Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 110 (2017) 266–273

Procedia Computer Science

www.elsevier.com/locate/procedia

The 12th International Conference on Future Networks and Communications (FNC 2017)

Systematic Polar Codes for Joint Source-Channel Coding in Wireless Sensor Networks and the Internet of Things

Charles Yaacoub*, Malak Sarkis

Department of Telecommunications, Faculty of Engineering, Holy Spirit University of Kalsik (USEK), P.O.Box 446 Jounieh, Lebanon

Abstract

The Internet of Things (IoT) is becoming an increasingly growing topic of interest in the research community. Its requirements meet those of the next generation 5G mobile communication system which is expected to be an enabling technology for IoT, where networks of large numbers of sensors require massive connectivity demands. As polar codes have strongly entered into action within the standardization of 5G, this paper proposes and investigates the use of systematic polar codes for joint-source channel coding of correlated sources thus allowing, on one hand, the compression of the volume of data to be transmitted over the network, and on the other hand, the protection of this data from channel impairments. Results show that systematic polar codes can achieve a distributed compression with rates close to the theoretical bound, with better error rates obtained for larger blocks. However, stronger compression and shorter block lengths allow for a better robustness against transmission errors.

Peer-review under responsibility of the Conference Program Chairs.

Keywords: channel coding; compression; distributed source coding; entropy; internet of things; systematic polar codes; wireless sensor networks

1. Introduction

Error correcting codes play a major role in the air interface of modern wireless and mobile communication systems, as they allow for protecting transmitted data from channel impairments. Research efforts for designing capacity achieving codes that perform close to Shannon theoretical limits[1] led to the development of Turbo codes[2], Low Density Parity Check (LDPC) codes[3], and Polar Codes[4]. LDPC and Turbo codes have been incorporated in different standards, such as in Digital Video Broadcasting (DVB)[5], the third (3G) and fourth (4G) generations of mobile communication

* Corresponding author. Tel.: +961-6-600-960; fax: +961-9-600-970.
E-mail address: charlesyaacoub@usek.edu.lb

1877-0509 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the Conference Program Chairs.
10.1016/j.procs.2017.06.094

systems (e.g. UMTS, LTE, LTE-A, …), while the more recent Polar coding is being considered for next generation (5G) systems[6].

The expected 5G will be an enabling technology for applications with massive connectivity demand[7], such as the Internet of Things (IoT) where large numbers of devices with multiple sensors and actuators exchange information and control commands, thus forming a wireless sensor network (WSN). The exchange of large amounts of information in the context of IoT brings to our concern the problem of data compression and error correction in WSNs, where distributed source compression (DSC) and joint source-channel coding (JSCC) techniques can be exploited. Based on Slepian-Wolf theorem[18], it is known that given two statistically correlated sources X and Y, both sources can be independently encoded and jointly decoded with the same compression efficiency as joint encoding and decoding. Consequently, if Y is compressed down to its entropy H(Y), X can be independently compressed down to the conditional entropy H(X|Y), given that Y is available at the decoder as side information for decoding X. Source correlation can be modeled as a noisy channel with one source (X) as the channel input and the other source (Y) as the output, and thus, channel coding techniques can be used to recover X by observing Y as noisy version of X[8-15]. When a transmission channel is taken into account in a DSC application, channel codes used for forward error correction (FEC) over the correlation channel can also be used as FEC codes for the transmission channel, thus allowing for joint source and channel coding.

Several channel coding techniques have been used in different DSC and JSCC applications, where LDPC and Turbo codes have proven to be the best performing codes. For instance, LDPC codes have been used[8] for the compression of binary sources with side information at the decoder. Farah et al.[9] used non-binary Turbo codes for the compression of correlated sources, and extended their study to the case of joint source-channel coding. Aaron et al.[10] and Yaacoub et al.[11,12] used turbo-codes for distributed video coding (DVC), whereas Ascenso et al.[13] used LDPC codes for DVC. Different schemes for DSC or JSCC in wireless sensor networks have also been proposed, based on Turbo[14] and LDPC[15] codes.

Since their invention by Arikan[4], polar codes have been well investigated in the literature. The idea behind polar codes is to create J new channels from J independent copies of a channel using a linear transformation, such that the new channels are polarized. Therefore, data can be transmitted over these synthesized good channels whereas only zeros (frozen bits) are sent over the bad channels, with the same overall capacity. Recent studies[16,17] have demonstrated the superior performance of polar codes compared to LDPC and Turbo codes in the context of 5G test scenarios. Furthermore, polar codes can be constructed and decoded using simple algorithms that are more computationally efficient than Turbo and LDPC codecs[6], which makes them suitable for a wide range of applications.

In contrast with previous studies[19-22] where the use of polar codes in DSC applications has been investigated, we previously proposed[23] the use of polar codes in their systematic form for DSC, due to their superior error correction capability compared to non-systematic codes[24] and their intuitive design approach for DSC such that only parity information is transmitted to the decoder where the side information replaces the missing systematic data. In this paper, we extend our study[23] to the case of joint source-channel coding, where the correlation between different sources is modeled with a Gaussian channel, and the transmission channel is considered Gaussian as well. While the Gaussian channel constitutes a simplified scenario compared to practical real-life systems, our paper presents a preliminary study where a JSCC system is designed based on systematic polar codes, thus meeting the latest technologies of the future generation (5G) of mobile communications. Our study can be projected to the context of IoT where a network of wireless sensors is communicating observed data to a central node (e.g. relay node or base station) for decoding. The remainder of this paper is organized as follows. In Section II, the JSCC system considered in this study is presented along with the source correlation model and a brief review of systematic polar encoding. Section III presents the simulation environment and setup, and discusses practical results. Finally, conclusions are drawn in Section IV.

2. System Description

Consider a network of wireless sensors observing a common source of information and transmitting their data to a central base station for decoding, as shown in the block diagram of Fig. 1 (showing a network of only 2 sensors, for simplicity). This model fits for several practical scenarios, such as a network of surveillance cameras observing the same scene, a network of fire detection sensors monitoring some protected forest area, etc… In Fig.1, one of the sensors (Sensor 2) employs conventional source and channel encoding (CSCE) techniques to transmit its observed