more and more significant to network services. Users hope that the network would be always reliable when network services are required. Thus, the reliability of network system is paid more and more attention.

There are many scholars who make a lot of research on communication network reliability. Conwell et al. (2009) complete a casualty report (CASREP) study using 169 CASREPs records aboard carriers and find that more than 50 percent of failures in network IT environments caused by human error [3]. Gray et al. (1991) note that the equipment failures are not the only driver of IT systems and most outages are caused by software faults. Tokuno et al. (2008) share the similar view. Snaith (2007) and Kuhn (1997) think some outages are caused by human errors. Bowls et al. (1990) generalize a model to compare the reliability and availability of Local Area whose parameters include software reliability. They point that software is a major component of computer networks and software reliability models' assumption is that failures are caused by logic errors in the design of the software. Vogt et al. (2003) describe a network modeling tool to estimate the reliability of services traveling IP networks considering individual service provider's experience and point that hardware redundancy alone will not achieve carrier grade availability without perfection of software configurations and operational procedures. Jurdana et al. (2011) generalize an availability analysis model of ship's communication network based on the reliability data of the elements of the system under consideration. They focus on the structure and component of ship's optical communication network.

Please cite this article as: Xin J., Guo L., Huang N., Li R., 2013, Network service reliability analysis model, Chemical Engineering Transactions, 33, 511-516 DOI: 10.3303/CET1333086

Most previous papers focus more on the reliability of the hardware equipment factors and the reliability of network is usually measured by if the equipment is normal running. It brings out a result that there is a gap between the state of services execution in terms of reliability and what the network reliability data suggests. Some papers consider the software factor for network reliability. This paper proposes a network system reliability analysis method based on service which can bridge the gap.
This paper is organized as follows. In the next section reliability is described and the new model of the network reliability based on services is proposed. The factors which have effects on the reliability of network are also discussed in this section. In Section 3, the procedure of the model of the network reliability based on services is described. A case will be analyzed in Section 4. The final section is the conclusions of the reliability analysis methods and the next steps.

2. Definition of Network Reliability

The practical definition of reliability is the probability that service will be continuously available over a given period of time. Quoting Vellela (2008):" The reliability of a system … represents the probability that the system will perform a mission action without a mission failure within a specified mission time, represented as t."
A kind of service reliability based on service is purposed. The definition of network service reliability is that the probability that a network service will be continuously available in a given time considering hardware failures, software faults and human errors. The service reliability focuses on the state of service execution. Consider a simple network with a client, a server and two routers and the client communicates with the server. When the client requests a web page from server, a Domain Name System (DNS) server is a part of web communication. The DNS server is the equipment with software executing. There is much equipment like the DNS server. The service performs its function well with hardware normal running and the software executing on equipment normally. If we consider usage factors u_i for each serviceS_i, we can define the system reliability as Eg(1)

$$\mathrm{R} = \sum_{i=1}^{n} R_{s_i} \times u_i \tag{1}$$

where u_i represents the fraction of service S_i execution of the system and R_{S_i} is the reliability of service S_i. (The sum of usage factors for all services is equal to 1.) 1) is quoted from the report completing by Isaac et al. (2010). The usage factor is a definite value and is determined by system.

3. Service Reliability Model

This section describes a model of network service reliability. First, we discuss the factors affecting the reliability of network services and identify their influence. Then, the process of how to build network service reliability model is described shown in *Figure 1*.

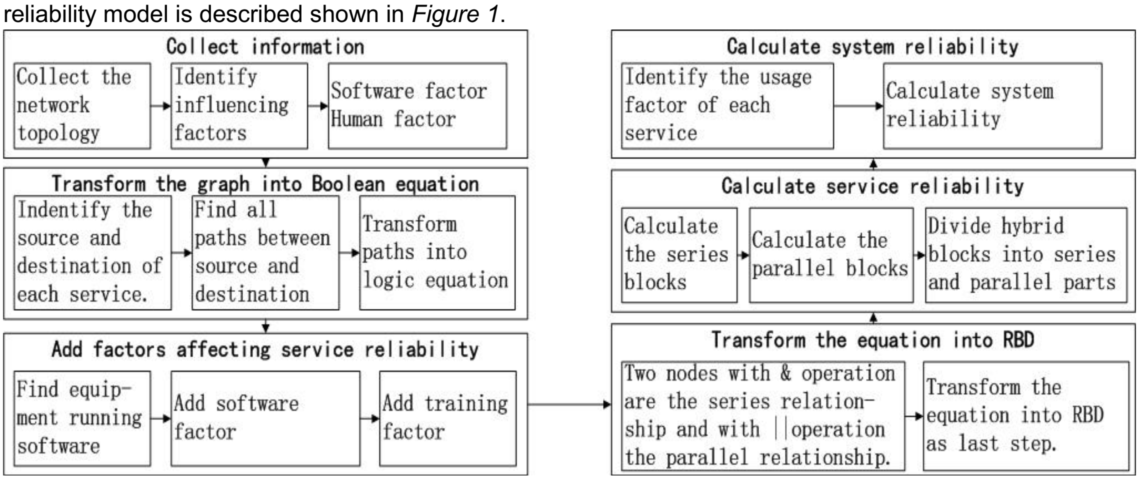

Figure 1 Process of network service reliability model

3.1 Driver of Network Reliability

We talk about the driver of the network reliability. A number of factors drive network reliability. We discuss these factors for building an analysis model of network reliability based on services. We discuss a casualty report (CASREP) study which is completed by PMW 750 using 169 CASREPs recorded aboard carriers. Most of the problems fell into seven categories as follow by Conwell et al. (2009).

Table 1 Outage time of network due to different failure cause

Cause	Outage time (%)	Outage time(days)
Training etc	35	1981
Hardware	32	1775
Software design	17	922
Configuration management	8	446
Settings	3	161
Others	4	215

It is obviously that about two-thirds of the CASREPs do not involve hardware equipment failures. A category called "human and human-defined process" can be created including training and so on which accounts for 35 percent of CASREPs. Training is the process to teach users how the service executes. Wrong training will lead the services down. Another category, "software", includes software design, configuration management, and settings accounting for 28 percent of CASREPs. Software design factor is the problem caused by source code and structure of software. For example, an input can cause the bounds of an array to be overrun. Configuring IP address and routing is a kind of configuration management. Settings refer to the choices of software options. These three factors belong to software category and the equipment with software running on should be focused on.

Traditionally calculation of a system's reliability is simple to measure the reliabilities of its dependent components. Human-defined process and software are two significant drivers of network reliability. When reliability is calculated, not only hardware factor should be considered but also human and software factor should be measured. Many network services require the software support. Users and maintainers are two different roles in the network services. Their activities are very important to the service. Human errors and software faults can lead to a gray time when hardware equipment is on normal running but the service cannot perform its function.

3.2 Process of Network Reliability Model

We describe a modeling effort to account for the reliability of individual components supporting the delivery of a service and factors that affect the network service reliability and are discussed in section 3.1. This model is an example of how additional resolution can be applied with different factors such as software and human-defined process included. The process of network reliability model is shown in *Figure 1* as follow:

1. Collect the graph of system network topology and the reliability of equipment. Identify the factors affecting service reliability including software and human factors. Software factors include software design, configuration management and settings and human factors refer to training and so on.
2. Map the steps of the service execution to the connectivity graph to find all possible paths between source and destination of each step in the execution. Transform the individual source-destination paths into Boolean equations by applying & (AND) operators between nodes in the same path and the || (OR) operator between parallel paths.
3. Find all the equipment with software running on and add software factors by applying & operation with the equipment. Apply & operation to add the training factors with the whole service getting the final logic expression.
4. Transform the expression into reliability block diagram. Two nodes with & operation are the series relationship and with ||operation the parallel relationship. Transform from part to whole.
5. Calculate the reliability of network services. The 2)

$$R_{S_i} = \prod_{j=1}^{n} R_j \quad (2)$$

is to calculate series blocks. If the blocks are parallel, use the 3)

$$R_{S_i} = 1 - \prod_{j=1}^{n}(1 - R_j) \quad (3)$$

to get the reliability. If blocks are hybrid, divide blocks into series and parallel parts then calculate. (R_j refers to the reliability of block j. R_{S_i} refers to reliability of service i.)

6. Identify the usage factor of each service (usage factor is discussed in section 2). And then calculate the reliability of network system according to 1).

The calculation of reliability in this model involved not only hardware factors but also software and human factors. This method can estimate objectively the system reliability by adding factors blocks into RBD and reflect the reliability influence factors.

4. Case Analysis

4.1 Statement of Case

We select a communication network system as our case study. The completed network diagram for the communication network system is described in *Figure 2*. The reliability data of components in the system is shown in *Table 2* . The system includes three services, chat service, file transfer service and email service. Chat service refers that a client communicates with another client using chat software running on the client. File transfer service is the service that files transfer between client and file server. Email service refers a process that a source client sends an email to a destination via mail server. In addition to the hardware failures, software faults and human errors can affect the reliability of the system. We consider the software factors including software design, configuration management and settings and human factors including training and so on when model the case. The reliability data of these factors is shown in *Table 2* . The data in *Table* 2 is quoted from the report completing by Isaac et al. (2010).

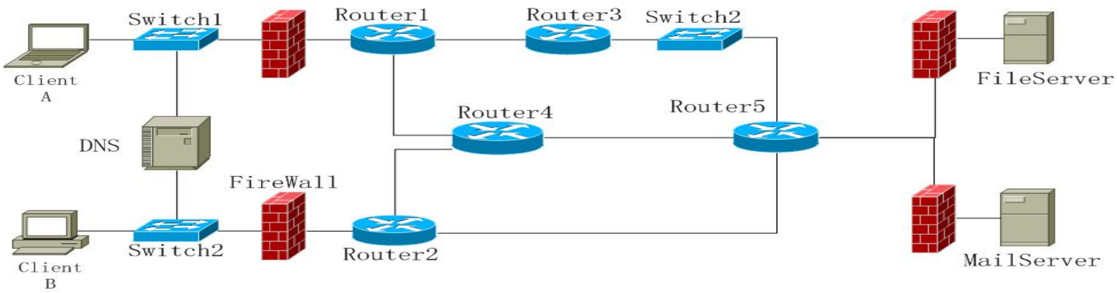

Figure 2 Topology graph of a communication network

Table 2 Reliability data of components and factors affecting the system

Component	Reliability data	Factors	Reliability data
Router	0.998937	Software design	0.997574
Switch	0.992876	Configuration management	0.998527
DNS	0.999411	Settings	0.999735
The given time is 1000 hours		Training	0.998261

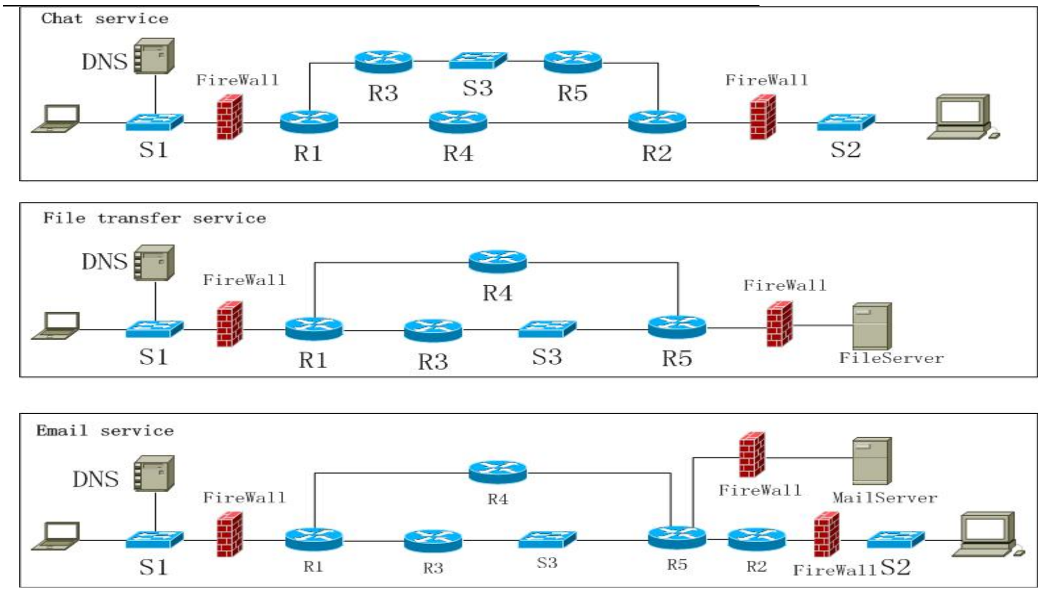

Figure 3 Paths of three services

4.2 Logic Expression of the Paths

We should note all the paths of these three services and then transform the paths into logic expression. The paths of the three services are shown in *Figure 3*.

Then we transform the paths into a Boolean equation as section 3.2 say. The equation is shown as below:

The logic expression of Chat service:

ClientA&Switch1&DNS&FireWall&Router1&(Router4||(Router3&Switch2&Router5))&Router2&FireWall&Switch2&ClientB (4)

The logic expression of File transfer service:

ClientA&Switch1&DNS&FireWall&Router1&(Router4||(Router3&Switch3))&Router5&FireWall&FileServer(5)

The logic expression of Email service:

ClientA&Switch1&DNS&FireWall&Router1&(Router4||(Router3&Switch3))&Router5&FireWall&MailServer&Router2&Firewall&Switch2&ClientB (6)

4.3 Adding Factors affecting reliability

We consider the influence of software and human and add the factors into the equation. First we find the equipment running software, like client, firewall, DNS, file server and mail server. Then we add the factor of software design, configuration management and settings involved in "Software Factor" into the equation by applying & operation connecting with the equipment running software. Lastly we should add the factor of training and so on by applying & operation connecting with the whole service. The result equation is described as below:

Chat service:

ClientA**&SoftwareFactor**&Switch1&DNS**&SoftwareFactor**&FireWall**&SoftwareFactor**&Router1&(Router4||(Router3&Switch2&Router5))&Router2&Firewall**&SoftwareFactor**&Switch2&ClientB**&SoftwareFactor&TrainingFactor** (7)

File transfer service:

ClientA**&SoftwareFactor**&Switch1&DNS**&SoftwareFactor**&FireWall**&SoftwareFactor**&Router1&(Router4||(Router3&Switch3))&Router5&FireWall**&SoftwareFactor**&FileServer**&SoftwareFactor&TrainingFactor** (8)

Email service:

ClientA&**&SoftwareFactor**Switch1&DNS**&SoftwareFactor**&FireWall**&SoftwareFactor**&Router1&(Router4||(Router3&Switch3))&Router5&FireWall**&SoftwareFactor**&MailServer**&SoftwareFactor**&Router2&Firewall**&SoftwareFactor** &Switch2&ClientB**&SoftwareFactor&TrainingFactor** (9)

4.4 The Reliability Block Diagram

We transform the Boolean equation described in 4.3 into the reliability block diagram of each service. The method has been discussed in 3.2. We get the RBD shown in *Figure 4*.

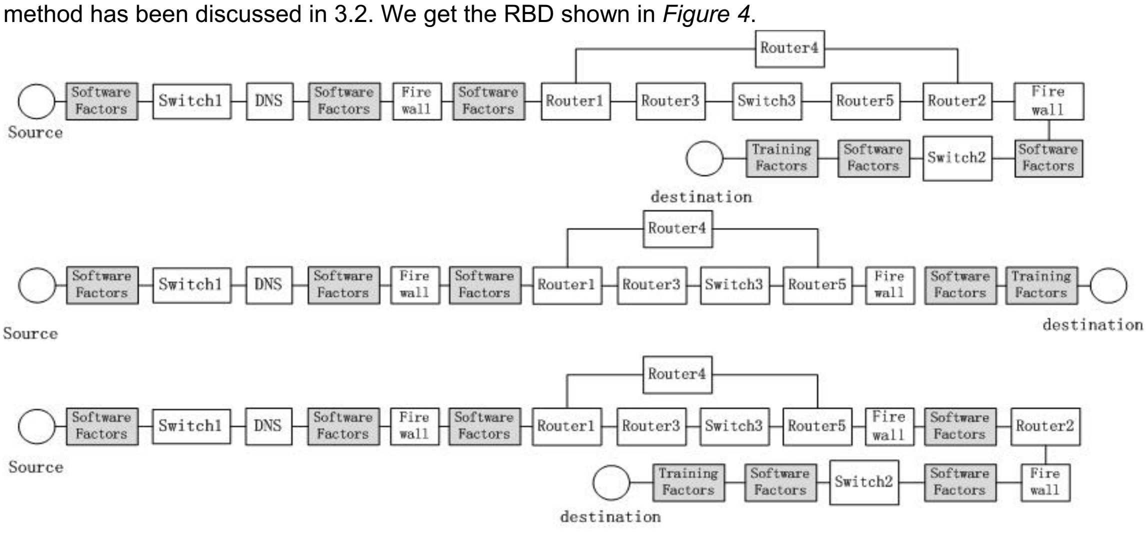

Figure 4 Reliability block diagram of three services

4.5 Calculate reliability of each service

We utilize the RBD shown in Figure 4 and the reliability data in *Table* 2 to calculate the reliability of these three services. Use 2) to calculate the series blocks and use 3) to calculate parallel blocks. We get the result as below:

R_{S_1}=0.976612, R_{S_2}=0.979440, R_{S_3}=0.972407

4.6 Calculate system reliability

In this communication network system, the using percent of chat service accounts for 60% and the file service for 30% with email service accounting for the rest. The usage factors of these three services are that: u_1=0.6, u_2=0.3 and u_3=0.1. According to Eg(1), the reliability of this communication network system is 0.977079.

Utilizing this method to calculate the reliability can estimate objectively. Hardware, software and human process are all involved in the calculation and the result reliability can reflect the system state better.

5. Conclusions and further research

This paper describes a service reliability model to account for the reliability of the network system considering software factor and human process involved in the service execution. We collect the information of network system and identify the factors affecting reliability of services. And then we transform paths of services into Boolean equation. The factors of software and human process are added to the equation and the equation is transformed into RBD. We calculate reliability according to the RBD and the data we collect. The calculation of this method takes account of user perception bridging the gap between the service experience of users in term of reliability and the result reliability. In the next step, we will study further the factors affecting the reliability of services and discuss the model of how factors affect the reliability of system in development stage.

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