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Wavelength routing in fibre-wireless networks with spectral selection and remote modulation

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Abstract: Deploying polarisation-independent reflective modulators at the ONUs and a flexible wavelength router cost-effectively located in a fibre-wireless network, can significantly improve the operation efficiency. Stable system performance has been shown in a field trial.

Introduction

The traffic load on current wireless networks is growing very fast. Mobile services are enjoying a quickly expanding customer base, the services themselves are becoming more diverse and bandwidth consuming (evolving from GSM to GPRS to UMTS), and many operators are entering the market. Nomadic wireless services are likewise expanding in customer base and in bandwidth, e.g. in wireless LAN environments. In the ACTS project PRISMA /1/ /2/, a dynamically reconfigurable fibre-wireless network has been developed and evaluated, which efficiently handles traﬃc loads shifting both in volume and location. Flexible wavelength routing is the key enabling technology for this.

System architecture

PRISMA’s system architecture, laid out for nomadic wireless services, is shown in Fig. 1. Multiple portable PCs have broadband (8-20 Mbit/s shared) wireless connections with the Radio Access Point (RAP), which is attached to an Optical Network Unit (ONU) with an ATM network termination function. The large number of ONUs is fed via M=8 wavelength channels, each carrying 622 Mbit/s ATM-framed signals. Each pair of up-/downstream wavelengths is handled by an Optical Line Termination (OLT). The upstream band is 1547-1550 nm, the downstream one 1538-1541 nm, and the wavelength spacing is 100 GHz.

The flexible wavelength router distributes the wavelength channels among the ONUs according to traffic demands. At the ONU, the upstream signals are transmitted by a reflective modulator, which deploys the continuous wave (CW) downstream wavelength channel selected by the wavelength router. The array of DFB lasers generating the CW wavelengths may be located at the router or even closer to the OLTs. The per-ONU costs are minimised by its universal non-wavelength-specific design without an active source, and by the high sharing factor of the router and DFB lasers. Typical split factors are N=8 and P=8. The master Network Management and Control (NM&C) at the OLT site controls the wavelength selection in the router and the spot distribution. By changing the wavelength selection via the NM&C, the operator can adapt the virtual topology of the network in order to accommodate fluctuating traffic loads.

Flexible wavelength router

The layout of the flexible wavelength router is shown in Fig. 4. The various wavelength channels are combined/separated by an HDWDM mux/demux, and via power splitters and thermo-optic Mach-Zehnder 1 x 8 switches ( realised in glass integrated optics) fed to the router outlets. The router can thus direct one or more wavelengths to an outlet. Insertion losses are around 13 dB, with polarisation dependency less than 1 dB and extinction ratio better than 20 dB. Switching times are less than 1 ms. Bi-directional optical amplifiers (OAs) with gains of 23 to 25 dB are used at each side of the router, which together with a 10 dB gain amplifier at the OLT yield sufficient power margin. Additionally, the router selects the appropriate CW laser wavelength for upstream modulation at the ONUs. The CW load to the outgoing OAs also reduces their gain variations for bursty upstream traffic. Fig. 5 shows the optical spectrum in downstream direction at one of the outlets, visualising the >20 dB suppression of the unwanted channels and the selected CW channel.

Remote modulator

At the ONU, a coarse WDM device separates the up- and downstream wavelength bands. As shown in Fig. 2, by separating the TE and TM polarisations of the downstream CW light in a Polarisation Beam Splitter (PBS), and by TM/TE conversion, the polarisation dependence of a LiNbO3 modulator can be circumvented. Thus a reflective modulator has been realised with a polarisation dependence less than 0.2 dB and an insertion loss of 6 dB.

Locating the wavelength router

The blocking performance of the system versus the offered load (normalised on the total capacity) has been analysed for various positions of the router. 343 RAPs have been assumed, of which 49 are hot spots (i.e., generating twice the load of a normal RAP), and 7 wavelength channels with a capacity of 622 Mbit/s each. Fig. 3 shows that at a given load, when positioning the router at LSC1, the blocking probability varies widely between the case where all hot spots are located on the same wavelength (worst case) and the case where they are evenly spread among the wavelengths (best case). Positioning the router at LSC3 offers the best blocking probability, insensitive to the hot spot distribution. Routing at LSC2 is only slightly worse; however, it reduces the per-ONU costs as the router is shared by much more ONUs. Therefore, the preferred location of the router in this system is at LSC2.
System measurements

The system has been successfully operated in a field trial during 2½ months in Ghent (B), supporting 8-20 Mbit/s ATM wireless connections to portable PCs in a shopping centre and university laboratories. The system operated very stable. Round Trip Times were around 6 ms for 64-bytes packets and 16 ms for 1024-bytes ones; the major RTT contributions were from the wireless system part.

Conclusions

Dynamic wavelength routing significantly improves the operation efficiency of a fibre-wireless system, and its performance for widely varying traffic loads. It can be cost-effectively implemented by optimising the router location, and by deploying a polarisation-independent reflective modulator at the ONU. Stable system performance has been shown under field trial conditions.

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References

/1/ ACTS 98, Project Summaries, Supplement covering 3rd Call, European Commission DGXIII-B