Adaptive dispersion compensation in transparent optical networks

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A novel approach to physical-layer impairment compensation, combined with an extended control plane, results in considerable quality-of-transmission improvements and reduced operating expenditure.

Optical-network developments are moving towards agile and transparent mesh networks by eliminating expensive electronic regenerators and introducing more intelligence in the control plane (CP), in turn reducing the capital and operating expenditure required. However, because of immature optical 3R technology (characterizing signal regeneration: retiming, retransmit, reshape) in transparent networks, optical-fiber chromatic dispersion and other physical-layer impairments (PLIs) will accumulate along a given light path and vary dynamically as a function of signal reconfiguration, fast reroute, mechanical vibrations, and so forth.

Many studies have looked at ways to incorporate PLI constraints into decision making by the routing engine in network layers. Most assume that the physical layer’s light-path performance is fixed. However, it can be adjusted dynamically using, for instance, tunable dispersion compensators (TDCs) or variable-gain optical amplifiers (OAs). Traditionally, these compensators are not aware of each other’s compensation state and operate in isolation. This results in disorderly performance adjustment and increases operating expenditure. Instead, dynamic adaptive-dispersion compensation has been proposed to reduce the network’s probability of being blocked and improve the robustness of signal transmissions.

In our novel approach, the function of the standard CP of the automatically switched optical network is expanded to detect signal degradation and decide whether dynamic dispersion compensation and quality-of-transmission optimization must be carried out. Figure 1 shows that the extended CP can collect up-to-date physical information for each tunable compensator and compute the joint adjustment budgets required, based on which the compensators are adjusted dynamically. Simultaneously, distributed signaling protocols are employed to collect signal-impairment information and deliver PLI compensation budgets (see Figure 2).

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We concentrated on the optimization objective by satisfying the system requirements for the residual dispersion, optical signal-to-noise ratio, and nonlinear phase shift at the receiver. Accordingly, we must introduce some limitation conditions into our mathematical model (see Figure 3). These include limits on, among others, transmission performance, physical-transfer functions of the optical components, and the compensation ability of TDCs and other impairment compensators. Here, we select the ‘greedy’ algorithm as the optimal solution because of its reduced time complexity and high computational accuracy.

We verified the performance of this proposed adaptive-dispersion compensation scheme based on a 10Gb/s optical-transmission system containing six nodes. Figure 4 shows that we only need to adjust three variable-gain OAs and three TDCs for end-to-end optimization, while nearly all 12 tunable compensators would need to be adjusted for separate optimization. Moreover, most of the adjustments are minor. Figure 5 shows eye diagrams for original transmission, separate impairment, and end-to-end compensation. Our proposed end-to-end optimization solution enables good reception of a transparent channel, thus minimizing the need for TDCs. It, therefore, enables easier dispersion-compensation management.

In summary, we have proposed a fast and efficient approach to dynamic adaptive-dispersion compensation. We extend the functions of the CP of optical networks based on generalized multiprotocol label switching to detect physical impairments and adjust transmission performance. We are working on establishing an adaptive multiservice optical-network testbed to validate this type of compensation and demonstrate other kinds of impairment control schemes.

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References


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