Linköping Studies in Science and Technology
Thesis No. 1493

Aspects of Control Signaling in Wireless Multiple Access Systems

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Linköping 2011

This is a Swedish Licentiate Thesis.
The Licentiate degree comprises 120 ECTS credits of postgraduate studies.

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LIU-TEK-LIC-2011:32
ISBN 978-91-7393-145-8
ISSN 0280-7971
Printed in Sweden by LiU-Tryck, Linköping 2011

Today is the tomorrow we worried about yesterday.

Abstract

From its first appearance, wireless communications has changed the life for many people worldwide. Currently, more than half of the world's population are using wireless devices for various purposes on a daily basis. While the early wireless systems could provide simple and specific low-rate services, today's systems can support a variety of more advanced services some of which require high data rate communications. This includes for example web-browsing and streaming multimedia applications. To meet the high demands on the current systems, many technical solutions have been proposed. Many of these solutions are powerful in the sense of boosting the system performance, but on the other hand, they impose a substantial *control signaling* overhead on the system. The control signaling refers to sending the control information that is necessary to establish and/or maintain the connection as opposed to the payload data that is transmitted during the connection.

In this thesis, we are interested in evaluating the relations between the gain of deploying new techniques and the amount of control signaling overhead they incur. Moreover we are interested in finding efficient algorithms that can potentially reduce the control signaling overhead. More specifically, we first focus on the part of the control signaling overhead that concerns sending the scheduling assignments that describe how the channel resources are allocated among the users. We compare two ways for the signaling of scheduling assignments and we will study how different parameters such as scheduling granularity impact the control signaling overhead. We also provide two schemes that reduce the control signaling overhead substantially. We then provide an algorithm for fast blind identification of channel codes. This algorithm is very useful in improving the so-called blind decoding performance. This is essential since blind decoding is used to achieve adaptive modulation and coding in the control channel of some of the wireless communication systems such as 3GPP Long Term Evolution.

Acknowledgments

First and foremost, I would like to thank my supervisor Prof. Erik G. Larsson. To most of us PhD students, Erik is the ideal researcher with a very keen insight on research related matters. Thank you Erik for offering me a research carrier and for your valuable criticism and support that guided me in the right direction.

Secondly, I would like to express my deepest gratitude to Dr. Jonas Eriksson for his guidance, help and being open to any brainstorming discussions. Also, I would like to thank our research sponsors at Ericsson Research Center at Linköping, specially Dr. Gunnar Bark, Dr. Niclas Wiberg and Dr. Pål Frenger for their close collaboration.

Many thanks to my colleagues at the Communication Systems division and our neighboring research group Information Coding division. Specially, I would like to express my appreciation towards Dr. Mikael Olofsson and Dr. Lasse Alfredsson for their guidance in teaching related matters, to Dr. Eleftherios Karipidis for his help, to my roommate T. V. K. Chaitanya for always listening to my immature ideas and Mirsad Čirkić for helping me out with programming related matters.

Finally, I would like to thank all the people that somehow made me choose the research carrier. This includes many teachers and professors in my home city Isfahan, during my master study at Chalmers University of Technology and at Swiss Federal Institute of Technology Zurich (ETHZ). Many thanks should be devoted to my family for always believing in me and for their supports. Especially, I would like to express my deepest gratitude to my parents from whom I have every thing in my life. Last but not least, I would like to thank my wife Tahmineh for her support, patience and kindness. Thank you Tahmineh for all the meaning and all the fortune that you brought to my life.

Linköping, June 2010
Reza Moosavi

Contents

Part I

Introduction

Control Signaling in Wireless Multiple Access Systems

During the 1890s, Guglielmo Marconi initiated the concept of using electromagnetic waves for communications which is now known as radio or wireless communications [1]. Half a century later, the first commercial wireless system was created in the United States, and since then many wireless systems have been introduced [2]. The early systems could provide some basic services to several individuals, whereas nowadays wireless systems provide more or less advanced services to more than half of the world's population. These advanced services generally require high data rate communications. In order to support these services, many techniques have been designed, which resulted in an enormous evolution of the wireless systems in the last two decades.

In this thesis, we are not interested in how the wireless systems have evolved nor in how these new techniques can enhance the performance, but rather we are interested in studying how these new coming technologies have affected the system structure. More precisely, we are interested in studying the "signaling overhead" associated with the deployment of these new techniques and in ways to reduce the corresponding signaling cost.

The remainder of this introductory chapter is organized as follows. We first briefly describe the main techniques that are used in today's wireless systems in order to enhance the system performance in Section 1. We then define what we mean by control signaling and how this has been affected by these techniques in Section 2. Although very briefly, we will study High Speed Packet Access (HSPA) as an example of a practical system deploying these techniques in Section 3. We then turn our attention to Long-Term Evolution (LTE) and we study how the control signaling is implemented in LTE in more detail in Sections 4 and 5. The reason that we consider LTE in more detail is the fact that many of our presented results have been evaluated on LTE-like systems and hence a good understanding of LTE structure is important. We then present the contributions of the thesis in Section 6.

1 Main Techniques to Achieve Higher Data Rates

Transmission over wireless channels is subject to errors. This is due to the fact that, the strength of the received signal in wireless channels is varying with time and/or frequency. Hence when the communication channel is in deep *fading*, that is when the communication channel does not have enough strength, it is very difficult to maintain a reliable data transmission. To combat the channel fading, new techniques have been found. The main techniques are as follows.

1.1 Adaptive Modulation and Coding

Traditionally, the transmission parameters (modulation format and channel code) were kept fix during data transmission. According to adaptive modulation and coding (AMC) technique, the transmitter selects the transmission parameters adaptively based on the instantaneous channel condition [3]. That is, when the communication link is good, the base station uses higher order modulation and a higher rate code and vice versa.

1.2 Channel Dependent Scheduling

Since in a wireless system, there are many users that request services from base station and since the channels of individual users change independently of each other, there is almost always a user whose channel is near its peak. By scheduling the user that has the best channel quality, a higher system throughput can be achieved. This is referred to as multi-user diversity in literature [4]. This technique along with AMC is actually a way to change the channel fading from a “foe” into a “friend”. In other words, instead of considering channel fading to be something bad that needs to be overcome, it is regarded as a tool to achieve higher data rate.

1.3 Hybrid Automatic Repeat Request

In many applications, the receiver needs to receive the packets without error. A classical approach to support error-free transmission is *automatic repeat request (ARQ)* mechanism [5]. In the ARQ scheme, the receiver discards the erroneously received packets and requests retransmission. However, despite the fact that the received packet was not possible to decode, it still contains information which is lost by discarding the erroneously received packets. In Hybrid-ARQ (HARQ), instead of discarding the erroneously received packets, the receiver will store it in a buffer memory and later, combine it with the packets from the retransmission to obtain a single, combined packet which is more reliable than its constituents.

1.4 Multiple Input Multiple Output (MIMO)

By using more than one antenna at the transmitter or at the receiver, one can increase the strength of the received signal at the receiver. This is referred to as transmitter or receiver “diversity”. By using two or more antennas both at the transmitter and at the receiver, there is also the possibility to use spatial multiplexing and consequently to enhance the system throughput [6]. This is typically referred to as multiple input multiple output (MIMO).

2 Control Signaling

No practical multiple access systems can be implemented without some sort of “control signaling” in the higher levels. The control signaling is referred to sending control information that is necessary to establish and/or maintain the connection. In the early wireless communication systems, the main task of the system was to provide a reliable voice connection between two entities as well as some simple services such as text messages. These services usually require low data rate and also they impose a low control signaling overhead on the system. For instance to establish a voice connection, terminal A who initiates the connection, sends the call request along with the identity of the terminal B, to whom it wants to call. Terminal B is then “called” or “paged” over the paging channel and provided that it is not busy and can accept the connection, a specific channel is dedicated for the corresponding call. Once the connection is established, no more control signaling is required.

However by introducing new packet oriented services such as web browsing, there was a need for much higher data rate connections. To support such services, many techniques such as those given in Section 1 were developed. While these techniques enhance the achievable data rate, they impose a substantial signaling overhead on the system. This is so because the price of using AMC and opportunistic scheduling is that the users must be informed about the transmission parameters as well as the locations where they are assigned, prior to the actual payload transmission in order to be able to correctly decode the information. Therefore, many practical systems dedicate some part of the channel resources for control signaling. In the next sections, we will study two well-known wireless multiple access systems, namely High Speed Packet Access (HSPA) and 3GPP Long Term Evolution (LTE).

3 High Speed Packet Access (HSPA)

HSPA is considered to be the evolution of Wideband Code Division Multiple Access (WCDMA) and was introduced to boost the performance of WCDMA. A complete treatment of WCDMA is beyond the scope of this thesis. Interested readers are referred to [7]– [9]. Since WCDMA uses code-division multiple access (CDMA) [10] as the communication method, the channel resources, that can be assigned to the terminals, are basically code and power. Each user is assigned a part of a *channelization code* that is used as the spreading code at the call setup. During a packet-data call, the code assignment for a user does not change (unless the transmission is reconfigured). However there is the possibility for power adaptation and power control commands are transmitted during the call, but these control commands do not put an excessive signaling overhead on the system.

HSPA consists of two major components: (i) High-Speed Downlink Packet Access (HSDPA) [11] and (ii) High-Speed Uplink Packet Access (HSUPA)

[12]. As their names suggest, HSDPA and HSUPA were developed to enhance the performance of WCDMA downlink and uplink respectively. The key technology in both HSDPA and HSUPA is the introduction of a so-called *shared-channel transmission*. The shared-channel transmission denotes some part of the physical channel resources (that is power and a part of code space), that is shared dynamically between users in time. In other words, a large part of the channel resources is assigned to a single user during a period in time, allowing for a higher data rate transmission. The scheduling assignments are valid for a duration of one *transmission time interval* (TTI) which is 2 ms in HSPA. In order to achieve higher data rates, channel dependent scheduling with AMC is implemented in HSPA. That is the shared channel is assigned to a user where her channel condition is good, which consequently allows for opting for a higher AMC level. Therefore, in order to support successful transmission, the terminals need to receive the control information every 2 ms. This is done via a *high-speed shared control channel* which carries the necessary information about spreading code, modulation format and coding rate to the terminals in the cell. As opposed to WCDMA, this imposes an extensive control signaling on the system.

4 A Brief Overview of LTE Downlink

As discussed earlier in Section 3, HSPA was designed to improve the performance of WCDMA. Therefore, HSPA needs to be backward compatible to the existing WCDMA structure. In parallel to HSPA, 3rd Generation Partnership Project (3GPP) introduced a new multiple access system known as Long-Term Evolution (LTE). LTE targets higher performance goals compared to HSPA and it does not need to be backward compatible with the existing structure. However, LTE has to be more flexible in terms of bandwidth and it should operate even in non-contiguous frequency bands [2].

We will first define the basic terminologies that are necessary for the upcoming discussions. Then we will study how the above techniques are implemented in LTE and how the control channel is designed to support successful data transmission. It is worth mentioning that the following description is very brief and does not cover every detail of the LTE implementation. For a detailed description, the readers are referred to [2] and the references therein.

LTE uses orthogonal-frequency division multiple access (OFDMA) [13] as the communication method in the downlink with the following specifications [14].

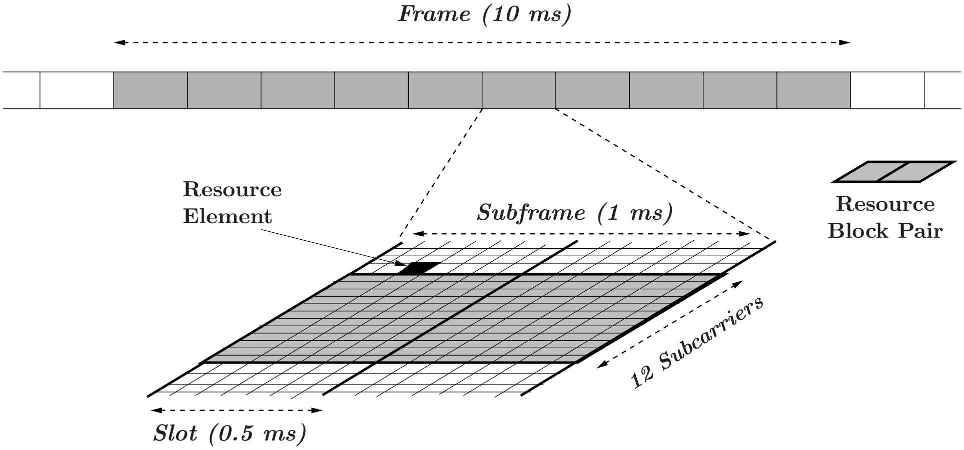

Figure 1: Physical layer channel resources in LTE.

The subcarrier spacing is 15 KHz. The communication is done within *frames* of length 10 ms. Each frame is divided into 10 equally sized *subframes*, hence the duration of a subframe is 1 ms. Each subframe is further divided into two equally long *slots* of duration 0.5 ms. LTE allows for two choices of cyclic prefix length: (i) normal cyclic prefix, and (ii) extended cyclic prefix. The main purpose of having an extended cyclic prefix is to enable a satisfactory operation when the channels have a huge delay spread. Each slot consists of 7 or 6 OFDM symbols in the normal cyclic prefix mode and in the extended cyclic prefix mode, respectively. In the LTE context, one OFDM subcarrier during one OFDM symbol is called a *resource element*. Also, 12 consecutive OFDM subcarrier in each slot is called a *resource block*. As we will see later, the minimum scheduling granularity in LTE consists of two resource blocks in each subframe which is referred to as a *resource block pair* [2, pp. 323-324]. Figure 1 illustrates the time/frequency domain structure of LTE downlink.

4.1 Channel Dependent Scheduling and Rate Adaptation

In LTE, the scheduling is made at the beginning of each subframe. In contrast to HSPA where the scheduler can exploit the channel variations only in time, LTE can exploit the channel variations both in time and in frequency, since the communication is based on OFDMA. However to reduce the signaling overhead, the minimum scheduling granularity is one resource block pair. Payload data is transmitted in the form of *transport blocks.* AMC is performed by the scheduler by using different *transport block formats.* Each transport block format determines the AMC parameters that are used for the transmission.

4.2 HARQ with Soft Combining

To each transport block, a cyclic redundancy check (CRC) of length 24 bits is attached [15]. The attached CRC is used to determine whether the received transport block is in error or not. If no error is detected, the receiver transmits a positive acknowledgment (ACK) to the transmitter and passes the transport block to the upper layers. In the case of detecting error(s), the receiver sends a negative acknowledgment (NACK) to the transmitter, but stores the transport block in its buffer for further processing. In order to facilitate a fast retransmission mechanism, the ACK/NACK messages should be transmitted to the transmitter as fast as possible. On the other hand, the terminals need to have enough time to perform a decoding attempt. In LTE, to support a fast HARQ mechanism and at the same time to give enough time to the terminals, the ACK/NACK messages are transmitted after 4 ms. In other words, the ACK/NACK message corresponding to the transport block transmitted at subframe n, is sent in subframe $n + 4$. The receiver uses *soft combining* [16] of the received packets to gain more reliable data in the case of retransmission.

4.3 Support for Multiple Antennas

In LTE, multiple antenna technology is supported at both the transmitter and the receiver [17]. Multiple antennas at the receiver facilitate transmit diversity, whereas multiple antennas at the transmitter support beam-forming as well. In the case of multiple antennas at the transmitter and at the receiver, that is in case MIMO is used, there is a possibility to transmit multiple data streams and hence this is the key technique to improve the system spectral efficiency in LTE.

5 The Control Channel in LTE Downlink

As we have seen, the scheduling decisions are made at the beginning of each subframe. This means that the scheduling decision as well as the information about AMC parameters used for the data transmission need to be sent to all scheduled users every 1 ms. In addition the HARQ ACK/NACK messages corresponding to the uplink transmission also have to be sent in each subframe. To support this, up to the first three OFDM symbols in each subframe can be used for control signaling. The size of the *control region* may be changed from subframe to subframe. The reason behind this is to adjust to the traffic situation. More precisely, when there are many users scheduled for the transmission in the subframe, that is in high traffic situations, then the size of the control region is 3 OFDM symbols, allowing to accommodate the control information of all users. In contrast, when there are few users scheduled for payload reception in the subframe, then the control region can be reduced to 1 OFDM symbol, allowing for a better usage of channel resources. The reason for having the control region at the beginning of each subframe is as follows: the scheduled users can find the information about the resource allocation and the transmission parameters as early as possible. Therefore, a terminal does not need to wait until the entire subframe transmission is over to find the transmission parameters and hence it can start the decoding process right after the transmission of the control information. This helps the terminals to reduce the decoding delay. The control region in LTE consists of three different physical channel types, that we will describe briefly in the following subsections.

5.1 Physical Control Format Indicator Channel

The *physical control format indicator channel* (PCFICH) is used to signal the size of the control region. Since up to three OFDM symbols may be used for the control region, the PCFICH consists of two information bits. Correct decoding of the PCFICH is essential, since it determines the size of the control region and consequently the start of the data region. More precisely, if a terminal fails to decode the PCFICH, it neither knows where to look for the control information nor where the data region starts.

Figure 2 illustrates how the PCFICH is transmitted in the control region. The two information bits are first encoded by a block code of rate 1/16 to gain enough error protection. The coded bits are then scrambled with a cell and subframe specific scrambling code. This is used to randomize the inter-cell interference. Then the scrambled bits are modulated using quadrature phase shift keying (QPSK) modulation [18] and the resulting QPSK symbols are mapped into 16 resource elements. Since the size of

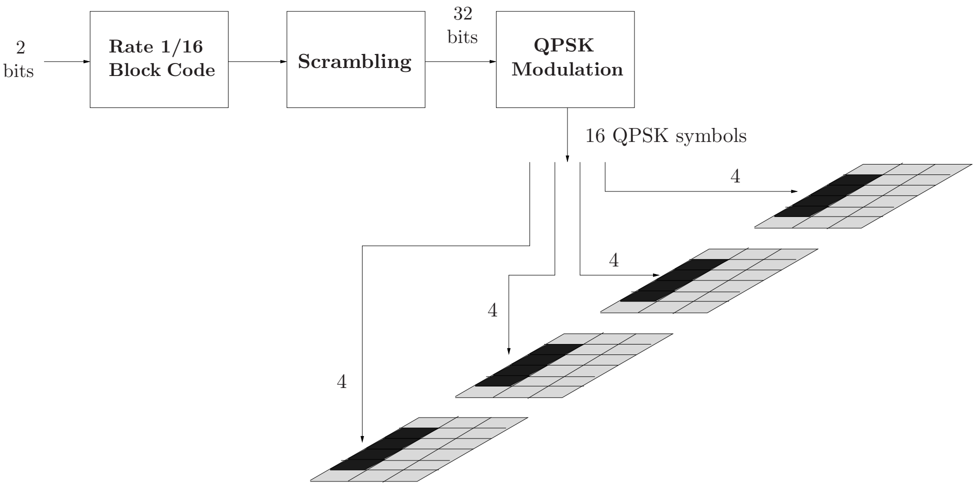

Figure 2: The PCFICH Structure. This figure is freely reproduced from [2, pp. 333].

the control information is not known until the successful decoding of the PCFICH, the modulated symbols are mapped into the first OFDM symbol. More specifically, they are mapped into groups of so-called *resource element groups* each consisting of four consecutive resource elements. To achieve frequency diversity, the corresponding resource element groups are separated well enough in frequency. It is also worth mentioning that the location of resource element groups depends on the cell identity. This is helpful to reduce the interference between neighboring cells.

5.2 Physical HARQ Indicator Channel

The *physical HARQ indicator channel* (PHICH) is used in response to the uplink data transmission to transmit the HARQ acknowledgments of the uplink transmission. Each PHICH carries the acknowledgment message (one information bit) of one uplink data session. The mapping of PHICH:s onto resource elements is subject to a certain structure which, as in the PCFICH mapping, is based on resource element groups. More precisely, several PHICH:s are first assigned to a certain *PHICH group*[1]. The PHICH:s in each

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[1] In the case of normal cyclic prefix operation mode, 8 PHICH:s forms one PHICH group [2].

group are code multiplexed onto 3 resource element groups as illustrated in Figure 3. Each PHICH is first encoded using rate 1/3 repetition encoding. The coded bits are then modulated using binary phase shift keying (BPSK) using either in-phase (I) or quadrature (Q) branches [18]. The resulting symbols are then spread via an orthogonal code of length 4. The resulting 12 symbols of all such branches (corresponding to one PHICH) are then added together to form 12 QPSK modulated symbols which are then mapped onto 3 resource element groups. Note that once again, the cell specific scrambling is done to randomize the interference and that the resource element groups are located far apart to achieve frequency diversity.

5.3 Physical Downlink Control Channel

The *physical downlink control channel* (PDCCH) is used to transmit the *downlink control information* (DCI). DCI includes many control information types. Most importantly, downlink scheduling assignments, information about what transport block format is used (which as discussed earlier determines the AMC parameters that are used for payload transmission), control information regarding spatial multiplexing (if MIMO is used) and HARQ information are included in DCI. It is worth mentioning that there exist different *DCI formats* each having different size [17]. The reason behind that is to give the opportunity to trade the scheduling granularity and the flexibility in choosing transport block formats for signaling overhead. For instance, one of the DCI formats, namely DCI format 1C, allows only QPSK modulation, has no HARQ support and hence it has a smaller size compared to the other DCI formats. Therefore, this format is useful when the control channel is congested due to its smaller size.

Since there might be several users scheduled for payload transmission in the subframe, and since each PDCCH carries one message according to one of the available DCI formats, there might be several simultaneous PDCCH transmissions within each subframe. Each PDCCH transmission is intended to one of the scheduled users.

Figure 4 illustrates the PDCCH processing in LTE. A CRC of length 16 is attached to the control information intended to each user [15]. The attached CRC is used not only to determine the correct reception of control information but also to pinpoint the user to whom the DCI is intended. This is done by using a user-specific CRC. In other words, instead of explicitly signaling

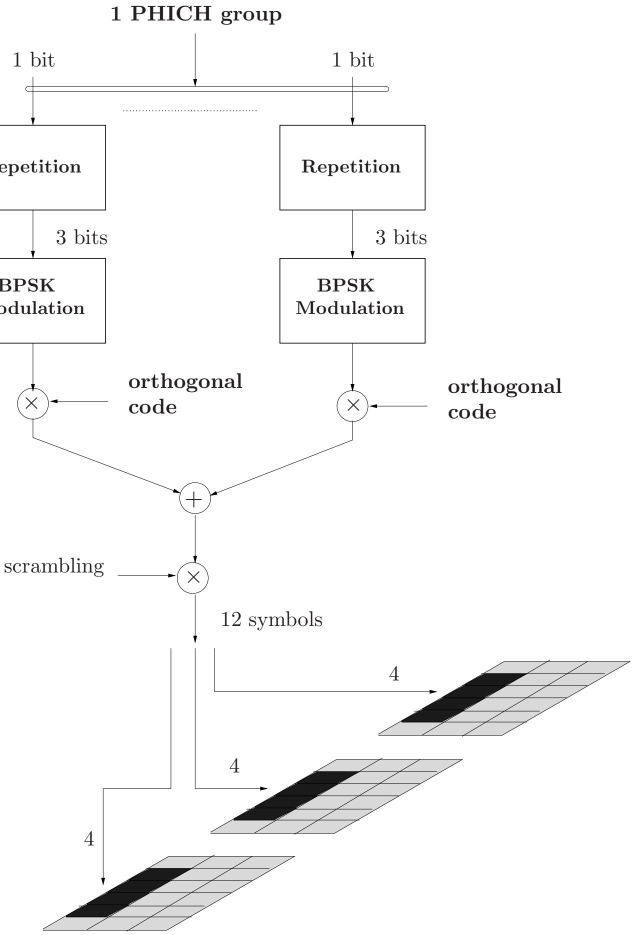

Figure 3: The PHICH Structure. This figure is freely reproduced from [2, pp. 337].

the identity of the user, the identity of the user is embedded in the CRC. As we will see shortly, the attached CRC is also used as a means to achieve adaptive coding and modulation. After CRC attachment, the output bits are encoded using a tail-biting rate 1/3 convolutional code [19].

The mapping of coded bits onto the resource elements is subject to a certain structure. More precisely, every PDCCH is mapped to 1, 2, 4 or 8 *control channel elements* (CCE:s). Each CCE consists of 9 resource element groups (that is 36 resource elements). The number of CCE:s used for PDCCH transmission is determined not only from the DCI message size, the number

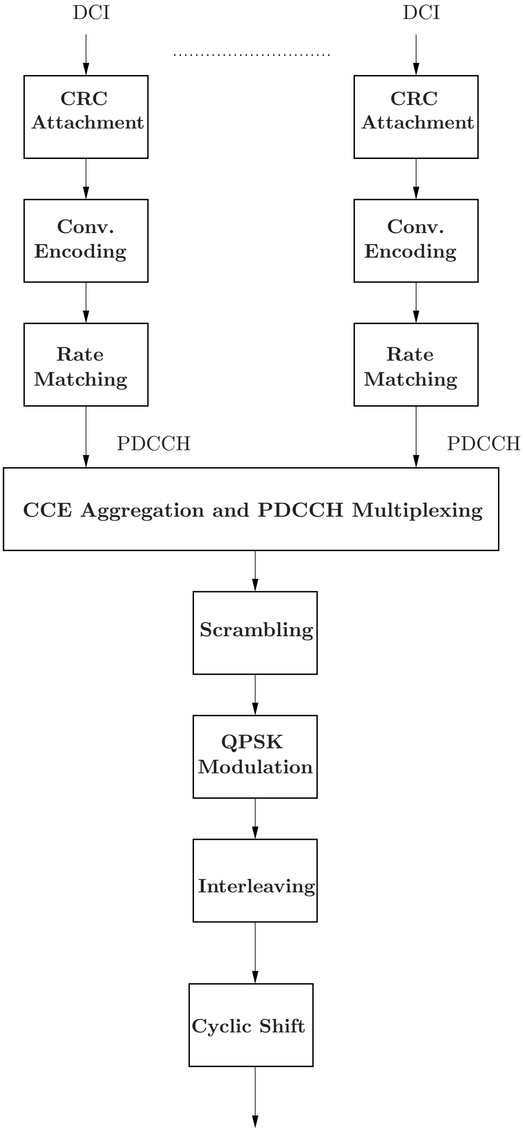

Figure 4: The PDCCH Structure. This figure is freely reproduced from [2, 353].

of OFDM symbols dedicated to the control region and the cell bandwidth but also from the instantaneous channel conditions. This is used to achieve AMC on the control channel. More precisely, the coded bits obtained from the convolutional code are matched (through puncturing in the case of good channel conditions and through repetition in the case of poor channel conditions) to fit the number of CCE:s reserved for the transmission of the corresponding PDCCH. After allocation of the PDCCH:s to the CCE:s, the bits are scrambled using a cell specific and subframe specific sequence number as before, to reduce the inter-cell interference. The resulting bits are QPSK modulated and mapped to the corresponding resource elements.

Blind Decoding of PDCCH:s

As we have seen, the number and/or the location of CCE:s used for the PDCCH transmissions[2] are not known to the users in advance. In order to find its control information, a terminal tries to blindly decode the incoming control information assuming different combinations of CCE:s and check for the CRC. If the CRC checks after a decoding attempt, then the terminal assumes that the corresponding PDCCH was intended for her and that the control information was decoded correctly. If the CRC does not match, then the terminal tries a new combination/location of CCE:s. In order to keep the number of decoding attempts low, LTE uses a so-called *search space* for each terminal. The search space determines the location/combination of CCE:s that the terminal needs to monitor for a possible control information. The size of the search space is 44 in LTE [2, pp. 358].

6 Contributions of the Thesis

The major part of the thesis considers the transmission of scheduling assignments and studies ways to reduce the associated signaling cost. The last part considers the blind decoding and introduces an algorithm for fast blind identification of channel codes. Brief summaries of the papers included in the thesis are given below.

Paper A: Comparison of Strategies for Signaling of Scheduling Assignments in Wireless OFDMA

Authored by R. Moosavi, J. Eriksson, E. G. Larsson, N. Wiberg, P. Frenger and F. Gunnarsson.

Published in the IEEE Transactions on Vehicular Technology, Nov. 2010.

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[2] This is referred to as CCE aggregation in the LTE context.

This paper considers transmission of scheduling information in OFDMA-based cellular communication systems such as 3GPP long-term evolution (LTE). These systems provide efficient usage of radio resources by allowing users to be scheduled dynamically in both frequency and time. This requires considerable amounts of scheduling information to be sent to the users. The paper compares two basic transmission strategies: transmitting a separate scheduling message to each user versus broadcasting a joint scheduling message to all users. Different scheduling granularities are considered, as well as different scheduling algorithms. The schemes are evaluated in the context of the LTE downlink using multiuser system simulations, assuming a full-buffer situation. The results show that separate transmission of the scheduling information requires a slightly lower overhead than joint broadcasting, when proportional fair scheduling is employed and the users are spread out over the cell area. The results also indicate that the scheduling granularity standardized for LTE provides a good trade-off between scheduling granularity and overhead.

Paper B: Reducing Physical Layer Control Signaling Using Mobile-Assisted Scheduling

Authored by R. Moosavi and E. G. Larsson.

Submitted to the IEEE Transactions on Wireless Communications, 2011.

We present a scheme for reducing the part of the downlink signaling traffic in wireless multiple access systems that contains scheduling information. The theoretical basis of the scheme is that the scheduling decisions made by the base station are correlated with the CSI reports from the mobiles. This correlation can be exploited by the source coding scheme that is used to compress the scheduling maps before they are sent to the mobiles. In the proposed scheme, this idea is implemented by letting the mobiles make tentative scheduling decisions themselves, and then letting the base station transmit “agreement maps” instead of raw scheduling maps to the mobiles. The agreement maps have lower entropy and they require less resources to be transmitted than the original scheduling maps do. The improvement can be substantial. We also model the task of finding the optimal scheduling assignments according to the proposed scheme as a combinatorial optimization problem and present an efficient algorithm to find the optimal solution.

Paper C: Differential Signaling of Scheduling Information in Wireless Multiple Access Systems

Authored by R. Moosavi, J. Eriksson and E. G. Larsson.

Published at the IEEE Global Communications Conference (GLOBECOM), Dec. 2010.

This paper considers the control signaling on the downlink in wireless multiple access systems, with focus on the part of the control signaling that carries information on the user's time/frequency scheduling assignments. A new idea is presented to reduce the amount of channel resources needed for this signaling. The idea is to exploit the fact that provided that only one single user is scheduled on each channel resource, then the different users' scheduling assignments are correlated. This correlation can be exploited by encoding the scheduling information differentially. In order to recover the scheduling information, a user must then decode the scheduling information of some of the others. This is possible, because on the downlink, all users can hear the transmission by the base station so that users with a high SNR may decode the control signaling sent to users with a lower SNR. We present a practical scheme to exploit this idea. Both analytical analysis and numerical examples illustrate that the proposed technique can provide a substantial reduction in signaling traffic.

Paper D: A Fast Scheme for Blind Identification of Channel Codes

Authored by R. Moosavi and E. G. Larsson.

Submitted to the IEEE Global Communications Conference (GLOBECOM), 2011.

We present a fast mechanism for determining which channel code that was used on a communication link. In the proposed scheme, the receiver does not need to receive the entire data to determine the actual code. Moreover, the proposed scheme can also be used to determine the interleaving/scrambling sequence that was used at the transmitter. We investigate the performance of the scheme for some standard convolutional codes.

6.1 Papers not Included in the Thesis

The following papers contain work done by the author but are not included in the thesis.

1. J. Eriksson, R. Moosavi, E. G. Larsson, N. Wiberg, P. Frenger and F. Gunnarsson, "On coding of scheduling information in OFDM," *in Proc. of IEEE VTC*, pp. 1-5, Apr. 2009.

Control signaling strategies for scheduling information in cellular OFDM systems are studied. A single-cell multiuser system model is formulated that provides system capacity estimates accounting for the signaling overhead. Different scheduling granularities are considered, including the one used in the specifications for the 3G Long Term Evolution (LTE). A greedy scheduling method is assumed, where each resource is assigned to the user for which it can support the highest number of bits. The simulation results indicate that the cost of control signaling does not outweigh the scheduling gain, when compared with a simple round-robin scheme that does not need signaling of scheduling information. Furthermore, in the studied scenario, joint coding and signaling of scheduling information over all selected users is found to be superior to separate coding and signaling for each user. The results also indicate that the scheduling granularity used for LTE provides better performance than the full granularity.

This publication reports preliminary results and discussions that later evolved into paper A.

2. R. Moosavi and E. G. Larsson, "Reducing downlink signaling traffic in wireless systems using mobile-assisted scheduling," *in Proc. of IEEE GLOBECOM*, pp. 1-5, Dec. 2010.

We present an idea to reduce the part of the downlink signaling traffic in wireless multiple access systems that contains scheduling information. The theoretical basis of the scheme is that the scheduling decisions made by the base station are correlated with the CSI reports from the mobiles. This correlation can be exploited by the source coding scheme that is used to compress the scheduling maps before they are sent to the mobiles. In the proposed scheme, this idea is implemented by letting the mobiles make tentative scheduling decisions themselves, and then letting the base station transmit "agreement maps" instead of raw scheduling maps to the mobiles. The agreement maps have lower entropy and they require less resources to be transmitted than the original scheduling maps do. The improvement can be substantial.

This publication is the conference version of Paper B.

3. J. Eriksson, R. Moosavi and E. G. Larsson, “Complexity reduction of blind decoding schemes using CRC splitting,” submitted to IEEE GLOBECOM 2011.

Blind decoding is a type of adaptive modulation and coding technique used on control channels of some multi-user wireless access systems. The idea is to adapt the modulation and coding scheme to the channel quality but instead of signaling the parameters used explicitly, the receiver blindly tries a number of fixed parameter combinations until a successful decoding attempt is detected, with the help of a cyclic redundancy check. In this paper we suggest a new method for reducing the complexity and energy consumption associated with such blind decoding schemes. Our idea is to use a mini-CRC injected early in the data stream to determine if the current decoding attempt is using the correct modulation and coding parameters. We analyze and exemplify the complexity gain of this approach and also investigate the impact of the rearrangement of the CRC scheme in terms of the probability of undetected error. The presented results for the complexity gain are promising and the impact on the error detection capability turns out to be small if any.

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