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Demonstration of an add-drop network node with time slot access for high-speed WDMA dual bus/ring packet networks

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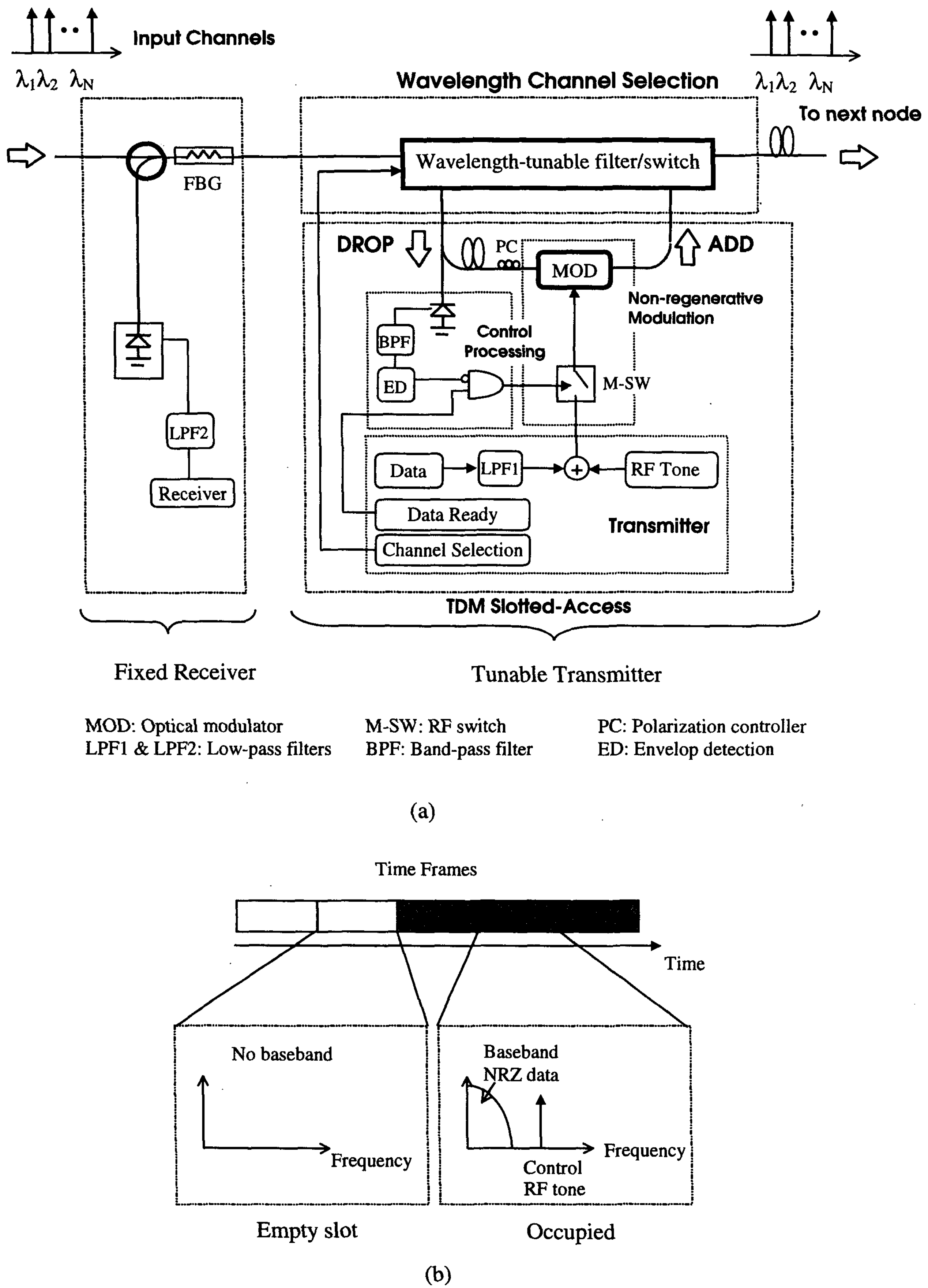
High-speed wavelength division multi-access (WDMA) ring and bus networks are very promising architectures to support multi-access of high-capacity data. Most WDMA networks[1-3] are configured with fixed transmitter and tunable receiver (FTTR) and employ decentralized light sources. However, they require complicated control signaling and suffer from a wavelength matching problem. In this paper, we propose and demonstrate a practical WDMA ring/bus packet network node using tunable transmitter and fixed receiver (TTFR) configuration. Centralized light sources are used and time slot access is controlled by our proposed signaling scheme.

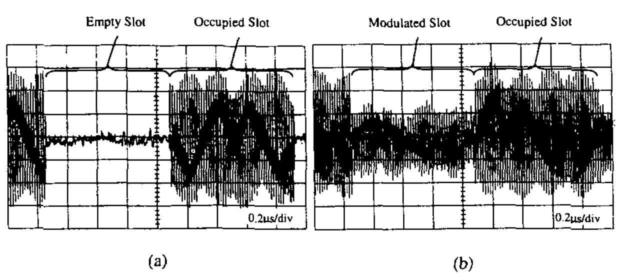
Figure 1(a) shows the architecture of our proposed network node. Multiple wavelengths with empty slots (unmodulated time slots with cw



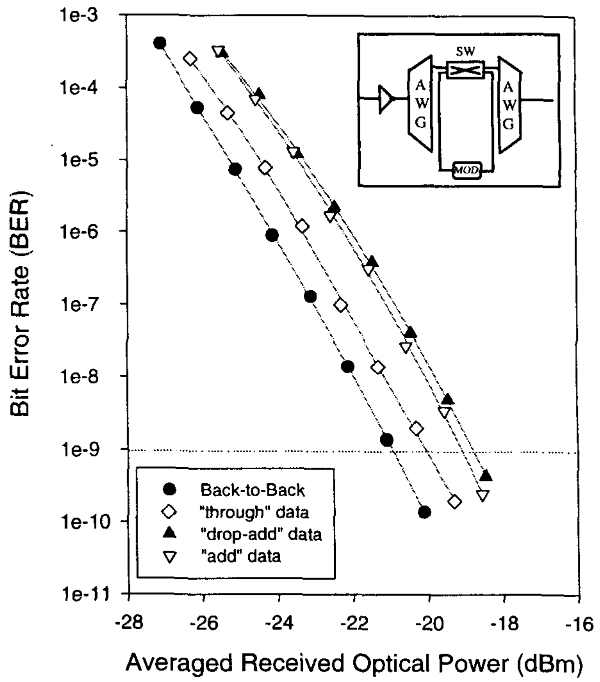
TuJ5 Fig. 1. (a) Proposed network node architecture; (b) Control signaling scheme for time slot access.

optical power) are generated as shared channels from the head node. Each transceiver comprises a tunable transmitter and a fixed receiver. For data reception, a fiber Bragg grating (FBG) with its center wavelength matched to its assigned wavelength is used. For data transmission, the node can compete for empty slots on the wavelength channel assigned to the destined node. In each data packet, an RF tone is multiplexed with the baseband data to signify the occupancy of that time slot [Fig. 1(b)]. The frequency of the RF tone can be identical for all wavelengths. Once the wavelength is selected by the wavelength-tunable switch, the transmitting node first senses the occupancy of the wavelength by detecting the presence of the RF tone. If it is detected, the electronic switch (M-SW) at the RF input of the modulator is opened, prohibiting any out-going data packets. If no RF tone is detected and there are data waiting to be sent, the M-SW will be swung close. The multiplexed data packets (with a locally generated RF tone) will modulate the empty slots on the selected wavelength through an optical modulator. If the node has nothing to send, all wavelengths will be forwarded to the next node without any local processing. Because the RF tone frequency is identical for all nodes, all transmitters and tone detection can be identical, thus greatly simplifies the system implementation.

We have demonstrated the proposed network node [Fig. 1(a)] in a four-wavelength WDMA packet network with a channel spacing of 100 GHz. The four wavelengths used are λ_1 = 1553.9 nm, λ_2 = 1554.7 nm, λ_3 = 1555.5 nm and λ_4 = 1556.3 nm. The wavelength λ_3 is directly modulated by a 622.08-Mbit/s (2^{23}-1 PRBS) NRZ baseband data stream multiplexed with a 1-GHz RF tone where the multiplexed signal is chopped by a periodic square waves of frequency 600 kHz. Thus, wavelength λ_3 carries alternate time slots of modulated and unmodulated signals. At the network node, the wavelength tunable switch is implemented by a pair of arrayed-waveguide gratings (AWG) (PIRI AWG-16 × 16-X-1.5) and a 2 × 2 optical space switch (UTP APE-2X-150) (see inset of Fig. 3). An optical amplifier (EDFA) is added before the wavelength switch to compensate the insertion loss of the wavelength switch. To send data on wavelength channel λ_3, the space switch on corresponding AWG output is set to cross-state to drop λ_3 to the local node. 95% of the dropped signal will be directed to a Mach-Zehnder modulator (IOAP-MOD9001A) through a fiber delay line of 100 meters and a polarization controller. To detect the RF tone, the remaining 5% tapped optical signal is first detected by a *p-i-n* detector, extracted by a bandpass filter centered at 1 GHz, then further amplified and low-pass filtered for envelope detection (ED). When there are data waiting to be sent, the output of 'Data Ready' is registered high. Together with the lack of RF tone being detected, the M-SW controlled by the AND gate will be closed. To send data, the baseband NRZ data are first filtered by a low-pass filter (LPF1, Δf_{3dB} = 770 MHz) and then multiplexed with a locally generated RF tone at 1 GHz. With the switch (M-SW) closed, the multiplexed signals will modulate the free time slots by the modulator and the modulated wavelength is added back to the network. Figures 2(a) and 2(b) show the respective waveforms before and after the data input from the network node to λ_3. The apparent amplitude fluctuations of the data are the result of insufficient sampling of the oscilloscope (bandwidth ~300 MHz). The electronic processing delay of the RF tone detection is about 0.5 μs and thus the 100-meter fiber delay is used.



TuJ5 Fig. 2. Recorded waveforms for channel 1. (a) input at the transceiver; (b) output of the transceiver.



TuJ5 Fig. 3. BER performance of baseband 622.08-Mbit/s 2^{23}-1 PRBS NRZ filtered data multiplexed with a single RF tone at 1 GHz. Inset: configuration of wavelength tunable switch using a pair of arrayed-waveguide gratings and an optical space switch in the experiments.

To retrieve the data carried on λ_3, an FBG with center wavelength at λ_3, $\Delta\lambda_{3,3dB}$, (3-dB bandwidth) = 0.4 nm, and R = 99.8% (power reflectivity) is used. The optical signals are first received by a *p-i-n* detector and the baseband electrical signals are filtered off by a low pass filter (LPF2, Δf_{3dB} = 540 MHz). Figure 3 shows the BER performance of the tunable transmitter with 622.08-Mbit/s (2^{23}-1 PRBS) NRZ continuous data stream for the following cases: (a) space switch in bar state and no local processing, ("through"); (b) space switch in cross state but no data modulation by the network node ("drop-add"); and (c) space switch in cross state but with data modulation by the network node ("add"). In each case, it is shown that there exists a power penalty of 1–2 dB and this is imposed by the space switch and the modulator.

In summary, a practical time slotted WDMA network node is demonstrated. The main advantages of our proposed scheme include all the advantages of TTFR and centralized light source and simple control signaling to avoid data collision during transmission.

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