MobCom 9sem 2006 : Project catalogue

Group size\(^1\) : has to be 4-6 students !!!

To learn more about the projects go and talk to the proposers

You have 1 week to form groups and come with a prioritized list of project wishes (max 3). Note the proposers might have restriction on number of projects they can run.

**Proposals from RATE**

1. Channel Quality Estimators Error modeling in OFDMA based System (GM, TBS)
2. Synchronization and Channel Estimation in the Uplink of Evolved UTRA/3.9G Systems (BEP, TBS)
3. Joint Link Adaptation and Scheduling for Cellular MIMO OFDM Systems (WiMAX, 3GPP LTE) (IMR, SSD, FBF)

**Proposals from APNET**

5. Dynamic Channel Selection for Cognitive Radio Network (PP, HY)
6. Radio Resource Allocation in cellular OFDM system with relays (MEK, PP)
8. Implementation of cooperative transmission techniques and evaluation using experimental data (PKy, PP)
9. Genetic algorithms for BER calculation in large delay spread channels (PKy)
10. Performance Analysis of a shared downlink channel under different Scalable-OFDMA sub-channel modes (PKy, HW)
11. Cooperative Cross-layer Hotspot Selection with Beamforming at User Side (CGL, FF)
12. Optimal spectral and spatial weighting schemes and their robustness to channel estimation errors (PKy, XZ)
13. Performance Improvement of WPAN by Using Multiple Antennas (YW)

\(^1\) Long/final project (1,2 or 3 students) covering both 9\(^{th}\) and 10\(^{th}\) semester, is only for students having had minimum one previous semester /project at AAU (new students will be surprised by the amount of structure /work required to do a good project, so they need to learn minimum from a separate 9sem project)
1 : Channel Quality Estimators Error modeling in OFDMA based System

Background:
Orthogonal Frequency Division Multiple Access (OFDMA) will most probably be the technology chosen to handle most of the future wireless access systems. OFDMA is indeed already included in the WiMax standard [1], as well as several others. Furthermore, many companies support OFDMA for being chosen by 3GPP for UTRA-LTE [2] (also called 3.9G) which is meant to be an opening towards 4G systems. OFDMA brings new challenges regarding Radio Resource Management and requires advanced cross layer optimizations. As an example, advanced scheduling algorithms utilize frequency diversity and schedule users on sub-carriers experiencing good channel quality [3] [4]. However, such a Packet Scheduling requires a complex Channel Quality Feedback (CQF) from the mobile user equipment since the base station cannot by itself derive such information in a frequency division duplex system.

In principle, the CQF is an estimate of the current frequency transfer function, based on pilot symbol information sent by the Base Station. This estimate is subject to errors due to noise and other cell interference. From studying packet scheduling it is known that the advantage of the more advanced packet schedulers is quite sensitive to the CQF information, hence it is of capital importance to reliably model the CQF error in order to determine the best PS strategy.

User Equipment

Interference

Noise

Interpretation

Pilots

CQF

Data

Base Station

Packet scheduling

Objectives:
- Build a Link level simulator with explicit implementation of Serving and interfering sectors, realistic fading, pathloss and shadowing, LTE compliant transmission frame structures including pilot symbol placement and Resource Block definitions (the basic scheduling unit)
- Implement several schemes for CQF, e.g. based on different signal to noise plus interference ratio estimators
- Determine the key components influencing the CQF error under different cell loading scenarios (fully and fractionally loaded)
- Build a realistic stochastic model of the CQF error

Prerequisite:
Due to the initial amount of work in implementing the link level simulator this project is most suitable for a one year student project. The student should have a basic understanding of Radio Resource Management (packet scheduling, link adaptation) issues in a multi-cell system. Good skills in mathematics are also expected. Furthermore, good skills in the Matlab language are required for implementing the simulator.
Supervisors:
Guillaume Monghal, Aalborg University, Denmark: gm@kom.aau.dk
Troels B. Sørensen, Aalborg University, Denmark: tbs@kom.aau.dk

References:
2 : Synchronization and Channel Estimation in the Uplink of Evolved UTRA/3.9G Systems

Proposers/Supervisors
Basuki Endah Priyanto / Troels B. Sørensen
(Radio Access Technologies Section (RATE), bep@kom.aau.dk, A6-108)

Evolved UTRA (EUTRA) is the next generation of wireless cellular communication systems designed as a step towards the 4G systems. Presently, the standardization on this system is actively discussed in the 3GPP forum. The system is targeting 2 GHz frequency band. The system will occupy a maximum 20 MHz bandwidth.

Within this setting we propose a project proposal with two different possible directions:

Project a)

Channel Estimation versus Channel Probing for Uplink in Evolved UTRA/3.9G Systems

Proposers/Supervisors
Basuki Endah Priyanto / Troels B. Sørensen
(Radio Access Technologies Section (RATE), bep@kom.aau.dk, A6-108)

Project b)

Synchronization Techniques for EUTRA Single Carrier FDMA

Proposers/Supervisors
Basuki Endah Priyanto / Troels B. Sørensen
(Radio Access Technologies Section (RATE), bep@kom.aau.dk, A6-108)

Descriptions for the two projects follows.
Channel Estimation versus Channel Probing for Uplink in Evolved UTRA/3G Systems

Proposers/Supervisors
Basuki Endah Priyanto / Troels B. Sørensen
(Radio Access Technologies Section (RATE), bep@kom.aau.dk, A6-108)

Background
Evolved UTRA (EUTRA) is the next generation of wireless cellular communication systems designed as a step towards the 4G systems. Presently, the standardization on this system is actively discussed in the 3GPP forum. The system is targeting the 2 GHz frequency band. The system will occupy a maximum 20 MHz bandwidth.

As the most appropriate multiple access scheme for the uplink of EUTRA 3GPP has selected Single Carrier Frequency Division Multiple Access (SC-FDMA) with cyclic prefix extension, which allows efficient frequency-domain equalization at the receiver. The channel estimate required for equalization is obtained from dedicated pilot symbols inserted to the uplink transmission.

In this scheme individual users may access the base station using either localized or distributed frequency resources so that in both cases users remain orthogonal within the serving cell. The basic structure for generation of the SC-FDMA signal is shown in Figure 1.

![Figure 1 Transmitter structure for SC-FDMA [1].](image)

The sub-carrier mapping block takes care of placing users in either the localised or distributed approach. With the localised approach it is possible to use advanced spatial and frequency (channel) dependent packet scheduling. However for this to work the scheduler needs to know the channel conditions over the whole frequency range (channel probing), and hence the requirement for sending pilot information outside of the range in which the actual user data is being sent (outband pilot information).

Main Objectives
The objective in this project is to see how the pilot information can be divided between inband and outband frequency ranges, including how much pilot information and at what power level. The trade-off is to sacrifice the coherent detection if too much pilot
information is sent outband. Also, in a multiple access scenario there is a need to define some scheme for how the outband information is sent since it will potentially interfere with other users’ transmissions.

Basically, the study should consider the link level performance of a single user link in terms of uncoded and coded BER under different pilot distribution schemes. However, certain aspects of the multiuser access needs to be considered to make the study useful.

**Content**
In the RATE section we have available an advanced link level simulation tool already capable of simulating the basic uplink. Simulations with channel estimation are also possible so as to give some initial idea about the impact of pilot information. However, extensions are required to study different pilot distribution schemes.

A possible project outline contains as the first step a basic understanding of the uplink multiple access situation and the SC-FDMA scheme. Next it is required to look into the simulation tool for the purpose of modifying it for the EUTRA frame structure and the insertion of inband/outband pilot information.

During the project, the students will have the possibility to study and acquire knowledge on the major components of a modern wireless communication system. Topics on OFDM will be taught during the semester.

**Pre-requisites**
As a half-year project, the students should have a good background in communication systems, be proficient in Matlab script programming, and have knowledge in C programming (optional). Contact the main supervisor for suggested literature (e-mail: bep@kom.aau.dk).

**References**
2. [www.3gpp.org](http://www.3gpp.org): TR.25.814

* The access to the link level simulation tool is subject to a non-disclosure agreement (NDA).
Synchronization Techniques for EUTRA Single Carrier
FDMA

Proposers/Supervisors
Basuki Endah Priyanto / Troels B. Sørensen
(Radio Access Technologies Section (RATE), bep@kom.aau.dk, A6-108)

Background
Evolved UTRA (EUTRA) is the next generation of wireless cellular communication systems designed as a step towards the 4G systems. Presently, the standardization on this system is actively discussed in the 3GPP forum. The system is targeting 2 GHz frequency band. The system will occupy a maximum 20 MHz bandwidth.

As the most appropriate multiple access scheme for the uplink of EUTRA 3GPP has selected Single Carrier Frequency Division Multiple Access (SC-FDMA) with cyclic prefix extension, which allows efficient frequency-domain equalization at the receiver. The channel estimate required for equalization is obtained from dedicated pilot symbols inserted to the uplink transmission.

In this scheme individual users may access the base station using either localized or distributed frequency resources so that in both cases users remain orthogonal within the serving cell. The basic structure for generation of the SC-FDMA signal is shown in Figure 1.

The sub-carrier mapping block takes care of placing users in either the localised or distributed approach.

When a user first makes access to the system there is a need for time and frequency synchronisation. The transmitter structure in Figure 1, with its reciprocal dual at the receiver side, can tolerate some inaccuracy, as long as it can be corrected or compensated in the pilot assisted (coherent) demodulation. To get within these tolerable limits an initial synchronisation operation needs to take place.

Main Objectives
The project has the main objective to study and investigate synchronization techniques for the uplink SC-FDMA system in the context of EUTRA. The system context implies
that specific frame structures are already defined. In addition to this, there are also implications as to the conditions under which synchronization shall be possible.

In the study we include both Carrier Frequency Synchronization, Symbol Timing synchronization, and Sampling Clock Synchronization. It is however likely that the study will emphasize only one or two of these. The study should consider the link level performance of a single user link in terms of uncoded and coded BER under different synchronization conditions and synchronization techniques.

Contents
In the RATE section we have available an advanced link level simulation tool*, already capable of simulating the basic uplink. In fact, with the current version of the tool it is already possible to study the impact to link performance from imperfections in the synchronisation. This will provide a good starting point for defining synchronisation techniques.

A possible project outline contains as the first step a basic understanding of the uplink multiple access situation and the SC-FDMA scheme. Next it is required to get experienced with the existing link level simulator; simulations can be performed to get an initial idea about the synchronization issue. From this starting point different synchronization techniques suitable for SC-FDMA can be studied and implemented to the simulator. Different techniques are then compared based on their link level performance, including their robustness to different synchronization conditions.

During the project, the students will have the possibility to study and acquire knowledge on the major components of a modern wireless communication system. Topics on OFDM will be taught during the semester.

Pre-requisites
As a half-year project, the students should have a good background in communication systems, be proficient in Matlab script programming, and have knowledge in C programming (optional). Contact the main supervisor for suggested literature (e-mail: bep@kom.aau.dk).

References
4. www.3gpp.org: TR.25.814

* The access to the link level simulation tool is subject to a non-disclosure agreement (NDA).
3 : Joint Link Adaptation and Scheduling for Cellular MIMO OFDM Systems (WiMAX, 3GPP LTE)

Number of Students: up to 4.
Supervisors: Muhammad Imadur Rahman, Suvra Sekhar Das, Fleming B. Frederiksen
Contact: imr@kom.aau.dk; ssd@kom.aau.dk; fbf@kom.aau.dk

Introduction: In a cellular scenario, channel dynamics (i.e. time and frequency behavior of the channel) can be efficiently exploited to obtain higher system performance. A logical response in the presence of channel variations will be to adopt the system parameters according to the channel parameters. Thus, it is of paramount importance to study the impact on bit error rate, BER (or frame error rate, FER or packet error rate, PER) depending on specific channel conditions and corresponding system parameters, such as modulation level, amount of transmission power etc.

Recent advances in multi antenna technologies have paved the way for exploiting spatial diversity for higher throughput and better service possibilities.

In a multi user system, different users experience different channel conditions at the same time. This can be exploited to increase the degrees of freedom to maximize the cell throughput using proper scheduling mechanism. Scheduling mechanisms are tightly bound to link adaptation and multiple antenna strategies and vice versa. Therefore it is highly important that these are studied in a holistic manner which is the goal of this project.

In Link Adaptation, recent works have suggested that joint application of power and rate adaptation does not provide any significant gain compared either power adaptation only or rate adaptation only systems. In such a situation, it can be said that power adaptation for OFDM is difficult to implement in cellular scenario, as it would increase inter cell interference, but it would enable a very simple receiver, for constant rate transmissions. On the other hand, rate adaptation would not cause higher inter cell interference, though it would require a more complex receiver due to multi-level modulations and demodulations. This is an important area of investigation in this project. This study will bring out the interplay between the numerous system parameters, such as modulation level, power level, forward error control coding etc. together with resource allocation for WiMAX like MIMO—OFDM wireless systems, to obtain optimum performance.

A novel link adaptation algorithm has been developed under our supervision in Spring 2006 [1]. The knowledge generate will serve as a basis for the initial part of the project. The project will mainly have the following key steps.

1. MIMO Mode selection
2. Joint resource allocation and link adaptation

Test scenario is as follows:
1. Cellular system with single frequency network and omni-directional base station.
2. Multi User system
3. Multi Antenna at MS and/or BS

Activities in the project
1. MIMO Mode Selection
   a. Find MIMO mode (Tx Div Alamouti, Antenna Selection, Rx Diversity, Spatial Multiplexing in a single link) performances (FEC coded) for Multi carrier at different regions of the cell (different interference conditions) i.e. MIMO mode selection with respect to location & interference conditions. Spatial correlation etc…. try to minimize overhead, study / analyze / identify link adaptation issues / scheduling issues related to this, whether the MIMO mode selection can be just an addendum to scheduling? or there needs to be an integrated design for optimum & realizable solution?

2. LA + Scheduling
   a. Generate SNR lookup tables for cellular (CCI/OCI) scenario
   b. Implement a proportional Fair Algorithm
   c. Work on
i. Scheduling + LA
   1. improved throughput
   2. minimum overhead
   3. minimum subscriber equipment complexity issues
   4. hybrid adaptation (fast+slow) for mobility parameter
   5. outage improvement

3. Analysis / Investigation of gains when Multi User diversity & Spatial diversity are together.
   (Refer to the bell theoretical analysis).
   a. Scenarios
      i. Diff cell size (scenario: Pico, Micro, Macro, urban, semi urban, rural)
      ii. Number of Users
   b. Propose the strategy: when to exploit spatial gain, and when to exploit multi-user gains
      when the reliability of CSI is varied across users?
   c. Analyze the situation when
      1. CSI imperfection is there
      2. Overhead is an issue
      3. When instantaneous and statistical adaptation is used.

Reference:
2. WiMAX forum: http://www.wimaxforum.org/home/
3. Intel Technology Journal: WiMAX issue:
4 : Impact of PAPR reduction mechanism on Bit and Power Loading Strategies for OFDM based Wireless Systems

Number of students: 4
Supervisors: Fleming B. Frederiksen  Suvra Sekhar Das, Muhammad Imadur Rahman
e-mail: ssd@kom.aau.dk, imr@kom.aau.dk ; fbf@kom.aau.dk

Problem description:

OFDM has been quite popular for broadband communication systems. It has enabled high spectral efficiency systems. A current realization is the WiMAX standard , i.e. IEEE 802.16a,d,e standard. This project deals with these two advanced PHYSICAL layer technologies, namely link adapatation and PAPR issues in WiMAX like OFDM systems.

Link Adaptation involves varying the bit loading (modulation level) and the power loading (power adaptation) for each sub carrier; subjected to total and peak power constraint. The strategy chooses the optimum power level and modulation order per sub-carrier, so that spectral efficiency is maximized. In the latest implementations, WiMAX is targeting optional link adaptation in OFDM. In short, link Adaptation in conjunction with OFDM promises to provide a massive improvement in system throughput.

On the other hand, OFDM systems suffer from large Peak to Average Power Ratio (PAPR) problem. The power amplifier has to operate with back off, so that the peak distortion due to power amplifier does not degrade the performance. Larger the PAPR, larger is the back off needed. The larger is the back off in the power amplifier, the higher the power loss and reduction in range (coverage) [1],[3]. Although Link Adaptation in OFDM promises to improve the spectral efficiency by a large margin, it has been analyzed in our previous work that they will be heavily influenced by the PAPR of the system.

It is worth noting here that link adaptation these studies do not consider the interaction of rate and power adaptation with PAPR mechanism. The study of influence of power and or rate adaptation on PAPR for OFDM is important since PAPR is already high for OFDM. If the above two link adaptation mechanisms increase the PAPR of the system, it would put heavy constraints on the power amplifier back off parameter. Either it would reduce the range coverage, or it will introduce bit error rate degradation. Therefore it is important to consider the aspects of PAPR for any improvement on OFDM system. It might turn out that one system is better in terms of PAPR compared to another. Now, if the spectral efficiency difference is not very high, then the link adaptation scheme with a better PAPR distribution may be selected.

The goal of this project is to analyze the joint performance of rate adaptation and power adaptation with PAPR reduction mechanisms in OFDM systems.
Assumptions:
1. Discrete modulation levels such as BPSK, QPSK, QAM-16, QAM-64, will be considered.
2. FEC rates: 1/2, 2/3, 3/4
3. Total power constraint will be considered.
4. Power Adaptation

Scenarios:
1. Only rate adaptation at constant transmit power
2. Only power adaptation for constant rate
3. Both power and rate adaptation
4. Sub channelization

Analysis:
1. To obtain the cumulative distribution numerically (by means of simulation), of the PAPR in each of the above cases.
2. To study the distribution of PAPR after applying a simple PAPR reduction mechanism (for example clipping and filtering), on OFDM systems using link adaptations mentioned earlier.
3. To develop the analytical expression of the PAPR
4. To find bit error rate & Frame Error Rate degradation (by simulation) in each of the above cases, when the threshold for the clipping (a PAPR reduction mechanism), is given, which is chosen without considering the PAPR effect of the link adaptation schemes
5. Find performance of Different PAPR reduction methods.
6. To find an optimization for one or two of the algorithms for the link adaptation mechanism
7. Evaluation in a multi user scenario

Outcome:
1. Report describing the effect PAPR reduction algorithms on rate and power control based link adaptation schemes for OFDM based systems.

Reference:
5 : Dynamic Channel Selection for Cognitive Radio Network

Supervisor:
Hiroyuki Yomo (APNet, yomo@kom.aau.dk, office: A6-212, tel: 9821), Petar Popovski (APNet, petarp@kom.aau.dk, A5-208, tel: 7528)

Background:
During the last few decades, the severe shortage of radio spectrum has been the main motivation always used by researchers in the field of wireless communications. It has been believed that this shortage is mainly due to the physical scarcity of radio spectrum and to the rapid spread of diverse wireless devices, such as mobile phones, laptop computers, home appliances, wireless tags, etc. However, a recent report published by the federal communication commission (FCC) in US has shown that the large part of the licensed spectrum is not utilized most of the time and space, and the frequency spectrum is actually abundant. This fact has resulted from the complicated and old regulations, which prevent us from utilizing more flexible and open access to these abundant bands. Apparently, in order to increase the efficiency of our natural spectrum resource utilization, more flexible spectrum management techniques and regulations are required.

Cognitive radio [1] [2] has been proposed as a novel means to achieve such flexible spectrum management, which drastically increases the efficiency of frequency utilization. Cognitive radio networks are allowed to access to the spectrum that is unutilized by its owner (called primary user) at certain time and space. A cognitive radio senses the spectral environment over a wide frequency band and exploits this information to opportunistically provide wireless links that can best meet the demand of the user, but also of its radio environments. A cognitive radio first senses the spectrum environment in order to learn the frequency spectrum unoccupied by primary users. Once such a spectrum is found, the cognitive radio adapts its transmission power, frequency band, modulation, etc., so that it minimizes the interference to the primary users. Even after starting the transmission, the cognitive radio should be able to detect or predict the appearance of a primary user so that it makes the spectrum available for the primary user.

Project Description:
The above cognitive radio technology can be applied to the current networks which suffer from the scarcity of the spectrum, such as wireless local area network (WLAN). Currently, WLANs operate in the unlicensed frequency bands which are notorious for the congested use by many different types of wireless networks. Once a WLAN has cognitive functions, it can operate in the frequency bands of primary users as well as the ordinary unlicensed bands. Thus, instead of the congested unlicensed band, cognitive WLAN can operate in a frequency owned by a primary user. However, the frequency bands of primary users are not always available (due to the activity of primary users) and they can also have more strict restriction on its usage (e.g. maximum-allowed transmission power) than the ordinary unlicensed bands. Therefore, the cognitive WLAN has to dynamically select the best operating frequency band according to congestion level and usage restriction in different bands. This selection has to be done in a distributed manner since it is generally difficult to assume the information exchange among different networks. This project aims to develop such a distributed channel
selection mechanism for cognitive radio networks. The main focus and objective of the project will be:

- To get familiar with cognitive radio technology
- To model different restrictions (e.g. maximum transmission power) on cognitive radio network in different frequency bands
- To propose distributed channel selection strategies for cognitive radio networks to efficiently coexist with the other cognitive radio networks as well as ordinary (non-cognitive) unlicensed networks
- To investigate the advanced method to enhance the network performance of cognitive radio network (e.g. multiple band operation) and propose the required channel selection strategies

Requirements:
Basic knowledge about PHY/MAC protocols for wireless network, and programming skills (for example, in MATLAB, C)

References
6: Radio Resource Allocation in cellular OFDM system with relays

Proposed by
Megumi Kaneko (mek@kom.aau.dk, room NJV14, 3-307)
Petar Popovski (petarp@kom.aau.dk, room A5-208)

Background
Radio resource management for Orthogonal-Frequency-Division-Multiplex (OFDM)-based 4th Generation (4G) system is currently a key research issue in wireless communications [1]. OFDM possesses some very desirable properties (high spectral efficiency, simple equalization), which made it a widely adopted transmission technology for the ongoing and future (4G) wireless standards, such as IEEE 802.16 (WiMax) [2]. One goal of the next-generation cellular system is to provide ubiquitous, high data rate coverage. But with the traditional cellular architecture, this is very costly to achieve since many Base Stations (BS) should be deployed to cover a wide area. Instead, the deployment of Relay Stations (RS) in each cell offers an attractive solution to the coverage problem, since high data rates can be forwarded in remote areas of the cell, while keeping a low cost of infrastructure. Currently, there is a lot of interest in the research of radio resource allocation strategies for cellular systems with relays [3][4], i.e., how to allocate time slot/frequency/code to the users in the cell depending on their channel states, required services, packet traffic status, etc. Several studies have shown that the effectiveness of relays will highly depend on these resource allocation algorithms [5][6]. The motivation for doing this project is the observation that there has been little work in the literature concerning the problem of resource allocation in relay-based cellular OFDM systems. A particular point about the relay-based cellular systems is that the relays introduce more stringent constraints for support of real-time services such as voice or video. This is because there is additional delay when a packet is passed through a relay before arriving to the destination user. Thus, the design of resource allocation algorithms will be crucial to enable the support of high data rates, wide coverage, and stringent Quality of Service (QoS).

Project Description
The project will start with a study on OFDM technology and an overview of some common scheduling algorithms, such as Max C/I, Round Robin, Proportional Fair Scheduling (PFS), etc. Also, the students will identify the basic QoS requirements for different service classes. In the next step, there should be a survey about resource allocation strategies for OFDM-based, relay-aided system. This will lead to identification of the key problems concerning the QoS constrained resource allocation in relay-based OFDM systems. In particular, the following aspects should be clarified:

- Design of the frequency/time allocation algorithms for the transmissions from the BS and the RS to the users
- Types of services and QoS levels to be considered
- How these QoS requirements can be satisfied by the scheduling and resource allocation algorithms?
- Feedback of the Channel State Information (CSI) from each user to the BS and the RS
- Performance metrics: throughput, fairness, QoS provision, coverage…

It is expected that innovative solutions will be proposed for some of the identified problems. The results should be validated by simulation and analysis.

Prerequisites
General knowledge of communication system and programming skills (Matlab).

Remark
The intellectual property items that will be proposed within the project may be subject to patenting within an ongoing industrial project. Therefore, the students will sign a suitable agreement before the start of the project.

References
Using Client Ad-Hoc Links for Enhancement of Localization Accuracy in Cellular Networks

Supervisors:
Simone Frattasi, APNET, NJ14-3.309, sf@kom.aau.dk, João Figueiras, Networking and Security, A5-216, jf@kom.aau.dk

Background:
The use of the Global Positioning System (GPS) for location of mobiles has been applied in the third generation (3G). However, the introduction of mobile handsets with built-in GPS receivers leads to an increased cost, size, battery consumption, and a long time for a full market penetration. Furthermore, the location estimation accuracy obtained by the GPS degrades in urban and indoor environments, which actually represent the greatest interest of cellular network providers and service providers in general [1]. Hence, investigations started in connection with the fourth generation (4G), where the new systems will take advantage of the emerging network heterogeneity [2]. The need is to define a polyvalent solution based on different communication technologies, which is also able to provide location information with a high level of accuracy anywhere and anytime!

Objective:
Motivation: 4G is expected to supply the increasing population of mobile users with a various range of appealing services (from pop-up advertisements to location-based and interactive or on-demand services – so called IP datacasting), which will definitely require a technological improvement in terms of data rate, energy consumption, coverage, and spectral efficiency [2]. Interesting solutions to achieve such requirements rely on the use of a combination of the cellular network model with the peer-to-peer (P2P) one, which is usually used only in a special class of wireless networks called ad-hoc networks [3]. Since the work on wireless location has mainly concerned the previous generations, how to implement the location service in such a system is an open area for research.

Goal: In this project, which is a step-ahead of the work in [4-5], we propose a method to perform the localization service in a system based on the coexistence of the cellular and the ad-hoc network models. Each mobile station (MS) is assumed to receive signals for localization purposes both from the base stations (BSs) and from neighboring MSs. As a reference system, we consider a Wireless Wide Area Network (WWAN) / Wireless Local Area Network (WLAN) system, such as the Universal Mobile Telecommunications System (UMTS) and the WLAN 802.11a, which integrates respectively two types of wireless access technologies: the Wideband Code Division Multiple Access (WCDMA) and the Orthogonal Frequency Division Multiplexing (OFDM). The positioning techniques employed in such a system are chosen to be the time difference of arrival (TDOA) and the received signal strength (RSS), respectively for the long- and short-range segments. Each MS retrieves and forwards its own set of time-difference and range-based estimations to the cellular network, which is then in charge of calculating the location estimates for all the cooperative mobiles. As a consequence, our target is to design the required protocols / algorithms to support such a cooperative localization scheme and show that it can outperform the conventional cellular localization schemes. Note that our approach may include modifications to Layer-2 protocols.

Benefits for students:
The students will be involved in a project that will advance the state of the art in the area of localization for mobile communications. It comprises both a theoretical and a practical part, which will form their knowledge and their reactivity in dealing with theoretical issues, and develop their implementation and programming skills.

The project outcomes will find directly strong interest from major industries and other players in the area of mobile communications, and the achieved results may be exploited for patents applications, conference and journal papers.
Relation to project courses and required knowledge:
This project fits well with all the basic and specialized courses of mobile communications, since it requires a basic knowledge of wireless communication protocols and technologies. Additionally, it requires some programming skills (e.g., MATLAB and SIMULINK).

Additional references:


8: Implementation of cooperative transmission techniques and evaluation using experimental data

Background

Let us assume that we have an access point (AP) that provides coverage to a cell C around it. Within this cell, there are several users that can receive downlink data from the AP. Depending on the quality of the link from the AP to each user, if a user $U_i$ is in an unfavorable channel situation, then it cannot receive data from the AP. However, it might be possible for the AP to send data to another user $U_j$, which can then forward them to $U_i$. The user $U_j$ is then referred to as a relay.

This concept is referred to as user cooperation and it is based on the idea that users might be able to exchange data locally over a separate short-range communication system to enhance each other’s reception quality. This way the capacity or the coverage of cellular systems can be extended. Clearly the performance of such a scheme depends on the quality of the link from the AP to the users and the link between the users.

Several strategies have been proposed to implement user cooperation (see for example [2]). For the most part they involve half-duplex transmission: half the time the relay station receives data from the transmitter. The other half of the time it re-transmits the data, either simply amplified or after decoding and re-encoding. [2] investigated the performance of these techniques under some assumptions for the channel statistics.

However, a set of cooperative channel measurements was reported (possibly the first in the world!) in [1]. They involve 2 user equipments (UEs) and 2 access points (APs), each equipped with 4 antennas.

The purpose of this project is to implement cooperative transmission schemes and evaluate their performance using the actual channel measurements.

Methodology

1. Understanding
   The first step is to understand the different cooperation strategies and select the ones to be implemented. For example the students can select two or more of the following:
   - Amplify and forward
   - Decode and forward
   - Selection relaying
   - Incremental relaying
2. Implementation
   The second step is to select the system parameters such as the coding, and the packet size, and to implement the cooperative transmission strategies.

3. Evaluation
   The third part is the evaluation of the different cooperative strategies.

References

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Name: Petar Popovski
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http://kom.aau.dk/~petarp/
9 : Genetic algorithms for BER calculation in large delay spread channels

Background:
Imagine we have a wideband system which is described by the channel impulse response

\[ h(t) = \sum_{l=0}^{L-1} h_l \delta(t - lT_s) \]

\( T_s \) is the symbol time, and there are \( L \) channel taps.
Let us assume that we are trying to perform symbol by symbol detection without the use of equalization or advanced coding techniques (e.g. Viterbi detection). Intersymbol interference (ISI) from the previous \( (L-1) \) symbols becomes the fundamental limiting factor and we observe the phenomenon of irreducible bit error rate (BER). Commonly irreducible BER is associated with the delay spread of the channel, and is aggravated by larger delay spreads.

If we are given a wideband channel and want to calculate the BER, we can:
- Approximate the ISI as additive white Gaussian noise and look at an equivalent SNR. In reality the ISI is neither white nor Gaussian and this approach tends to overestimate the BER.
- Simulate the bit transmission for very long trains of bits.
- Calculate the exact value of the ISI for all \( M^{(L-1)} \) possible values of the ISI (where \( M \) is the size of the constellation), and from that the BER, and then average over the possible realizations of the ISI.

Clearly the last two solutions are very computationally intensive, and the first one is inaccurate. So what can we do?

Project Description:
Commonly genetic algorithms are used to find extrema within a very large set of options. With appropriate tweaking, we can use genetic algorithms to find averages over a set of options (see [1]). We can use this to find the average BER as in the third approach above, keeping in mind that few combinations of previously transmitted bits can lead to low BERs.

The purpose of this project is to:
- Develop the genetic algorithm for BER calculation (the code has mostly been implemented in Matlab, but needs some work).
- Study the performance in terms of accuracy and runtime for different channel parameters.
- Specifically look at the achievable BERs for channels with and without time reversal (TR). It is expected that the symmetries in the response with TR will reduce the BER, even though the delay spread is the same.

Prerequisites:
FP8-25 Propagation, Antennas and Diversity
FP8-26 Inverse filtering, Deconvolution and Equalization
This project is incredibly interesting but requires a strong stomach for advanced math.

References
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Performance Analysis of a shared downlink channel under different Scalable-OFDMA sub-channel modes

Proposed by:
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Motivation:
OFDM (orthogonal frequency division multiplexing) is a multi-carrier modulation (MCM) technique in which a data stream is split into several lower data-rate sub-streams and they are used to modulate several sub-carriers in parallel. One of the main advantages of OFDM is its robustness against frequency selective fading and narrow-band interference. Furthermore, it can be implemented cost efficiently with FFT using the powerful and cheap DSP chips available nowadays.

Recently, OFDM has been proposed as a multiple access technique, giving rise to what is known as OFDMA (orthogonal frequency division multiple access). The idea is that groups of sub-carriers can be allocated to different users in the system. Scalable-OFDMA(S-OFDMA) was introduced to WiMAX by IEEE 802.16 Task Group e (TGe) to support both fixed and portable/mobile users with low cost. Scalable OFDMA is based on variable FFT sizes which support variable channel bandwidths from 1.25MHz to 20MHz. There are basically two sub-channel modes under S-OFDMA: the adjacent mode and the distributed mode [1].

As illustrated in the figure above, in the adjacent mode, OFDMA sub-channels consist of adjacent sub-carriers, while in the distributed mode the sub-carriers of each sub-channel are pseudo-randomly distributed in the frequency domain.

For a shared downlink channel possibly for cell broadcast or multicast services, which channel mode would be more robust is worth to be investigated.
Project Description:

1. Understanding the OFDM/OFDMA transmission techniques and OFDM channel model.
2. Defining the performance metric to evaluate the two SOFDMA channel modes.
3. Analyzing the performance for both S-OFDMA adjacent channel mode and distributed channel mode for a shared downlink channel. There are several optional scenarios to be selected by the student group:
   (1) One cell scenario, the multicast transmission need to overcome the fading and the diversity of different mobiles (e.g., different speed which will effect the multi-path fading).
   (2) Multi-cell scenario, where the multicast downlink channel needs to overcome the inter-cell interference from neighboring cells, possibly from other multicast services or unicast services. To simplify the investigated mobile group might be limited only to the ones located close to the cell border and with the same mobility model.
4. Implementing a simulation model to evaluate the analysis in item 3. Some related S-OFDMA channel models and simulation tools can be found in [2].

References:
Project description

In data traffic dense area, it is normally covered by several overlapped hotspots. Each user has to choose a hotspot to join by associating with the corresponding access point. Currently, this is implemented based on received signal strength indicator (RSSI). The user will join the hotspot which gives strongest RSSI. However, in the real environment, the high RSSI does not necessarily mean high user capacity. It also depends on other factors like interference level and multi-user situation. For a simple example, without considering interference, the data rate basically relies on the RSSI. In multi-user scenario, user capacity depends not only on data rate but also on MAC delay because multiple users share the same channel. In the best case without considering packet and MAC protocol overhead, $User\ capacity = \frac{Data\ rate}{Number\ of\ users}$. Sometimes, a terminal should select a less crowded hotspot instead of the highest data rate hotspot. In this case, the cross-layer information should be taken into consideration to smartly select a hotspot to join.

In previous work, we have investigated a terminal beamforming system, as shown in Fig. 1, which is capable of steering its antenna beam to the related direction of the associated access point. It can significantly increase the user capacity by array gain and interference reduction. Beamforming terminals can see more access points due to array gain, and therefore offer more access possibilities. A number of possible beamforming settings with respect to different access points are possible, whereas only one will provide the optimal capacity.
A simple example is shown in Fig. 2. Without smart hotspot selection, both terminals would go for AP2, as this offers the best performance in data rate (or RSSI). In this case both terminals share the capacity resulting in 27Mbit/s. For a smarter selection, WT1 should go for AP1 (getting 36Mbit/s), and then WT2 would be 54Mbit/s with AP2. The capacity is significantly increased for both terminals.

The smart selection can be done individually in a complete distributed manner only relying on the self information. Another interesting possibility is to achieve it through the cooperation between terminals to share the access information by the inter communication, as shown in Fig. 2. In this project, the participants will investigate different scenarios and explore the possible methods to realize this smart hotspot selection scheme.

**Prerequisites**

- General knowledge of wireless network protocols and wireless propagation
- Matlab programming skills for simulations
- Optionally, if the participants want to do experimental implementation with the testbed, C programming skills are needed, preferable having Linux programming experience.
12 : Optimal spectral and spatial weighting schemes and their robustness to channel estimation errors

Background:
Time reversal (TR) is a technique that has various applications in ultrasound and underwater sound. Only recently has it emerged as a promising technique in wireless communications. Its potential lays in three primary properties: temporal focusing, spatial focusing and statistical stability.
Temporal focusing can be interpreted as a form of pre-equalization that simplifies the requirements on the receiver design. Spatial focusing can be interpreted as a type of broadband beam-forming that can increase the security of the communication link or increase the user density. Statistical stability indicates robustness in channel variations.
It can be shown that time reversal alone with a limited number of transmitters is not optimal. Advanced spatial and spectral filtering techniques have been developed to exploit the properties of time reversal and guarantee optimal performance. Should these be used in an actual wireless system though, it is expected that channel state information will be limited or outdated.

Project Description:
The purpose of this project is to investigate how the performance of these weighting techniques depends on the accuracy of the channel state information (CSI). The parameters that we will investigate are the achievable error rates with imperfect CSI, and the robustness of spatial focusing. We will investigate two types of channel estimation error: noise during the channel estimation process, and continuous channel fading. They are expected to affect the temporal/ spatial focusing in different ways. The investigation of continuous channel fading can also serve as an indication of the robustness of the training requirements that these techniques pose on the system design.
The evaluation will be based on simulations and/ or measurements. For the simulations, we will use the 802.11n channel model, which is already implemented in a Matlab simulator. Alternatively, we can try to approach the problem theoretically, but this requires advanced mathematical skills (random matrix theory, multiple applications of the central limit theorem would be common tools).
Hopefully this project will help demonstrate the robustness of time reversal based ideas, as theoretically expected.

Prerequisites:
FP8-25 Propagation, Antennas and Diversity
FP8-26 Inverse filtering, Deconvolution and Equalization

References


Previous projects

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Performance Improvement of WPAN by Using Multiple Antennas

Work area: PHY Layer

Proposed by: Yu Wang (yw@kom.aau.dk), Patrick Eggers (pe@cpk.auc.dk)

Background
Low Data Rate (LDR) Wireless Personal Area Network (WPAN) has broad applications ranging from personal health care systems to industrial control and environment monitoring systems. Several legacy and emerging systems will compete for the potential markets. By using multiple antennas, the performance of WPAN systems is expected to be improved. However, the gain a multiple antenna system is ultimately decided by the radio channels. The goal of this project is to evaluate how much gain a multi-antenna system can achieve in personal area network (PAN) and/or body area network (BAN) environments.

Figure 1: Example of WPAN LDR system

Project Description
Students will simulate a WPAN system over PAN/BAN channels. ZigBee and Bluetooth are two existing standards, and both are suitable for LDR WPAN applications. In an ongoing EU project, MAGNET, a new air interface was designed for LDR radio links based on the Frequency Modulation – Ultra-Wideband (FM-UWB) technology. It is students’ decision that which system is chosen to evaluate. The way using multiple antennas is also up to students. Considering the cost limits of LDR systems, we suggest relatively low complexity schemes, i.e. selection spatial diversity. As one important part of this project, channel measurement data performed in typical PAN and BAN environments will be available to students.

Benefits for students
By doing the project, students will have a better understanding on multiple antenna systems and how radio channels decide the performance of wireless communications systems. The project consists of both existing standards and emerging techniques, and provides a good opportunity to strengthen learning and programming skills.