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A NOVEL PROTECTION GUARANTEED, QoT AWARE RWA ALGORITHM FOR ALL OPTICAL NETWORKS

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ABSTRACT

All optical transparent networks carry huge traffic and any link failure or failure to restore the link failed lightpath can cause loss of gigabits of data; hence guaranteed protection becomes necessary at the time of failure. Many protection schemes were presented in the literature, but none of them speaks about protection guarantee. Also, in all optical networks, due to non availability of regeneration capabilities, the physical layer impairments due to optical fibers and components accumulates along the lightpaths (LP) which causes sharp degradation of the Quality of Transmission (QoT), as measured by signal bit error rates (BER) , which is a dominating factor for blocking probability(BP) of transparent optical networks. The problem of protection with QoT issues was rarely studied in the literature. In this work, a novel protection backup path guaranteed, QoT aware Routing and Wavelength Assignment (RWA) Algorithm called "Virtual Lit –Exhaustive Highest Q factor" (V-Lit EHQ) is presented which exhibits desirable qualities for reliable network operation. The proposed scheme possesses the merits and excludes the demerits of Lit and Dark protection schemes. The results of the proposed work are compared with the standard QoT aware versions of the Shortest Path-First Fit schemes for both lit and dark protection. The BP, Vulnerability ratio (VR), and BER, are taken as the performance metrics and the proposed algorithm found to be outperforming in all metrics as shown through simulations.

Keywords: *Routing and Wavelength Assignment, Path Protection, QoT, Physical layer impairments, Blocking probability,*

1. INTRODUCTION

All optical transparent networks carry a huge traffic and any interruption in lightpath can cause huge data losses, therefore survivability is important in optical networks. As regenerators are not available in transparent networks, the physical layer impairments (PLI) such as Polarization Mode Dispersion (PMD), Amplified Spontaneous Emission (ASE), Cross Talk, Chromatic Dispersion (CD), Cross Phase Modulation (XPM), Four Wave Mixing (FWM) etc accumulates on lightpaths and if not properly dealt with, the LPs may no longer be useful, as impairments will pull the QoT in terms of BER to below threshold which is not at all acceptable. Therefore, during failures, it is necessary to have lightpath protection as well as adequate QoT in backup protection path. In this work a carefully designed routing and wavelength assignment (RWA) scheme is proposed to take care of both the above issues.

Conventional studies on RWAs proposed many algorithms without considering PLIs. In recent days, the importance of PLI aware RWAs gained momentum and many papers discussed this issue [1-4]. Most of the papers on PLI aware RWA considers only few PLI issues and neglect others on one reason or others, for example in [5], cross talk was dominant issue, in [6] and [7] Four Wave Mixing was the dominant issue. Furthermore, except few, almost all protection/restoration mechanisms available in the literature assume the presence of an ideal physical layer, i.e., the existing methods did not consider the effect of PLIs which will have adverse effects on the QoT and BP performances. Further, the protection paths are longer than the primary paths and accordingly will have additional QoT degradations on individual paths as well as on whole network. Hence it is important to consider QoT and PLI issues.

In this paper all dominant impairments are considered and incorporated in quality factor (Q) calculations for both the primary and backup paths. In the RWA process, the LPs having the highest Q is searched in an exhaustive way, opposite to traditional way, where RWA process is stopped as

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and when a QoT valid path is found. This will lower the BERs of LPs and keep far away from the QoT threshold rather than close to it. Lower BERs allow for higher network scalability and flexibility, robustness in the context of hardware aging is improved by operating far from the threshold and finally, lower BERs imply fewer retransmissions.

For survivability shared or dedicated protection may be employed. As shared protection is having many drawbacks, dedicated protection is preferred. Also a study shows that the CAPEX difference of shared and dedicated path protection schemes is much lower in transparent optical networks compared to opaque counterpart [8]. Thus dedicated protection is attractive in transparent optical networks.

In dedicated path protection, every connection has two link-disjoint lightpaths, a primary path and a backup path to handle single-link failures. The backup path may be Lit or dark. Having the lit backup will just double the live LPs, which will have strong adverse effects on the QoT of other lightpaths and as well as on the whole network by increasing the chances of FWM, Cross talk, inter channel effects etc throughout the network operation. Thus increases the QoT blocking of lightpaths. This effect is more severe in transmission-impaired transparent optical networks. The amplifier load will increase by just two fold; network monitoring load also increases proportionally. This will over use the network resources and consequently resource blocking will be more. In dark backup case, when the backup path is lighted up, it increases the impairments for other lightpaths due to added crosstalk, interference, etc and leads to QoT blocking of LPs. Thus backup path is no longer usable, and protection is no longer guaranteed.

In this paper, a Novel path protection guaranteed QoT aware RWA is proposed which uses Virtual Lit dark backup. In this scheme, the backup path is assumed to be lit as in the case of lit protection, but actually it will be dark. Under such assumptions, the RWA is carried out and its QoT parameters are updated in the network accordingly. Any future LP request(s) will be processed considering virtually lit (actually dark) backup(s). Due to this, during link failure, if the backup path is lighted up, this path will always be a QoT feasible path as its effects are already been incorporated in the RWA process, thus protection is being guaranteed.

The survivability against single link failures is quantified using a metric called *Vulnerability Ratio* as defined in [9], which describes the vulnerability of the algorithms to a failure.

The paper is organized as follows. In Section 2 related works is presented elaborately, physical layer model and system description is presented in Section 3. In Section 4, the proposed Virtual –lit EHQ algorithm is discussed while in Section 5 simulation and results are presented. Finally in Section 6, this paper is concluded.

2. RELATED WORKS

Many previous works proposed several schemes for PLI aware RWA and some of them considered path protection. The RWA that consider the dynamic impairments for survivable optical networks were first presented in [10] in which a new metric called the vulnerability ratio was defined to quantify the resilience of proposed algorithms. The authors of [11] examined path and link protection, as well as restoration, in physically impaired optical networks under single-link failures. In [12], it was shown that, Link protection has the lowest wavelength blocking probability, but has the highest overall blocking since the backup paths were too long and hence drastically reduced the QoT.

A study in [13] considers consider ASE noise, FWM, and XPM as the main physical impairments and ignores other impairments. Primary paths are selected based on link weights, for favoring links with less impairment. The backup paths are allowed to share their bandwidth for multiple primary paths. On selecting route, the FF wavelength is chosen for the primary path, while a last-fit wavelength is chosen for the backup path.

The authors in [14] addresses the problem of Impairment-Aware Routing and Wavelength Assignment (IA-RWA) in transparent all optical networks considering dedicated path protection. The main objective in this paper is to minimize the number of lightpath requests that are rejected due to unacceptable QoT. The authors proposed a heuristic called RS-RWA-Q by putting the protected lightpath requests before unprotected one. They claim that their enhanced RS-RWA-Q heuristic exhibits lesser blocking rate compared to the RS-RWA proposed by literature.

A comparison of dedicated path protection and shared path protection is presented in [15]. It was stated that, dedicated path protection has lower blocking probability and provisioning complexity compared to shared path protection. However,

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dedicated path protection has less resource usage efficiency than shared path protection.

The paper [16] introduces a novel dedicated protection scheme called generalized dedicated protection with network coding (GDP-NC). GDP-NC generalizes all the dedicated protection schemes and routing architectures, while further being incorporated with NC functionality at each node. Though authors claim that, the proposed GDP-NC can provide reduced blocking probability compared with the others, its complexity is inevitable.

A technique called Coded Path Protection (CPP) was proposed in [17], this proposal makes use of symmetric transmission over protection paths and link-disjointness among the connections in the same coding group. This scheme is complex and makes transmission in backup paths mandatory. A shortest path algorithm with dedicated protection path to was proposed in [18]. The wavelength assignment problem is studied by two algorithms. The first one is looking for available wavelengths out of the busy wavelength space and the second one in the busy wavelength space. It was claimed that the second algorithm has significant benefits versus the first one because it uses fewer resources than the other one. It is clear that this proposal is vulnerable to crosstalk (resulting high BER or low QoS) as wavelengths are tightly packed to a maximum possible extend though resources are spare.

In [19], a multicost approach to provide protection in impairment constrained optical networks is presented. The authors proposed the application of the worst case interference assumption for the selection of the backup lightpath and showed that this can be quite beneficial for the survivability of the backup lightpaths, when the network is heavily loaded. This proposal may try hard for backup lightpath feasibility in terms of QoS, but higher blocking ratios for future requests are expected due to worst case assumptions.

The authors in [20] proposed a novel QoS aware crosstalk reducing routing and wavelength assignment in all optical networks with path protection consideration, in which the crosstalk was the main criteria to tackle with. Wavelength preordering was used to further reduce crosstalk. HQ and MaMiQ are the two RWAs proposed, where first intend to improve BER, the later is to operate the network away from QoS threshold. In these proposals, BP and BER are traded off. In [21], a QoS aware RWA incorporating physical layer impairments called WpDp-MaMiQ was proposed. In this proposal also, Wavelength pre ordering technique based on its spectral differences was used to minimize crosstalk. At the routing stage, the path that maximises the Q factor was chosen, to enable the network to operate away from QoS threshold rather than merely close to it. Though its BP is appreciable, BER performance still be improved.

None of these works guarantee the path protection during failures. Most of these works aims at improving BP, but not bothered about BER performance. Many of these works failed to look on after failure scenario.

3. SYSTEM DESCRIPTION

In this work, a network of bidirectional links with C equally spaced wavelengths in each direction are considered. Physically, the links consist of one or several spans; each span in turn consists of single mode fiber, an optical amplifier (EDFA) that compensates for the fiber linear attenuation, and a dispersion compensation fiber (DCF) that compensates for the fiber chromatic dispersion. Links are separated by Optical cross connects (OXC) where switching and demultiplexing takes place. The receiver is modeled by an optical filter (for demultiplexing purposes), followed by a photo detector per channel. Wavelength conversion is assumed to be not available; hence a call must use the same wavelength from source to destination. A centralized network management system is assumed to perform entire call process and typically, a low-speed control channel is reserved to manage the network operations.

The ASE noise arise from optical amplifiers, Polarization Mode Dispersion (PMD) arises in an optical fiber due to asymmetries in the fiber core that induce a small amount of birefringence that randomly varies along the length of the fiber. The strongest linear crosstalk; node crosstalk originates from two sources: *fabric crosstalk* due to power leaking of in-band signals traversing the switch, and *adjacent-port crosstalk* due to imperfect power isolation in the demultiplexers of network nodes. The filter concatenation (FC) effects arise due to optical filter pass band misalignments because of device imperfections, and aging. Chromatic Dispersion or Group Velocity Dispersion (GVD) causes the broadening of the optical pulses as they propagate through the fiber which in turn causes Inter-Symbol Interference (ISI).

Non linear cross talk arise from optical fiber due to non linear effects, the strongest nonlinear fiber crosstalk comes from two sources, FWM and XPM.

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The severity of the crosstalk in both cases depends partly on the spectral spacing of the interfering signals [20]. All these effects have been considered in this work.

Most commonly, QoT for a signal is measured by its BER, and Q factor for a lightpath is related to the signal's BER. For an On-Off modulated signal, assuming Gaussian distributions for the '0' and '1' samples after photo detection, the Q factor is given by [22]

$$Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sigma_1} \quad (1)$$

Where μ_0 and μ_1 are the means of the '0' and '1' samples, respectively, and σ_0 and σ_1 are their standard deviations. BER and the Q factor of a signal are related by

$$BER = \frac{1}{2} erfc\left(\frac{Q}{\sqrt{2}}\right) \quad (2)$$

A BER of 10^{-9} corresponds to a Q factor of 6 and in this work every established lightpath is expected to have of a minimum Q value of 6. The ISI, ASE, and node crosstalk are accounted in Q factor through its noise variances σ_i^2 , σ_n^2 and σ_x^2 respectively. The non linear effects XPM and FWM are accounted through the noise variance termσ_{nx}^2. Incorporating these effects, Q factor of a lightpath can be written as,

$$Q = \frac{\mu_1 - \mu_0}{\sigma_0 + \sqrt{\sigma_i^2 + \sigma_n^2 + \sigma_x^2 + \sigma_{nx}^2}} \quad (3)$$

Noticing that $\mu_0 \ll \mu_1$ and following [23], filter concatenation is modeled through a penalty on μ_1, yielding a new quantity $\mu_1{}'$ that accounts for the eye closure incurred by filter concatenation. The PMD effect is modeled through a penalty on Q via a multiplicative factor ηPMD as in [24]. Hence Q is actually defined as:

$$Q_{est} = \frac{\eta_{PMD}\, \mu_1{}'}{\sigma_0 + \sigma_1} \quad (4)$$

Since node crosstalk, XPM and FWM are dynamic effects that depend on the network state they have to be computed on-line.

While call blocking probability is defined as in the standard practice, the vulnerability ratio to quantify resilience of the network to a random link failure is defined as in [9]. Vulnerability Ratio is the probability that a randomly picked ongoing connection (at the time of failure) cannot be restored because of unacceptable QoT.

Averaging over the entire simulation period, the Vulnerability Ratio is given as,

$$\nu = \frac{1}{\sum_{i=1}^{S} \tau_i} \sum_{i=1}^{S} P_i\, \tau_i$$

$$= \frac{1}{L} \frac{1}{\sum_{i=1}^{S} \tau_i} \sum_{i=1}^{S} \sum_{j=1}^{L} \frac{D_i^j}{T_i} \quad (5)$$

Where D_i^j is the number of the connections that are going to be dropped (due to unacceptable QoT), T_i is the total number of ongoing connections in the state i, L is the number of links, and S is the total number of network states during network evaluation. P_i is the probability that a random ongoing connection fails, in the network state i. τ_i is the duration of the state i.

Calls are assumed to arrive in the network according to a Poisson process with average arrival rate load and call durations follow an exponential distribution with unit mean, such that load is the total offered load of the network in Erlang. The sources and destinations of the calls and link failures are assumed to be uniformly distributed over the network.

4. VIRTUAL LIT EXHAUSTIVE HIGHEST Q FACTOR RWA ALGORITHM (V-LIT EHQ)

The proposed algorithm is shown in the flowchart in fig.1. In the proposed RWA, The primary path is established first and then the backup path is marked in the following manner. As and when a new LP request arrives, the possible routes between the source and destination are calculated and Route Set is formed. To this route set, in an exhaustive manner, each wavelength is tried to assign by maintaining wavelength continuity constraint as wavelength conversion is not available and thus Candidate LP Set is formed. If no LP is found in candidate LP set, then call is blocked. If LPs are available, then QoT is checked at this stage for the candidates LPs and all the LPs above the QoT threshold and does not bring the QoT of the already established LPs to below threshold level are stored in Usable LP Set. Here QoT threshold is fixed at BER=10^{-9} , which corresponds to Q=6. From this usable LP set, the LP having the highest Q is chosen as the as primary LP and network database is updated (As all routes are tried with all the available wavelengths, the

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highest Q route selected form usable LP set is the best possible LP in terms of QoT). If no LP is found in the Usable LP set, then call is dropped.

While forming usable LP set for primary path, the entire wavelength space and route space are searched in an exhaustive manner, which is complex but yields best result.

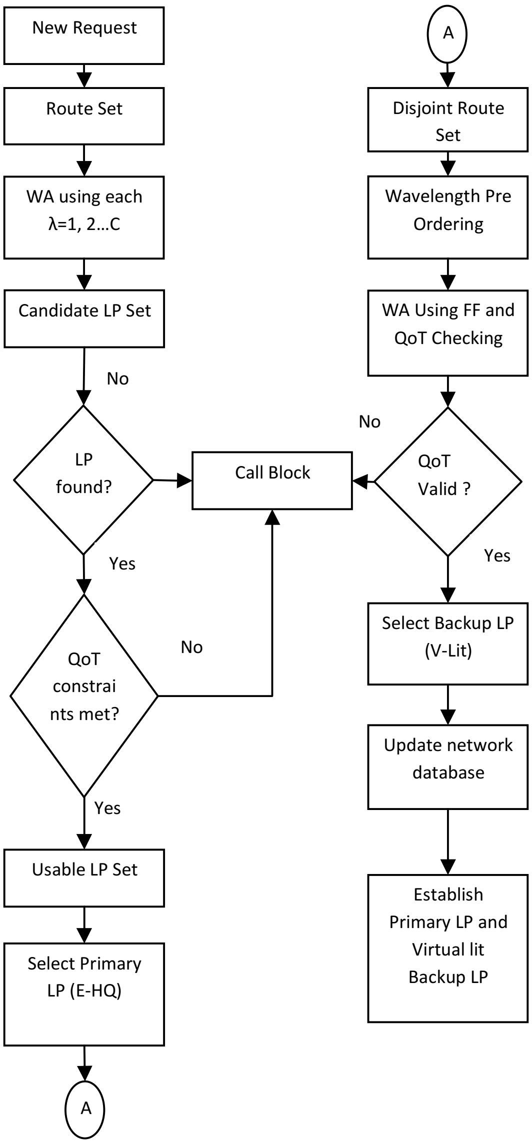

Figure 1: Flow Chart For V-Lit EHQ Routing And Wavelength Assignment Algorithm

But for establishing a backup path also if same procedure is followed, the complexity becomes two fold. Hence traditional FF technique is proposed for backup path establishment as it is simple and reduces total complexity. Also, this route will come in to live only when primary path fails. However this will result in selection of paths having lower Q. To offset this, Wavelength Pre Ordering (WpO) is used for backup path selection. In WpO technique, wavelengths are ordered in a set such that the wavelengths that are spectrally far away are placed first and spectrally closer wavelengths are placed at last. By this, spectrally closer wavelengths are avoided on the links, which will reduce the crosstalk impact and its corresponding BER.

The backup path is selected as follows. The link disjoint backup LP is chosen after marking a primary LP. The links that constitute a primary LP are removed from the network topology and then the routes between source and destination are computed in the new topology and backup disjoint route set is formed. For assigning wavelengths to routes for backup paths, Wavelength Pre Ordering (WpO) is used which is as in [21].

Then, standard First Fit (FF) wavelength assignment is technique is applied using the Wavelength Pre Ordered set to the disjoint route, and the QoT checking is done sequentially for every resultant LP. As and when a QoT valid LP is found, WA process is stopped and the LP is marked for backup path and the central network database is updated accordingly. Call is blocked if no feasible LP is found either at WA stage due to wavelength unavailability or at QoT testing stage due to QoT constraints. This backup LP is kept dark until link failure appears. For new call requests, this backup LP will also be taken in to consideration for QoT calculations. For any future requests, this virtually lighted backup path is considered as if it was lit and alive working path, and new LPs are established accordingly. For QoT calculations of backup path, currently marked primary path is not considered as the primary LP is no more in live, when backup LP come in to picture

5. SIMULATIONS AND RESULTS

The proposed, Protection Guaranteed, QoT aware RWA algorithm is evaluated on the down scaled NSF topology shown in Fig.2 , with C=8 wavelengths per link in each direction. For simplification purpose, it is assumed that all links were made of one or more 70 km long spans.

The physical parameters used in the simulations are given in Table 1; these are standard parameters for a realistic regional area network [20].

It is assumed that wavelength conversion is not feasible and thus a call must use the same wavelength from source to destination. The call

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pattern is as described in section 3. Link failure location and time of failure are randomly (uniformly) distributed over their respective domains.

Due to QoT constraint enforced, any call, at any time, should use a path with a Q factor at least equal to Q = 6, which corresponds to a BER of 10^{-9} .This holds good for back up path too. However as the LPs having exhaustive highest Q is selected for primary path, the BER of these paths are far away from QoS threshold, thus giving better performance in terms of BER.

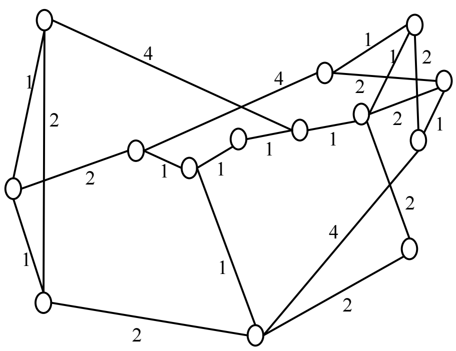


Figure 2: Topology Used In The Simulations. A Downscaled 14 Node NFS Net Topology Is Used. The Link Weights On The Figure Correspond To The Number Of Fiber Spans.

Table 1: Physical Parameters For The Simulated Network

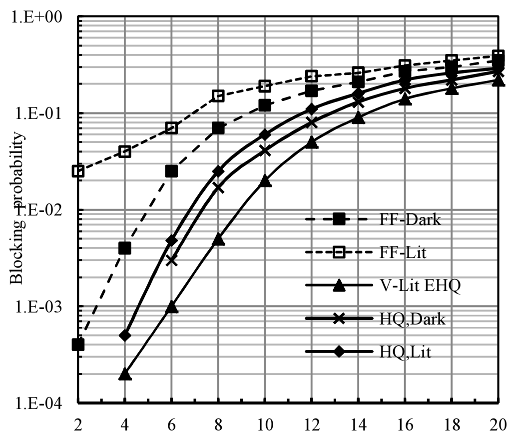
Description	Value
Span length	70 km
Signal peak power	2 mW
Pulse Shape	NRZ
Bit duration	100ps
Fabric crosstalk	-40 dB
Adj. port crosstalk	-30 dB
Non adj. port crosstalk	-60 dB
Fiber loss	0.2 dB/km
Nonlinear coefficient	2.2 $(W\ km)^{-1}$
Linear dispersion	17 ps/nm/km
Dispersion compensation	100% post DC
Noise factor	2
Receiver electrical bandwidth	7 GHz
Number of wavelengths	8
Minimum Q factor	6

The proposed RWA algorithm is evaluated against three performance matrices namely blocking probability, BER and Vulnerability ratio.

The blocking probability performance against load is given in fig.3. It is seen that the proposed V-lit EHQ protection outperforms the standard FF-Dark and FF-Lit schemes as well as the techniques proposed in [12] ; "HQ,Dark" and "HQ,Lit". It is seen that the dark protection schemes outperforms compared to its Lit backup counterparts. This outperformance margin is more at lower loads.

In HQ-Dark protection, the QoT of backup path is not checked and the shortest disjoint path is marked for backup, due to this, the backup path may not be usable/ feasible during link failure due to inadequate QoT. This leads to BP.

In dark protection backup, paths are lit only when it is required, where as in FF-Lit protection, the backup LPs are always lit, and therefore the overall alive LPs are almost double in FF-lit protection causing increased network load and interference by backup LPs which leads to QoT blocking of call requests.



Total Load (Erlangs)
Figure 3: Average Blocking Probability

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interference by backup LPs which leads to QoT blocking of call requests.

The blocking in V-lit EHQ protection scheme is due to its primary paths only (as backup paths are QoT readily available) where as in FF-dark and FF-lit protection case, blocking is depends on both primary and backup paths. In FF-dark and FF-lit protection schemes, as the QoT of backup path is not bothered during establishment of primary path, the availability of backup path during failure is uncertain; this increases blocking probability. In the proposed scheme, QoT blocking of backup path is null as it's QoT is well ensured during the establishment of primary paths itself

The proposed V-Lit EHQ RWA scheme outperforms at big margin at lower loads and mid loads. At higher loads, the wavelength availability shrinks due to already established connections; therefore blocking performance is closer but better than FF-Dark lit.

The biggest merit of the proposed algorithm is its guaranteed hundred percent availability of backup paths during link failures. Vulnerability ratio is the indication of capability of these algorithms to recover from failure.

In lit protection, when connections affected by failures switch to backup paths, a fraction of these backup paths may not have adequate QoT, causing the corresponding connections not to be restored due to unavailable (Due to inadequate Q) backup paths. Lit FF protection is the worst performer in terms of vulnerability ratio.

In Dark protection, during failures if backup paths are lighted up, these backup paths itself may not have adequate QoT or some of these lighted up backup paths may affect other ongoing connections, thus causing the backup paths to be unavailable. Due to this the affected paths may not be restored. Its VR performance is better than the Lit protection. In the proposed V-Lit EHQ RWA algorithm, as QoT of all the backup paths are considered during the new LP establishments, the backup paths are readily available with adequate QoT during failures for all the primary paths. Hence all primary LPs can easily be routed through backup paths during failures without any call blocks due to unavailability of backup paths.

The VR for the three schemes is given in table2. It is seen that FF-Dark has less vulnerability than FF-lit due to above said obvious reasons. The proposed V-Lit EHQ scheme outperforms both the dark and lit schemes with the ideal VR score of zero. This means that all the paths can be restored to backup paths during failures without dropping even a single connection thus giving a highest reliability.

The BER performance of the three schemes is shown in fig.4. As said above, the due to increased alive LPs and its corresponding interferences the BER performance of Lit backup is the worst next to dark FF-backup case.

In V-lit EHQ protection scheme, as the LPs having highest Q is selected in a exhaustive manner is, its BER performance is the best at huge margin. Even, if future new requests downgrade the QoT of already established paths, it is offset by the fact that the established LPs already far away for threshold due to EHQ selection mechanisms.

Table 2: Vulnerability Ratio Vs Load

Load (Erlangs)	Vulnerability Ration (ν)				
	FF-Dark x 10^{-3}	FF-Lit x 10^{-3}	HQ, Dark x 10^{-3}	HQ, Lit x 10^{-3}	V-Lit EHQ
2	2	2.5	1.3	2	0
4	5	3.5	4	5	0
6	8	6	6	18	0
8	10	10	10	40	0
10	13	15	15	80	0
12	14	22	20	110	0
14	16	27	24	170	0
16	15	33	25	180	0
18	15.5	35	28	190	0
20	16	40	30	200	0

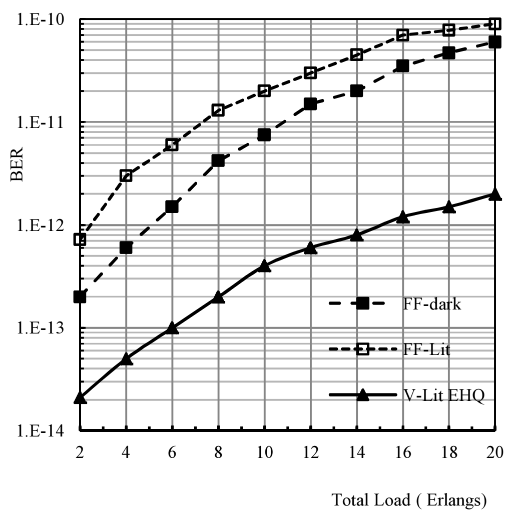

Figure 4: Average BER

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6. CONCLUSION

In this work, the problem of dedicated path protection has been addressed in a new perspective along with physical layer impairments consideration. A new, novel RWA algorithm called "V-lit EHQ" for all optical networks was presented and compared with the standard SP-FF and with the recent proposals in the literature for dark backup (FF-Dark) and lit backup (FF-Lit). The proposed V-Lit EHQ clearly outperforms FF-Dark, FF-Lit, HQ-Dark and HQ-lit backups in terms of blocking probability and BER at both low and high network loads. The ideal value of vulnerability ratio of the proposed algorithm implies the guaranteed hundred percent availability of backup paths during failure, giving highly reliable network operations. The exhaustive highest Q selection mechanism employed for primary paths and V-lit scheme employed for backup paths in the proposed work, lowered the BER and BP considerably. The proposed algorithm involve intensive computations, but worth to afford it for the guaranteed recovery from failures and better BER performances. In future, this work may be extended for double and multiple link failures.

REFERENCES:

[1] G. Markidis, S. Sygletos, A. Tzanakaki, and I. Tomkos, "Impairment aware based routing and wavelength assignment in transparent long haul networks", *Proceedings of IFIP ONDM 2007, Athens, Greece,* May 2007, pp. 48–57.

[2] S. Rai, C. Su, and B. Mukherjee, "On provisioning in all-optical networks: An impairment-aware approach", *IEEE/ACM Transactions on Networking,* vol. 17, no. 6, Dec 2009, pp. 1989–2001.

[3] C. Pinart, N. Sambo, E. Le Rouzic, F. Cugini, and P. Castoldi, "Probe schemes for quality-of-transmission-aware wavelength provisioning", *Journal of Optical Communications and Networking,* vol. 3, no. 1, 2011, pp. 87–94.

[4] M. Bakri, M. Koubaa, M. Menif, and Ouerda, "Static lightpath establishment with transmission impairments consideration in wdm all-optical networks", *Proceedings of 7th International Workshop on Design of Reliable Communication Networks, 2009.* pp. 251-258.

[5] T. Deng, S. Subramaniam, and J. Xu, "Crosstalk-aware wavelength assignment in dynamic wavelength-routed optical networks", *Proceedings of the IEEE International Conference on Broadband Networks (Broadnets), San Jose, CA, USA,* Oct. 2004, pp. 140–149.

[6] A. Marsden, A. Maruta, and K. Kitayama, "Routing and wavelength assignment encompassing FWM in WDM lightpath networks", *Proceedings of IFIP ONDM 2008, Spain,* March 2008.

[7] I. Fonseca, M. Ribeiro, R. Almeida, and H. Waldman, "Preserving global optical QoS in FWM impaired dynamic networks", *Electronics Letters*, vol. 40, no. 3, Feb 2004, pp. 191–192.

[8] D. Staessens, D. Colle, M. Pickavet, and P. Demeester, "Path protection in WSXC switched networks", *Proceedings of European Conference on Optical Communications (ECOC),* Sep. 2008.

[9] Y. Zhai, Y. Pointurier, S. Subramaniam, and M. Brandt-Pearce, "Performance of dedicated path protection in transmission impaired DWDM networks", *Proceedings of the IEEE International Conference on Communications (ICC)*, Glasgow, Scotland, Jun. 2007.

[10] A. Askarian, Y. Zhai, S. Subramaniam, Y. Pointurier, and M. Brandt-Pearce, "Protection and restoration from link failures in DWDM networks: A cross-layer study", *Proceedings of international Conference on Communications,* Beijing, China, June 2008, pp. 5448–5452.

[11] A. Askarian, S. Subramaniam, and M. Brandt-Pearce, "Evaluation of link protection schemes in physically-impaired optical networks", *Proceedings of international Conference on Communications (ICC).* Dresden, Germany, June 2009

[12] A. Askarian, Y. Zhai, S. Subramaniam, Y. Pointurier, and M. Brandt-Pearce, "Cross-layer approach to survivable DWDM network design", *Journal of Optical Communications and Networking,* vol. 2, no. 6, June 2010, pp. 319–331,.

[13] K. Georgakilas, K. Katrinis, A. Tzanakaki, and O. Madsen, "Performance evaluation of impairment-aware routing under single- and double-link failures", *Journal of Optical Communications and Networking,* vol. 2, no. 8, Aug. 2010, pp. 633–641.

[14] S. Azodolmolky, M. Klinkowski, Y. Pointurier, M. Angelou, D. Careglio, J. Sole-Pareta, and Tomkos, "A novel Offine physical layer impairments aware rwa algorithm with

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dedicated path protection consideration", „*Journal of Lightwave Technology,*vol.28, no.20 ,Oct. 2010, pp.3029-3040.

[15] M. A. Farabi, S. M. Idrus, S. N. Fariza, Nadiatulhuda Zulkifli, M. A. Al-Shargabi, "A Comparison of Path Protections with Availability Concern in WDM Core Network", *International Journal of Computer Applications,* Vol. 24,No.4, June 2011.

[16] P. Babarczi, J. Tapolcai, Pin-Han Ho, and M. Medard, "Optimal dedicated protection approach to shared risk link group failures using network coding", *Proceedings of the IEEE International Conference on Communications (ICC)*,June 2012, pp.3051-3055.

[17] S .N .Avci, and Ayanoglu, "Coded Path Protection: Efficient Conversion of Sharing to Coding", *IEEE Transactions on Communications*, vol.61, no.10, October 2013, pp.4294-4309.

[18] T. Stefanos, and Mylonakis , "Full Dedicated Optical Path Protection in the WDM Mesh Networks without Wavelength Conversion" , *Proceedings of the Ninth International Conference on Networking and Services* , March 2013,Lisbon, Portugal.

[19] P.Kokkinos, K.Manousakis, and Varvarigos, "Path Protection in WDM Networks with Quality of Transmission Limitations", *IEEE International Conference on Communications (ICC)*, May 2010, vol.1, no. 5, pp. 23-27.

[20] K.Ramesh Kumar, and R.S.D.Wahida Banu, "A novel QoS aware crosstalk reducing routing wavelength assignment in all optical networks with path protection consideration", *Proceedings of the International Conference on Communications and Signal Processing (ICCSP),*India, April 2012, pp.47- 51.

[21] K.Ramesh Kumar, and R.S.D.Wahida Banu, "A Novel QoS Aware RWA with Dedicated Path Protection Consideration for All Optical Networks", *WSEAS Transactions on Communications,* issue 7, vol.11, pp.251-261,July 2012.

[22] G.P. Agrawal, *Fiber-Optic Communication Systems*, 3rd ed. Wiley, New York, NY, USA. 2002.