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Mathematical Based Model on Survivability for WDM Networks

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Abstract-:* Survivability is a new field of research, and is viewed by many as distinct from the traditional areas of security and fault-tolerance. Survivability is the ability of any system to continuously withstand its adequate performance and minimizing the impact of faults, failures and accidents. In the present competitive world of Information Technology where innovation is the key to the sustainability, new systems have to be designed for survivability - capability to serve the purpose in a timely manner and committed Quality of Services (QoS) continuously, striving for the decrease in failures and accidents in the presence of various failure scenarios. The common methods for finding the Survivability of an Information System are ELF (excess loss due to failure), availability model and MRM (Markov reward model). For the application of the above said tool it is assumed that the basic understanding of network topology and link capacity is known in advance. Link represents a fibre in the WDM network and capacity of the link represents the number of wavelength in the link. In this research paper author has made an attempt to find the ELF by using defined capacity and its flow. After finding ELF, availability analysis of each link has been done and Link has been combined with MRM model to evaluate the survivability.
Keywords— WDM, Survivability, ELF (excess loss due to failure).

I. INTRODUCTION

Network survivability estimates the capability of the network to sustain the committed Quality of Services (QoS) continuously in the presence of various failure scenarios. It is an conservatory of the QoS guarantee that the network providers commit to the communication users. In the case of failures, it is very difficult to guarantee such QoS requirements without properly pre-planning additional spare resources. Network survivability techniques include a set of tools to pre-plan and utilize the spare resources to improve the QoS assurance even upon failures. The causes of failures in networks include element defects, software bugs, inadequate maintenance procedures, disasters (lightning, hurricane, earthquake, flood), accidents (backhoe, auto crashes, railroad derailment), and interrupt (hackers, disgruntled employees, foreign powers) [1]. Most of these failure scenarios are hard to forecast and eliminate nevertheless it is possible to mitigate the impact of a set of specific failure scenarios by incorporating of survivability strategies into the network design phase. Traditional network survivability techniques have two aspects, survivable network design and network restoration [2].

A key characteristic of survivable systems is their capability to deliver essential services in the face of attack, failure, or accident [3, 4]. It is important to define minimum levels of such quality attributes that must be associated with essential services. These quality attributes are so important that definitions of survivability are often expressed in terms of maintaining a balance among multiple qualities attributes, such as performance, security, reliability, availability, modifiability, and affordability. Recent advances in optical switching, and in particular, wavelength division multiplexing (WDM) have enabled next generation networks to be able to operate at several tera bits per second [5, 6]. Wavelength routed optical networks consist of optical switching nodes interconnected by one or more fibre links. In such networks, failures (links or nodes) may result in huge data losses due to the enormous bandwidth per fibre. Moreover, survivability in optical networks can be realized by protection (pro-active) or by restoration (reactive) mechanisms. In protection based schemes, each incoming connection request is provided with a primary path and a link-disjoint backup path at setup time. In restoration based schemes, an alternate path is determined only after the failure occurs. A typical approach to the design of survivable networks is through a protection scheme that pre-determines and reserves backup bandwidth considering single, multiple link, node failure scenarios. One of the key challenges in survivable optical networks is to devise strategies to determine primary and backup paths such that the network throughput is maximized and resource consumption is minimized.

II. FAILURE ISSUES OF SURVIVABILITY

Many type of faults often results from external causes, cable cuts are very frequent especially in terrestrial networks since fibre

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cables often share other utility transport conduits such as gas or water pipes and electrical cables. The link failure scenario is the most widely studied scenario. This is mainly due to two factors: it is more prevalent compared to other failures due to the high frequency of fibre cuts and the techniques used to protect against link failures can be extended for other failures, such as node failures. Fibre cuts are a more likely cause for this type of failure. There are two types of failure. Firstly, single link failure which is affected among all the links of the network. This type of failure is the simplest one among the others in terms of implementation of recovery methods. Secondly, multi-link failure links are affected at the same time during a failure. Compared to single link failure this type of failure's recovery methods are difficult to implement.

III. APPROACH TOWARDS RECOVER FROM FAILURE

A link based restoration scheme provides protection or restoration for each link and a local detouring of the failed link is employed during a link failure. Unlike path protection where the end nodes of the connection need to be signaled to handle the failure, the backup path signalling is handled at the end nodes of the link. This will lead to a lower recovery time for link protection when compared to that of path protection. However, link protection is less flexible because the backup paths are usually long and fewer in number, and in wavelength-selective networks, the backup route must use the same wavelength as the primary route, since its working segment is retained [8]. Second, Path based protection, link-disjoint or node-disjoint back up light paths are pre computed and take over when a primary light path fails. In path based restoration, the source and the destination nodes of each connection request (light path) affected by a failure run a distributed RWA algorithm to vigorously determine the backup path and wavelength on an end-to-end basis. If the algorithm finds a free backup light path, the traffic is then routed on that path on appropriate wavelength after signalling its cross-connects. If not, the connection is blocked

IV. NETWORK MODEL FOR SURVIVABILITY

For finding the network Survivability, we have considered a network topology having 5 nodes and 8 links, where each link represents a fibre in the WDM network. With the help of incidence matrix we have prepared flow of the network. Incoming link to a node denoted by -1. Outgoing link from a node denoted by 1.If there is no link between a nodes denoted by 0. The incidence matrix is given below in Table 1.The incidence matrix can be represented the pictorial form given in the fig.4.1. The direction of arrow show the flow e_1, e_2……e_8 shows the link

Table 1: Incidence matrix for 5 node network

	e_1	e_2	e_3	e_4	e_5	e_6	e_7	e_8
Node1	1	0	1	0	0	0	0	0
Node2	-1	1	0	1	0	0	0	-1
Node3	0	-1	0	0	1	1	0	0
Node4	0	0	0	0	0	-1	-1	0
Node5	0	0	-1	-1	1	0	1	1

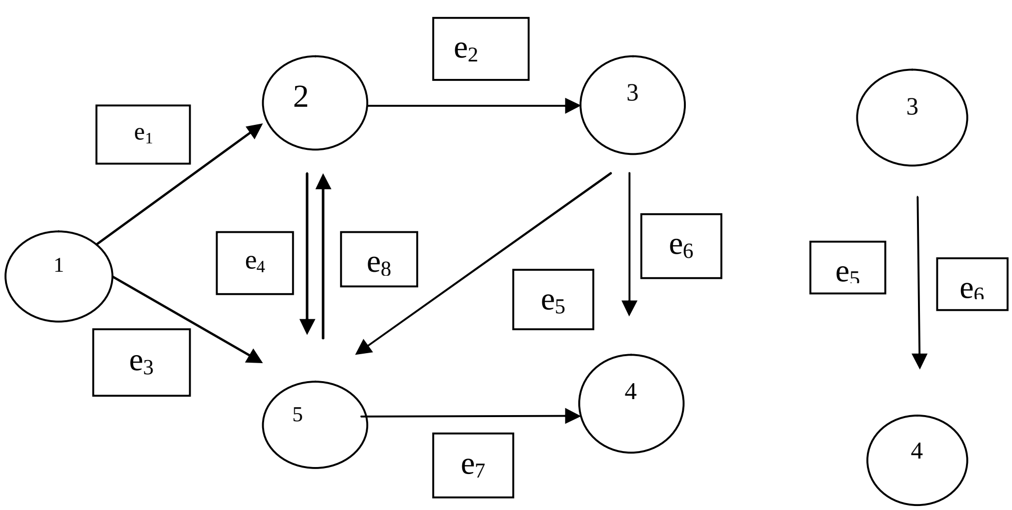

Fig.1 Shows Network model of survivability

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After making a network model, we have to define capacity of each links which represents the number of wavelength in a link. When the link fails between any two nodes, there may be an alternative path which connects these nodes; this alternative path is called the restoration path.

We have considered the capacity and flow of each link as follows: Capacity of link e_1 is 5and flow is 3. Capacity of link e_2 is 5 and flow is 2.Capacity of link e_3 is 7and flow is 4.Capacity of link e_4 is 3and flow is 1.Capacity of link e_5 is 5and flow is 3.Capacity of link e_6 is 4and flow is 2. Capacity of link $e_7$is 6and flow is 4.And Capacity of link e_8 is 3and flow is

Table 2: Restoration paths for each link failure, residual capacity and flow

Failed link	Restoration path	Residual Capacity	Flow
e_1	$\{e_3,e_8\}$	2	3
e_2	_	_	2
e_3	$\{e_1,e_4\},\{e_1,e_2,e_5\}$	2,2	4
e_4	$\{e_2,e_5\}$	2	1
e_5	_	_	3
e_6	$\{e_5,e_7\}$	2	2
e_7	$\{e_3,e_2,e_6\}$	2	4
e_8	_	_	1

The capacity constraint is considered to be greater or equal to the flow of the link.

$F(e_i) \leq Cap(e_i)$ (1)

Here, $f(e_i)$ shows the flow of link and $Cap(e_i)$ shows the capacity constraint of the link. The flow on each link e_i can be increased by as much as

$C_f(e_i) = Cap(e_i) - f(e_i)$ (2)

$C_f(e_i)$ is called the residual capacity of link e_i. When a new path P is established, the increase on all of the links of path *P* must be equal. So $C_f(P)$, the residual capacity of path P, is defined as

$C_f(P) = \{\min\{C_f(e_i)|e_i \in P\}\}$ (3)

ELF (excess loss due to failure) is defined as the fraction of traffic on the link that is not restored after failure:

ELF (ei) = L (ei)/f (ei) (4)

Where Loss L (ei) = f (ei) - Residual capacity (5)

Survivability = 1 – Susceptibility (6) Susceptibility tells how the system is unavailable; we can calculate it by using excess loss due to failure, availability model and Markov reward model.

A. Availability Analysis

Availability analysis tells us that how much a system is available in case of failure. Availability analysis plays a vital role for calculating Survivability. We can say for finding Survivability firstly we have to calculate availability.

1) *Availability Analysis of link e_7*: For availability analysis of link e_7, considering the model given in fig.2.1.We have to build a probabilistic model, using Markov process. There is two path $P_1 = \{e_7\}$, path $P_2 = \{e_8, e_2, e_6\}$.In this model λ is failure rate and μ is repair rate.

$P_r(P_1P_2)$ = Probability when both path$P_1$and path P_2 are available.

$P_r(P_1'P_2)$ =Probability when path P_1 is not available and path P_2 is available.

$P_r(P_1'P_2)$ =Probability when path P_1 is available and path P_2 is not available.

$P_r(P_1'P_2')$ = Probability when both path P_1 and P_2 are not available.

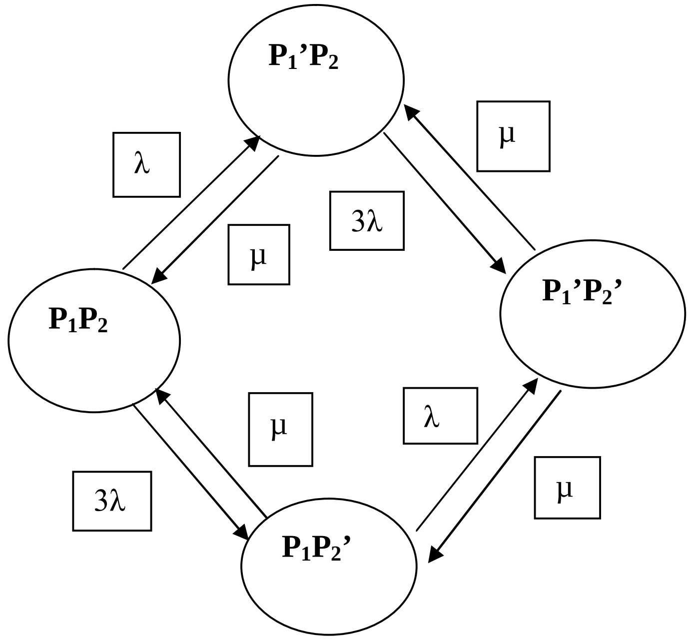

Fig.2 Availability State diagram for link e_7

Path $P_1= \{e_7\}$
Path $P_2= \{e_8, e_2, e_6\}$
At node P_1P_2
Incoming links =Outgoing links
$\lambda P_r (P_1P_2) + 3\lambda P_r(P_1P_2) = \mu[P_r (P_1'P_2) + P_r (P_1P_2')]$
$4\lambda P_r (P_1P_2) = \mu [P_r (P_1'P_2) + P_r (P_1P_2')]$ (7)
At node $P_1'P_2'$
$\mu P_r (P_1'P_2') + \mu P_r (P_1'P_2') = \lambda P_r (P_1P_2') + 3 \lambda P_r (P_1'P_2)$
$2\mu P_rP_1'P_2' = \lambda [P_r(P_1P_2') + 3P_r (P_1'P_2)]$ (8)
At node $P_1'P_2$
$3\lambda P_r (P_1'P_2) + \mu P_r (P_1'P_2) = \mu P_r (P_1'P_2') + \lambda P_r (P_1P_2)$
$[3\lambda+ \mu]P_r (P_1'P_2) = \mu P_r (P_1'P_2') + \lambda P_r (P_1P_2)$ (9)
At node P_1P_2'
$\lambda P_r (P_1P_2') + \mu P_r (P_1P_2') = \mu P_r (P_1'P_2') +3 \lambda P_r (P_1P_2)$
$[\lambda+ \mu] P_1P_2' = \mu P_r (P_1'P_2') +3 \lambda P_r (P_1P_2)$ (10)
$P_r (P_1'P_2) +P_r (P_1'P_2') +P_r (P_1P_2') + P_r (P_1P_2) =1$ (11)
By solving equation 1, 2, 3, 4, 5, we get
$P_r (P_1P_2) = (\mu^2/3\lambda^2)P_r (P_1'P_2')$ (12)
$P_r (P_1'P_2) =(\mu/3\lambda)P_r (P_1'P_2')$ (13)
$P_r (P_1P_2') = (\mu/\lambda)P_r (P_1'P_2')$ (14)
$P_r (P_1'P_2') = [3\lambda^2/ (\mu^2 +4\mu\lambda + 3\lambda^2)]$ (15)

Similarly we can do the availability analysis of each link. We have proposed a network model and by using probabilistic theory after obtaining the availability analysis in the event of each different link failures, we have computed the survivability. With the results of Availability analysis and ELF we find out the Survivability of each link, which is done using the Markov reward model to the survivability.

V. RESULTS AND DISCUSSION

We find the Availability, ELF (excess loss due to failure) and Survivability by using Matlab tool using Matlab mathematical codes.

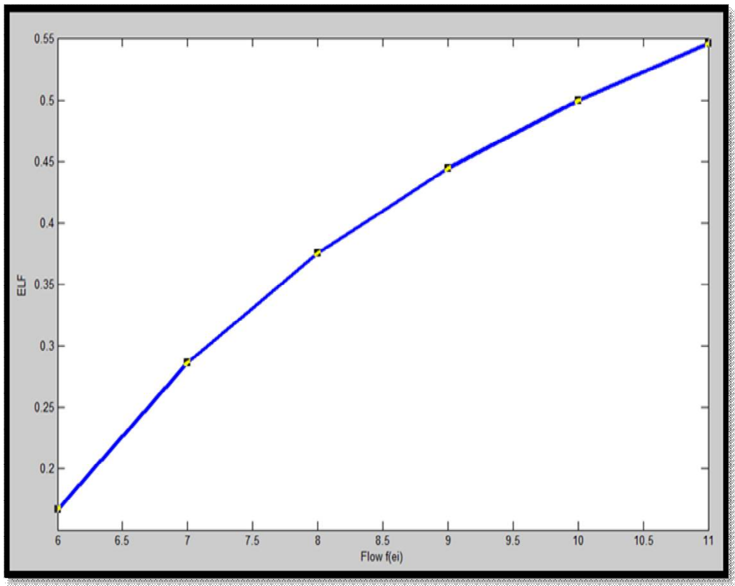

Fig.3 ELF Vs Flow

ELF (excess loss due to failure) is basically degradation system performance in the event of failure. ELF is depends upon the capacity and flow of the link, Here ELF is calculated using Matlab tool by using mathematical formulae. Fig.3 shows how ELF depends upon the flow .As we know Flow is a function of ELF In the fig.3, we see that as we increase the Flow the ELF (excess loss due failure) is increases. Availability tells us how a system is available in failure condition. As we know that the Availability depends upon the Failure rate (λ) and Repair rateμ. Steady state availability is given as

$A= [\mu/ (\mu+\lambda)]$

As we know Availability is depends upon the failure rate. There is high impact on Availability with the changes in Failure rate .Here we analyse the availability behaviour with reference to failure rate by using Matlab tool. In fig.4, we see as we increase the failure rate kept repair rate constant the Steady state Availability is decreases.

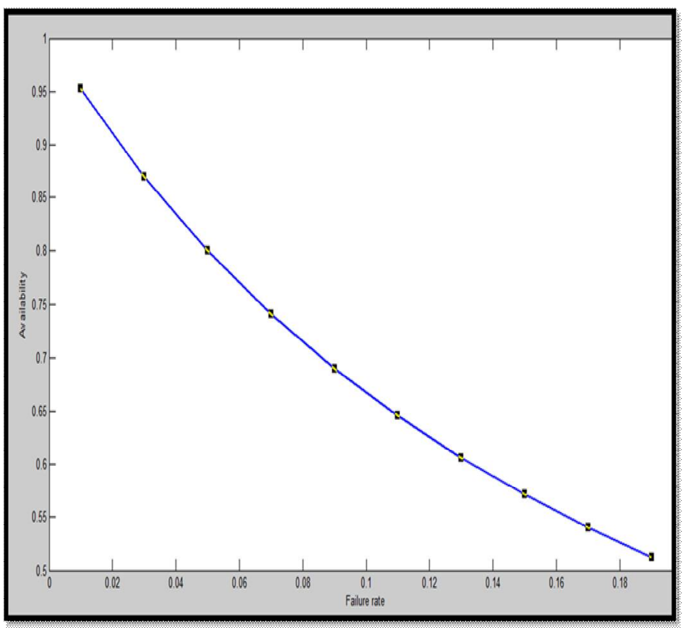

Fig.4 Avaiblity vs Failure rate

S_1 for link e_1,S_2 for link e_2,S_4 for link e_4,S_5 for link e_5,S_6 for link e_6,S_7 for link e_7 and S_8 for link e_8. When Failure rate λ= 0.02 and Repair rate μ=0.2.

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Table 3: Show results of ELF and Survivability

Failed Link (e_i)	Excess loss due to failure 39/(ELF_i)	Survivability (S_i)
e_1	0.3333	0.9596
e_2	1	0.9091
e_4	0	0.9848
e_5	1	0.9091
e_6	0	0.9848
e_7	0.5000	0.9441
e_8	1	0.9524

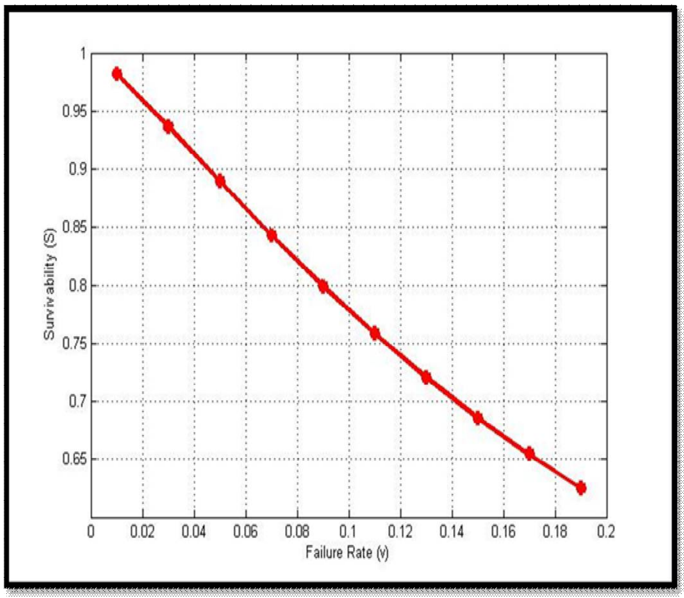

Fig.5 Survivability Vs Failure rate

In Fig.5, it is shown as the Failure rate increases the survivability is decreases with constant repair rate. We calculate the Survivability by using Survivability formulation with the help of matlab tool in different failure rates.

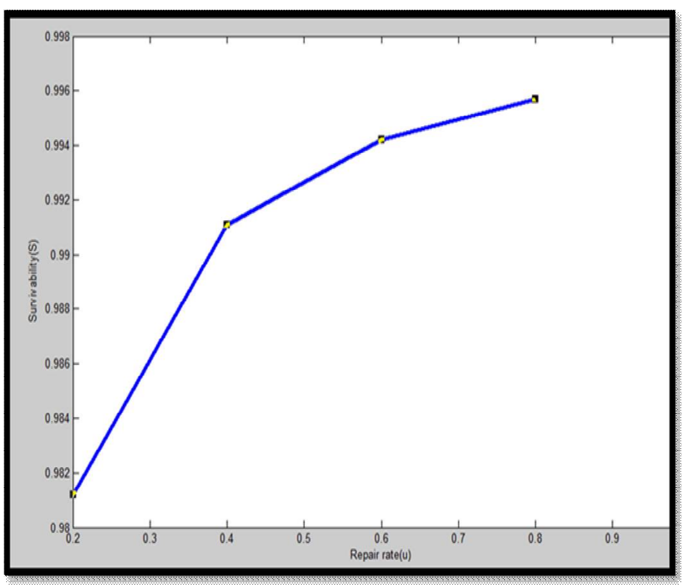

Fig.6 Survivability vs Repair Rate

In Fig.6, it is shown as the Repair rate increases the Survivability increases. As we know Survivability depends upon both repair rate and failure rate. When Failure rate are kept constant, than the Survivability only depends upon the Repair rate. Survivability is calculated using Matlab in different values of Repair rate and the behaviour of Survivability with increasing Repair rate is shown in Fig 5.4.

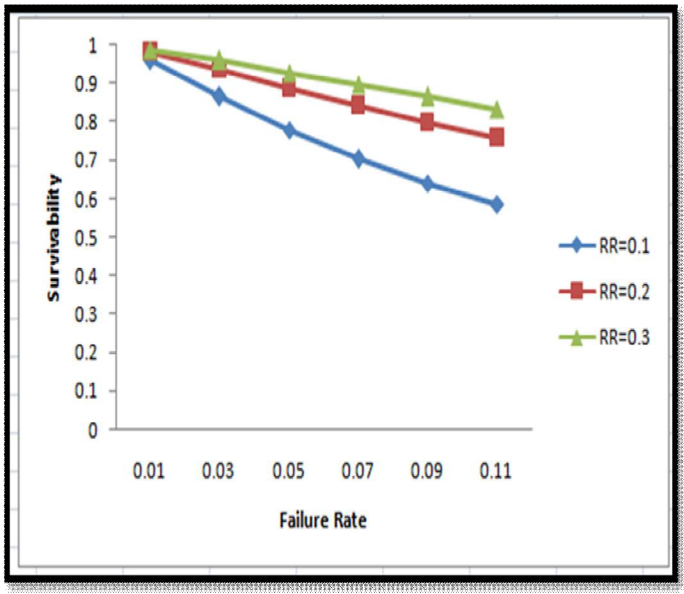

Fig.7 Survivability versus Failure rate with different Repair rate

We analysed the Survivability with different Repair rates (constant Failure rate). We use three different Repair rates RR=0.1, RR=0.2, RR=0.3.In the Fig. 7 we see the Survivability at RR=0.3 have more values than others RR=0.1 and RR=0.2 in different failure conditions.

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