A Novel Method for Non linear effect Cross Phase Modulation due to various data rates in Dynamic Wavelength Routed Multifiber WDM networks

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Abstract: The optical communication might have achieved tremendous growth, but the fiber non linearity limits its performance. The non linear impairments in optical networks have crucial effects when data rates, transmission lengths, number of wavelengths in wavelength conversion and optical signal power level increases, so the non linear effects must be overcome.

As the need for new bandwidth intensive applications, such as video and interactive TV, growing global internet traffic the data rate of optical networks has to be upgraded. In order to support both low data rate and high data rate applications, it can have different date rates over same fiber links. To achieve this different modulation formats can be used, but this will produce non linear effects of cross phase modulation.

Whenever light path set up request arrives, the light path will be dynamically established and only selected numbers of network nodes have wavelength conversion capabilities. This paper proposes a novel method to overcome the effect of cross phase modulation by using RWA algorithm. This problem focuses on wavelength routed WDM networks.

Keywords- WDM Networks, RWA, Non linear Effects, Cross phase Modulation.

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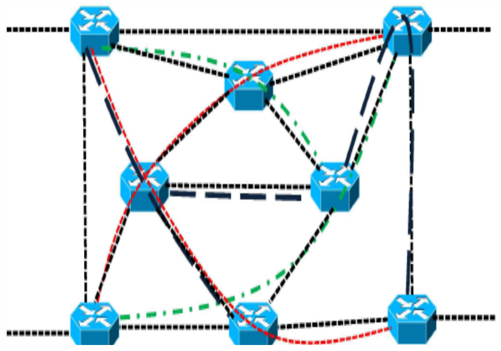
I INTRODUCTION

The non-linear effects in optical fiber occur either due to change in the refractive index of the medium with optical intensity (power) or due to inelastic-scattering phenomenon. The dependence of refractive index on power is responsible for Kerr effect which produces three different kinds of effects—self-phase modulation (SPM), cross phase modulation (XPM), and four-wave mixing (FWM), depending on the type of input signal. At high power levels, the light waves (optical signals) interact with the phonons of the fiber medium resulting in scattering phenomenon. The intensity of scattered light grows exponentially if the incident power exceeds a certain threshold value. The inelastic scattering phenomenon can induce stimulated effects such as stimulated Brillion scattering (SBS) and stimulated Raman scattering (SRS). The Brillion generated phonons (acoustic) are coherent and give rise to a macroscopic acoustic wave in the fiber, whereas, in Raman scattering, the phonons (optical) are incoherent and no macroscopic wave is generated.

All nonlinear effects, except SPM and XPM, provide gains to some channel at the expense of depleting power from other channels. SPM and XPM affect only the phase of the optical signal and can cause spectral broadening, which leads to increased dispersion. The importance of non-linear effects is growing due to1) increase in optical power levels to increase the optical reach, 2) recent developments in optical components such as EDFA and DWDM systems to build more flexible networks, 3) increase in channel bit-rate to increase the traffic carrying capacity of wavelengths, and 4) decrease in channel spacing to increase the number of wavelengths and overall network capacity. Although the individual power in each channel may be below the one needed to produce non-linearity, the total power summed over all channels in a wavelength Division multiplexing(WDM) system can become significant. The combination of high total optical power and a large number of channels at closely spaced wavelengths is ideal for many kinds of non-linear effects.

The emergence and establishment of bandwidth intensive applications (IPTV, youtube and cloud computing) has led to an explosive growth of the heterogeneous internet traffic. Many technologies have been proposed as candidates for the upgrade of the network's capacity and the greater utilization of optical fiber's limited bandwidth. However, the concept of MLR optical network has recently drawn the academic community's attention due to its cost and energy efficiency [1],[2], [3]. Other advantages of mixing different rates within the same fibre link are the more gradual and cost-effective upgrade of the capacity and the fact that it is possible to apply into the current WDM network infrastructure without many modifications [4].

Until recently, the highest data rate available in a wavelength channel was 10 Gbps achieved through on-off keying (OOK) modulation format within the standard ITU grid of 50 GHz. In order to migrate to higher data rates with the same spectral separation more advanced and spectral efficient phase modulation schemes are needed. The most promising candidates, in terms of noise resiliency, for 40 Gbps and 100 Gbps transmission have been DQPSK and PM-QPSK respectively and are the ones that are considered in our study. Figure 1 depicts such an optical network with mixed line rate and multiple modulation formats. Nevertheless, the biggest obstacle for the realization of a MLR optical network is XPM occurred to the xPSK channels by the adjacent 10 Gbps OOK channels. This non-linear impairment is caused by **the Kerr effect [5].** The high optical intensity of the propagated OOK pulses generates oscillations in the refractive index of the fiber's material. The changes of the refractive index produce a non-linear phase shift to the adjacent xPSK channels and thus increase the bit error rate at the receiver. In order to overcome this impairment that affects performance a more sophisticated physical impairment (PI) aware routing and wavelength assignment (RWA) scheme that ensures quality of transmission (QoT) is needed.



- - - - - - OOK 10Gbps
- - - - - - DQPSK 40Gbps
- - - - - -PM–QPSK 100 Gbps

Figure 1.A wavelength switched optical network with mixed line rates and multiple modulation format

II. WDM NETWORKS WITH SPARSE WAVELENGTH CONVERSION

In multifiber WDM networks, multiple light paths can be established with the same wavelength in the same link as shown in Fig. 2, where each link has two fibers. In this figure, we assume that a light path with a given wavelength from fiber1 in input link 1 to fiber 2 in output link 2 has already been established at an intermediate node. If the number of fibers in output link 2 is 1, i.e., single fiber link, a new lightpath for output link 2 cannot be established with the same wavelength.

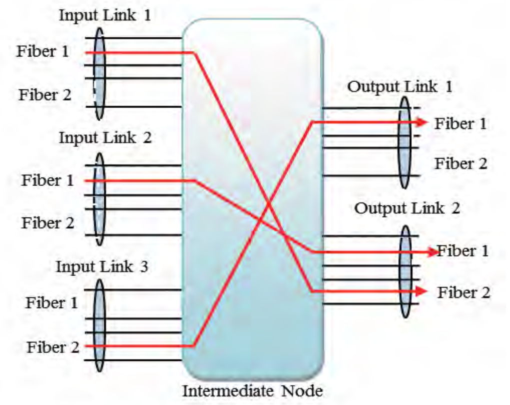


Fig. 2. Intermediate node in multifiber WDM networks.

On the other hand, in multifiber networks, a new lightpath with the same wavelength can be established in a different fiber of output link 2 as long as the wavelength is available in the fiber as shown in the figure. Thus multifiber environments improve the blocking performance of WDM networks.

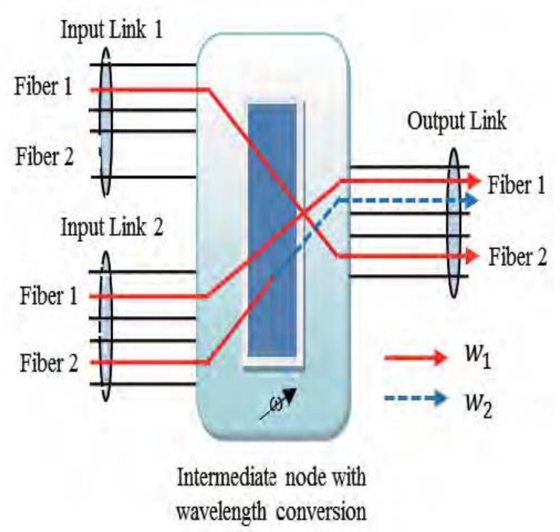


Fig.3. Intermediate node with wavelength conversion capability.

The wavelength conversion technology further improves the blocking performance of WDM networks. In this paper, we focus on multifiber WDM networks with sparse wavelength conversion. Specifically, a subset of nodes in a multifiber WDM network has full-range wavelength conversion capability. In the nodes, a given wavelength can be converted to any wavelength. show an example with Fig. 3, where each link has two fibers. In this figure, we assume that fibers 1 and 2 in the output link have already been used by lightpaths with wavelength w_1.

In this case, a new lightpath with the same wavelength cannot be established in the output link. Thus, the new lightpath establishment with wavelength w_1 is blocked if the node does not have wavelength conversion capability. On the other hand, if the node has wavelength conversion capability, the new lightpath can be established by converting an input wavelength (i.e., w_1 the figure) to an available wavelength (i.e., w_2 in the figure).

III. *PROPSED METHOD: PI- RWA Scheme*

In a MLR optical network, the provisioning of the lightpaths requires different treatment between OOK and xPSK requests. For the 10 Gbps connections, the path with the shortest length or minimum number of hops remains the optimal choice, since ASE noise is the main impairment. Nevertheless, this cannot be applied to the Xpsk lightpaths since QoT metrics, such as BER, cannot be added linearly in every link or hop. Moreover, when searching an optimal route for an OOK lightpath, it should be investigated whether its set up can lead to a serious XPM impairment to the already established xPSKlightpaths In this paper, a modified Dijkstra algorithm is proposed to calculate the path that offers the minimum BER on a selected wavelength for a source-destination pair. To achieve this, to every link, a weight is assigned that equals to the phase noise variance of that link. Since the phase variances per link can be added linearly, by finding the "shortest" path in terms of weights, to ensure that the least OOK congested links will be selected and that this path will offer low BER. At this point, it should be noted that, besides the XPM noise variance, the ASE induced noise variance can also be added linearly per link. If the distributed amplification through EDF A modules is considered, then for a link i the ASE phase noise variance is calculated as

$$\sigma^2_{ASE,i} = \frac{1}{\rho} = 1/(n.B_{REF}TSNR_O) = P_{ASE,i}/n.B_{REF}T.P_{IN}$$

Where $P_{ASE,i}$ is the ASE noise in link i

Algorithm steps:

Step 1*:* When a new connection request arrives, select a wavelength according to the First-Fit/Last-Fit strategy described above. If no available wavelength is found then block the request;

Step 2: If a wavelength is available then selected it as the candidate wavelength, and find the optimal route for this wavelength:

1) For xPSK requests a modified Dijkstra algorithm aforementioned is employed by setting a weight to each link, i.e., with the value of the phase noise variance of that link.

2) For OOK requests standard Dijkstra algorithm for shortest path calculation is employed. The links where the candidate wavelength is already occupied, are considered to have infinite weight/length. If no route to destination is found, then go back to Step 1 to select another candidate wavelength;

Step 3: If a route to destination is found then calculate the BER. If it is below threshold:

1) For xPSK requests establish the lightpath.
2) For OOK establish only if it does not violate the QoT of already existing xPSKlightpaths.If the BER is not satisfied or there is violation to the existing lightpaths then go to Step 1 to select another candidate wavelength;

Step 4: If a new OOK lightpath is established update the XPM variances and BER of the affected xPSKlightpaths.

IV. SIMULATION AND RESULTS

To evaluate the proposed method we compare it with the shortest path and minimum hop routing schemes. Both of them will use the same QoT metrics presented in section II to define whether the incoming request will be blocked or not. The simulations use NSF network's topology with 14 nodes and 21 bidirectional links. In the current study the length of the network's links is downsized by a factor of 10, instead of thousand kilometers per link, hundreds are considered in the simulations.

In this paper, three scenarios of MLR optical networks are investigated: i) 1 0-40 Gbps ii) 10-100 Gbps and iii) 10-40-1 00Gbps. the total number of wavelengths per fiber is assumed to be 40,20 numbers of wavelength being 10Gbps channels with OOK scheme. The blocking probability performances for three scenarios are plotted in Figure4, Figure5 respectively.

The figures show that the proposed method offers superior performance at least under moderate traffic load. When the traffic load increases the advantage of the proposed scheme over the compared methods diminishes

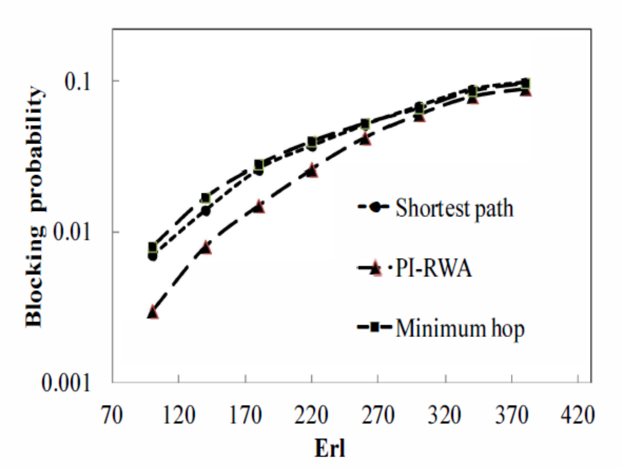


Figure 4. Blocking probability in the 10-40 Gbps scenario

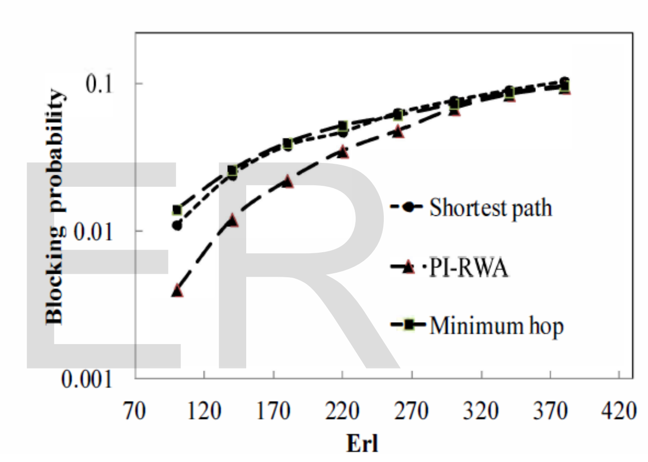


Figure 5. Blocking probability in the 10-100 Gbps scenario

V. CONCLUSION

In this paper, a PI-Aware RWA scheme for MLR optical networks was presented. A new algorithm was introduced for 40-100 Gbps lightpaths that mitigates the XPM impairment by adjacent OOK channels and outperforms conventional shortest path and minimum hop routing schemes. It is shown that, in the case of a MLR optical network, QoT based provisioning of the lightpaths can have a strong impact on the network's performance.

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