Coding for Optical Channels

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with Chapter 8 contributed by
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To my parents (Blagoje and Verica), brother Slavisa, and to Milena.
Ivan Djordjevic
To Stephanie, Faith, Grant, Luke, and the Bandii.
William Ryan

Preface

Recent years have witnessed a dramatic resurgence of interest in channel coding within the optical communications community, as evidenced by the increase of the number of publications, and many eye-catching implementations and experimental demonstrations presented at major conferences. The main drivers behind the emergence of channel coding in optical communications are: (1) high demands in bandwidth thanks to the recent growth of Internet usage, IPTV, VoIP, and YouTube; and (2) rapid advance of silicon signal processing capability. In recent years, with the rapid growth of data-centric services and the general deployment of broadband access networks, there has been a strong demand driving the dense wavelength division multiplexing (DWDM) network upgrade from 10 Gb/s per channel to more spectrally efficient 40 Gb/s or 100 Gb/s per channel, and beyond. The 100 Gb/s Ethernet (100 GbE) is currently under standardization for both local area networks (LANs) and wide area networks (WANs). The 400 Gb/s and 1 Tb/s are regarded to be the next steps after 100 Gb/s and have started already attracting research community interests. Migrating to higher transmission rates comes along with numerous challenges such as degradation in the signal quality due to different linear and nonlinear channel impairments and increased installation costs. To deal with those channel impairments novel advanced techniques in modulation and detection, coding, and signal processing should be developed. Such topics will be described in detail in this book.

The introduction of sophisticated electronic digital signal processing (DSP), coherent detection, and coding could fundamentally alter the optical networks as we see them today. DSP has played a vital role in wireless communication and has enabled so-called software-defined radio (SDR). Thanks to the recent resurgence of coherent detection and the recent drive toward dynamically reconfigurable optical networks with transmission speeds beyond 100 Gb/s, DSP and forward error correction (FEC) are becoming increasingly important. Regardless of the data destination, an optical transport system (OTS) must provide the predefined bit-error rate (BER) performance. To achieve a target BER regardless of the data destination, the future OTS should be able to adjust the FEC strength according to the optical channel conditions. Such an approach leads us toward the *software-defined optical transmission* (SDOT) in which the transponder can be adapted or reconfigured to multiple standards, multiple modulation formats, or code rates, a concept very similar to SDR.

Although channel coding for optical channels has gained prominence and emerged as the leading ultra-high-speed optical transmission enabling technology, FEC seems to be rather alien to many optical engineers. The optical engineers are aware that FEC potentially hold the keys to solving many major problems for today's "fragile" and "rigid" optical networks, but feel intimidated by sophisticated coding terminology. This book is intended to give a coherent, self-contained, and comprehensive introduction to the fundamentals of channel coding and DSP for optical communications. It is designed for three diverse groups of researchers: (1) optical communication engineers who are proficient in the optical science and are interested in applying coding theory and DSP, but not familiar with basic coding concepts, (2) wireless communication engineers who are very much adequate with their DSP and coding skill sets, but are disoriented by the perceived huge gap between optical and RF communications worlds, and (3) coding experts interested in entering the world of optical communications. An attempt has been made to make the individual chapters self-contained as much as possible while maintaining the flow and connection between them.

This book is organized into 11 chapters, and treats topics related to modulation, DSP and coding for optical channels starting from the fundamentals of optical communication and major channel impairments and noise sources, through DSP and coding, to various applications, such as single-mode fiber transmission, multimode fiber transmission, free space-optical systems, and optical access networks. This book presents interesting research problems in the emerging field of channel coding, constrained coding, coded-modulation, and turbo equalization and touches on the intriguing issue related to future research topics in coding for optical channels. The main purpose of this book is: (1) to describe the FEC schemes currently in use in optical communications, (2) to describe different classes of codes on graphs of high interest for next-generation high-speed optical transport, (3) to describe how to combine multilevel modulation and channel coding optimally, and (4) to describe how to perform equalization and soft decoding jointly, in a so-called turbo equalization fashion.

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