Reconfigurable Network

Related terms:

Amplifier, Fiber Optic Networks, Network-on-Chip, Smart Grid, Wavelength, Pilot Tone

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Location Information Processing

David Munoz, ... Rogerio Enriquez, in Position Location Techniques and Applications, 2009

Reconfigurable networks, such as ad hoc and sensor networks, must be aware of these services and applications as well, but their specific characteristics change the traditional PL point of view in a wireless scenario. In these networks, satellite-based positioning, such as GPS, is not a good solution since line-of-sight problems would make indoor positioning practically impossible. In addition to that, the power consumption of satellite-based positioning would reduce node battery life and the use of satellite positioning devices would dramatically increase node cost and size.

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Technology and Applications of Liquid Crystal on Silicon (LCoS) in Telecommunications

Stephen Frisken, ... Simon Poole, in Optical Fiber Telecommunications (Sixth Edition), 2013

18.5.4 Colorless, directionless, contentionless ROADMs

A limitation of reconfigurable networks installed to date is that while the core of the network has been able to be reconfigured without affecting other traffic flowing through it, the options have been much more limited for the local add/drop wavelengths. It is conceptually simple to conceive of a solution involving existing network architectures and a large photonic switch to configure any local add/drop wavelength to any available port (channel and direction) [46]. However, the scaling of this to multidirectional nodes involves very large-port-count switches, which are currently not commercially feasible.

Furthermore such architectures, which generally use an Arrayed Waveguide Grating [5] for wavelength selectivity in the drop section, do not address the need for flexible bandwidth required for elastic networks as outlined above. The development of flexible grid multidirectional multiplexing and demultiplexing is therefore an area of active research and the network elements derived from this have come to be known as colorless, directionless, contentionless (CDC) [2] ROADMs. There is also considerable interest in simpler architectures, where the contention management is handled through approaches such as client side fiber cross-connects [47].

Figure 18.21 shows an example of a CDC ROADM architecture known as "Route and Select" in which the back-to-back configuration of high port count WSS provides (a) the core routing capability with, in this case, seven of the ports configured to route the core traffic between directions and (b) the add/drop capability using the remaining ports. The add/drop ports are then available to be connected to mux/demux modules associated with "shared" transceiver banks.

In the Route and Select architecture, the filtering arising from an add/drop operation is in general the sum (in dB) of the filter response of each stage of the wavelength switch. This in turn means that the requirement on concatenation is in fact increased as a typical link will now have twice the number of transits of a WSS. To achieve this special care should be paid to achieving the optimal optical resolution and it is possible to now consider sculpting of the amplitude response of the filter to achieve an enhanced concatenated 3 dB bandwidth as described in Section s0120. This can be done without sacrificing the extinction bandwidth (clear bandwidth centered about the ITU grid that achieves a required blocking ratio) as the blocking ratio is also doubled because of the use of two WSSs.

It is likely that in future the two WSS would use the same optical module utilizing different wavelength processing regions of a single matrix switch such as LCoS [48,49], provided that the issues associated with device isolation are able to be appropriately addressed. Channel selectivity ensures only wavelengths required to be dropped locally (up to the maximum number of transceivers in the bank) are presented to the mux/demux module through each fiber, which in turn reduces the filtering and extinction requirements on the mux/demux module.

An architecture that takes advantage of this reduced filtering requirement is a multicast switch module [27]. A recent commercial incarnation of this [50] employs no wavelength selectivity but integrates eight 1 × 12 broadcast splitters with 12 8 × 1 switches and therefore allows each of 12 transceivers to be connected to eight WSS devices in an eight-degree node, and hence the signal from each transceiver can leave the node in one of the eight selectable directions, without an issue of contention. The use of broadcast splitters/combiners in a multicast module requires the use of additional amplification stages to overcome the intrinsic losses associated with this architecture. Coherent transmission systems provide a natural filtering between the remaining wavelengths from the local oscillator of a heterodyne receiver, thus reducing system cost and complexity. However, for direct detection systems, an array of tunable filters is still required. One solution to this that has been proposed employs an array of wavelength blockers on a single LCoS backplane [51] to provide a high-density tunable filter array.

Looking further out, a potential solution is to employ wavelength selectivity directly in the multiplexer stages [52]. This requires multiple independent wavelength processing regions on the LCoS chip and is a generalization of the use of two wavelength processing zones discussed above. Most importantly, wavelength selectivity in the form of a multidirectional wavelength selective mux/demux removes the significant multicast loss penalty and brings additional filtering suitable for direct detection also. In these cases the filtering must be low loss and address the requirement for variable optical bandwidths, but as it is traversed only once some of the concatenation characteristics are less.

More generally, there is still much investigation required to determine the optimum architectures and trade-offs for adding and dropping superchannels in the core network. Many of the factors such as loss budgets and amplification requirements are specific to the requirements of particular proprietary systems and the level of flexibility required. In particular, it is unclear whether, if individual carriers of a superchannel are to be separately processed, that the capacity gains anticipated can be achieved in practice. However, where a superchannel is to be added or routed as a whole then there is a significant opportunity to reduce the loss budget through wavelength selectivity in multiplexing or demultiplexing to a transceiver bank.

> Read full chapter

Terrestrial-Based Location Systems

David Munoz, ... Rogerio Enriquez, in Position Location Techniques and Applications, 2009

Location in Reconfigurable Networks

The basic scenario for a PL application in reconfigurable networks can be seen in Figure 5.11. We have nodes with random coordinates in a rectangular area with certain connectivity defining a network topology. Some of those nodes are the APs that are in charge of connectivity to other networks or the Internet.

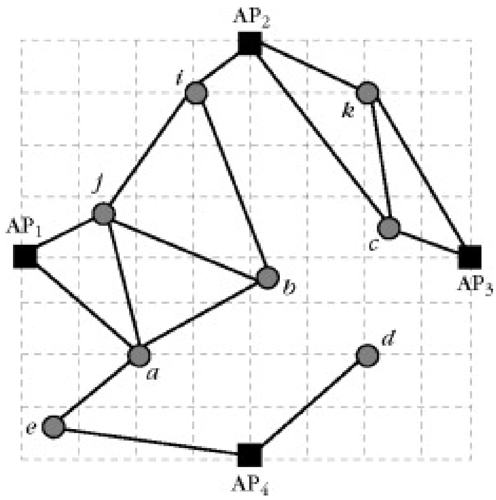

FIGURE 5.11. Fundamental scenario in reconfigurable networks.

APs are primary pieces of a wireless network and they have a finite range. APs are actually the "hub" of a wireless network. Each AP is connected to a wired network and every node on the wireless network speaks to an AP, which connects that node to the rest of the world. These APs can have multiple links. Also, when nodes establish a node discovery and service discovery algorithm, APs will be the objectives in terms of applications, connectivity, IP addresses, servers, gateways, and so on.

An AP can be a location mobile unit (LMU). In global systems for mobile communications (GSM), several LMUs are introduced. LMUs have limited capabilities to support PL functions. We propose supporting the location process in ad hoc networks through the use of three APs in a cluster or in any area of the ad hoc network. In most of the methods presented in Chapter 4 to solve the PL problem, three APs act as nodes in the network and provide fixed references in the network for PL purposes.

The evolution of network density and mobility makes necessary certain special nodes located at strategic points in the area so that connectivity is not compromised whenever node density is low. For example, at certain times during the day, there will be a few nodes in the area that might not be capable of establishing a multipath route to an AP. Those special nodes can then be turned on in order to provide coverage at those times every day. These special nodes can have features different from the regular nodes, such as higher transmission power to provide the needed coverage. Also, the nodes can have higher complexity and intelligence in order to turn themselves on and off according to network conditions, so they should be monitoring certain network and air interface variables.

The recent literature has reflected interest in location estimation algorithms for wireless sensor networks [55, 62]. Distributed location algorithms offer the promise of solving multiparameter optimization problems even with constrained resources at each sensor [70]. Devices can begin with local coordinate systems [7] and then successively refine their location estimates [1, 69]. Based on the shortest path from a device to distant reference devices, ranges can be estimated and then used to triangulate. Distributed algorithms must be carefully implemented to ensure convergence and to avoid error accumulation in which errors propagate serially in the network. Centralized algorithms can be implemented when the application permits deployment of a central processor to perform location estimation. In Celebi and Arslan [9], device locations are solved by convex optimization. Both Moses et al. [55] and Patwari et al. [62] provide ML estimators for sensor location estimation when observations are AOA, TOA [55], and RSS [62].

Since a classical multilateration process cannot be applied directly in an ad hoc environment due to the lack of direct connectivity of users to well–located APs, multihop algorithms are needed. The goal of typical multihop localization schemes is to estimate the position of all nodes in the network based on a few APs with known positions. Nodes in the proximity of APs are located first and then these nodes become new land references (with a certain degree of uncertainty) used to locate a new set of neighbors. This process continues in an iterative fashion until positions of all the nodes in the network have been estimated. This type of iterative algorithm suffers from error accumulation throughout the iterations and requires a considerable amount of processing from all nodes in the network. Many multihop localization algorithms such as APS [59, 60, 74] are geometric in nature and hence do not profit from statistical knowledge of the environment. Further, these methods require communication of the nodes with all immediate neighbors, and at some point they may even require the broadcasting of distance correction factors to the entire network, rendering them power inefficient.

In the literature, statistical multihop positioning schemes have been proposed in Savvides et al. [70], where the methods are based on accurate ranging measurements and linearized least–squares multilateration solutions. These methods require that each node with an unknown position be at a one–hop proximity from at least three land references (some may be APs, and some may be nodes that obtained position estimates from previous iterations of the positioning scheme). Further, the cited schemes rely on the solution of global nonlinear optimization problems to avoid error accumulation in the position estimates. Even when the computations are distributed through the nodes in the network, the amount of computational load required at each node may render these schemes impractical in many situations. Efforts to statistically characterize error–inducing parameters in multihop localization schemes have appeared in Savvides et al. [71] where ranging and AOA estimation errors are assumed to be Gaussian distributed.

We divide cooperative localization into centralized algorithms, which collect measurements at a central processor prior to calculation, and distributed algorithms, which require nodes to share information only with their neighbors, but possibly iteratively. Both methods are described in the following.

> Read full chapter

ROADM-Node Architectures for Reconfigurable Photonic Networks

Sheryl L. Woodward, ... Paparao Palacharla, in Optical Fiber Telecommunications (Sixth Edition), 2013

15.5 Conclusions

In this chapter we have outlined how today's ROADM-enabled backbone networks can evolve into rapidly reconfigurable networks capable of providing highly dynamic services. ROADMs in future networks will need to maintain the characteristics that we have come to depend on: they must scale gracefully to large or small nodes, sustain signal quality through many cascaded nodes, enhance network availability, and support high fiber degree for span relief as traffic grows. The first, critical step will be the deployment of colorless, non-directional ROADMs that optimize utilization of both electronic and optical resources. Additional advanced features, such as contentionless architectures and flex-grid designs, will follow when (and if) they can justify the costs associated with their introduction. Flex-grid, in particular, goes far beyond the ROADM hardware, implying a complete ecosystem of flexible transponders and regenerators, automated wavelength and bandwidth grooming, and new algorithms for network routing and operations. To complete the dynamic photonic layer, a client-side cross-connect (C-XC) will extend reconfigurability down to the subtending clients, enabling efficient utilization and protection of transponders and client interfaces.

We have also considered some proposed applications of rapidly reconfigurable networks. Rapid provisioning schemes, such as service velocity, and automated wavelength restoration both depend on pre-deployment of optoelectronic equipment that is not dedicated to a single customer; as such, they represent a major departure from prior practice. We have reviewed simulations and lab demonstrations that point to the most promising directions. Finally, although the focus of this chapter has been on the hardware, development of the network control plane must happen at the same time. Driven by the need for networks that are bigger, faster, smarter, and more efficient, we expect to see continued advancement in reconfigurable photonic networks in the years to come.

> Read full chapter

Introduction

William Shieh, Ivan Djordjevic, in OFDM for Optical Communications, 2010

1.6 What Does OFDM Bring to the “Game”?

In Section 1.2, we presented an overview of the trends in optical communications and the evolution toward highly reconfigurable networks at the channel speed of 100 Gb/s and beyond. We also reviewed technological advances in silicon technology indicating that the time has come for SDOT. To capture the gist of the past few sections, here we show that optical OFDM which combines the merits of the coherent detection and OFDM technology has arrived in time for the next-generation optical networks.

1.6.1 Scalability to the High-Speed Transmission

To cope with upgrades to the next transmission speed in optical systems, the WDM equipment needs to be significantly redesigned. Sometimes perhaps a new type of fiber is required to be redeployed. Specifically, the optical transmission systems have advanced from direct modulation in multimode fiber to modulation in single-mode fiber, such as externally modulated NRZ modulation, RZ modulation, DPSK modulation, and single-carrier coherent systems, or perhaps optical OFDM systems. A significant capital investment is required for each technology advance involving high-speed circuit design and testing and also system-level testing and evaluation. There is significant risk regarding whether the investment can be recouped. As such, it is critical to identify a technology that will have a maximum life span and that can be adapted to the next generation of the product with minimum modification in hardware and software. We aim to show that optical OFDM is the ideal future-proof technology that can be gracefully scaled to ever increasing transmission speed.

As we alluded to in Section 1.4, because the information in optical OFDM is managed in the frequency domain, it is relatively simple to partition the entire broad OFDM spectrum into many sub-bands whenever the bandwidth bottleneck occurs for the

DAC/ADC signal processing elements. This ensures a smooth migration path of CO-OFDM from 40 to 100 Gb/s, or even 1 Tb/s, by augmenting the spectrum through OFDM band multiplexing.[16,7] In doing so, the hardware and software design developed for 40 Gb/s will very likely be reused at 100 Gb/s, or even Tb/s, without a major design overhaul. Although OFDM modulation does not appear to be as familiar as single-carrier modulation in terms of its transmitter and receiver design as well as the associated signal processing, significant benefit will be gained by developing such a technology that will be reused in the next-generation products for the foreseeable future. This is a much better scenario than adopting a modulation format at 40 Gb/s that may not be applicable to 100 Gb/s or future Tb/s systems.

1.6.2 Compatibility to the Future Reconfigurable Optical Networks

The optical network today is predominately based on point-to-point connections, involving laborious human intervention in installation, maintenance, and bandwidth provisioning. As discussed in Section 1.2, modern optical networks are evolving toward those that are highly adaptive and reconfigurable, similar to the wireless LAN. This concept of plug-and-play optical networks minimizes the cost associated with expensive human intervention and will be critical to the future optical networks that can economically meet the capacity demand from bandwidth-rich Internet video traffic. We identify the following attributes of optical communication systems that are essential to the future optical networks and show how optical OFDM can gracefully meet each challenge that may not be sufficiently addressed with the conventional modulation formats:

Transmission agnostic to the underlying physical link: The optical fiber links deployed throughout the past three decades comprise fibers with differing chromatic dispersion and polarization mode dispersion, as well as varying span distance from 40 to 120 km and varying mechanical stability, dependent on whether the fibers are buried in the ground, hung from poles, or located along disturbance-prone rail tracks. The large divergence in optical dispersion and mechanical stability makes it difficult for conventional modulation formats, such as direct-detection NRZ/RZ or DPSK, to meet these challenges for high-speed transmission at 100 Gb/s and beyond. CO-OFDM, with its intrinsic resilience to any optical dispersion and a simple and convenient method of adaptive equalization based on the pilot subcarriers/symbols, is an ideal candidate for meeting these challenges.

Adaptive data rate provisioning: Because of the vast diversity of physical link, the supported link data rate may not be predetermined or may be too costly to be predetermined. Because CO-OFDM supports digital signal processing at the transmitter and receiver, the optimum data rate can be obtained through the bit and power loading or subcarrier-level manipulation. At the beginning of the life, the carried data rate can be higher than the nominal rate when the margin is available. On the other hand, when the margin is not sufficient, the data rate can be simply reduced through loading less subcarriers or adding more forward error correction (FEC) redundancy. The concept of the link operation at the downscaled rate is beneficial compared to the alternative scenario in which the link is rendered useless if a full rate is enforced. The software provisioning of multiple data rate obviously reduces the inventory counts and its associated cost.

Sub-wavelength granularity bandwidth access: The optical transmission channel data rate is envisioned to advance to 400 Gb/s or even 1 Tb/s within the next decade. CO-OFDM provides a seamless pathway to 1 Tb/s Ethernet from the current generation of 100 Gb/s Ethernet.[81] This enormous data rate of 1 Tb/s may make sense among the major nodes, but it would be beneficial to provide a pathway for a smaller intermediate node to economically access the 1 Tb/s traffic at a lower rate because some of the intermediate nodes may not need 1 Tb/s bandwidth but still need to access the multicast traffic at 1 Tb/s. Band-multiplexed OFDM is ideal for such a purpose. Figure 1.9 shows the 1 Tb/s link between two major nodes, nodes A and B, where the CO-OFDM signal is composed of 12 of 100 Gb/s sub-bands. In the intermediate node C, only the third band is accessed. This is done by simply tuning the receive laser to the center of the third band and passing the down-converted RF signal to a low-pass RF filter. Because the entire receiver signal processing is performed at 100 Gb/s, the cost for the intermediate load can be cheaper than that of the major node at 1 Tb/s. Of course, future bandwidth expansion of the intermediate node can be achieved by adding more circuit cards at 100 Gb/s.Figure 1.9. Illustration of sub-wavelength bandwidth access of 1 Tb/s CO-OFDM signal for an intermediate node C with a 100 Gb/s receiver. The selectivity is done by tuning the local laser to the center of the desired OFDM band (e.g., the third band in the illustration).

Self-performance monitoring: CO-OFDM is heavily reliant on the channel estimation for equalization, and subsequently various important system parameters can be acquired without resorting to separate monitoring devices.[82,83] Parameters that can be extracted from CO-OFDM receivers include chromatic dispersion, PMD, laser phase noise, OSNR, nonlinearity, and Q-factor. These are important parameters for network monitoring and maintenance. For instance, Q-factor statistics can be gathered to give the operator a clear view of the margin for the link, advanced warning for the replacement, or to indicate optical power adjustment before the system collapses into outage.

Energy efficiency awareness: As the channel rate and the overall capacity increase to meet the exponential growth of IP traffic, there is a growing concern about the energy consumption of the telecommunication equipment in the context of its environmental and social impact. It has been recognized that the electrical energy consumption is a significant contributor to greenhouse gasses.[84–86] Conventional transmission systems are designed to operate properly during the worst-case scenario, or all the transponders may be overprescribed. In optical OFDM-based systems, the dynamic adaptation of the bit resolution, RF amplifier power, FEC gain, as well the complexity of the channel estimation will inevitably reduce the unnecessary signal processing and subsequently improve energy efficiency. For instance, most of the time the optical link is quite stable; the rate of the PMD variation is slow (<10 Hz). Therefore, channel estimation can be done less frequently; it only needs to be updated at the faster rate when the fiber link is occasionally disturbed due to human actions at the central office. On average, the computational complexity and its associated power consumption due to the channel estimation are dominated by the slow dynamics of the fiber optics, and therefore energy efficiency is enhanced over that of the design that assumes the fast-varying channel all the time.

> Read full chapter

Optical signal-to-noise ratio monitoring

Jun Haeng Lee, Yun C. Chung, in Optical Performance Monitoring, 2010

2.2.3 Potential problems

Linear interpolation techniques are very useful for measuring the OSNR of WDM signals in point-to-point optical links. However, in dynamically reconfigurable networks, the accuracy of these techniques could be severely degraded because the spectrum of the ASE noises could have irregular levels that vary with the wavelength.[11] Figure 2.5(a) shows an example of such a case in an optical network consisting of ROADMs. Eight wavelength channels are multiplexed and transmitted over seven add/drop multiplexing (ADM) nodes. At each ADM node, a certain wavelength channel is dropped and a new channel having an identical wavelength is added. The other wavelength channels pass through the node transparently in the optical layer. In this scenario, each wavelength channel should traverse a different number of ADM nodes. Thus, the wavelength channels have different OSNR levels when they are observed at point A of the link. Figure 2.5(b) shows the optical spectrum obtained at point A when unmodulated continuous-wave (CW) signals are transmitted. The spectrum of the ASE noises is significantly reshaped due to optical filtering at each

ADM node. Since the ASE noises between channels are significantly filtered out at every node, the levels of the ASE noises under the channel wavelengths have no correlation with those between the channels. In addition, it is not easy to identify the levels of the filtered ASE noises if the channels are modulated at a high bit rate, as shown in Figure 2.5(c). Thus, in such a case, linear interpolation techniques could induce a large error in OSNR measurement.

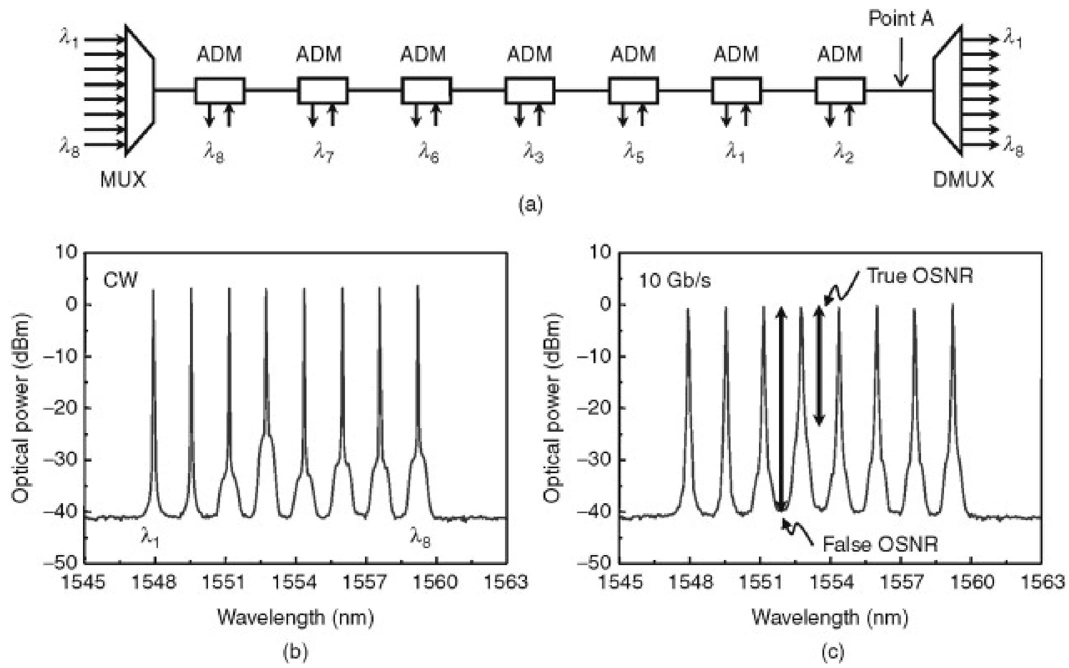

Figure 2.5. (a) Example of a dynamically reconfigurable transparent optical network configured with ROADMs. Optical spectrum measured at point A, (b) when unmodulated CW signals are transmitted, or (c) when 10-Gb/s NRZ signals are transmitted. (Resolution bandwidth: 0.05 nm.)

The situation is exacerbated when high-speed phase-modulated signals are transmitted with dense channel spacing. The spectral power of the phase-modulated signals tends to be well distributed like ASE noises since they often have no carrier component carrying strong optical power. Figure 2.6 compares the spectrum of 43-Gb/s return-to-zero (RZ) differential quadrature phase-shift keying (DQPSK) signals with that of CW signals; the spectrum was measured after turning off the modulators. One group of channels (i.e., the four channels located on the left side) was transmitted over a longer route than the other. Thus, the channels in this group have worse OSNR values than those in the other, as clearly seen in Figure 2.6(b), which was obtained when the CW signals were transmitted. However, it is impossible to identify this difference from the spectrum in Figure 2.6(a), which was obtained with the 43-Gb/s RZ-DQPSK signals. Based on this optical spectrum, the linear interpolation techniques may determine that all channels have the same OSNR. Therefore, to accurately monitor the OSNR in reconfigurable transparent optical networks, it is necessary to measure the in-band ASE noises under the channel's wavelength.

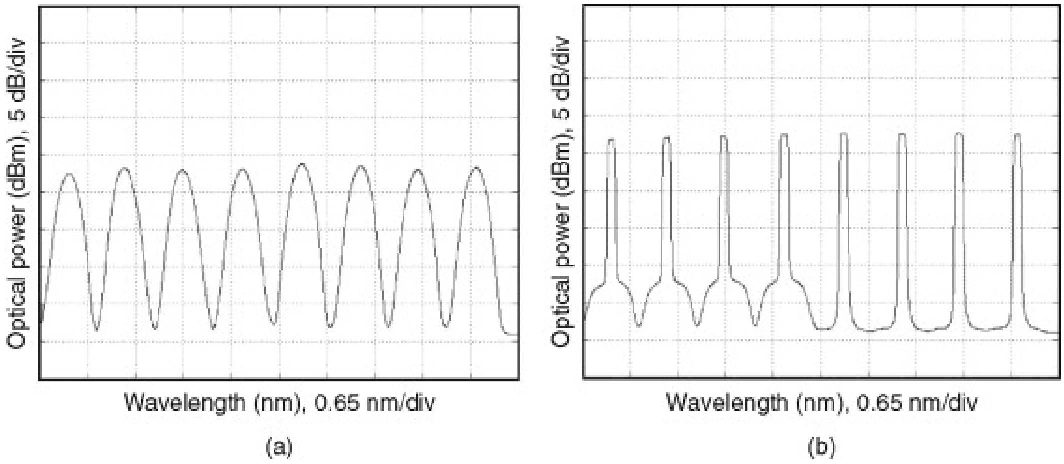

Figure 2.6. (a) Optical spectrum of 43-Gb/s RZ-DQPSK signals. (b) Optical spectrum measured after turning off modulators. (Resolution: 0.1 nm; div, division.)

> Read full chapter

Cognitive radio evolution

Joseph MitolaIII, in Cognitive Radio Communications and Networks, 2010

20.1 INTRODUCTION

Introduced in 1998–1999, cognitive radio has become an all-encompassing term for a wide variety of technologies from dynamic spectrum access to reconfigurable networks. As originally published [6,678], the concept emphasized enhanced quality of information (QoI) for the user, with spectrum agility framed as a means to an end and not as an end in itself. The first research prototype cognitive radio (CR1), for example, learned to initiate a simulated Bluetooth link to exchange business cards in a wireless manner based on the detection of the user's a prototypical setting of "introductions," in a simulated verbal exchange among users. This intelligent agent embedded in the programmable digital assistant (PDA) had not been specifically programmed for this use case but rather learned this behavior from observing a prior user-initiated business card exchange. The embedded machine learning technology of case-based reasoning (CBR) in this architecture "observed everything" and therefore was able to associate the user's prior manual use of its own Bluetooth chipset to exchange business cards, associating contemporaneous cues in the speech domain such as phrases like "May I introduce" and "Very pleased to meet you." CR1 synthesized a CBR template to autonomously perform the actions Power-up Bluetooth, Exchange Business cards, Power-down Bluetooth when the situation Introductions is detected.

Because of CBR, CR1 also could “learn by being told,” which moves the expense of creating business logic rules from the service provider (where programming business logic is an overhead cost) to the device and the user, where the costs have to do with user acceptance of the embedded CBR technology. In addition, embedded CBR enables cognitive radio to learn etiquettes for sharing radio spectrum with legacy radios.

During the past five years, the world’s radio research and engineering communities have been developing software-defined radio (SDR) and cognitive radio (CR) for dynamic radio spectrum sensing, access, and sharing [679–681], revealing many regulatory, business, market, and open architecture needs implicit in the broad potential that cognitive radio architecture (CRA) introduces [17, 575, 682]. Radio architectures from wearable nodes and radio access points to the larger converged networks have evolved from the niche market of single-band, single-mode car phones of the 1970s to today’s ubiquitous multiband, multimode fashion statements. This chapter characterizes architecture evolution, including the near-term multimedia heterogeneous networks that converge traditional cellular architectures with Internet hot spots. This chapter also looks ahead toward the evolution of policy languages [683] and to sentient spaces [365, 684], integrated wireless environments that merge wireless technologies with increasing interplay of radio engineering with related information services of computer vision [685] and human language technologies (HLT) [686].

Contributions to CRA evolution span leading institutions across the globe, including (alphabetically) CVTR, Trinity College, Ireland; General Dynamics; Harris Corporation; Harvard University; IMEC, Belgium; Intel, KTH, the Royal Institute of Technology, Stockholm; Microsoft; Motorola; NICT Japan; Philips; RWTH Aachen, Germany; Samsung; Stanford University; Teknische Universitat Karlsruhe, Karlsruhe, Germany; TU Delft and Twente, The Netherlands; University of California at Berkeley; Virginia Tech; Virtual Center of Excellence (VCE) Wireless, United Kingdom; Zhejiang University, Hangzhou, China; to all of whom the author is particularly indebted.

Although the concept of cognitive radio stimulated research, development, and regulatory policy evolution, contemporary CRA emphasizes dynamic spectrum access [182]. Questions remain regarding the cost of implementing dynamic spectrum access regulatory and business policies in evolvable hardware, software, and network services. This chapter therefore considers this challenging problem from the perspective of cognitive linguistics, a branch of the humanities concerned with neonatal development of human language and its use in social settings. The current phase of CRA evolution includes greater integration of the user as the eighth layer of the protocol stack, more efficient network and node reconfigurability, and enhanced regulatory, business, security, and network operations policy languages.

20.1.1 Organization

This chapter first reviews the concept of radio architecture, including prototypical architectures for dynamic spectrum and embedded agents. It then describes the apparent lack of a comprehensive meta-level architecture for distributed heterogeneous networks and their related meta-level superstructures, including regulatory rule making and spectrum auctions. Changes in use case drive wireless architecture, so Section 20.3 shows how the historically significant striving for ubiquity and high data rate is beginning to give way to evolved value propositions where high quality of service (QoS) is the starting point for higher QoI. Section 20.4 therefore develops the potential for greater integration of cross-discipline information sources like video surveillance and human language technology in future cognitive radio architectures. To help guide this evolution, QoI is characterized along its several dimensions in Section 20.5, while Section 20.6 introduces the contributions of cognitive linguistics to policy language evolution and Section 20.7 offers a review of challenges and opportunities before the conclusion in Section 20.8.

> Read full chapter

Optical Wavelength-Division Multiplexing for Data Communication Networks

Klaus Grobe, in Handbook of Fiber Optic Data Communication (Fourth Edition), 2013

5.2.7.2 ROADM applications

Relevant ROADM applications and advantages over static networks include the following:

- Any-to-any connectivity and single-channel add/drop in large rings
- Simplified service planning and connection provisioning
- Reconfigurable networks, which includes optical restoration

Cost savings of ROADM networks mostly refer to operational expenditures (OpEx) rather than capital expenditures (CapEx). OpEx savings result from fast reconfigurations of any-to-any connections on a per-wavelength basis. This decreases connection setup and increases system utilization as compared to static OADMs. In banded static systems, the node number was typically limited to ~16. Larger node numbers were possible, but led to inflexible systems with long traffic downtimes during reconfigurations. The increase in system utilization is demonstrated in Figure 5.16 for ring (degree 2) and mesh (higher degree) networks.

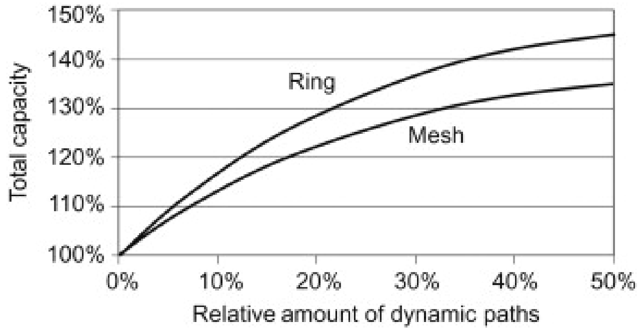

Figure 5.16. Advantage of providing reconfigurability in meshed networks.

The capacity gain (or the corresponding cost decrease per bit per second) that can be achieved by increased flexibility is in the range of 50% [18–20]. The capacity increase can hold for the WDM transport and the IP/MPLS client layer. Flexibility can also lead to lower latency.

Client-layer capacity increase can be enabled by core router offloading. With increasing total traffic, transit traffic can lead to problems for routers. Either latency increases (finally leading to decrease in throughput) or routers have to be oversized to cope with transit traffic. Flexible router bypass supports higher throughput. ROADMs enable router bypass on demand where necessary and when necessary. This is shown in Figure 5.17. For fully automated bypass, WDM-IP/MPLS control-plane interworking is required.

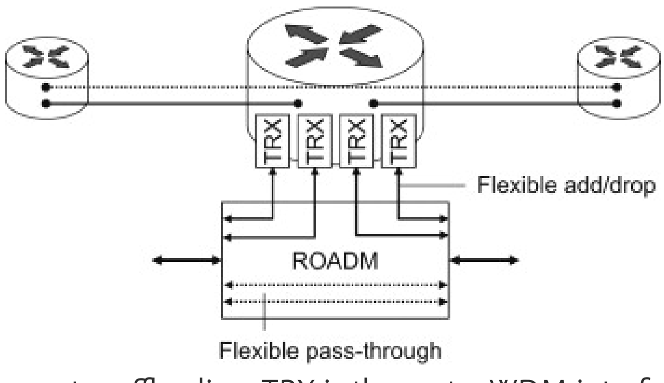

Figure 5.17. Core router offloading. TRX is the router WDM interface.

Wavelength provisioning and connection setup is automatically controlled by the NMS and/or a GMPLS control plane, including constraint-based routing. This reduces human errors and allows very fast-automated traffic engineering (TE), which is required for optical restoration.

Connection setup can even be *fully* automated, given the client layer (IP/MPLS, Ethernet) and the WDM control planes have common interfaces. Then, customers can request connections through the UNI-C (the GMPLS User-Network Interface–Client implementation). This direct request seems unlikely in commercial carrier networks. It may be prohibited by security considerations. Then, the UNI-C will remain a part of the transport network. Here, it can serve as the demarcation point towards customers, still enabling fast (but non-real-time) service provisioning. In scientific backbones, however, the concept of real-time *user-enabled networks* is seriously discussed [21].

ROADMs provide optical per-channel (and OMS) monitoring and power balancing. This improves network diagnostics, fault management, and resilience. Automated power balancing also maintains a high signal/noise ratio for all WDM channels, thus increasing transparent path lengths and per-link node number. It is one of the basic technologies for long-haul links.

ROADM networks must be engineered to meet the WDM signal requirements (regarding noise, dispersion, crosstalk, nonlinearity) for the most challenging connections even if these worst paths are never actually configured. This may require additional amplification, raising the CapEx compared to static networks. Unlike service planning, path engineering becomes more complex due to the necessity to *potentially* support *any* path.

Computational grids flexibly connect customers with huge bandwidth demands. Computational grids are hardware and software infrastructures that provide dependable, consistent, pervasive, and inexpensive access to computational capabilities [22]. These grids consist of network, resource (high-performance compute clusters), middleware, and applications layers. Applications that rely on high-performance grids involving ROADM networks include medicine, climate, geophysics, radio astronomy, and high-energy particle physics. Examples are the pan-European and worldwide ROADM networks, which connect various data centers around the world to the Large Hadron Collider (LHC) at CERN in Geneva.

National Research and Education Networks (NRENs) were among the early adaptors for ROADM networks, driven by the bandwidth requirements of their client universities. A large ROADM and GMPLS network example is the Polish NREN called PIONIER. PIONIER is a fully reconfigurable DWDM network that also connects to the surrounding NRENs and to the pan-European research network. The network uses multidegree ROADMs and can support services with 100 Gb/s. It is shown in Figure 5.18.

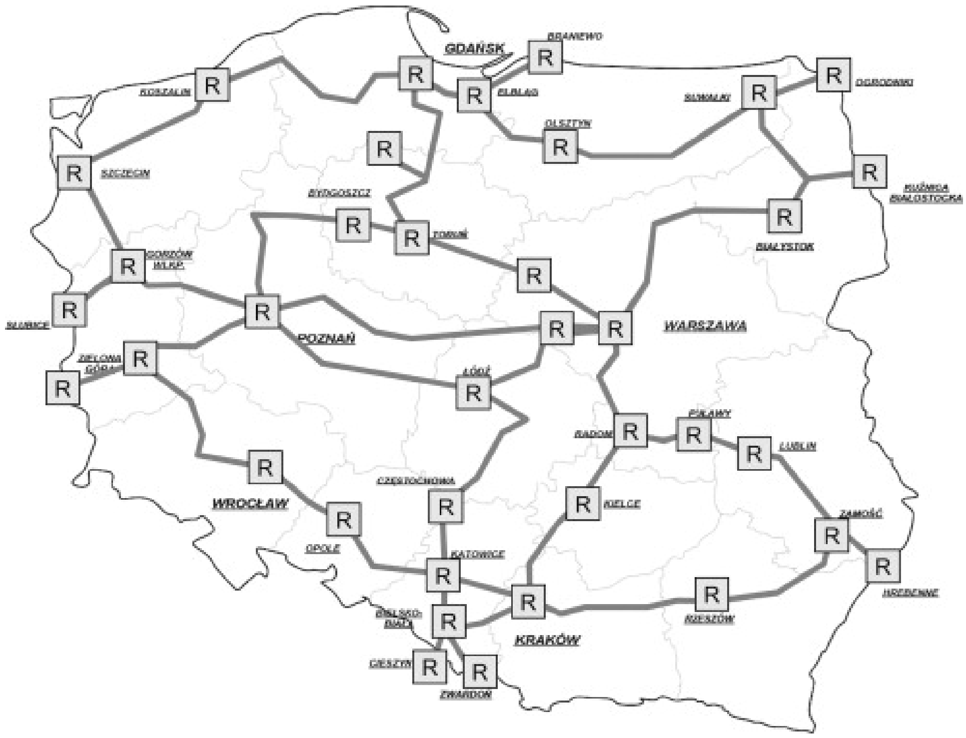

Figure 5.18. The PIONIER NREN. R denotes ROADM sites.

On a more regional network scale, ROADMs can create networks with a centralized client layer (L2, L3). The L2/L3 equipment is centralized in a single hub node or in two redundant nodes. All connections are flexibly provided through the ROADM network. An example network is shown in Figure 5.19.

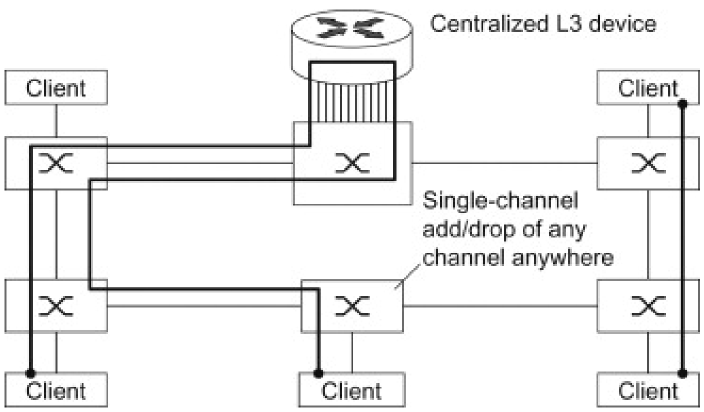

Figure 5.19. Network with centralized L3 equipment.

Centralized L2/L3 networks can lead to significant cost savings. The lifetime of the optical transport equipment typically exceeds the lifetime of the L2/L3 client layer by a factor of 3–5. Hence, ROADM networks have to support approximately four generations of client equipment. Due to the centralization, no hardware changes (gateway upgrades) are necessary in the client nodes. In addition, this approach leads to leaner and cheaper L2/L3 equipment because the centralized devices are automatically offloaded from transit traffic. Centralized L2/L3 and ROADM networks are discussed for use in scientific and educational networks.

ROADMs, together with GMPLS, also enable restoration in the optical transport domain. Optical restoration is efficient against fiber failures but usually does not protect against equipment (WDM transceiver) failures. For very high path availabilities, 1+1 protection can be combined with restoration. In the case of a first failure, the protection gets active. In the case of a less probable secondary failure in the protection path, the slower restoration can still be used to maintain a connection. A simple meshed WDM network with CD-ROADMs capable of supporting restoration is shown in Figure 5.20.

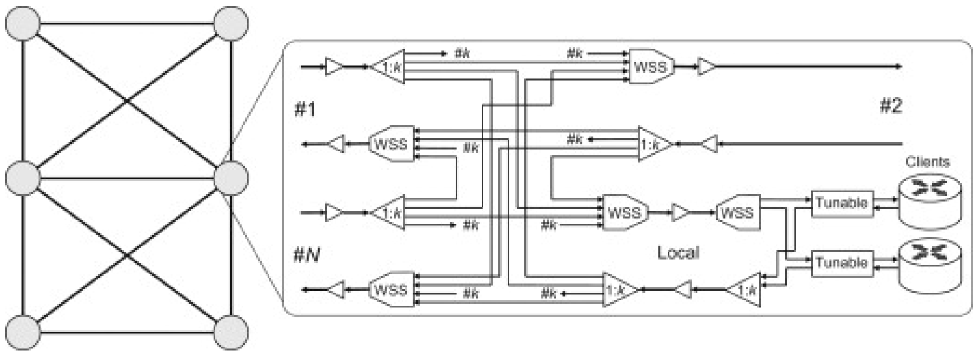

Figure 5.20. Meshed network with CD-ROADMs.

This simple network is now used to demonstrate the advantage of CD-ROADMs in restoration scenarios. In particular, the colorless functionality helps avoiding blocking or the requirement for dedicated wavelength converters (i.e., regenerators). It can also decrease link lengths, that is, latency. This is explained in Figure 5.21.

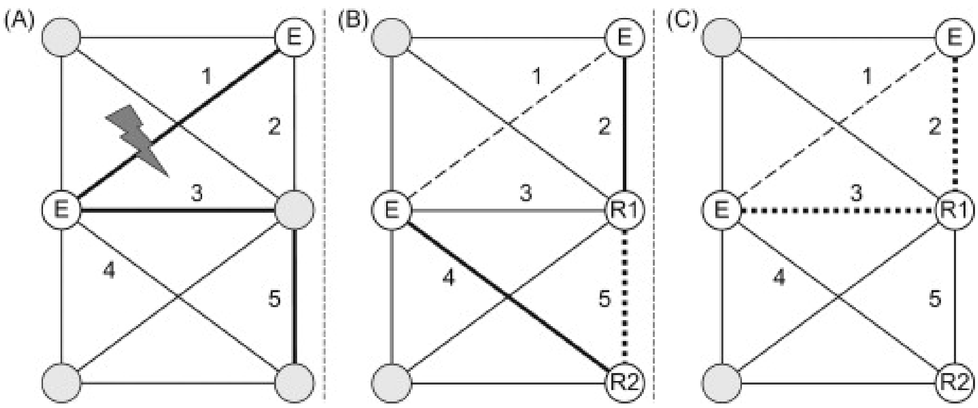

Figure 5.21. Restoration example.

Link #1 between two end (E) nodes fails, as indicated in Figure 5.21A. Links #3 and #5 carry the same wavelengths as link #1, indicated by the bold lines. However, these links still have resilience capacity in the form of other unused wavelengths. Unnumbered links do not have this capacity. With colored ROADM interfaces, successful establishment of a resilient path requires regenerator nodes (R1, R2), which perform additional wavelength conversion, as shown in Figure 5.21B. If the end (E) nodes were also colorless, they could establish a new path by tuning to the respective wavelength. In our example, this path runs via R1 but does not require regeneration. It is shorter than the path via R1 and R2 (Figure 5.21C).

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Definition of Smart Distribution Networks

Emilio Ghiani, ... Gianni Celli, in Operation of Distributed Energy Resources in Smart Distribution Networks, 2018

1.1.2 Challenges in Smart Distribution Network Implementation

The development of effective SDNs needs to control electricity productions, consumptions and storage, as well as power flow by means of a DMS/EMS, and to implement features in order to manage a more flexible and reconfigurable network structure. The possibility of having a large number of controllable DER, DG units and loads under demand side management (DSM) control, electrical vehicles (EVs) and distributed ESSs require the use of a hierarchical control scheme, which enables an effective and efficient control of this kind of system, in which the DMS operates at the higher level and is able to exchange information with local control systems. A multidisciplinary approach will be necessary and focused on the development of new communication systems and their interfacing with the power system elements and the development of DMS/EMS able to manage in a smart way the distributed system for energy production, consumption, and storage [5].

Communication technology is seen as an essential enabling component of future smart grids. In particular, the smart metering, protection and control communication is the major component of the overall smart grid communication architecture and consists of smart meters, protection and control systems which are two-way communicating devices with the central SG controller.

The whole system could be organized according to hierarchical structure with a HAN formed by appliances and devices within a home to support different distributed applications, NAN that collects data from multiple HANs and delivers the data to data concentrator, WAN which carries metering data to central control centers and, finally, a hateway which is in charge of collecting or directly measuring energy usage information from the HAN members and that transmits this data to interested parties.

Wireless architecture can be either an option for HANs, NANs and WANs, or mandatory in case of vehicle-to-grid (V2G) communications.

Wired communication will offer a valid counterpart to wireless connection in the SG. Different technologies are available for usage depending on the desired coverage area. Fiber optic links may be adopted for WAN coverage of transmission lines (tens of kilometers, and more). Power line communications (PLCs) may instead provide a good compromise for NANs and HANs coverage of local/micro SG portions (up to hundreds of meters).

Advances over the state-of-the-art are needed since the amount of information that will be exchanged in the SG will be much higher than in current systems, which are mostly limited to over relaxed time scales (days). Also, optimization necessarily needs to be matched to specific application requirements in a world in which the target application is still unclear, the interest being today focused on advanced metering infrastructures (AMI) aspects (centralized/distributed micro grid control), but being likely to converge in a longer time scale to a fully distributed management of distributed resources (the so-called energy Internet scenario).

Communication technology needs to accomplish the IEC 61850 standard to be used with DERs and power distribution networks. IEDs with security features and control are becoming standard equipment for power system components, new substations, and are also used to improve the systems of protection and control of existing substations. These smart devices are required for power flow congestion, voltage regulation, DG, load control, and fast reconfiguration. Microprocessor based protection relays provide, in addition to the basic function of protection, different functions, such as measurement, data acquisition, recording events and disturbances, tools for failure analysis, and control.

EMS/DMS and SCADA systems will be extensively used to manage data from distributed elements of the transmission and distribution system. The SCADA system transmits the measurement data, provided by an AMI and by a set of remote collecting data devices (RTUs) placed in strategic positions along the smart grid, to the EMS/DMS.

New ICT infrastructure supporting a more efficient smart grid will offer new challenges for DSM allowing to communicate frequent price updates to follow the evolution of the balance between supply and demand in near real-time. Thanks to this ICT infrastructure, much more dynamic, reactive pricing mechanisms required to take into account real-time availability of fluctuating renewable sources will be carried out.

Electric energy storage will play a key role in smart grids because it enhances flexibility of renewable DGs and of loads. Most of the problems in power quality, distribution reliability, and power flow management can be solved with the widespread roll-out of energy storage devices intelligently controlled.

Flexibility of loads can be regarded as a significant DER thanks to the large number of loads that are connected to distribution systems. The actual capabilities and potential of load flexibility are still to be investigated in the real applications. Flexibility can be introduced in two ways. In the first case, loads can be shifted in time, i.e., it can be modified for the starting time and, partially, the duration of the consumption cycle; these loads absorb a fixed consumption of energy. In the second case, loads can be curtailed for a time interval, i.e., they are temporarily disconnected or reduced; the energy that is not absorbed is not recovered in another time interval. Typical examples are washing machines as shiftable loads and lights as curtailable loads. In both the cases, smart control and communication capabilities are required at load level.

The complexity of the several aspects underlined requires to rethink the planning of the power distribution networks. Novel planning techniques should integrate operation models within planning as well as the models of the communication system. The simulation planning tools have to be capable of reproducing fluctuating renewable generation caused by the moving of cloud patterns and/or to simulate local meteorological conditions, and the cosimulation of both power and communication systems will be an essential part of the planning process.

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Optical performance monitoring based on RF pilot tones

Paul K.J. Park, Yun C. Chung, in Optical Performance Monitoring, 2010

9.2.4.2 Optical path and channel identification

In the future all-optical transport network, it is envisioned that the optical paths of WDM signals can be frequently changed by the optical crossconnects (OXCs). Thus, for the proper operation and management of such a dynamically reconfigurable network, it will be necessary to monitor the optical paths of every WDM channel. Pilot tones are well suited for this purpose since they are bound to follow their corresponding optical signals in the network. Thus, the optical paths of WDM signals can be monitored by simply tracking their corresponding tone frequencies since every channel is assigned to a unique tone frequency. In earlier studies, it has been proposed to monitor the optical paths of WDM signals within the OXC by using low-frequency pilot tones (0.1–5 KHz).[21–23] These techniques added pilot tones to WDM signals at the input of OXC and then monitored them at the OXC's output in order to verify that the optical path was reconfigured as desired. However, these pilot tones could propagate to the next nodes along with WDM signals and cause confusions to network operators (if every OXC utilized an identical set of tone frequencies). In addition, these low-frequency tones could generate ghost tones while traversing the amplified transmission link. In order to avoid these problems, it has been proposed to erase the pilot tones at the outputs of OXC by fiber Bragg gratings (FBGs)[22] and voltage-controlled attenuators.[23] There have been some efforts to extend these monitoring techniques for use in the entire network.[3,4,7] For this purpose, every channel in the network should be assigned to a unique tone frequency. Thus, the channel power and the optical path of a WDM signal can be monitored from the originating node to the destination node by tracking its corresponding pilot tone. However, the performances of these techniques can be seriously impaired by XGM and SRS, particularly in a long-haul network with a large number of WDM channels. In order to overcome this problem, we measured the pilot tones after the WDM signals were demultiplexed in the OXC.[7] Thus, unlike the previous techniques, this technique is not sensitive to ghost tones. Figure 9.15 shows the experimental setup used for demonstrating this technique. In this demonstration, four 4×4 OXCs, made of waveguide-grating routers and thermo-optic polymer switches, were used. We transmitted four WDM signals operating at 1550.92 to 1555.75 nm from OXC 1 to OXC 4 via 640 km of SMF and 8 EDFAs. These WDM signals had unique tone frequencies in the range of 80 to 110 kHz. We also sent one channel from each OXC, all operating at 1550.92 nm, to OXC 4. In OXC 4, we monitored the pilot tones at the outputs of optical switches.

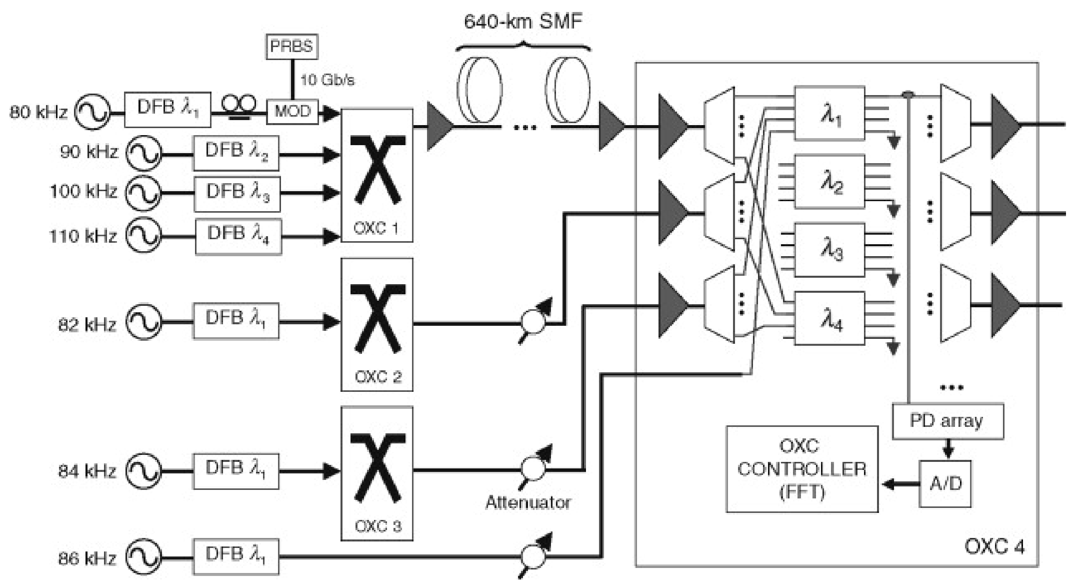

Figure 9.15. Experimental setup used for demonstration of pilot-tone-based monitoring technique for optical path and crosstalk.[2]

Figure 9.16(a) shows the electrical spectrum measured at one of the output fibers of the optical switch for λ_1 in OXC 4. From this figure, we can easily identify the optical path of channel 1, originating from OXC 1 by measuring the frequency component at 80 kHz. The optical power of this channel can also be monitored by measuring the magnitude of the pilot tone. Figure 9.16(a) also shows the ghost tones (at 90, 100, and 110 kHz) generated by XGM during the transmission over 640 km of SMF. However, it should be noted that there is no ghost tone at 80 kHz since we demultiplexed the WDM channels before the detection of pilot tones. When the optical switches in OXC fail to operate properly, intraband crosstalk—which is a difficult parameter to measure by using only optics—may be generated. This technique could also be used for the monitoring of such intraband crosstalk. In order to simulate the failure of an optical switch, we replaced the optical switch for λ_1 in OXC 4 with a 4×4 coupler and measured the pilot tones. The crosstalk level was adjusted by using the variable attenuators placed at the input fibers to OXC 4. The result in Figure 9.16(b) clearly shows the crosstalk components at 82, 84, and 86 kHz (caused by the WDM signals operating at the same wavelength with channel 1 but originating from different OXCs). This technique may require considerable tone frequencies since every channel in the network has to utilize a unique tone frequency. In order to mitigate this problem, the use of dual tones for each channel has been proposed.[4] In this technique, the first tone represents the originating node, while the second tone indicates the channel number. Thus, we can monitor the optical paths of every channel in the network with a small number of tone frequencies. However, as the number of WDM channels increases, the performance of this technique can be seriously impaired by ghost tones (since all the WDM channels originating from the same node have an identical first tone).

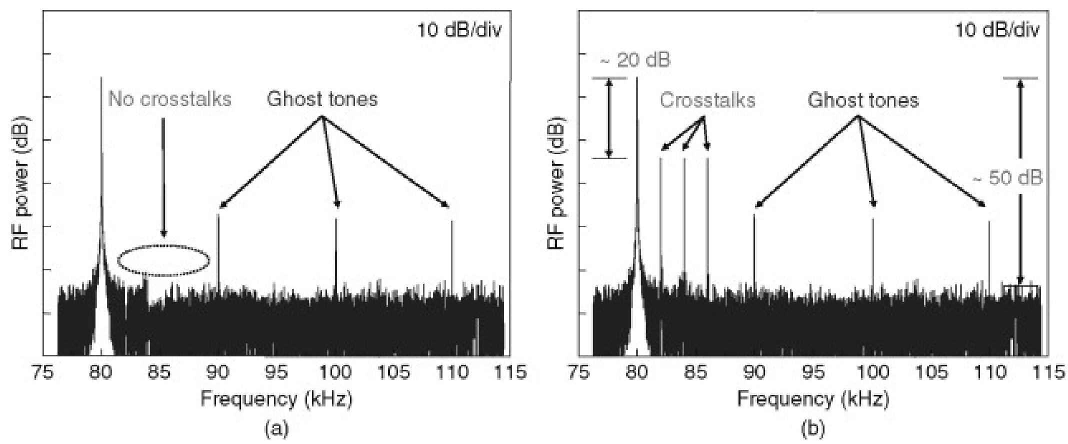

Figure 9.16. Electrical spectra of pilot tones measured at the output of the switch for λ_1 in OXC 4 (a) under normal operation, and (b) under switch failure condition.[2]

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