Reliability and Profit Analysis of a Soft Hot Standby PUSH VOD System based on Markov Model

Tian Chen, Xie Lanchi, and Wang Xingjun
Shenzhen Key Lab. of Information Sci&Tech/Shenzhen Engineering Lab. of IS&DRM Department of Electronic Engineering/Graduate School at Shenzhen, Tsinghua University, China
Email: livagain@sina.com, xielanchi @139.com,wangxingjun@tsinghua.edu.cn

***Abstract*—Based on Markov model, this paper analyzes a soft standby's reliability and safety in PUSH system for digital TV, which is constituted by two PUSH VOD severs working on master-slave mode. It illustrates 5 interesting rules that can guide us to design a more reliable and more secure system. We will see some key parameters that is positive correlated with the reliability may be negative correlated with the safety at the same time. What's more, it shows that using different algorithm for mutual checking can hold system's safety even though each algorithm may be not so efficient. Profit evaluations of such hot standby and advices to design are also given.**

***Index Terms*—reliability; safety; PUSH system design; soft hot standby**

I. Introduction

Nowadays, in the impact of Internet, the digital TV industry in China is undergoing profound changes. In order to provide customers with high-quality video services, state-owned operators use technologies such as VOD, PUSH VOD, cloud video platform. Among them, PUSH VOD systems are serving millions of Chinese families. So the system's reliability and improvement have been urgent to be studied.

As we know, redundant standby systems are very wide applied, such as PLC systems [1], supply systems[2]. And from the view of types, redundant system can be classified into numerous ones, including standby redundant, parallel redundant and so on [3]. For k-n out warm standby, preventive maintenance, distribution systems reliability, lots of good study have been done[4]-[7].

According to whether there is a common storage medium, the hot standby can be divided into 2 ways: shared storage and pure-software styles. The former style is more reliable, the latter one costs less but need content synchronization. This paper studies reliability and safety of a soft hot standby in PUSH VOD system. Part II gives a short explanation for the system's redundant mechanism. Then Part III builds up an evaluation model for such system's reliability and safety, and gives a deep insight into some key parameters' roles and their relationship, which turns out to be some interesting rules for systems' design. Part IV provides a simple formula to judge the profit of standby. Finally, Part V makes a short conclusion and discusses some topics that need to be studied further.

Manuscript received February 28, 2013; revised April 2, 2013.

II. Mechanism of Soft Hot Standby PUSH VOD System

The mechanism is shown in Fig. 1. We should notice that not only 2 PUSH server software works in a master-slave mode, but also there're 2 additional monitor software running in such mode. And we see this as a mutual checking standby network.

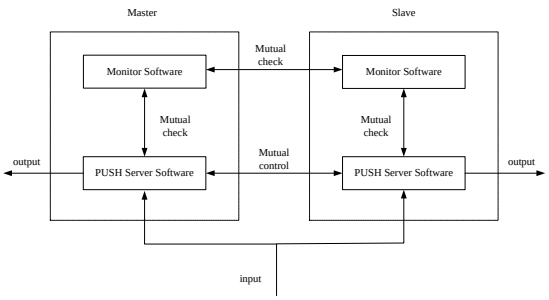

Figure 1. Mechanism of soft hot standby.

III. Study on the Reliability of Soft Hot Standby Push VOD System based on Markov Model

A. Basic Hypothesis

Markov model is a portrait of a dynamic state transition matrix. In order to facilitate this model study, we need to make the following hypothesis .

Hypothesis 1: In the aspects of hardware and software, there is no different between master and slave machine.

Hypothesis 2: Master and slave software's failure rate is the exponential distribution and independent of each other.

Hypothesis 3: The errors in the system can be divided into the observable and the unobservable, technician will repair error in a reasonable time.

doi: 10.12720/lnit.1.3.140-143

B. Basic Model of Reliability and Safety

We define the monitor software's failure rate is λ_0, PUSH server's is λ_1. Mutual detection ratio for monitors is κ_0. Mutual detection ratio for monitor and PUSH server is κ_1. To the same hot standby software failure, the PUSH server and monitor software simultaneously detection ratio is κ_3. Also, failure can be divided into the security failure and the hazard failure[8]. So a hazard ratio is defined as η. At the same time, we set up the technicians' fixed expenses as C_0. Unit cost per up time is C_1. Success rate of repair is μ and system's revenue per up time is B_0.

With these parameters, we define the following possible states:

State 1:All unit work properly, PUSH system can provide video push service.

State 2:When a machine is working properly and the other is to be isolated, the system is in a controlled state. There are several possible reason to make this happen:

(1) Master PUSH software has a observable failure, the slave software startup[9].

(2) The opposite situation of the above one.

In both situation, the PUSH system is under control.

State 3: Either Master or slave machine has a unobservable failure. In this state, the system may operate normally, but is out of control. For example, the master machine may has some trouble, but due to the unobservable, master's PUSH software will continue to run. The system is still normal to provide service for customers. However, when the master PUSH software fails, the standby will start up. At this point, the whole hot standby system state is undefined, and the system enters into a dangerous state.

State 4: System security failure state. In this state, although the whole system will stop providing video output, but everything is under control. The reasons can cause this are as follows:

(1)When only one machine is at work, this working machine's PUSH software happened to occur an observable error.

(2)When only one machine is at work, this working machine's monitor software happened to occur an observable error.

State 5: System risk failure state. Reasons as below:

(1)When system start up, master has an observable error.

(2)When system is in State 2，an unobservable error happened.

(3) When system is in State 3，an unobservable error happened.

Fig. 2 shows the model of state transition.

Then, we can get the following differential equations(1):

$$P_1'(t) = -(2\lambda_0 + \lambda_1 + 3\mu)P_1(t) + \mu P_2(t) + \mu P_4(t) + \mu P_5(t)$$

$$P_2'(t) = [\lambda_1\kappa_1 + 2\lambda_0(\kappa_0 + \kappa_1 - \kappa_3)]P_1(t) - (\lambda_1 + \mu)P_2(t)$$

$$P_3'(t) = -\lambda_1 P_3(t) + [2\lambda_0(1 - \kappa_0 - \kappa_1 + \kappa_3)]P_1(t)$$

$$P_4'(t) = \lambda_1\kappa_1(1-\eta)P_2(t) - \mu P_4(t)$$

$$P_5'(t) = \lambda_1(1-\kappa_1)P_1(t) + [\lambda_1(1-\kappa_1) + \lambda_1\kappa_1\eta]P_2(t) + \lambda_1 P_3(t) - \mu P_5(t)$$

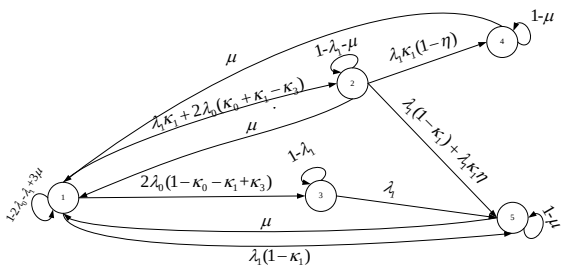

Figure 2. State transition of soft hot standby

In order to study the characteristics of this set of equations, we do a simple processing. Assuming no maintenance staff repairs machine and improve software, we set μ =0. Then, simplified equations can be solved with initial conditions P(0)=[1 0 0 0 0]:

$$P_1(t) = e^{-(2\lambda_0+\lambda_1)t}$$

$$P_2(t) = \frac{[\lambda_1\kappa_1 + 2\lambda_0(\kappa_0 + \kappa_1 - \kappa_3)]}{\lambda_0 + \lambda_1} e^{-\lambda_0 t}(1 - e^{-(\lambda_0+\lambda_1)t})$$

$$P_3(t) = \frac{[2\lambda_0(1 - \kappa_0 - \kappa_1 + \kappa_3)]}{\lambda_0 + \lambda_1} e^{-\lambda_0 t}(1 - e^{-(\lambda_1+\lambda_0)t})$$

$$P_4(t) = \frac{\lambda_1\kappa_1(1-\eta)}{\lambda_0(2\lambda_0 + \lambda_1)}[\lambda_1\kappa_1 + 2\lambda_0(\kappa_0 + \kappa_1 - \kappa_3)] + \frac{\lambda_1\kappa_1(1-\eta)[\lambda_1\kappa_1 + 2\lambda_0(\kappa_0 + \kappa_1 - \kappa_3)]}{\lambda_1 + \lambda_0} * \left(-\frac{1}{\lambda_0}e^{-\lambda_0 t} + \frac{1}{2\lambda_0 + \lambda_1}e^{-(2\lambda_0+\lambda_1)t}\right)$$

set $H = \frac{\lambda_0}{\lambda_1}$, $K = \kappa_0 + \kappa_1 - \kappa_3$.

Then, we define the reliability and safety of soft hot standby respectively:

$$R(t) = P_1(t) + P_2(t) + P_3(t) = e^{-\lambda_1(2H+1)t} + \frac{\kappa_1 + 2H}{H+1} e^{-\lambda_0 t}(1 - e^{-\lambda_1(H+1)t})$$

$$S(t) = R(t) + P_4(t) = [1 + \frac{\kappa_1(1-\eta)(\kappa_1 + 2HK)}{(2H+1)(H+1)} - \frac{\kappa_1 + 2H}{H+1}]e^{-\lambda_1(2H+1)t} + (\frac{\kappa_1 + 2H}{H+1} - \frac{\kappa_1(1-\eta)(\kappa_1 + 2HK)}{H(H+1)})e^{-\lambda_0 t} + \frac{\kappa_1(1-\eta)}{H(2H+1)}(\kappa_1 + 2HK)$$

Not surprisingly, the reliability shows an exponential distribution. But it is worth to notice that the mutual checking ratio turns out to be a linear relationship with reliability. This is very strong positive factor to design a reliable system. To the safety formula, it is hard to see

some obvious clues. But we can guess there're some relationship between K and safety.

C. The Analysis of Reliability and Safety

In purpose of deep insight into reliability and safety, we set a number of parameters to see what will happen.

First, we take the H 's influence into consideration. Let λ_0 =0.05, κ_1=0.9, H =[1 0.8 0.6 0.4 0.2], we get Fig. 3. Obviously, H doesn't play a big role as it seems to be. But we can think it in another positive way, that is even when H is very low which means λ_1 is very high, the PUSH system can hold a steady reliability. Because λ_0 is very low, and all software are checking each other. So let's put this idea further and get rule 1.

Rule 1(anti-Cask -principle): *In a system with a mutual check reliable network, the high reliable component not the low one hold the basic reliable level.*

Next, we study the parameter κ_1 . Set λ_0 =0.05, H =0.1, κ_1 =[1 0.9 0.5 0.3 0.1], we get Fig. 4. In this picture, no surprise, we get a rule 2.

Rule 2: *Mutual check algorithm for monitor and service is strongly positive correlative to system's reliability.*

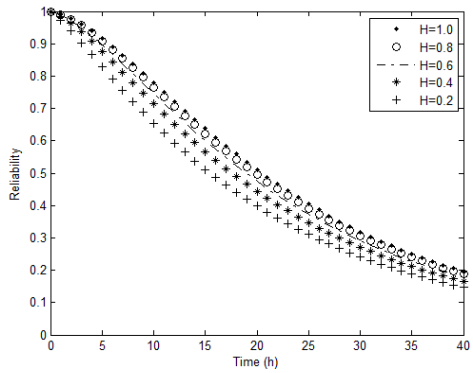

Figure 3. Reliability of standby and H

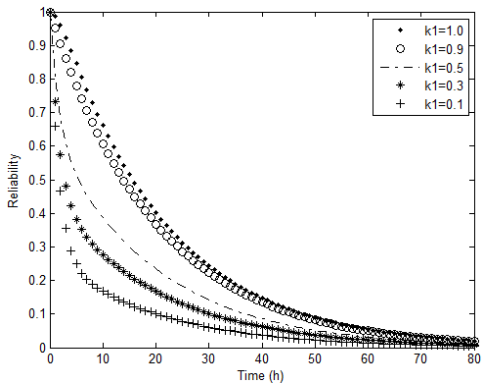

Figure 4. Reliability of standby and mutual detection ratio κ_1

Then, we have to try on the safety analysis.We want to see how H can affect the safety. Let λ_0 =0.05, K =0.9, κ_1=0.9, η=0.1, H =[1 0.95 0.9 0.85 0.8], Fig.5 jumps out in front of us. Surprisingly, H is strongly negative correlative with the safety. This result implied that when PUSH server shuttles down, this error can be guided into State 4 with high probability. So we also can get another rule.

Rule 3: *In mutual check standby system, some internal parameter may cause paradoxes between reliability and safety.(H is such a case.)*

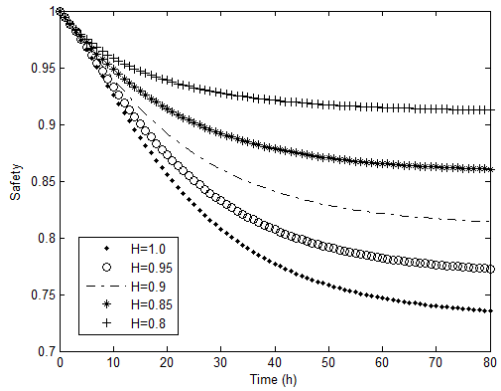

Figure 5. Safety of standby and H

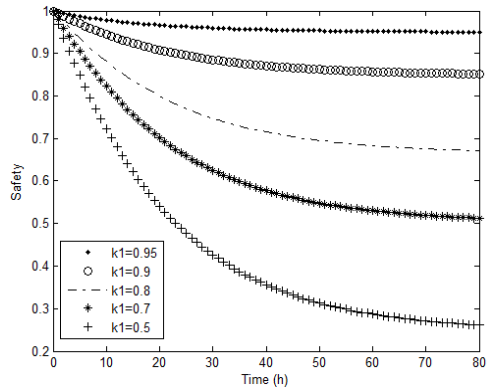

Figure 6. Safety of standby and mutual detection ratio κ_1

Then, Let's study κ_1 . Set λ_0 =0.05, κ_0 =0.9, κ_3 =1, H =1, κ_1 =[0.95 0.9 0.8 0.7 0.5], Fig. 6 shows up. Keeping consistency with reliability, κ_1 is strongly correlative with safety. This is rule 4.

Rule 4: *Mutual check algorithm for monitor and service is strong positive correlative to system's safety.*

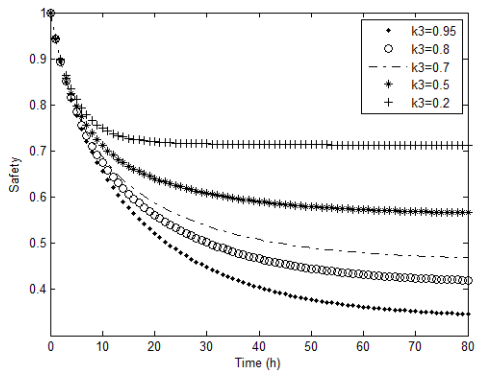

Figure .7. Safety of standby and κ_3

Next, because there're 2 kinds of mutual checking, we want to know whether the diversity of checking algorithm

will make a contribution to the safety. So let λ_0 =0.05, κ_1=0.5, κ_0=0.5, H =0.4, κ_3=[0.95 0.8 0.7 0.5 0.2], Fig. 7 demonstrates an exciting fact that even κ_0, κ_1 are pretty low, we can still get a relatively high safety if κ_0, κ_1 algorithm have enough different. That is:

Rule 5: *Taking different algorithm for 2 types of mutual check will obviously improve safety.*

Finally, we add maintenance staffs into consideration. We rewrite equations(1) in matrix and use Markov steady state analysis.

$$\begin{bmatrix} P_1'(t) \\ P_2'(t) \\ P_3'(t) \\ P_4'(t) \\ P_5'(t) \end{bmatrix} = \begin{bmatrix} 1\text{-}2\lambda_0\text{-}\lambda_1\text{-}3\mu & \mu & 0 & \mu & \mu \\ \lambda_1\kappa_1 + 2\lambda_0(\kappa_0+\kappa_1-\kappa_3) & -\lambda_1\text{-}\mu & 0 & 0 & 0 \\ 2\lambda_0(1-\kappa_0-\kappa_1+\kappa_3) & 0 & -\lambda_1 & 0 & 0 \\ 0 & \lambda_1\kappa_1(1-\eta) & 0 & -\mu & 0 \\ \lambda_1(1-\kappa_1) & \lambda_1(1-\kappa_1)+\lambda_1\kappa_1\eta & \lambda_1 & 0 & -\mu \end{bmatrix} \begin{bmatrix} P_1(t) \\ P_2(t) \\ P_3(t) \\ P_4(t) \\ P_5(t) \end{bmatrix} \quad (2)$$

TABLE I. RELIABILITY AND SAFETY OF THE STEADY SYSTEM

Case	$\vec{v}$	$R(\infty)$	$S(\infty)$
A	[0.9 0.05 0.05 0.9 0.9 0.5 0.05]	0.9469	0.9467
B	[0.1 0.05 0.05 0.9 0.9 0.5 0.05]	0.7279	0.6797
C	[0.9 0.5 0.5 0.9 0.9 0.3 0.05]	0.8142	0.8145
D	[0.9 0.5 0.5 0.9 0.9 0.3 0.05]	0.7052	0.6337
E	[0.9 0.8 0.8 0.9 0.9 0.3 0.05]	0.6910	0.4922
F	[0.3 0.5 0.5 0.5 0.5 0.9 0.05]	0.2647	0.4227

Let $\lim_{t\to\infty} P_j(t) = \pi_j$, j=1, 2, 3, 4, 5 and $\sum_{j=1}^{5}\pi_j = 1$. When $t \to \infty$, the PUSH system tend to be steady. With these conditions, we can solve (b). Because the result's algebraic expression is too complex, we do not list π_j's expressions in the paper. Instead, we take some specific value to see what we can find in steady state analysis.

Let $\vec{v}$=[μ λ_0 λ_1 κ_0 κ_1 κ_3 η], then the above Table I shows some results.

A and B's data shows maintenance staffs' repair work improve system's reliability and safety. C's data again proves *Rule 5*. Looking at D and E's data, it shows that when PUSH server and monitor software failure rate drop dramatically, the reliability can hold a steady state but the safety will drop greatly. F's data means the system will be in a dangerous state if there is lack of mutual checking and maintenance staffs.

IV. PROFIT ANALYSIS OF SOFT HOT STANDBY

With parameters mentioned in part III, we define profit function as

$$P(\pi) = \frac{B_0\pi_1}{B_0\pi_1 + C_1(\pi_2+\pi_4+\pi_5) + C_0}$$

V. CONCLUSION

Redundant standby systems have been widely applied in industry. With quantitative analysis of a soft hot standby system, we get some interesting rules. These rules can guide us to build a more reliable and safer system. But how to judge the difference level between mutual checking algorithm, how the topology structure of the reliable network influence systems' reliability and safety, these are questions that need further study.

REFERENCES

[1] B. Parashar and G. Tanejahen, "Reliability and Profit Evaluation of a PLC hot standby system based on a master-slave concept and two types of repair facilities," *IEEE Trans. on Reliability*, vol. 56, no. 3, September 2007.

[2] S. Ren and C. Zhang, "Study on the reliability of Hot standby repairable supply system based on Markov model," in Proc. *6th International Conf. Service Systems and Service Management*, Xiamen, China, 2009, pp. 318-322.

[3] A. Kumar and M. Agarwal, "A review of standby redundant system," *IEEE Trans. on Reliability*, vol. R-29, no. 4, October 1980.

[4] S. V. Amari, H. Pham, and R. B. Misra, "Reliability characteristics of k-out-of-n warm standby systems," *IEEE Trans. on Reliability*, vol. 61, no. 4, December 2012.

[5] Rahman, F. Abdul, Varuttamaseni, Athi, K. Meyer, Michael, et al, "Application of fault tree analysis for customer reliability assessment of a distribution power system," *Reliability Engineering & System Safety*, vol. 111, pp. 76-85, March 2013.

[6] Andrade and Waltencir, "Reliability evaluation of distribution system with renewable distributed generation and load variation models," in *Proc. 20th International Conf. Electricity Distribution*, January 2009, pp. 1030.

[7] W. Kuo and R. Wan, "Recent adcances in optimal reliability allocation," *IEEE Trans. on System, Man and Cybernetics Part A-Systems and Humans*, vol. 37, pp. 143-156, March 2007.

[8] J. Yan and X. Wang, "Reliability and safety analysis of two modes of dual module hot spare architecture," *Journal of the China Railway Society*, vol. 22, no. 3, June 2000.

[9] V. Chandra and K. V. Kumar, "Reliability and safety analysis of fault tolerant and fail safe node for use in a railway signaling system," *Reliability Engineering and System Safety*, pp. 177-183, 1997.

Tian Chen received the B.S. degree in technique and instrumentation of measurements from Harbin university of science and technology, Harbin, China, in 2010. He will receive M.S. degree in electronic and communication engineering from Tsinghua University, China, in 2013. His major studies are in reliability modeling and digital right management in media industry.

Xie Lanchi received the B.S. degree in science and technology of electronic information from Tsinghua University, Beijing, China, in 2010. She will receive M.S. degree in information and communication from Tsinghua University, Beijing, China, in 2013. Her major studies are in digital right management of family network and digital watermarking for videos.

Wang Xingjun received the M.S. degree in electronic and communication system and Ph.D. degree in signal and information processing from Tsinghua University, China, in 1994 and studied in University of Michigan, USA, from 1994 to 1996. His major studies are in digital TV, electronic and communication system.

In China, he is a famous expert in digital TV. He invented USB2.0-card technique and set up related national technology standard. Recently, he is the headman of the national digital right standard and family network workgroup.