

# Chapter 26

## Energy–Efficient Optical Interconnects in Cloud Computing Infrastructures

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### ABSTRACT

*This chapter discusses the rise of optical interconnection networks in cloud computing infrastructures as a novel alternative to current networks based on commodity switches. Optical interconnects can significantly reduce the power consumption and meet the future network traffic requirements. Additionally, this chapter presents some of the most recent and promising optical interconnects architectures for high performance data centers that have appeared recently in the research literature. Furthermore, it presents a qualitative categorization of these schemes based on their main features such as performance, connectivity, and scalability, and discusses how these architectures could provide green cloud infrastructures with reduced power consumption. Finally, the chapter presents a case study of an optical interconnection network that is based on high-bandwidth optical OFDM links and shows the reduction of the energy consumption that it can achieve in a typical data center.*

### INTRODUCTION

The rise of cloud computing and other emerging Web applications has increased significantly the network traffic inside the data centers. Current technologies based on electrical switches have to consume high power to face the network traffic

increase and currently they account for a high portion of the total power consumption of the data center equipment. Optical interconnection networks have been proposed as a promising solution that can provide high bandwidth with reduced power consumption. In this chapter we present the rise of optical interconnection networks for data centers in order to meet the network traffic

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requirements and to reduce the power consumption of the data centers. We discuss the types of optical interconnection networks that have been presented and we discuss the main benefits and drawbacks of each approach. Furthermore, we present a case study of an optical interconnection network that is based on all-optical OFDM links that can provide higher throughput and reduced power consumption in the data centers.

## FUTURE DATA CENTER REQUIREMENTS

Cloud computing is a “model for enabling ubiquitous, convenient and on-demand network access to a shared pool of computing resources,” according to NIST (Mell, 2011). The computing resources are located in private or public data centers that can be scaled from a few servers to warehouse data centers with thousands of servers. These servers require a high bandwidth interconnection network in order to facilitate the fast communication between the servers in cloud computing applications. At the same time, the interconnection network must be energy-efficient in order to reduce the total amount of energy dissipated by the data center.

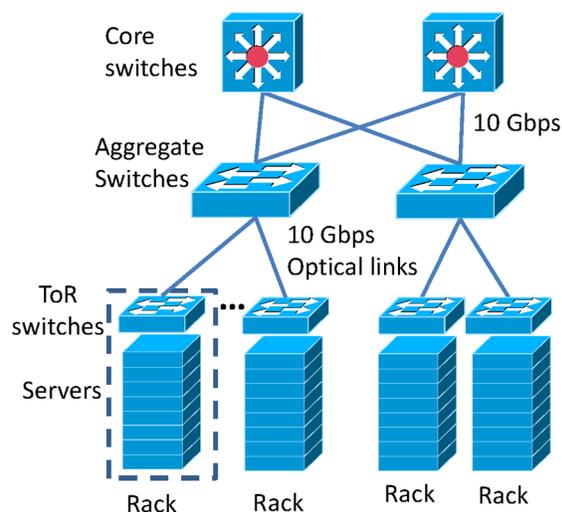
Figure 1 shows the high-level block diagram of a typical data center network. Most of the current data centers are based on commodity switches for the interconnection network. The network is usually a canonical fat-tree 2-Tier or 3-Tier architecture. The servers (usually up to 48 in the form of blades) are accommodated into racks and are connected through a Top-of-the-Rack Switch (ToR) using 1 Gbps links. These ToR switches are further interconnected through aggregate switches using 10 Gbps links in a tree topology. In the 3-Tier topologies (shown in the figure) one more level is applied in which the aggregate switches are connected in a fat-tree topology using the core switches using either 10 Gbps or 40 Gbps links (using a bundle of 10 Gbps links). The main advantage of this architecture is that it can

be scaled easily and that it is fault-tolerant (e.g. a ToR switch is usually connected to 2 or more aggregate switches).

However, the main drawback of these architectures is the high power consumption of the ToR, aggregate and core switches and the high number of links that are required. The high power consumption of the switches is mainly caused by the power consumed by the Optical-to-Electrical (O-E) and E-O transceivers and the electronic switch fabrics (crossbar switches, SRAM-based buffers, etc.). Furthermore, a significant drawback in the case of the current commodity switches is that the power consumption of these devices is not directly proportional to the network traffic load. The power consumption of an idle switch is very close to the maximum power consumption when all of the ports are fully loaded which translates to low energy efficiency (Hlavacs, 2009).

The following subsections describe the data center traffic requirements in the future data centers and the need for more energy-efficient networks that can sustain the increased network traffic without consuming excessive amount of energy.

Figure 1. Current data center networks



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