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Tutorial

Trends in optical access and in-building networks

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Abstract

As users require ever more speed, variety and personalization in ICT services, the capacity and versatility of access networks needs to be expanded. The first generation of point-to-point and of point-to-multipoint time-multiplexed passive optical networks (PON) is being installed. More powerful wavelength-multiplexed and flexible hybrid wavelength-time multiplexed solutions are coming up. Radio-over-fibre techniques create pico-cells for high-bandwidth wireless services. Next to bringing the bandwidth luxury to the doorstep, it must be distributed inside the user's home. By advanced signal processing techniques, high-capacity wired and wireless services are jointly distributed in a low-cost converged in-building network using multimode (plastic) optical fibre.

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Ton (A.M.J.) Koonen was with Bell Laboratories of Lucent Technologies for more than 20 years, as technical manager of applied research in broadband systems up to end 2000. From 1991 to 2000, he also was a part-time professor at Twente University. Since 2001, he is full professor in the COBRA Institute at Eindhoven University of Technology, and chair of the Electro-Optical Communication Systems group since 2004. He is a Bell Labs Fellow since 1998, IEEE Fellow since 2007, and elected member of the LEOS Board of Governors since 2007.
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Extended Abstract

As the thirst of users keeps increasing for higher capacity, more diversity and more personalization of services, the capacity and versatility of access networks needs to be expanded. Next to fast internet and high-definition video services, peer-to-peer file exchange and multi-party video-rich gaming are driving the need for bandwidth. Optical fibre is coming in, in order to relieve the shortcomings of the copper network, and also is able to outperform the power consumption of today's electronic solutions. Moreover, by exploiting the wavelength domain optical fibre is uniquely capable of integrating services with widely differing characteristics independent from each other into a single infrastructure.

First-generation fibre-to-the-home (FTTH) networks are being installed in point-to-point (P2P) and point-to-multipoint (P2MP) time-multiplexed passive optical network (PON) architectures. As a major part of the infrastructure is shared among the users, the PON architecture may offer lower installation and maintenance costs beyond a certain reach and number of users, but it requires a well-tailored medium access control protocol for fair sharing of the capacity among them. Most popular nowadays is the time-division multiple access (TDMA) protocol, where functions can be readily implemented with digital electronics. It is being used in BPON (ATM-based, up to 622 Mbit/s symmetrically), GPON (Gigabit PON, with speeds up to 2.5 Gbit/s, for ATM and also Ethernet packets plus native TDM), and EPON (Ethernet PON, optimized for variable-length Ethernet packets). Alternatively, one may consider Subcarrier Multiple Access (SCMA), requiring more costly RF electronics, or Optical Code Division Multiple Access (OCDMA), requiring more costly optical spectrum slicing filters. Gaining popularity is Wavelength Division Multiple Access (WDMA), where each user on the WDM-PON gets an individual pair of wavelengths for up- and downstream communication, thus in effect getting a P2P link (with its advantage of easy per-user upgrading) on a P2MP physical infrastructure. With so-called 'colour-less' optical network units (ONUs) at the user side, using for instance reflective semiconductor optical amplifiers, more expensive wavelength-specific ONU solutions are avoided; this reduces the costs of the WDM-PON. Hybrid WDM-TDM PON networks can combine the large multiple-channel capacity offered by WDMA with the dynamic bandwidth sharing enabled by TDMA. Notably for PONs with larger ONU numbers and longer reach such hybrid schemes are attractive. Augmented with dynamic optical routing, capacity-on-demand with remarkably reduced congestion probability can be provided, while also improving the efficiency by which the resources installed in the local exchange are used.

For supporting broadband wireless services in fixed wireless access, radio over fibre (RoF) techniques enable to consolidate the microwave signal generation and modulation functions in a single site, which facilitates upgrading and more comprehensive radio schemes. Advanced optical techniques generate extremely pure microwave carriers, and thus enable comprehensive radio signal constellations for high-capacity wireless data links. Dispersion-tolerant RoF techniques support long-reach operation, and link switching in reconfigurable architectures.

Next to bringing the luxury of a high bandwidth to the doorstep by means of FTTH, it must be distributed inside the user's home. As cost is an even more important factor there, easy-to-install large-core multimode (plastic) optical fibre is an attractive medium for implementing a converged single infrastructure which can support wired as well as wireless broadband services. Comprehensive signal modulation formats, such as multi-tone quadrature amplitude modulation schemes, enable to transport high-capacity data wired services via the highly-dispersive fibre infrastructure. Dispersion-robust RoF techniques can support pico-cell radio cell architectures. Using optical routing techniques, such cells may be dynamically merged into reconfigurable wireless private networks, in response to changing traffic patterns.