International Journal of Emerging Engineering Research and Technology
Volume 4, Issue 5, May 2016, PP 10-19
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Formation of Virtual Topology on Fiber Optic Networks with HLDA on Link Failure Networks- a Comparative Study

Y.Rama Mohan[1], V.Raghunatha Reddy[2]

[1] *CSE Department, G.Pulla Reddy Engineering College, Kurnool, India (Assistant Professor)*
[2]*Department of Computer Science, S.K.U Engineering College, Ananthapuram, India (Assistant Professor)*

ABSTRACT

Fiber optic networks- WDM technology - The formation of virtual topology on existing physical network- Link failure transfer of data loss of network - Heuristic logical design Algorithm (HLDA) implemented to find shortest path varying number of optical transceivers. A study on 4-node, 7-node and 14-node NSFNET traffic matrices- A study of performance evaluation

Keywords: Optical Fiber, WDM, Virtual topology, Link failure

INTRODUCTION

Optical fiber is a predominant transport medium in telecommunication systems considering that of its benefits in capability, reliability, cost, and scalability. An appealing characteristic of optical fiber is its enormously big capability, on the order of some terabits per second. The fiber optic medium is the one equipped of supplying high-bandwidth service cost-effortlessly. In these days, optical fiber is broadly deployed in backbone networks. Nevertheless, simplest a small fraction of the full ability of the mounted optical fiber has been realized as a consequence some distance. The optical networks are applied utilizing Wavelength Division Multiplexing (WDM) techniques for high speed wide area networks. In a WDM optical network the fiber link carries many wavelength and data packets transmitted laterally light paths. Even as transmitting packets from source to destination, the dissimilar wavelength variety is used for communication between two nodes. But it is not supported by all the links, in that case the wavelength continuity constraint occurs. It is rectified by wavelength converters to support different range of wavelengths most common disasters took place in an optical network is cuts in the fibers, since optical links carry a high volume of data.

In an optical network, even as communication from source to destination or from one node to another node there arise certain problems the predicament are: 1.Disjoint 2.Wavelength continuity constraint. These disjoints have to be rectified and it need to fulfil the wavelength continuity constraint i.e. every node must support same wavelength. These issues may also be overcome by using wavelength converter.

Failures in communication networks are common and can result in tremendous losses in the late 1980s, the AT&T telephone network encountered a number of extremely publicized failures [1], [2]. In a single case, much of the long distance service along the East Coast of the U.S. was disrupted when a construction crew accidentally severed a major fiber optic cable in New Jersey. As a result, 3.5M call attempts were blocked. On one more social gathering, of the 148M calls placed during the nine-hour-long period of the failure, only half went through, resulting in tens of millions of dollars' worth of collateral damage for AT&T as well as many of its major customers.

A failure of an optical network element, e.g., due to a fiber cut or a node failure, can lead to a large loss of capacity. At present information society relies increasingly on advanced communication networks. This has lead to massive investments in increased *communication* network capacity. In order to utilize these investments the network operators perform *traffic engineering*, i.e., route communication in order to maximize the utilization of the capital invested in the communication

Address for correspondence:

yrmgprec@gmail.com

network. Here we will consider traffic engineering of circuit switched networks where protection against single link failures is required.

For critical applications that require rapid service recovery, many protection schemes have been proposed. However, many applications can tolerate short term outages and can be exempt from the added expense of providing protection. These applications can then be classified under best-effort traffic, which is rerouted when there is a failure. This process can take seconds to minutes in contrast to protected traffic with rapid recovery (50 to 100ms). Differentiating traffic based on the level of survivability on IP/GMPLS networks has been studied in the past to take advantage of the cost saving opportunity the different types of traffic presents the impact of link failures on a dynamically routed network, beyond the initial failure management stage (where broken connections are rerouted). First, we start with the re reputability ratio of failed connections on a well dimensioned (low blocking with balanced capacity) network. We then Quantify the longer term impact of link failures, which we show is critical to network performance

Preferably, each message is transmitted from the source to a destination without any optical to-electronic conversion within the network. Such all-optical communication can be comprehended by using a single wavelength in the multicast tree to establish a connection to each destination, but in general it may not be possible to find a single wavelength which is available on every physical link in the tree. Otherwise, all-optical wavelength converters may be used to convert from one wavelength to another within the network but such converters are prospective to be excessively exclusive for most applications in the predictable future

A second approach is to use multi-hop routing in which a path from the source to a destination may include multiple sub paths which may use different wavelengths. In this tactic a set of light-paths or light-trees are entrenched in the multicast tree. A light-path is a path including channels on a single wavelength. The message is transmitted at the origin of the light-path on a particular wavelength. Within a light-path, transmission is entirely optical. At the terminus of a light-path the data is converted into electronic form and is delivered to the local node if it is a destination node. In addition, the data may be retransmitted at this node on one or more light-paths to reach other destination nodes. Intermediate nodes on a light-path allow the data to pass through optically, but do not necessarily access the data themselves. Thus, a single light-path from node x to z passing through intermediate node y is different from two light-paths, one from x to y and one from y to z, even if these two light-paths use the same wavelength. Similarly, light-trees are a generalization of light-paths in which the source of the light-tree transmits the data on a particular wavelength and this may be split in a tree-like fashion to reach multiple nodes. The collection of light-paths or light-trees is called the virtual topology.

Demand for dynamic scaling and benefits from economies of scale are driving the creation of mega data centres to host a broad range of services such as Web search, e-commerce, storage backup, video streaming, high-performance computing, and data analytics. To host these applications, data centre networks need to be scalable, efficient, fault tolerant, and easy-to-manage. Recognizing this need, the research community has proposed several architectures to improve scalability and performance of data centre networks [3, 4, 5, 6, 7, 8]. However, the issue of reliability has remained unaddressed, mainly due to a dearth of available empirical data on failures in these networks

PROPOSED WORK

The set of light paths established over a physical topology forms a virtual topology. The higher layer in a transport network makes use of the virtual topology on the optical path layer for message transmission. Virtual topology is also referred to as a logical topology or as a light path network consisting of a set of nodes and the set of physical links in opposite directions. In a multi fiber network, a physical link between two nodes consists of a bundle of fiber links. Every fiber link carries a specific number of wavelengths

In a virtual topology, the nodes correspond to the network nodes and the edges correspond to light paths. The in-degree of a node in a virtual topology is the number of light paths incident on the node. The out-degree of a node in a virtual topology is the number of light paths leaving the node. Consider a node with physical in-degree D^p_{in} and physical out-degree $D^p_{out.}$ In a virtual topology, the in-degree D^v_{in} of this node can be at most W x D^p_{in} and the out-degree D^v_{out} of this node can be at most W X D^p_{out}. Here, W is the number of wavelengths available on a fiber link.

In a case the link failure occurs in physical topology, the formation of virtual topology pardon occurs. We observed different traffic matrices, the checked different link failures occurs here 4-node traffic matrices, 7-node traffic matrices and 14-node traffic matrices for different link failures and different objective functions light paths, Wavelengths, Hop weight, Average Hop weight, Max-congestion and Min congestion

$$\begin{bmatrix} 0 & 8 & 7 & \infty \\ 10 & 0 & \infty & 8 \\ 7 & \infty & 0 & 5 \\ \infty & 3 & 9 & 0 \end{bmatrix}$$

In the above Traffic Matrix 4-Node Traffic Matrix

$$\begin{bmatrix} 0 & 8 & 7 & \infty \\ 10 & 0 & \infty & 0 \\ 7 & \infty & 0 & 5 \\ \infty & 3 & 9 & 0 \end{bmatrix}$$

In the above Traffic Matrix 4-Node one Link Failure that is 2->4(8)

$$\begin{bmatrix} 0 & 8 & 0 & \infty \\ 10 & 0 & \infty & 0 \\ 7 & \infty & 0 & 5 \\ \infty & 3 & 9 & 0 \end{bmatrix}$$

The above Traffic Matrix 4-Node the two Link Failures that is 2->4(8) and 1->3(7)

In table 1 implementation of HLDA on 4-node up to 2 transceivers shows the results up to two link failures obtained for several objective functions like the utilization of Light paths, Wave Lengths, Hop Weight, Average hop Weight, Maximum Congestion and Minimum Congestion

Table1. *4-Node after Link Failure for HLDA*

4-node	trans	light paths	Wave lengths	Hop weight	Avg Hop weight	Max-congestion	Min congestion
HLDA	1	4	0	32	1	1 -> 0 (10)	2 ->3(5)
	2	8	1	57	1	1 -> 0 (10)	3 ->1(3)
HLDA-lk1	1	4	0	32	1	1 -> 0 (10)	2 ->3(5)
	2	7	1	49	1	1 -> 0 (10)	3 ->1(3)
HLDA-lk2	1	4	0	32	1	1 -> 0 (10)	2 ->3(5)
	2	6	1	42	1	1 -> 0 (10)	3 ->1(3)

$$\begin{matrix} 0 & 7 & \infty & 5 & \infty & \infty & \infty \\ \infty & 0 & \infty & 3 & 10 & \infty & \infty \\ 4 & \infty & 0 & \infty & \infty & \infty & \infty \\ 0 & 0 & 12 & 0 & 2 & 8 & 9 \\ \infty & \infty & \infty & \infty & 0 & \infty & 6 \\ \infty & \infty & 13 & \infty & \infty & 0 & \infty \\ \infty & \infty & \infty & \infty & \infty & 10 & 0 \end{matrix}$$

In the above traffic matrix is 7-node traffic matrix

0	7	∞	5	∞	∞	∞
∞	0	∞	3	10	∞	∞
4	∞	0	∞	∞	∞	∞
0	0	12	0	2	0	9
∞	∞	∞	∞	0	∞	6
∞	∞	13	∞	∞	0	∞
∞	∞	∞	∞	∞	10	0

In the above traffic matrix is 7-node one link failure occurs then the failure link is 4->6 (8)

0	7	∞	5	∞	∞	∞
∞	0	∞	3	10	∞	∞
4	∞	0	∞	∞	∞	∞
0	0	12	0	2	0	9
∞	∞	∞	∞	0	∞	6
∞	∞	0	∞	∞	0	∞
∞	∞	∞	∞	∞	10	0

In the above traffic matrix is 7-node two link failures occurs then the 4->6 (8) and 6->3(13) two link failures

0	7	∞	0	∞	∞	∞
∞	0	∞	3	10	∞	∞
4	∞	0	∞	∞	∞	∞
0	0	12	0	2	0	9
∞	∞	∞	∞	0	∞	6
∞	∞	0	∞	∞	0	∞
∞	∞	∞	∞	∞	10	0

In the above traffic matrix is the three link failures occurs then 4->6(8), 6->3 (13) and 1->4 (5) three link failures

Table2. *7-Node after Link Failure for HLDA*

7-Node	trans	Light paths	Wave lengths	Hop weight	Avg hops	Max-congestion	Min congestion
HLDA	1	6	0	53	1	5 -> 2 (13)	2 ->0(4)
	2	12	2	93	1	6 -> 5 (20)	1 ->3(3)
	3	16	4	127	1	5 -> 2 (26)	1 ->3(3)
	4	19	7	154	1	6 -> 5 (30)	1 ->3(3)
HLDA-lk1	1	6	0	53	1	5 -> 2 (13)	2 ->0(4)
	2	12	2	93	1	6 -> 5 (20)	1 ->3(3)
	3	17	5	131	1	6 -> 5 (30)	3 ->4(2)
	4	20	9	158	1	6 -> 5 (40)	3 ->4(2)
HLDA-lk2	1	6	0	49	1	3 -> 2 (12)	2 ->0(4)
	2	11	2	80	1	6 -> 5 (20)	1 ->3(3)
	3	16	5	118	1	6 -> 5 (30)	0 ->3(5)
	4	19	9	135	1	6 -> 5 (40)	3 ->4(2)
HLDA-lk3	1	6	0	49	1	3 -> 2 (12)	2 ->0(4)
	2	11	2	82	1	6 -> 5 (20)	1 ->3(3)
	3	15	5	113	1	6 -> 5 (30)	1 ->3(6)
	4	18	9	131	1	6 -> 5 (40)	3 ->4(2)

In the above Table 2 implementing HLDA on 7-node up to 4 transceivers shows the results up to three link failures obtained for several objective functions like the utilization of Light paths, Wave Lengths, Hop Weight, Average hop Weight, Maximum Congestion and Minimum Congestion

0	93	89	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
39	0	14	77	∞	∞	∞	∞	∞	∞	44	∞	∞	∞
78	∞	0	∞	∞	39	∞	∞	∞	∞	∞	43	98	∞
∞	5	∞	0	∞	∞	33	∞	25	∞	∞	∞	∞	∞
∞	26	∞	∞	0	∞	∞	28	∞	23	∞	∞	∞	∞
∞	∞	7	∞	∞	0	∞	97	40	∞	∞	∞	∞	∞
∞	∞	∞	61	∞	∞	0	∞	∞	36	∞	∞	∞	42
∞	∞	∞	∞	61	49	∞	0	∞	17	∞	∞	∞	∞
∞	∞	∞	12	∞	57	∞	∞	0	∞	∞	∞	∞	∞
∞	∞	∞	∞	42	∞	97	47	∞	0	∞	∞	∞	∞
∞	29	∞	∞	∞	∞	∞	∞	∞	∞	0	41	28	∞
∞	∞	54	∞	∞	∞	∞	∞	∞	∞	63	0	∞	87
∞	∞	26	∞	∞	∞	∞	∞	∞	∞	81	∞	0	3
∞	∞	∞	∞	∞	∞	43	∞	∞	∞	∞	4	58	0

In the above Traffic Matrix Is 14-Node Traffic Matrix

0	93	89	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
39	0	14	77	∞	∞	∞	∞	∞	∞	44	∞	∞	∞
78	∞	0	∞	∞	39	∞	∞	∞	∞	∞	43	98	∞
∞	5	∞	0	∞	∞	33	∞	25	∞	∞	∞	∞	∞
∞	26	∞	∞	0	∞	∞	28	∞	23	∞	∞	∞	∞
∞	∞	7	∞	∞	0	∞	97	40	∞	∞	∞	∞	∞
∞	∞	∞	61	∞	∞	0	∞	∞	36	∞	∞	∞	42
∞	∞	∞	∞	61	49	∞	0	∞	17	∞	∞	∞	∞
∞	∞	∞	12	∞	57	∞	∞	0	∞	∞	∞	∞	∞
∞	∞	∞	∞	42	∞	97	47	∞	0	∞	∞	∞	∞
∞	29	∞	∞	∞	∞	∞	∞	∞	∞	0	41	28	∞
∞	∞	54	∞	∞	∞	∞	∞	∞	∞	63	0	∞	87
∞	∞	26	∞	∞	∞	∞	∞	∞	∞	0	∞	0	3
∞	∞	∞	∞	∞	∞	43	∞	∞	∞	∞	4	58	0

In the above traffic matrix is14-node traffic matrix then one link failure that is 13->11 (81)

0	93	89	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
39	0	14	77	∞	∞	∞	∞	∞	∞	44	∞	∞	∞
78	∞	0	∞	∞	39	∞	∞	∞	∞	∞	43	98	∞
∞	5	∞	0	∞	∞	33	∞	25	∞	∞	∞	∞	∞
∞	26	∞	∞	0	∞	∞	28	∞	23	∞	∞	∞	∞
∞	∞	7	∞	∞	0	∞	97	40	∞	∞	∞	∞	∞
∞	∞	∞	61	∞	∞	0	∞	∞	36	∞	∞	∞	42
∞	∞	∞	∞	61	49	∞	0	∞	17	∞	∞	∞	∞
∞	∞	∞	12	∞	57	∞	∞	0	∞	∞	∞	∞	∞
∞	∞	∞	∞	42	∞	97	47	∞	0	∞	∞	∞	∞
∞	29	∞	∞	∞	∞	∞	∞	∞	∞	0	41	28	∞
∞	∞	54	∞	∞	∞	∞	∞	∞	∞	63	0	∞	87
∞	∞	26	∞	∞	∞	∞	∞	∞	∞	0	∞	0	0
∞	∞	∞	∞	∞	∞	43	∞	∞	∞	∞	4	58	0

In the above traffic matrix is14-node traffic matrix then two links failures that is 13->11(81) and 13->14 (3)

0	93	89	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
39	0	14	77	∞	∞	∞	∞	∞	∞	44	∞	∞	∞
78	∞	0	∞	∞	39	∞	∞	∞	∞	∞	43	98	∞
∞	5	∞	0	∞	∞	33	∞	25	∞	∞	∞	∞	∞
∞	26	∞	∞	0	∞	∞	28	∞	23	∞	∞	∞	∞
∞	∞	7	∞	∞	0	∞	97	40	∞	∞	∞	∞	∞
∞	∞	∞	61	∞	∞	0	∞	∞	36	∞	∞	∞	42
∞	∞	∞	∞	61	49	∞	0	∞	17	∞	∞	∞	∞
∞	∞	∞	12	∞	57	∞	∞	0	∞	∞	∞	∞	∞
∞	∞	∞	∞	42	∞	97	0	∞	0	∞	∞	∞	∞
∞	29	∞	∞	∞	∞	∞	∞	∞	∞	0	41	28	∞
∞	∞	54	∞	∞	∞	∞	∞	∞	∞	63	0	∞	87
∞	∞	26	∞	∞	∞	∞	∞	∞	∞	0	∞	0	0
∞	∞	∞	∞	∞	∞	43	∞	∞	∞	∞	4	58	0

In the above traffic matrix is14-node traffic matrix then three links failures that is 3->11(81), 13->14 (3) and 10 ->8 (47)

0	93	89	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞	∞
39	0	14	77	∞	∞	∞	∞	∞	∞	44	∞	∞	∞
78	∞	0	∞	∞	39	∞	∞	∞	∞	∞	43	98	∞
∞	5	∞	0	∞	∞	33	∞	25	∞	∞	∞	∞	∞
∞	26	∞	∞	0	∞	∞	28	∞	23	∞	∞	∞	∞
∞	∞	7	∞	∞	0	∞	97	40	∞	∞	∞	∞	∞
∞	∞	∞	61	∞	∞	0	∞	∞	36	∞	∞	∞	42
∞	∞	∞	∞	61	49	∞	0	∞	17	∞	∞	∞	∞
∞	∞	∞	12	∞	57	∞	∞	0	∞	∞	∞	∞	∞
∞	∞	∞	∞	42	∞	97	0	∞	0	∞	∞	∞	∞
∞	29	∞	∞	∞	∞	∞	∞	∞	∞	0	41	28	∞
∞	∞	54	∞	∞	∞	∞	∞	∞	∞	63	0	∞	87
∞	∞	0	∞	∞	∞	∞	∞	∞	∞	0	∞	0	0
∞	∞	∞	∞	∞	∞	43	∞	∞	∞	∞	4	58	0

In the above traffic matrix is14-node traffic matrix then four links failures that is 13->11(81), 13->14 (3), 10 ->8 (47) and 13->3(26)

Table3. *14-Node (NSFNET) after Link Failure for HLDA*

14-node	node	trans	Light paths	Wave lengths	hop-wei	avg-hop	max-con	min-con
HLDA	14	1	12	0	837	1	2 -> 12 (98)	4 ->9(23)
	14	2	27	2	1536	1	2 -> 12 (98)	8 ->3(12)
	14	3	40	3	1908	1	2 -> 12 (98)	12->13(3)
	14	4	54	5	2522	1	0 -> 1 (186)	12 ->13(3)
HLDA-lk1	14	1	12	0	782	1	2 -> 12 (98)	4 ->9(23)
	14	2	26	2	1460	1	2 -> 12 (98)	8 ->3(12)
	14	3	39	3	1827	1	2 -> 12 (98)	12 ->13(3)
	14	4	52	5	2360	1	0 -> 1 (186)	12 ->13(3)
HLDA-lk2	14	1	12	0	782	1	2 -> 12 (98)	4 ->9(23)
	14	2	26	2	1460	1	2 -> 12 (98)	8 ->3(12)
	14	3	38	3	1824	1	2 -> 12 (98)	13 ->11(4)
	14	4	51	5	2357	1	0 -> 1 (186)	5 ->2(7)
HLDA-lk3	14	1	12	0	782	1	2 -> 12 (98)	4 ->9(23)
	14	2	25	1	1418	1	2 -> 12 (98)	8 ->3(12)
	14	3	37	3	1777	1	2 -> 12 (98)	13 ->11(4)
	14	4	49	5	2236	1	0 -> 1 (186)	5 ->2(7)
HLDA-lk4	14	1	11	0	756	1	2-> 12 (98)	4->9(23)
	14	2	24	1	1392	1	2-> 12 (98)	8->3(12)
	14	3	37	3	1758	1	2-> 12 (98)	13->11 (4)
	14	4	49	5	2299	1	0-> 1 (186)	5->2 (7)

In table 3 implementing HLDA on 14-node up to 4 transceivers shows the results up to four link failures obtained for several objective functions like the utilization of Light paths, Wave Lengths, Hop Weight, Average hop Weight, Maximum Congestion and Minimum Congestion

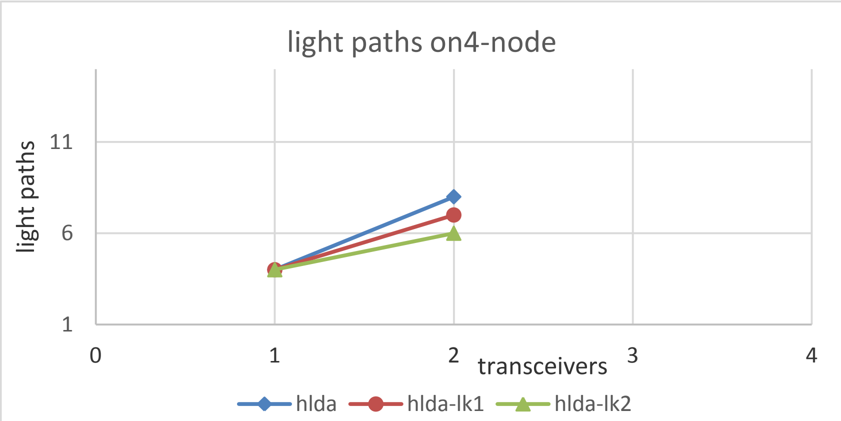

Figure1. *4-node light paths Vs transceivers*

In the above figure utilization of light paths on 4-node with 2 transceivers with HLDA with link failures1 and link failures2

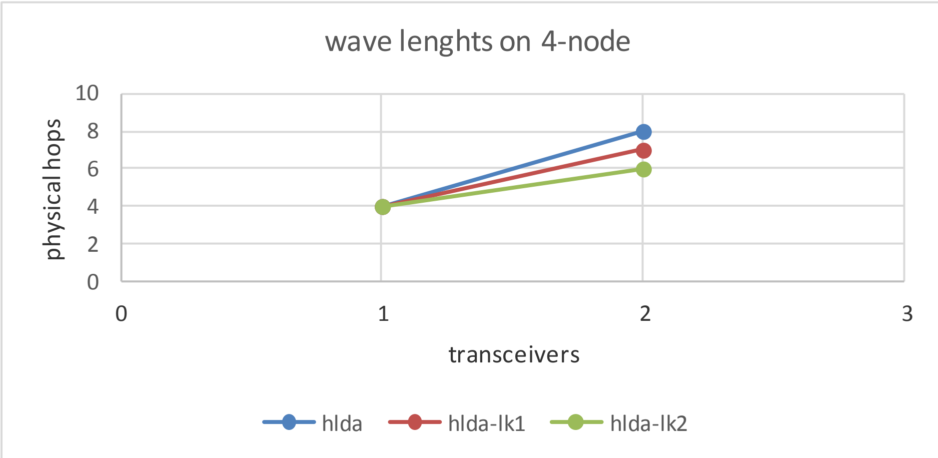

Figure2. *4-node wave lengths Vs transceivers*

In the above figure utilisation of wave lengths on 4-node with 2 transceivers with HLDA with link failures1 and link failures2

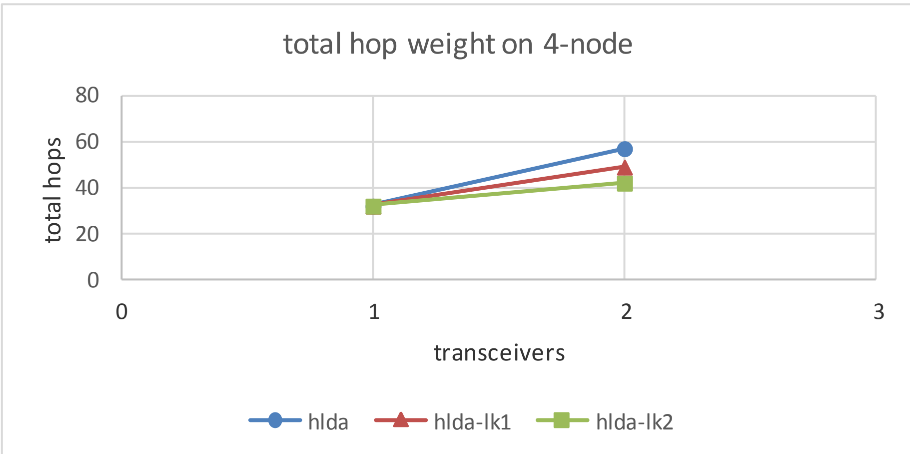

Figure3. *4-node total hop weight Vs transceivers*

In the above figure usage of hop weight on 4-node with 2 transceivers with HLDA with link failures1 and link failures2

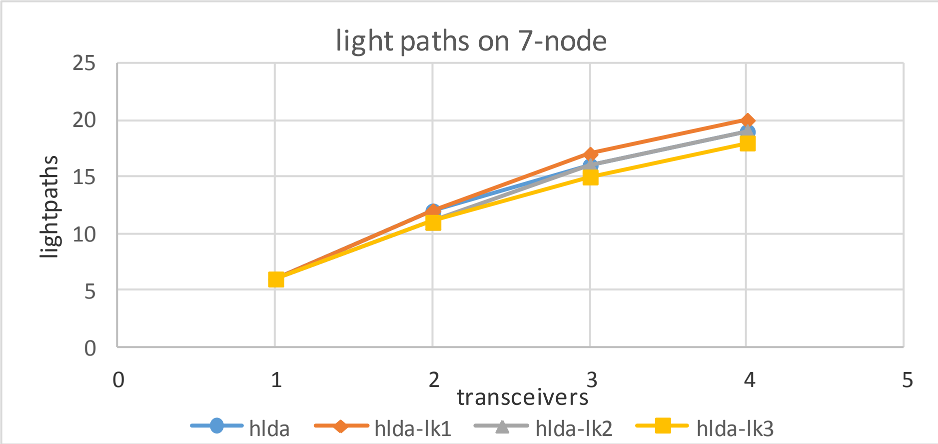

Figure4. *7-node light paths Vs transceivers*

In the above figure utilization of light paths on 7-node with 4 transceivers with HLDA with link failures1, link failures2 and link failure3

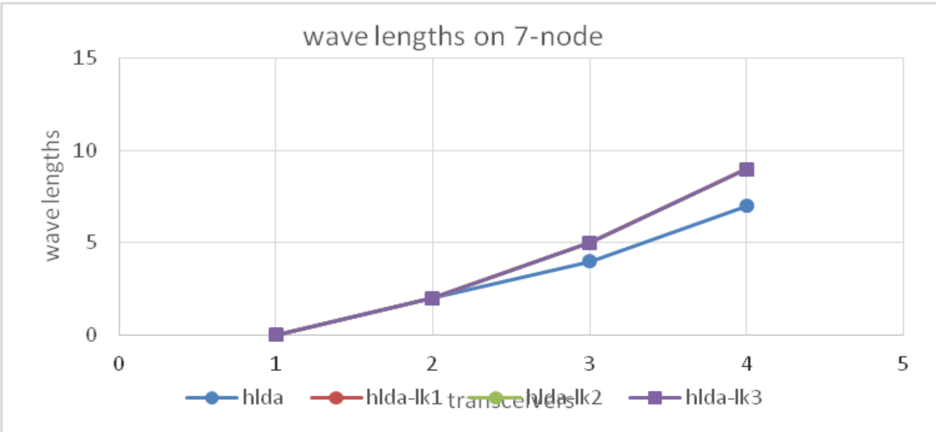

Figure5. *7-node wave lengths Vs transceivers*

In the above figure utilization of wave lengths on 7-node with 4 transceivers with HLDA with link failures1, link failures2 and link failure3

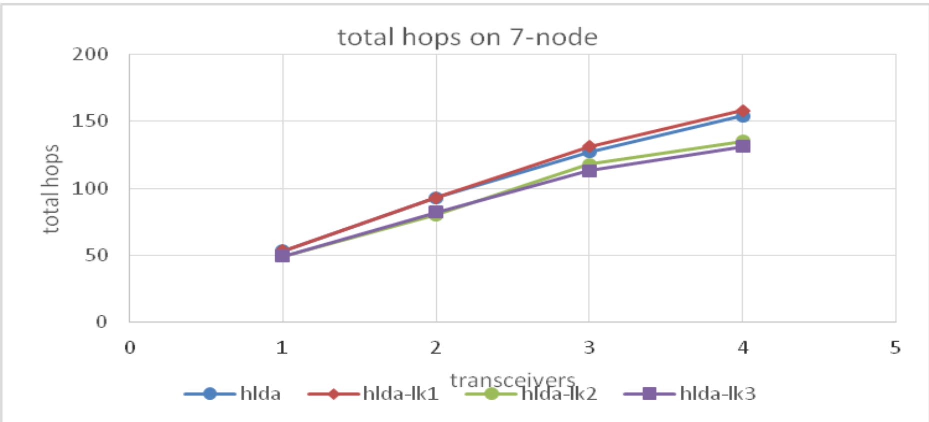

Figure6. *7-node total hop weight Vs transceivers*

In the above figure usage of hop weight on 7-node with 4 transceivers with HLDA with link failures1, link failures2 and link failure3

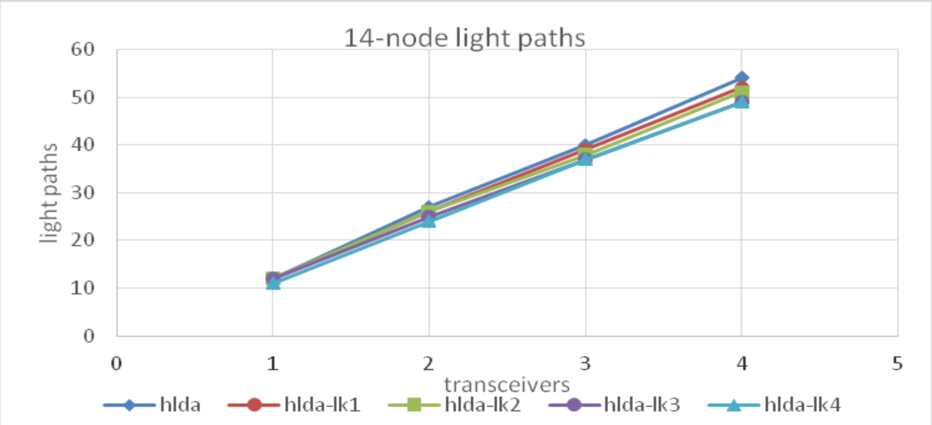

Figure7. *14-Node (NSFNET) Light Paths Vs Transceivers*

In the above figure utilization of light paths on 14-node with 4 transceivers with HLDA with link failures1, link failures2, link failure3 and link failure 4

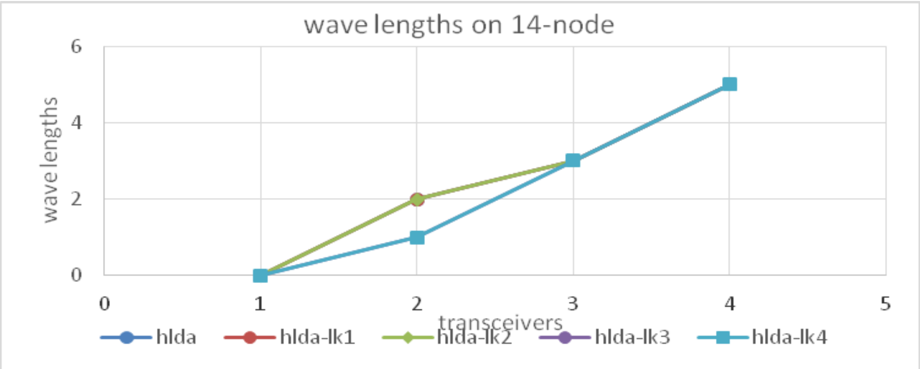

Figure8. *14-Node (NSFNET) Wave Lengths Vs Transceivers*

In the above figure utilization of wave lengths on 14-node with 4 transceivers with HLDA with link failures1, link failures2, link failure3 and link failure 4

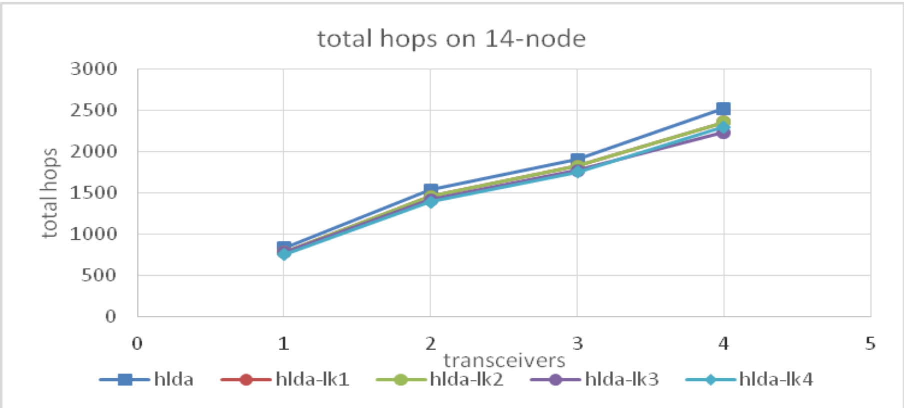

Figure9. *14-Node (NSFNET) Total Hop Weight Vs Transceivers*

In the above figure usage of hop weight on 14-node with 4 transceivers with HLDA with link failures1, link failures2, link failure3 and link failure 4

CONCLUSION

In this paper Heuristic logical design Algorithm (HLDA) is implemented to find shortest path on Link failure Optical Fiber Networks. This is implemented by varying Opto Electric Converters. The Performance of variation is observed on 4-node, 7-node and 14-node NSFNET traffic matrices. The path effectiveness is observed by meeting the different objective functions such as utilization of Light paths, Wave Lengths, Hop Weight.

Figs: 1 to 3: On 4-node Network with two link failures maximum wave lengths utilization observed but light paths total hop weight utilization is reduced.

Figs: 4 to 6: On 7-node Network, if one link failure occurs the Light paths and total hop weight is maximum as equal to full network. Whereas on failure of three links efficiency of wavelength is observed.

Figs: 7 to 9: On 14- node (NSFNET) networks light paths and total hop weight is maximum on full network. Whereas if one link gets failure efficiency in the utilisation of wavelengths is observed.

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AUTHORS’ BIOGRAPHY

Y.Rama Mohan, received his B.Tech degree from Madras University, Chennai in the year 2002. He received M.Tech degree from DR.M.G.R University, Chennai in the year 2005.He is presently working as Assistant Professor in the CSE Department at G.Pulla Reddy Engineering College, Kurnool, Andhra Pradesh.

Dr.V.Raghunatha Reddy, obtained his B.Sc. from Sri Krishnadevaraya University Ananthapur India in 1991 and MCA from Madurai Kamaraju University, Tamilnadu India in 2002,M.Phil from MKU Tamilnadu, India in 2005 and PhD degree from SKU Ananthapur India in 2009.