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Profit Comparison of Computer System with Hardware Redundancy Subject to Different Repair Activities

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Abstract

In this research paper, main concentrate of the authors on the profit comparison of computer system with hardware redundancy by introducing the concept of priority to software up-gradation, hardware preventive maintenance (PM) and hardware maximum repair time (MRT). The system fails independently from normal mode. All the repair activities such as hardware repair, software up-gradation, hardware preventive maintenance before failure and hardware replacement after maximum repair time are carried out by a single server immediately on need basis. All random variables are statistically independent. The negative exponential distribution is taken for the failure time of the component while the distributions of repair time, up-gradation time, preventive maintenance and replacement time are assumed arbitrary with different probability density functions. Semi-Markov process and regenerative point technique are used. The behaviour of profits of the system models have been examined for different parameters and costs.

Key Words: Computer System, Hardware Redundancy, Priority to Software Up-gradation, Repair, Preventive Maintenance, Replacement, Profit Analysis and Stochastic Modelling.

1. Introduction

In current age, computer systems have become an essential part of life, having significant impact on modern society. The importance of computer systems cannot be denied in the corporate or business world, at the workplace and even in one's personnel life. Several techniques have been suggested by the designers and engineers for performance improvement of the systems. The unit wise redundancy technique has been considered as one of these in the development of stochastic models for computer systems. Malik and Anand (2010), Malik and Sureria (2012) and Kumar et al. (2013) analyzed computer systems with cold standby redundancy under different failures and repair policies. Also, Munday et al. (2014, 15, 16) tried to establish a stochastic model for a computer system by providing hardware redundancy in cold standby.

The basic interest of the authors on the profit comparison of computer system with hardware redundancy by introducing the concept of priority to software up-gradation, hardware preventive maintenance (PM) and hardware maximum repair time (MRT). The system fails independently from normal mode. All the repair activities such as hardware repair, software up-gradation, hardware preventive maintenance before failure and hardware replacement after maximum repair time are carried out by a single server immediately on need basis. All random variables are statistically independent. The negative exponential distribution is taken for the failure time of the component while the distributions of repair time, up-gradation time, preventive maintenance and replacement time are assumed arbitrary with different probability density functions. Semi-Markov process and regenerative point technique are used. The behaviour of profits of the system models have been examined for different parameters and costs.

2. Notations

E	:	Set of regenerative states
E^{-}	:	Set of non-regenerative states
O	:	Computer system is operative
Scs	:	Software is in cold standby
PM	:	Preventive Maintenance
MRT	:	Maximum Repair Time
a/b	:	Probability that the system has hardware / software failure
α_0/β_0	:	The rate by which hardware component undergoes for replacement/preventive maintenance
λ_1/λ_2	:	Hardware/Software failure rate
HFUr /HFWr	:	The hardware is failed and under repair/waiting for repair
SFUg/SFWUg	:	The software is failed and under/waiting for up-gradation
HFURp /HFWRp	:	The hardware is failed and under replacement/waiting for replacement
HFUPm /HFWPm	:	The hardware is failed and under replacement/waiting for Preventive maintenance
HFUR/HFWR	:	The hardware is failed and continuously under repair / waiting for repair from previous state
SFUG/SFWUG	:	The software is failed and continuously under up-gradation /waiting for up- gradation from previous state
HFURP/HFWRP	:	The hardware is failed and continuously under replacement / waiting for replacement from previous state
HFUPM/HFPM	:	The hardware is continuously under/waiting for Preventive maintenance from previous state
g(t)/G(t)	:	pdf/cdf of hardware repair time
f(t)/F(t)	:	pdf/cdf of software up-gradation time
r(t)/R(t)	:	pdf/cdf of hardware replacement time
m(t)	:	pdf/cdf of hardware preventive maintenance time
$q_{ij}(t)/Q_{ij}(t)$	:	pdf / cdf of first passage time from regenerative state S_i to a regenerative state S_j or to a failed state S_j without visiting any other regenerative state in (0, t]
$q_{ij.k}(t)/Q_{ij.k}(t)$ state	:	pdf/cdf of direct transition time from regenerative state S_i to a regenerative S_j or to a failed state S_j visiting state S_k once in (0, t]

$M_i(t)$: Probability that the system up initially in state $S_i \epsilon E$ is up at time t without visiting to any regenerative state

$W_i(t)$: Probability that the server is busy in the state S_i up to time 't' without making any transition to any other regenerative state or returning to the same state via one or more non-regenerative states.

μ_i : The mean sojourn time in state S_i which is given by

$$\mu_i = E(T) = \int_0^\infty P(T > t)\, dt = \sum_j m_{ij} ,$$

where T denotes the time to system failure.

m_{ij} : Contribution to mean sojourn time (μ_i) in state S_i when system transits directly to state S_j so that

$$\mu_i = \sum_j m_{ij} \ and \ m_{ij} = \int_0^\infty t dQ_{ij}(t) = -q_{ij}^{*\prime}(0)$$

&/© : Symbol for Laplace-Stieltjes convolution/Laplace convolution

*/** : Symbol for Laplace Transformation (LT)/Laplace Stieltjes Transformation (LST)

P : Profit of the Model as shown in Munday et al. (2019)

P1 : Profit of the present model

3. System models with Different Repair Activities as shown in following Figures

State Transition Diagram (Basic Model)

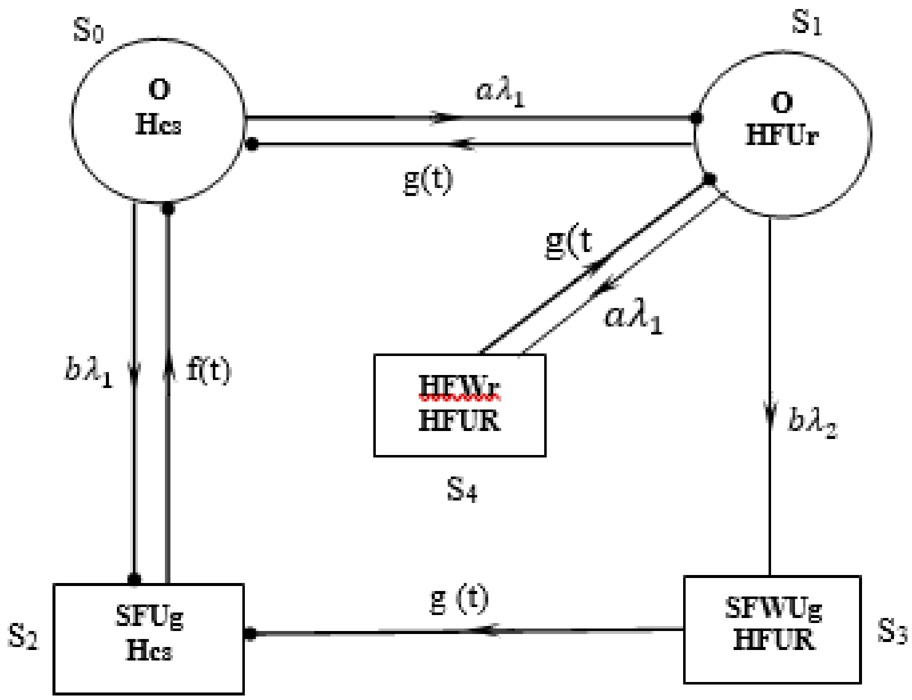

Fig. 1 (Model discussed in research paper [10])

State Transition Diagram (Priority to S/w Up-gradation)

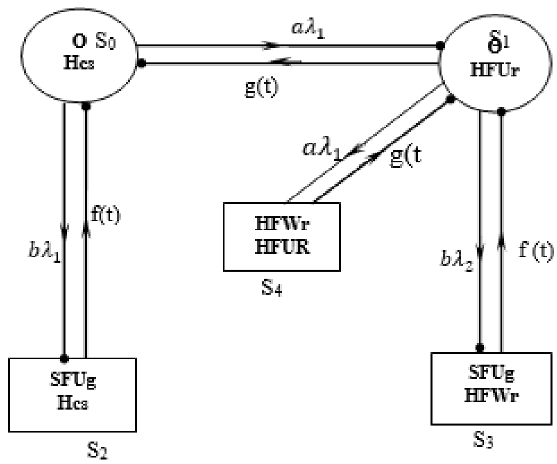

Fig. 2 (Model discussed in research paper [13])

State Transition Diagram (Subject to Maximum Repair Time)

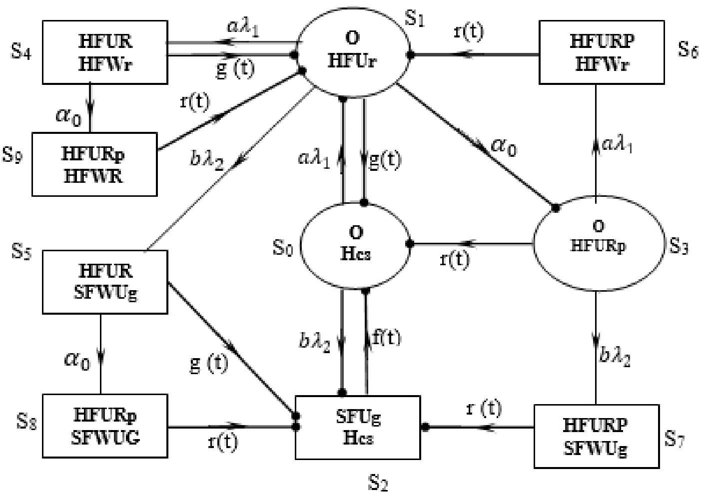

Fig. 3 (Model discussed in research paper [12])

State Transition Diagram (Subject to Preventive Maintenance)

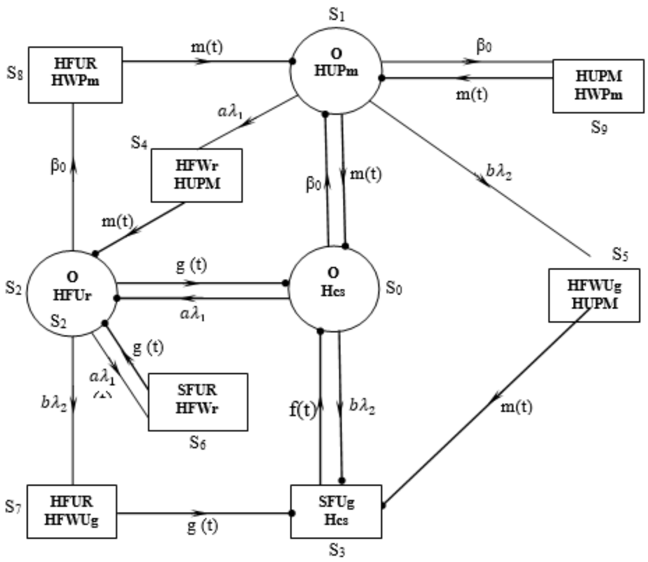

Fig. 4 (Model discussed in research paper [15])

4. Tabulation of Profit of system model as shown in Fig. 1

Table 1: Fig. 1 Profit Vs Hardware Failure Rate (λ1)

λ_1	λ_2=0.001, α=2, θ=5, a=0.6, b=0.4	λ_2=0.002	α=3	θ=7	a=0.4, b=0.6
0.01	14986.15005	14984.40795	14987.22013	14986.50857	14989.3419
0.02	14973.8227	14972.07423	14976.09294	14974.18092	14981.19235
0.03	14961.28466	14959.52998	14964.88333	14961.64258	14972.94843
0.04	14948.53851	14946.77776	14953.59207	14948.89612	14964.61091
0.05	14935.58681	14933.82014	14942.2199	14935.9441	14956.18055
0.06	14922.43211	14920.65966	14930.7676	14922.78906	14947.6581
0.07	14909.07695	14907.29887	14919.23592	14909.43356	14939.04433
0.08	14895.52387	14893.7403	14907.6256	14895.88012	14930.34
0.09	14881.77539	14879.98647	14895.9374	14882.13127	14921.54585
0.1	14867.83402	14866.0399	14884.17208	14868.18952	14912.66264

Table 2: Fig. 2 Profit Vs Hardware Failure Rate (λ1)

λ_1	λ2=0.001, α=2, θ=5, a=0.6, b=0.4	λ2=0.002	α=3	θ=7	a=0.4, b=0.6
0.01	14986.17	14984.44	14987.23	14986.53	14989.35501
0.02	14973.88	14972.15	14976.12	14974.23	14981.22646
0.03	14961.39	14959.66	14964.93	14961.75	14973.01136
0.04	14948.72	14946.99	14953.67	14949.07	14964.71044
0.05	14935.85	14934.13	14942.34	14936.21	14956.32442
0.06	14922.8	14921.08	14930.93	14923.16	14947.85399
0.07	14909.57	14907.85	14919.46	14909.93	14939.29988
0.08	14896.16	14894.44	14907.91	14896.51	14930.6628
0.09	14882.56	14880.85	14896.29	14882.92	14921.94344
0.1	14868.79	14867.08	14884.6	14869.15	14913.14252

Table 3: Fig. 3 Profit Vs Hardware Failure Rate

λ1	λ2=0.001, α0=0.01, α=2, β=3, θ=5, a=0.6, b=0.4	λ2=0.002	α0=0.05	α=3	β=5	θ=7	a=0.4, b=0.6
0.01	14986.87669	14985.142	14985.5336	14986.99648	14987.69222	14987.23514	14989.81529

0.02	14975.40488	14973.66832	14972.71854	14975.65595	14977.17183	14975.76305	14982.19425
0.03	14963.84923	14962.11074	14959.83001	14964.24402	14966.70136	14964.20713	14974.53657
0.04	14952.20769	14950.46719	14946.86609	14952.76038	14956.27663	14952.56531	14966.8416
0.05	14940.4783	14938.73571	14933.8249	14941.20474	14945.89355	14940.83563	14959.10875
0.06	14928.65913	14926.91438	14920.70466	14929.57682	14935.54815	14929.01617	14951.33741
0.07	14916.74835	14915.00138	14907.50363	14917.87637	14925.23655	14917.1051	14943.527
0.08	14904.74418	14902.99494	14894.22014	14906.10314	14914.95496	14905.10063	14935.67696
0.09	14892.64493	14890.89336	14880.85259	14894.2569	14904.69969	14893.00108	14927.78672
0.1	14880.44896	14878.69499	14867.39944	14882.33743	14894.46714	14880.8048	14919.85576

Table 4: Fig. 4 Profit Vs Hardware Failure Rate

λ1	λ2=0.001, α=2, θ=5, a=0.6, b=0.4, γ=0.034, β0=0.001	λ2=0.002	α=3	θ=7	a=0.4, b=0.6	γ=0.035	β0=0.002
0.01	14746.89757	14654.87877	14749.70071	14747.05796	14940.02286	14918.22227	13562.17649
0.02	12848.66272	12842.17838	12851.78506	12848.80856	13695.14039	13051.04641	10923.33206
0.03	11891.55427	11900.87843	11895.18429	11891.69515	12669.37714	12110.30533	9687.682737
0.04	11272.32349	11286.20489	11276.5463	11272.46154	11998.10191	11499.77337	8931.175733
0.05	10828.51496	10843.71529	10833.38288	10828.65102	11509.35371	11060.63657	8410.608473
0.06	10491.25006	10506.58437	10496.80109	10491.38456	11132.11764	10725.81911	8027.165459
0.07	10224.67343	10239.66075	10230.93827	10224.80666	10829.77302	10460.40756	7731.522159
0.08	10007.79845	10022.24182	10014.80362	10007.9306	10580.84656	10243.93432	7495.856783

0.09	9827.360699	9841.189259	9835.130147	9827.491909	10371.65855	10063.43406	7303.132825
0.1	9674.502817	9687.704714	9683.058799	9674.633202	10192.9746	9910.228142	7142.276752

Particular Cases

For $g(t) = \alpha e^{-\alpha t}$, $f(t) = \theta e^{-\theta t}$, $r(t) = \beta e^{-\beta t}$ and $m(t) = \Upsilon e^{-\Upsilon t}$

5. Comparative Study of Profit of System Models

The profit of the basic model has been compared with the profits of other repair activities already discussed in research papers as given in references. It is revealed that the basic model is less profitable as compared to the system models with the concepts of priority to s/w up-gradation and maximum repair time to hardware component but profitable over the concept of preventive maintenance of hardware component. And, hence we can say that the concept of hardware preventive maintenance in a computer system with hardware redundancy in cold standby is not much helpful in making the system more profitable. The graphical presentation of profits of the system models with respect to hardware failure rate (λ1) have been shown numerically in tables 1 to 4. Finally, it is concluded that a computer system can be made more reliable and profitable to use by providing hardware redundancy in cold standby and maximum hardware repair time to the server.

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