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AVAILABILITY AND PROFIT ANALYSIS OF UNI-DIRECTIONAL AND REVERTIBLE 1:1 PROTECTION SWITCHING SCHEME IN OPTICAL COMMUNICATION PROCESS

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Abstract: The present paper gives the availability and profit analysis of a system comprising four optical lines out of which two are operative (working paths) and the other two are cold-standby (protection paths). Each working line has its own cold standby. On the failure of the working path, signal is transmitted and received from its own protection path and failed unit is gone under repair immediately by a repairman. If a working path and its corresponding protection path both get failed then system is said to be failed. The system is analysed by making use of semi-Markov processes and regenerative point technique. Various measures of system effectiveness have been obtained and the profit is also evaluated along with graphical studies.

AMS Subject Classification: 60K15, 90B25, 60K10, 94A05
Key Words: 1:1 protection scheme, reliability, availability, profit

1. Introduction

In socio economic sphere of the present age, communication plays a vital role.

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Fiber optic networks are emerging as the back bone of modern communication system [1]. In WDM networks, the optical signal spectrum is divided into number of non overlapping wavelength bands and allowing transmitting through single optical fiber. Any failure of network components e.g. fiber cut, an optical cross connect, an amplifier, a transceiver may result in the failure of several optical channels thereby leading to losses large data and revenue.

Survivability of optical networks has become an important research direction. Techniques for network survivability contains various switching schemes included 1+1 and 1:1 protection schemes (standby). 1+1 protection is technique in which traffic of a circuit is transmitted on two link disjoint paths and the receiver selects the stronger of the two signals; 1:1 protection, which is similar to 1+1 except that traffic is not transmitted in the back path until failure take place; Availability and cost benefit analysis have been carried out by various researchers included [2, 11] in the field of reliability but none of them obtained such measures for 1+1 or 1:1 protection switching scheme. The authors have already examined a " Availability and profit analysis of uni-directional and revertible 1+1 protection switching scheme in optical communication process " with reference no. 662.26 in international journal of performability engineering [12], communicated for publication .The apart of availability and profit analysis need to be studied for 1:1 protection switching scheme and hence present paper. So in this paper we examine the availability and profit analysis of an optical communication system with a unidirectional and revertible 1:1 protection scheme on the basis of data/information collecting from a company. By a unidirectional and revertible 1:1 protection scheme, we mean that there are two optical fibers for transmission of signals from user 1 to user 2, out of which one is working path (main unit) and the second is protection path (cold standby). Similar structure is used from user 2 to user 1 as shown on Figure 1.

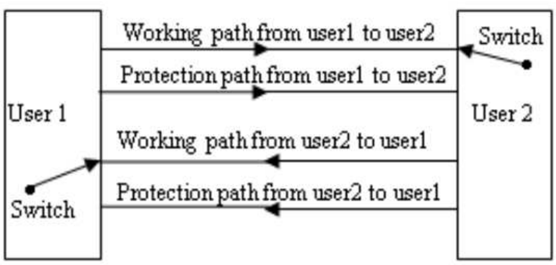

Figure 1: 1:1 Unidirectional protection switching scheme

In this way, four units system is discussed two units are main unit (protection path) and each main unit has its own cold standby (protection path). User-1 and user-2 transmit signals through corresponding working path and their protection paths are unused. Signals are transmitted through protection path by any user only when its working path get failed/cut. After fail, repairing is started by single repairman facility. As working path is repaired, signals are again received from working path (meaning of revertible). System is said to be failed if any working path along with its protection path get fail/cut. Further, assumptions are given below:

1. Initially working paths are operative and protection paths are as cold standby.

2. The system becomes inoperable if any working path and its corresponding protection paths get failed.

3. All random variables are independent.

4. The failure times are assumed to be exponentially distributed.

5. The failures are self-announcing and switching is perfect and instantaneous.

6. Failed unit is repair by single repairman.

7. If two units are waiting for its repair, priority for repair is given in the following order:

a) Repairing of already undertaken unit is not left in between.
b) Repairing of the protection path will be started if working path is operable.
c) Priority for repairing is given to protection line from user-1 to user-2 in comparison to user-2 to user-1.

2. Materials and Methods

The system is analysed by making use of semi-Markov processes and regenerative point technique and various measures of system effectiveness such as Mean time to system failure, Steady state availability, Expected busy period to repair the failed unit and Expected number of visits by repairman. Profit is also evaluated using these measures.

Symbol and Notations :
o : operative unit;

cs : cold standby unit;
λ_1 : constant failure rate of first operable unit;
λ_2 : constant failure rate of second operable unit;
WP_{1ur} : first unit of working path is under repair;
WP_{2ur} : second unit of working path is under repair;
PP_{1ur} : first unit of protection path is under repair;
PP_{2ur} : second unit of protection path is under repair.

3. State Transition Probabilities and Mean Sojourn Times

The transition states for present model are:

$S_0 = \left(WP_{1op,2op}; PP_{1cs,2cs}\right)$, $S_1 = \left(WP_{1ur,2op}; PP_{1op,2cs}\right)$,
$S_2 = \left(WP_{1op,2ur}; PP_{1cs,2op}\right)$, $S_3 = (\mathrm{WP}_{\mathrm{1ur,2wr}}; \mathrm{PP}_{\mathrm{1op,2op}})$,
$S_4 = (\mathrm{WP}_{\mathrm{1ur,2}}; \mathrm{PP}_{\mathrm{1wr,2}})$, $S_5 = (\mathrm{WP}_{\mathrm{1wr,2ur}}; \mathrm{PP}_{\mathrm{1op,2op}})$,
$S_6 = (WP_{1,2ur}; PP_{1,2wr})$, $S_7 = (WP_{1ur,2wr}; PP_{1wr,2})$,
$S_8 = (WP_{1ur,2wr}; PP_{1,2ur})$, $S_9 = (WP_{1op,2op}; PP_{1ur,2cs})$,
$S_{10} = (WP_{1ur,2ur}; PP_{1wr,2})$, $S_{11} = (WP_{1wr,2ur}; PP_{1,2wr})$,
$S_{12} = (WP_{1op,2op}; PP_{1cs,2ur})$, $S_{13} = (WP_{1op,2ur}; PP_{1wr,2op})$,
$S_{14} = (WP_{1,2ur}; PP_{1,2wr})$, $S_{15} = (WP_{1wr,2}; PP_{1ur,2})$,
$S_{16} = (WP_{1op,2wr}; PP_{1ur,2op})$, $S_{17} = (WP_{1ur,2op}; PP_{1op,2wr})$,
$S_{18} = (WP_{1wr,2op}; PP_{1op,2ur})$, $S_{19} = (WP_{1,2wr}; PP_{1,2ur})$,
$S_{20} = (WP_{1,2ur}; PP_{1wr,2wr})$, $S_{21} = (WP_{1wr,2wr}; PP_{1ur,2})$,
$S_{22} = (WP_{1,2wr}; PP_{1ur,2ur})$, $S_{23} = (WP_{1ur,2}; PP_{1wr,2wr})$,
$S_{24} = (WP_{1wr,2wr}; PP_{1,2ur})$, $S_{25} = (WP_{1wr,2}; PP_{1wr,2ur})$,
$S_{26} = (WP_{1op,2op}; PP_{1ur,2wr})$, $S_{27} = (WP_{1wr,2}; PP_{1ur,2wr})$.

The epochs of entry into states 0 to 27 are regenerative points and thus are regenerative states. The transition probabilities are:

$dQ_{01} = \lambda_1 e^{-(\lambda_1+\lambda_2)t}dt$, $dQ_{02} = \lambda_2 e^{-(\lambda_1+\lambda_2)t}dt$,
$dQ_{13} = \lambda_2 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$, $dQ_{14} = \lambda_1 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$
$dQ_{10} = \alpha e^{-(\lambda_1+\lambda_2+\alpha)t}dt$ $dQ_{25} = \lambda_1 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$,
$dQ_{26} = \lambda_2 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$, $dQ_{20} = \alpha e^{-(\lambda_1+\lambda_2+\alpha)t}dt$,
$dQ_{37} = \lambda_1 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$, $dQ_{38} = \lambda_2 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$,
$dQ_{32} = \alpha e^{-(\lambda_1+\lambda_2+\alpha)t}dt$, $dQ_{49} = \alpha e^{-\alpha t}dt$
$dQ_{5,10} = \lambda_1 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$, $dQ_{5,11} = \lambda_2 e^{-(\lambda_1+\lambda_2+\alpha)t}dt$,
$dQ_{51} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt$, $dQ_{6,12} = \alpha e^{-\alpha t}dt$,
$dQ_{7,13} = dQ_{8,14} = \alpha e^{-\alpha t}dt$, $dQ_{9,15} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt$,
$dQ_{9,16} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt$, $dQ_{90} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt$,
$dQ_{10,4} = dQ_{11,17} = \alpha e^{-\alpha t}dt$, $dQ_{12,18} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt$,

From	S_0	S_0	S_1	S_1	S_1	S_2	S_2	S_2	S_3	S_3	S_3	S_4
To	S_1	S_2	S_3	S_4	S_0	S_0	S_5	S_6	S_2	S_7	S_8	S_9

From	S_5	S_5	S_5	S_6	S_7	S_8	S_9	S_9	S_9	S_{10}
To	S_1	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}	S_0	S_{15}	S_{16}	S_4

From	S_{11}	S_{12}	S_{12}	S_{12}	S_{13}	S_{13}	S_{13}	S_{14}	S_{15}	S_{16}
To	S_{17}	S_0	S_{18}	S_{19}	S_9	S_{10}	S_{20}	S_{12}	S_1	S_2

From	S_{16}	S_{16}	S_{17}	S_{17}	S_{17}	S_{18}	S_{18}	S_{18}	S_{19}	S_{20}
To	S_{21}	S_{22}	S_8	S_{12}	S_{23}	S_1	S_{24}	S_{25}	S_2	S_{26}

From	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}	S_{26}	S_{26}	S_{27}
To	S_5	S_6	S_{26}	S_3	S_4	S_{12}	S_{22}	S_{27}	S_{17}

Table 1: Possible transitions of states

$dQ_{12,19} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{12,0} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{13,10} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt$ $dQ_{13,20} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{13,9} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{14,12} = \alpha e^{-\alpha t}dt,$
$dQ_{15,1} = \alpha e^{-\alpha t}dt,$ $dQ_{16,21} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{16,22} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt$ $dQ_{16,2} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{17,23} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{17,8} = \lambda_2 e^{-(\alpha+\lambda_{11}+\lambda_{12})t}dt,$
$dQ_{17,12} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{18,25} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{18,24} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{18,9} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{19,2} = dQ_{20,26} = \alpha e^{-\alpha t}dt,$ $dQ_{21,5} = \alpha e^{-\alpha t}dt,$
$dQ_{22,6} = dQ_{23,26} = \alpha e^{-\alpha t}dt,$ $dQ_{24,3} = \alpha e^{-\alpha t}dt,$
$dQ_{25,4} = \alpha e^{-\alpha t}dt,$ $dQ_{26,27} = \lambda_1 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{26,22} = \lambda_2 e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$ $dQ_{26,12} = \alpha e^{-(\alpha+\lambda_1+\lambda_2)t}dt,$
$dQ_{27,17} = \alpha e^{-\alpha t}dt$
The nonzero element p_{ij} are given by

$$p_{ij} = \lim_{s\to 0} q^*_{ij}(s).$$

The mean sojourn time μ_i are:

$\mu_0 = \frac{1}{(\lambda_1+\lambda_2)},$
$\mu_1 = \mu_2 = \mu_3 = \mu_5 = \mu_9 = \mu_{12} = \mu_{13} = \mu_{16} = \mu_{17} = \mu_{18} = \frac{1}{(\lambda_1+\lambda_2+\alpha)}$
$\mu_4 = \mu_6 = \mu_7 = \mu_8 = \mu_{10} = \mu_{11} = \mu_{14} = \mu_{15} = \frac{1}{\alpha}$
$\mu_{19} = \mu_{20} = \mu_{21} = \mu_{22} = \mu_{23} = \mu_{24} = \mu_{25} = \mu_{26} = \mu_{27} = \frac{1}{\alpha}$

Sum of the unconditional mean times $\sum m_{ij}$ taken to transit to state j from the state i are: at

$$m_{ij} = \int_0^\infty t dQ_{ij}(t),$$

so that:

$$m_{01} + m_{02} = \mu_0, \quad m_{13} + m_{14} + m_{10} = \mu_1,$$

$$m_{25} + m_{26} + m_{20} = \mu_2, \quad m_{37} + m_{38} + m_{32} = \mu_3,$$

$$m_{49} = \mu_4, \quad m_{5,10} + m_{5,11} + m_{51} = \mu_5, \quad m_{6,12} = \mu_6, m_{7,13} = \mu_7,$$

$$m_{8,14} = \mu_8, \quad m_{9,15} + m_{9,16} + m_{90} = \mu_9, \quad m_{10,4} = \mu_{10},$$

$$m_{11,17} = \mu_{11}, \quad m_{12,18} + m_{12,19} + m_{12,0} = \mu_{12},$$

$$m_{13,10} + m_{13,9} + m_{13,20} = \mu_{13}, \quad m_{14,12} = \mu_{14},$$

$$m_{15,1} = \mu_{15}, \quad m_{16,21} + m_{16,22} + m_{16,22} = \mu_{16},$$

$$m_{17,23} + m_{17,8} + m_{17,27} = \mu_{17}, \quad m_{18,9} + m_{18,24} + m_{18,25} = \mu_{18},$$

$$m_{19,2} = \mu_{19}, \quad m_{20,26} = \mu_{20}, \quad m_{21,5} = \mu_{21}, \quad m_{22,6} = \mu_{22},$$

$$m_{23,26} = \mu_{23}, \quad m_{24,3} = \mu_{24}, \quad m_{25,4} = \mu_{25}, \quad m_{27,17} = \mu_{27}.$$

4. Mean Time to System Failure (MTSF)

Regarding the failed states as absorbing states and employing the arguments used for regenerative process, we have the following recursive relation for MTSF i.e. $\phi_i(t)$:

$$\begin{aligned}
\phi_0(t) =& Q_{01} Ⓢ \phi_1(t) + Q_{02} Ⓢ \phi_2(t), \\
\phi_1(t) =& Q_{13} Ⓢ \phi_3(t) + Q_{10} Ⓢ \phi_0(t) + Q_{14}(t), \\
\phi_2(t) =& Q_{20} Ⓢ \phi_0(t) + Q_{25} Ⓢ \phi_5(t) + Q_{26}(t), \\
\phi_3(t) =& Q_{32} Ⓢ \phi_2(t) + Q_{37}(t) + Q_{38}(t), \\
\phi_5(t) =& Q_{51} Ⓢ \phi_1(t) + Q_{5,10}(t) + Q_{5,11}(t).
\end{aligned}$$

Taking Laplace-stieltjes transforms of equations and solving for $\phi_0^{**}(s)$ using L'Hospital rule we have

$$MTSF = \lim_{s \to 0} \frac{(1 - \phi_0^{**}(s))}{s} = \frac{N}{D},$$

where

$$N = \mu_0(1 - p_{13}p_{32}p_{25}p_{51}) + \mu_1(p_{01} + p_{02}p_{25}p_{51}) + \mu_2(p_{02} + p_{01}p_{13}p_{32}) + \mu_3(p_{01}p_{13} + p_{02}p_{25}p_{51}p_{13}) + \mu_5(p_{02}p_{25} + p_{01}p_{13}p_{32}p_{25}),$$

and

$$D = (1 - p_{02}p_{20} + p_{01}p_{13}p_{32}p_{20} + p_{02}p_{25}p_{51}p_{10} + p_{13}p_{32}p_{25}p_{51} - p_{01}p_{10}).$$

5. Availability Analysis

Using the probabilistic arguments, we have the following recursive relations for $A_i(t)$:
$A_0(t) = M_0(t) + q_{01}(t)©A_0(t) + q_{02}(t)©A_2(t)$
$A_1(t) = M_1(t) + q_{13}(t)©A_3(t) + q_{14}(t)©A_4(t) + q_{10}(t)©A_0(t)$
$A_2(t) = M_2(t) + q_{25}(t)©A_5(t) + q_{26}(t)©A_6(t) + q_{20}(t)©A_0(t)$
$A_3(t) = M_3(t) + q_{32}(t)©A_2(t) + q_{37}(t)©A_7(t) + q_{38}(t)©A_8(t)$
$A_4(t) = q_{49}(t)©A_9(t)$
$A_5(t) = M_5(t) + q_{51}(t)©A_1(t) + q_{5,10}(t)©A_{10}(t) + q_{5,11}(t)©A_{11}(t)$
$A_6(t) = q_{6,12}(t)©A_{12}(t), A_7(t) = q_{7,13}(t)©A_{13}(t)$
$A_8(t) = q_{8,14}(t)©A_{14}(t)$
$A_9(t) = M_9(t) + q_{90}(t)©A_0(t) + q_{9,15}(t)©A_{15}(t) + q_{9,16}(t)©A_{16}(t)$
$A_{10}(t) = q_{10,4}(t)©A_4(t), A_{11}(t) = q_{11,17}(t)©A_{17}(t)$
$A_{12}(t) = M_{12}(t) + q_{12,0}(t)©A_0(t) + q_{12,18}(t)©A_{18}(t) + q_{12,19}(t)©A_{19}(t)$
$A_{13}(t) = M_{13}(t) + q_{13,9}(t)©A_9(t) + q_{13,10}(t)©A_{10}(t) + q_{13,20}(t)©A_{20}(t)$
$A_{14}(t) = q_{14,12}(t)©A_{12}(t), A_{15}(t) = q_{15,1}(t)©A_1(t)$
$A_{16}(t) = M_{16}(t) + q_{26,2}(t)©A_2(t) + q_{16,21}(t)©A_{21}(t) + q_{16,22}(t)©A_{22}(t)$
$A_{17}(t) = M_{17}(t) + q_{17,8}(t)©A_8(t) + q_{17,12}(t)©A_{12}(t) + q_{17,23}(t)©A_{23}(t)$
$A_{18}(t) = M_{18}(t) + q_{18,9}(t)©A_9(t) + q_{18,24}(t)©A_{24}(t) + q_{18,25}(t)©A_{25}(t)$
$A_{19}(t) = q_{19,2}(t)©A_2(t), A_{20}(t) = q_{20,26}(t)©A_{26}(t)$
$A_{21}(t) = q_{21,5}(t)©A_5(t), A_{22}(t) = q_{22,6}(t)©A_6(t)$
$A_{23}(t) = q_{23,26}(t)©A_{26}(t), A_{24}(t) = q_{24,3}(t)©A_3(t)$
$A_{25}(t) = q_{25,4}(t)©A_4(t)$
$A_{26}(t) = M_{26}(t) + q_{26,12}(t)©A_{12}(t) + q_{26,22}(t)©A_{22}(t) + q_{26,27}(t)©A_{27}(t)$
$A_{27}(t) = q_{27,17}(t)©A_{17}(t)$
where
$M_0(t) = e^{-(\lambda_1+\lambda_2)t}dt, M_2(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt,$
$M_3(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt, M_4(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt,$

$M_5(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt, M_6(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt,$
$M_9(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt, M_{12}(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt,$
$M_{13}(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt, M_{17}(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt,$
$M_{18}(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt, M_{26}(t) = e^{-(\lambda_1+\lambda_2+\alpha)t}dt$

Taking Laplace transforms of equations and solving them for $A_0^*(s)$ and then finding the steady state availability of the system (A_0), we have $A_0 = \lim_{s\to 0} sA_0^*(s) = \frac{N_1}{D_1}$

The expression obtained for this availability has not been shown here as the numerator as well as the denominator is the determinants of order 28 each, which have been solved using MAT LAB for particular case taken at the end.

6. Other Measures of System Effectiveness

By probabilistic arguments, other measures of system effectiveness have been obtained and are given as under:

Expected fraction of time during which repairman remains busy in repairing unit $(B_0) = (\frac{N_2}{D_1})$.

Expected number of visits per unit time by the repairman $(V_0) = (\frac{N_3}{D_1})$.

Here N_2, N_3 and D_1 are the determinants of order 28 each and have been solved using MAT LAB for particular case taken at the end.

7. Profit Analysis

Expected profit incurred to system is given by

$$\text{Profit } (P) = C_0A_0\text{-}C_1B_0\text{-}C_2V_0,$$

where: C_0 = Revenue per unit up time,
C_1 = Cost per unit up time for which the repairman is busy for repair,
C_2 = Cost per visit of repairman.

8. Numerical Results and Discussion

Setting

$$\lambda_1 = 0.0011, \quad \lambda_2 = 0.0011, \quad \alpha = 0.125,$$

the values of various measures of system effectiveness are:
MTSF =52350.1666943 hrs,
Availability =0.99983,
Expected busy period of repairman =1.759708629,
Expected number of visits by repairman =1.759708629.

It has been observed from the plotted graph that MTSF as well as Availability (A_0) gets increases with the increase in the values of repair rate (α) and has lower values for higher values of λ_1 .The behavior of profit (P) with respect to revenue per unit up time (C_0) for different values failure rate (λ_1) is depicted in Figure 2.

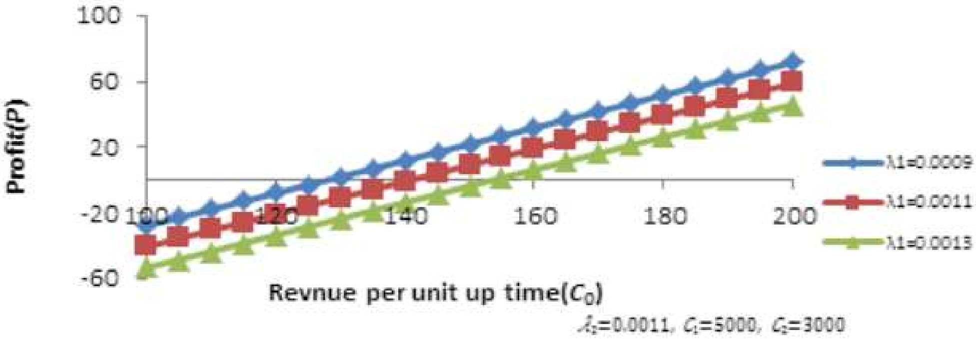

Figure 2: Profit (P) vs Revenue per unit up time (C_0) for different values of Failure Rate (λ_1)

We observe the following from the graph:

The profit increases with the increase in the values of C_0 and has higher for lower values of λ_1.

For λ_1 =0.0009, the profit is positive or zero or negative according as C_0 $>$ or $=$ or $<$ 128 and hence revenue per unit up time should be fixed not less than 128.

For $\lambda_1 = 0.0011$, the profit is positive or zero or negative according as $C_0 >$ or $=$ or $<$ 140.80 and hence revenue per unit up time should be fixed not less than 141.

For $\lambda_1 = 0.0013$, the profit is positive or zero or negative according as C_0 $>$ or $=$ or $<$ 153.6 and hence revenue per unit up time should be fixed not less than 154.

Figure 3 presents the behavior of profit (P) with respect to Failure Rate (λ_1) for different Failure Rate (λ_2). We observe the following from the graph.

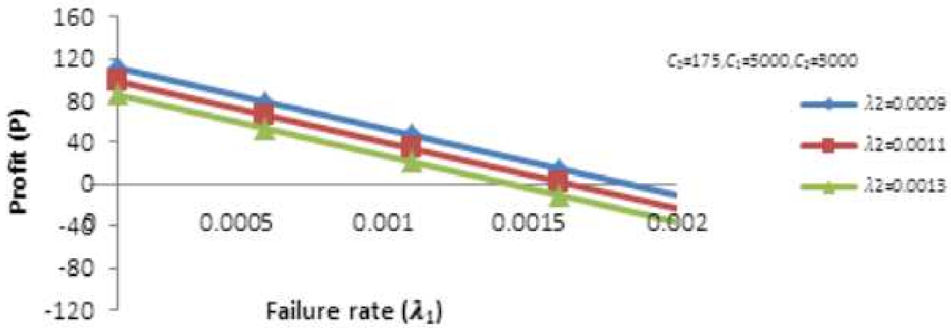

Figure 3: Profit (P) vs Failure rate (λ_1) for different values of Failure rate (λ_2)

The profit decreases with the increase in the values of Failure Rate λ_1 and has higher for lower values of λ_2.

For $\lambda_2 = 0.0009$, the profit is positive or zero or negative according as Failure Rate $\lambda_1 <$ or $=$ or > 0.00185 and hence failure rate should not be greater than 0.00185.

For $\lambda_2 = 0.0011$, the profit is positive or zero or negative according as Failure Rate $\lambda_1 <$ or $=$ or > 0.00162 and hence failure rate should not be greater than 0.00162.

For $\lambda_2 = 0.0013$, the profit is positive or zero or negative according as Failure Rate $\lambda_1 <$ or $=$ or > 0.00142 and hence failure rate should not be greater than 0.00142.

9. Conclusion

In this paper, we have obtained the service availability and other measures of system effectiveness for a 1:1 protection switching scheme. MTSF, availability and the profit decrease as failure rate of working paths or protection paths or both increase but increase as repair rate is increased.

Graphs of Profit versus Revenue per unit up time (C_0) and also the profit versus Failure rate (λ_1) show some cut off points which help in deciding as to when the system profitable and workable. The client who is thinking to install 1:1 protection switching scheme can collect the data for the systems he/she is using and can draw interesting conclusions and process in same way as processed in this paper, which provide him very useful result to take right decision.

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