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TECHNICAL REPORT

colour inside

Roadmap of optical circuit boards and their related packaging technologies

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IEC 62658, which is a technical report, has been prepared by IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86/442/DTR	86/453/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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ROADMAP OF OPTICAL CIRCUIT BOARDS AND THEIR RELATED PACKAGING TECHNOLOGIES

1 Scope

This Technical Report covers the roadmap of optical circuit boards, and its related packaging technologies including optical circuit board connectors and optical modules on boards.

2 General

2.1 Background of optical packaging technology road map

The volume of network traffic is dramatically increasing due to the amount of data being captured, processed, conveyed and stored as digital information. This information is generated from many sources, including critical business applications, email communications, the Internet and multimedia applications which have collectively fuelled an increase in demand for data networking and storage capacity. In addition, the proliferation of media rich applications, such as digital music and video sharing services is fuelling a concurrent increase in data processing in data centres [1][1]. The growth in network traffic attributed to personalized content is 20 % per month, giving rise to a doubling of network traffic every 1,5 years. However, this is out of step with the input/output (I/O) performance or I/O throughput of servers, which doubles every 2 years. Therefore, there is an increasing gap between the performance evolution of network equipment such as servers, and the growth in network traffic (Figure 1) [2].

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[1] Figures in square brackets refer to the Bibliography.

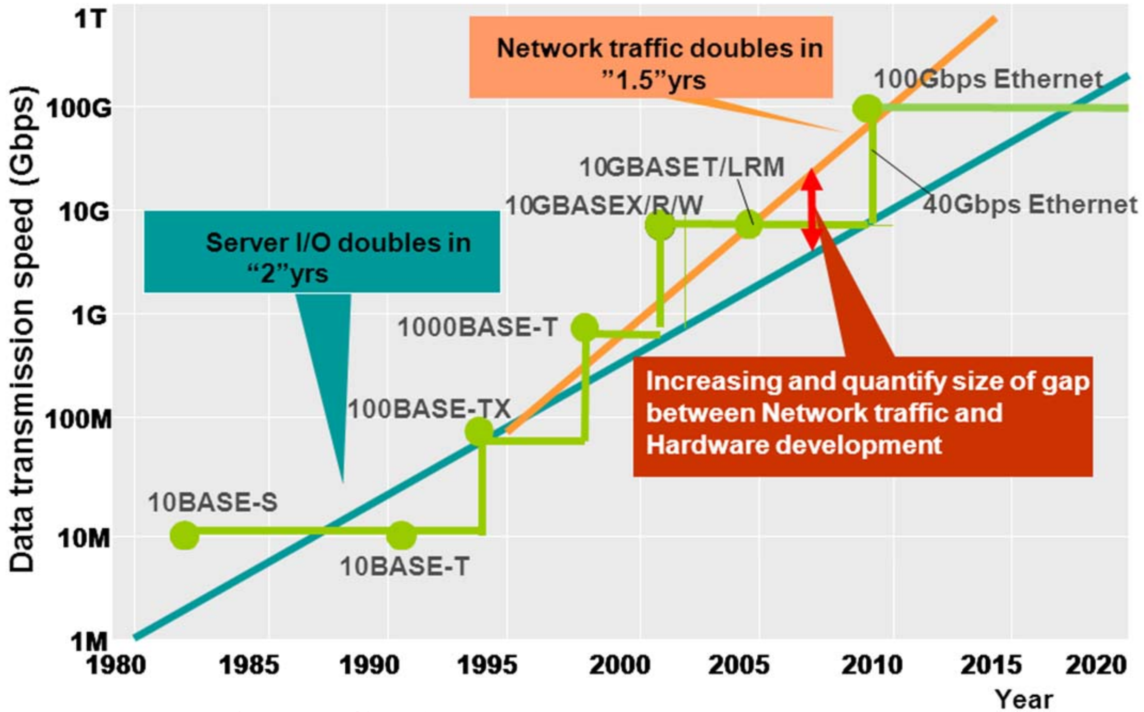

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Figure 1 – Data transmission speed and capability trends for network traffic and server systems [2]

In general, system power consumption will increase as the volume of internet traffic expands. By 2020, power consumption in network routers in Japan will reach the gross power generation of Japan in 2005. An energy saving by 3 to 4 orders of magnitude in network router technology is required in 2030 to meet the stipulated targets in the Kyoto protocol [3] (Figure 2).

In addition, the bandwidth and density requirements for interconnects within high-performance computing systems are becoming unmanageable, due to increasing chip speeds, wider buses and larger numbers of processors per system [4]. The increase in system bandwidth and density required to satisfy this demand would impose unmanageable cost and performance burdens on future data networking and storage technologies.

An alternative to the current electrical printed circuit board (PCB) interconnect technology is required across multiple high-speed application spaces to mitigate this common trend. Optical interconnects are expected to bridge the performance gap between network hardware and traffic, and give rise to a reduction in hardware power consumption while increasing bandwidth density by over two orders of magnitude.

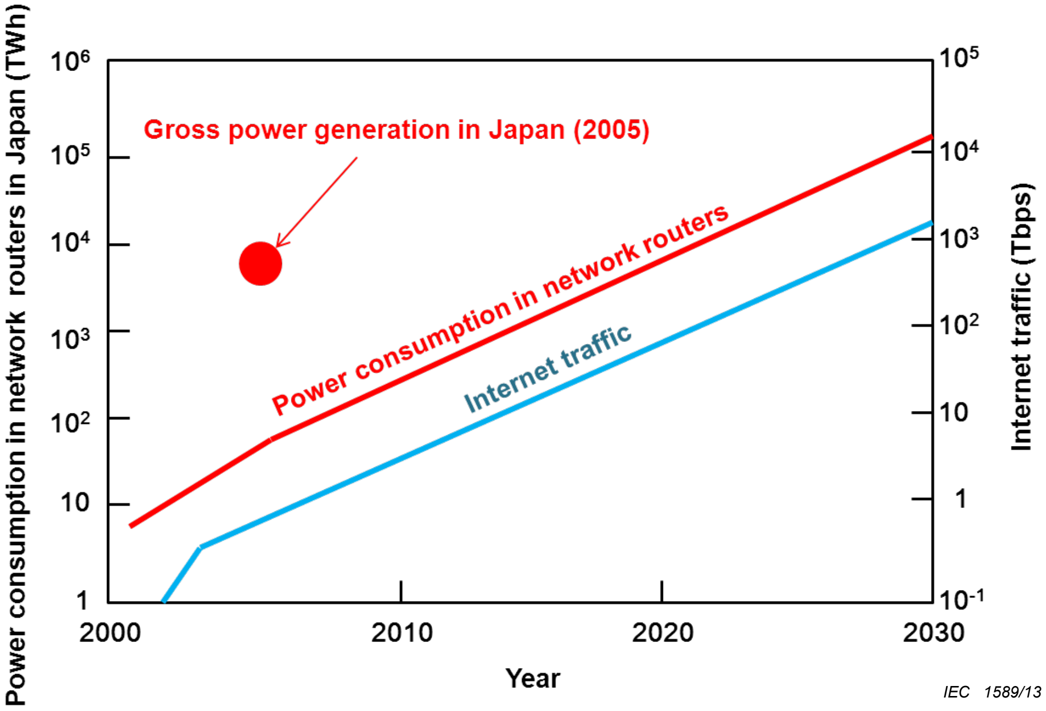

Figure 2 – Internet traffic and router power consumption in Japan [5]

2.2 Advantages of optical interconnects

Optical interconnects will be fundamental in further scaling the performance of networking, server, router, data storage and high performance computing technologies.

The design and development of future higher capacity network hardware will be hindered by high-frequency electronic constraints such as crosstalk, dielectric loss, skin effect, electro-magnetic interference (EMI) and high sensitivity to impedance matching. The maximum permissible density of electronic transmission lines is determined by the crosstalk incurred between electronic channels. The higher the signal frequency, the greater the separation between electronic channels required to keep crosstalk within acceptable levels. For example, the line pitch between adjacent electronic channels required to convey a signal data rate of 10 Gbps is 3 times larger than that required to convey a signal data rate of 3 Gbps. This makes it more difficult to design and manufacture a high-capacity printed circuit board, as the electronic transmission line density must decrease as the signal speeds increase. The adoption of optical interconnects will mitigate these design constraints. Optical waveguides neither produce nor are affected by electro-magnetic interference, and are therefore not constrained by electromagnetic compatibility regulations that impose a severe cost burden on the design of high-speed copper printed circuit boards (PCBs) and supporting interconnect technologies, such as connectors. The layout advantages offered by optical waveguides will give rise to a reduction in the functional area and layer count of the PCB. The level of reduction will strongly depend on the application, with the more I/O intensive applications subject to the greatest potential reduction in PCB volume.

Another advantage of the adoption of embedded optical interconnects in high-capacity networking, server, router, data storage and high performance computing technologies is a reduction in power consumption.

As the network traffic increases, the power consumption of network hardware is expected to increase 5 fold by 2025 and 12 fold by 2050 [6]. For data transmission at speeds greater than 10 Gbps, current electrical interconnects will need to be enhanced by active signal conditioning devices such as pre-emphasis and equaliser circuitry to ensure that the signal distortion or degradation due to the mitigating factors described above remains within acceptable levels. In addition, the power consumption of electronic signal drivers will also increase. As signal frequencies increase, an electronic signal driver will need to ramp up the signal power in order to overcome the fundamental loss mechanisms on a copper transmission line. These loss mechanisms include dielectric loss, skin effect, and the surface roughness of the copper trace, which accentuates skin effect by increasing the effective surface area. Dielectric loss effects can be mitigated to some extent by using specially high frequency printed circuit board laminate materials, however at mounting cost to the system. Long distance optical interconnects such as single mode optical fibres for multi-kilometre data transfer also require adaptive equalisation, but for very short distances, such over a system backplane this is certainly not required (Figure 3).

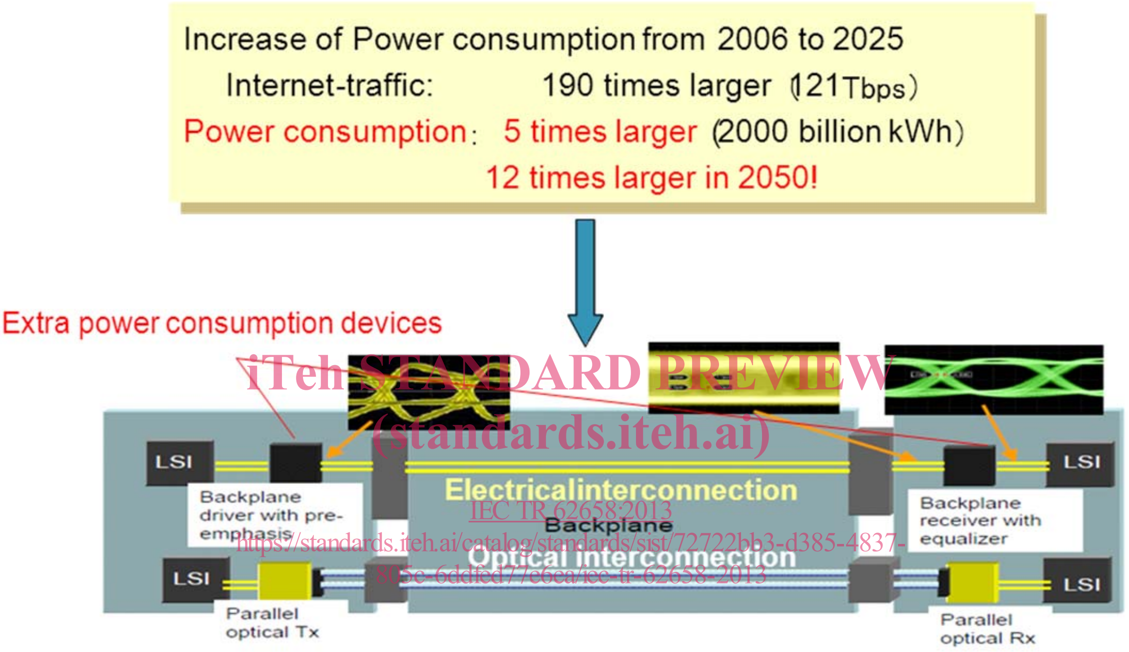

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Figure 3 – Increase of power consumption in future network

Though optical interconnects will require active devices to convert electronic signals to optical signals and vice versa, it is expected that the power consumption due to these conversion technologies will be less than those due to electronic signal driver and signal conditioning technology for interconnects over a given length. Cisco’s green story [7] provides a breakdown of power consumption in network technology systems. Among prevailing network technologies, servers are the most power consumptive accounting for 50 % of all power consumption in the network systems space, followed by data storage systems, which account for 35 % [8]. This indicates that the adoption of optical interconnects in network server and storage systems would be an effective path to realizing green information and communication technology [9]. Figure 4 shows the comparative power consumption profiles of a 10 Tbps electrical router and a 10 Tbps optical router, whereby the optical router consumes 20 % less power than the electrical router.

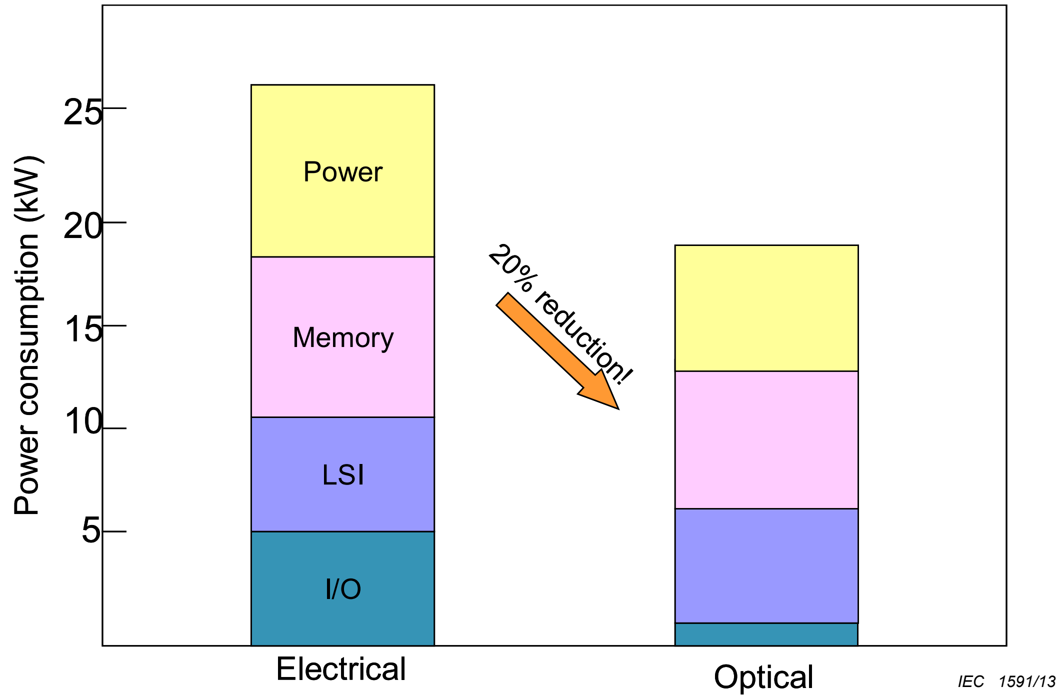

Figure 4 – Comparison of power consumption of 10 Tbps electrical and optical routers

2.3 Planar embedded optical waveguides

It is proposed that the resulting performance bottleneck due to the electrical constraints described above be substantially reduced by conveying high-speed data optically instead of electronically. This requires that optical channels be incorporated into the system at the printed circuit board (PCB) level. While many technology solutions have been put forward and commercially deployed to support embedding conventional optical fibres onto printed circuit boards, there has been a great deal of research and development activity centred in Europe looking at the fabrication and deployment of planar optical waveguide channels on/ in printed circuit board substrates[10] to [18]. The key academic contributors to research into planar optical waveguides include University of Cambridge, University College London, Vrije Universitaet Brussels, University of Ghent, Loughborough University, Heriot-Watt University and Fraunhofer Institute IZM, while the key industrial contributors include IBM Research in Zürich, Xyratex Technology, TTM Technologies, Vario-optics, TE Connectivity, FCI and Dow Corning.

Collectively research and development activities in this field have included a wide range of planar waveguide fabrication techniques, in-plane and out-of-plane waveguide coupling and connector solutions. Though this activity has been mostly centred on polymer waveguides, some research and development has been carried out on embedded planar glass waveguides as well.

3 Standardization of board-level optical packaging

3.1 Role of IEC TC86/JWG9 (with TC91)

Broadband technologies and services using optical networking systems have come into widespread use, not only at the backbone level but also at the access level. As data bandwidths continue to increase, the optical interconnect must be driven even further down, to the system level, which requires the development of suitable opto-electronic packaging and interconnect solutions to accommodate the system environment.