MobCom 9sem 2009 : Project catalogue

Group size\(^1\): has to be 4-6 students !!! (unless final thesis, then 1-3 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. Precoded transmission in TDD mode for LTE-A Uplink
2. System Level Evaluation of Uplink LTE-Advanced Systems with Carrier Aggregation
3. Distributed System Solutions for Local Area Indoor Hotspot

**Proposals from APNET**
5. On the definition of a simple formula for the MIMO capacity
6. Pirate sensor system feasibility
7. Interference Scenarios and Spectrum Sensing for Cognitive Radios in the 700 MHz Bands
8. Practical Retransmission schemes for MIMO Systems
9. Multi Antenna terminal System investigation; towards the antenna of the future (small, efficient and tuneable)
11. Mobile distributed wireless stereo

By the 11th Sept the latest, send me and study secretariat (Mette Billeskov) your project choice (or your prioritised wishes) + the names of the other members in the group and the group room you choose

\(^1\) 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)
Motivation
The 3rd Generation Partnership Project (3GPP) is currently standardizing the requirements for the Long Term Evolution – Advanced (LTE-A) mobile communication systems, aiming at peak data rates of 1 Gbps in the downlink and 500 Mbps in the uplink [1]. These ambitious targets can be achieved only by using advanced Multiple Input Multiple Output (MIMO) antenna techniques as well as wide spectrum allocation, of 100 MHz and more. The air interface of the LTE-A systems is based on Orthogonal Frequency Division Multiple Access (OFDMA) [2] for the downlink and Single Carrier Frequency Division Multiple Access (SC-FDMA) for the uplink [3]. Both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) mode are expected to be supported by LTE-A (see Fig.1).

In practical mobile communication systems, the knowledge of the channel over which the transmission is performed is needed to properly perform the detection task in the receiver. Furthermore, it is well known that the capacity of MIMO systems can be enhanced when some degrees of channel knowledge are also available on the transmitter side through a channel-aware precoding operation of the data streams [4]. This means, the data streams are multiplied with a precoding matrix which depends on the current channel conditions, at the purpose of enhancing the Signal-to-Noise Ratio (SNR) in the receiver. Reliable transmission of multiple data streams over spatially multiplexed channels is heavily dependent on accurate channel information and the proper joint treatment (coding) of the multiple communication links.

In TDD mode, UE and BS operate instead over the same band in different time instants; the UE could therefore derive some channel knowledge from a previously received data frame and use it for precoding the data when it switches to the transmit mode, thus avoiding the feedback signaling. Intuitively, the channel reciprocity in TDD mode can only be exploited in case of a slowly variant channel.

Problem description
The aim of this project is to investigate the precoded MIMO transmission in TDD mode for LTE-A uplink. The emphasis is on the transmission of multiple data streams over spatially multiplexed channels, and the feasibility for practical implementation. Solutions based on blind transmission [5] as well as precoded pilots [6] are expected...
to be evaluated, assuming realistic impairments such as channel estimation and calibration errors. The gain of the precoded transmission over the open loop (i.e. non precoded) has to be verified for different numbers of data streams in order to justify the use of the channel reciprocity in TDD mode.

**Prerequisites and tools**
The students must get to know about OFDM-based techniques as well as the issues related to the multiple antenna transmission over fading channels. Good Matlab programming skills are also needed. An LTE-A compliant link level simulator will be made available as a basic environment for the implementation of the aforementioned solutions.

**References**
2: System Level Evaluation of Uplink LTE-Advanced Systems with Carrier Aggregation

Supervisor: Yuanye Wang, ywa@es.aau.dk

Short motivation
Long Term Evolution (LTE)-Advanced is the 4\textsuperscript{th} Generation system that tries to provide user with high data rate. It supports a wide spectrum of up to 100 MHz. This is obtained via carrier aggregation of multiple Component Carriers (CCs) \cite{1}. As an example, Fig. 1 shows a case when 5 CCs (each of 20 MHz) are aggregated together to form a 100 MHz spectrum.

![Aggregated wide bandwidth for LTE-Advanced](image)

Fig. 1. Carrier aggregation of multiple continuous component carriers.

The evolving from single to multiple CC has been studied for multi-carrier High Speed Packet Access (HSPA) \cite{2}, and multi-carrier Code Division Multiple Access (CDMA) system \cite{3}. However, LTE-Advanced is Orthogonal Frequency Division Multiple Access (OFDMA) based, which allows the multiplexing of multi-users in the frequency domain. It is therefore worthwhile to evaluate the performance of a multi-CC LTE-Advanced system, and provide the guideline for deploying the forthcoming 4G systems.

Project description and expected work
In a multi-user multi-CC system, the performance can be improved in several ways. E.g.,

1. Carrier load balancing: balance the load across multiple CCs by properly assigning the users to each CC. Existing load balancing methods include: Round Robin balancing, Mobile Hashing balancing etc \cite{4}.

2. Packet scheduling: exploit the multi-user diversity to improve the system performance. For instance Search-Tree based algorithm \cite{5}.

This project will focus on the system level evaluation of uplink LTE-Advanced system. Students are expected to build the basic framework of a multi-user multi-CC system. Afterwards, they can choose to work on either of the topics listed above, or both of them. The students are also encouraged to study other related techniques and develop their own algorithms.

Prerequisite: Familiar with Matlab programming.

References
3: Distributed System Solutions for Local Area Indoor Hotspot

Supervisor: Zhen Liu, zl@es.aau.dk, Troels Sorensen, tbs@es.aau.dk

Short motivation
High speed data transmission is foreseen to count for the main volume of mobile traffic consumption in the future wireless networks. Moreover, 80% of the data traffic is expected to be generated inside of buildings, i.e., an office building, airport or on campus. Along with the fast evolution of data traffic need, the capacity requirement from such a ‘hotspot’ area will overflow the existing macro site networks.

A typical solution to this for an indoor area is to offload the macro networks by installing a base station inside the building and use a distributed system for large coverage. A distributed system can be composed of either multiple small base stations, or a distributed antenna system [3]. Moreover, the performance of a distributed system can be affected by several features, i.e., cell configuration, link selection criteria [6], transmission mode [4] [5], etc.

Project description and expected work
In this project, we look at a hotspot as represented by a single building and multiple users, and investigate different solutions for serving users. The project will focus on a distributed system solution and its system level downlink performance. The task to be performed include for example:

3. Generate the building model and the correct link budget for a multi-user indoor system according to path-loss model in [1] or [2].
4. Investigate into the effect of different link selection criteria and transmission modes for multi-user performance. Analysis of the pros and cons with each solution.
5. Based on observations from 1 and 3, propose a solution (algorithm) for given specified performance, and analyse this by simulation.

The study will be done mainly by simulation analysis, therefore students need to build the framework of a multi-user in-building system.

Prerequisites: Familiar with radio access concepts (OFDMA) and MATLAB is preferable.

References

5
Introduction

The system requirements for the next generation of mobile communication systems called IMT-Advanced (IMT-A) are currently being specified by ITU. IMT-Advanced services in local area deployment will require a large bandwidth; up to 100 MHz. Operators will not be able to have such a large bandwidth in an exclusive manner. A possible solution is to share the spectrum amongst different networks, as a practical implementation of a Cognitive Network [Akyi06]. Cognitive Radio (CR) techniques provide the capability to use or share the spectrum in an opportunistic manner. Dynamic spectrum access techniques allow the CR to operate in the best available channel and dynamically share the spectrum amongst networks.

Game Theory is on spotlight in recent art as a foundation for practical spectrum sharing solutions for cognitive radios [Suris07] [Niyato07] [Berlemann05]. While Game Theory is more well-known for solving problems where there is no room for cooperation, Game Theory also deals with cooperation amongst players. In terms of protocols, cooperative solutions require signaling. It is still an open issue whether the gains provided by cooperation surpass the incurred overhead and additional complexity.

Background

**Spectrum Sharing:** The function of a cognitive radio responsible to determine how the networks in the same geographical area can achieve coexistence in the same spectrum pool and a fair share of spectrum allocation.

**Game Theory:** The study of mathematical models of conflict and cooperation between rational decision makers. It has several applications in economics, social sciences, biology and engineering problems.

Problem Description

The solution proposed in [Suris07] can be considered an interesting term of comparison for flexible spectrum use in CRs. Its performances in several controlled scenarios need to be evaluated, verifying the algorithm’s behavior with an increasing number of players, starting from the basic number of 2.

Research Steps

The following steps are suggested for carrying out this project:

2. Analysis of the current simulation tool used to simulate IMT-like Local Area scenarios
3. Implementation of the [Suris07] algorithm within the simulation framework
4. Definition of the scenarios of interest that will be simulated according to what verified in 1.
5. Analysis of the simulation output.

**Possible Outcomes**

1. Simulation results in several spectrum occupancy conditions.
2. Evaluation of the algorithm complexity (simulation time) with an increasing number of players
4. Comparison with an existing GT-based algorithm

**Continued Work**

There is possibility to have a continued version of this project for the 10th semester.

**References**


5: On the definition of a simple formula for the MIMO capacity

Supervisors:
Prof. Gert F. Pedersen, APNet Section, A6-206, gfp@es.aau.dk
Ivan Bonev Bonev, APNet Section, A6-209, ibb@es.aau.dk

Problem Definition

It is well known that with the introduction of Multiple Input Multiple Output (MIMO) technique, the capacity of the channel increases. In this project, we will investigate the possibility (availability) of a simple formula for the capacity of MIMO channels in terms of a small number of parameters. The latter will depend on the environment (outdoor or indoor) and on the characteristics of the antennas arrays. The idea for searching of a simple expression is based on the work in [1],[2], where the authors have found mathematical expression for the upper and lower bounds of the capacity in terms of some parameters linked with the transfer matrix. However, for finding of more concrete mathematical expression for the capacity, statistics of several parameters are needed for each particular environment.

Prerequisite

Some knowledge in antennas, propagation and statistics
Good Matlab skills

Outcome

The expected outcome is to obtain knowledge for the possibility of a simple expression of the capacity for one particular environment and to further the investigation for different environments and antennas.

References

[3] F.Bentosela, “Can we give a simple formula for the MIMO capacity”, COST 2100, Valencia, Spain
6: Pirate Sensor System feasibility
Patrick Eggers, APNET (room A6-214, email: pe at es.aau.dk)
Industrial Partner/motivator: Terma A/S, Lystrup / Axel Thomsen

Background
The threat from pirates has been a major problem for vessels in an increasing area of the world [1]. While some systems exist for alerting actual boarding [1], actual preboarding/approach alert systems are typically not found.
The pirates use small dinghies which are difficult to detect by normal navigation sensor systems (radar etc) onboard the vessels for two reasons; first of all the short range detectability is often limited by shadowing and blind zones close to the vessels and secondly: the signal strength from the dinghies is often less than the signal from the surrounding waves (multi path) and the signal processing in the standard navigation systems can not subtract the wanted signal from the non-wanted.

As new technologies move the optimum cost balance between hardware and processing power, new sensor systems may emerge. Based on integrated on-board systems, a new sensor system may be based on multiple fixed sensor elements distributed at the rail of the vessel. This system may include MIMO-techniques in characterizing the surroundings and signal coding for channel isolation. Other coherent processing techniques may by necessary to extract the wanted signals.

Contents
The main goal for the project is to investigate the possibility of using MIMO-techniques in characterizing the surroundings of a distributed electromagnetic sensor system. The initial study may produce a set of system requirements that can be used for a coverage calculation or principal characterizations. A major challenge in the coverage calculation is to include the under sampled array of sensor elements as under sampled arrays has ambiguous detection cells. Another challenge is to include the near field of the sensor element array in the aspect in the system performance. The analysis shall be based on typical and worst case scenarios regarding threats and interfering clutters. Possibly other sensor signals like IR (heat)[2], may be included - as also know from the aeronautical world [3] – though IR is mostly restricted to night time exploitation.
Results
The applicability of the concept shall be evaluated and shortcomings shall be described.

As part of this, the project shall state requirements and expected performance of proposed concept. The requirements may be a function of application or required detectability. The requirements shall/can include:
   1) Concept (and hardware configuration, at least wrt antenna system and link budget)
   2) Technologies necessary for the system
   3) Processing power

Prerequisites
Very good background & level in digital signal processing and stochastic radio propagation, equivalent to courses
2-2 Propagation, Antennas and Diversity
3-14 Special topics in antenna systems
+Good work morale and dedication

References
[3] http://www.engineerlive.com/Hydrographic-\Forward\View/Pirates: holographic_radar &%23039%3Bcould_have_seen_them_c\oming&%23039%3B/21126/, assessed 1/9 2009
7: Interference Scenarios and Spectrum Sensing for Cognitive Radios in the 700 MHz Bands

Supervisors:
Petar Popovski, Antennas, Propagation, and Radio Networking (APNet),
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External supervisor:
Jonathan Duplicy, Agilent Technologies, mail: jonathan_duplicy@agilent.com

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. 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 and drastically increase the efficiency of frequency utilization. Cognitive radio networks are allowed to access to the spectrum that is owned by a legacy system (called primary user) as long as the interference level toward the primary user is below a required level. IEEE has timely recognized the practical aspects and value of the cognitive radio concept and started to develop a cognitive radio standard, IEEE 802.22 [3], which is addressing the radio interface for operation in the frequency bands that are allocated to TV broadcast. In this band, TV system and 802.22 networks are, respectively, the primary and the cognitive users. 802.22 networks try to utilize the white spaces, i.e. resources allocated to the TV system which are underutilized at a given time/space/frequency. The operation of the above cognitive radio technology in the TV bands has attracted a lot of interest among many companies, like Google and Verizon. Hence, an explosive growth of novel wireless systems and applications is expected once the regulatory framework for utilization of the TV bands is at place. Nevertheless, the Federal Communication Commission (FCC) in USA is taking cautious steps towards releasing the TV broadcast bands for cognitive radio usage [4]. This is primarily because there is a large uncertainty about the resulting interference from cognitive toward primary users, as well as among the different cognitive users.

Project description
In the coming period a crucial step in obtaining a workable version of cognitive radio is to assess the above interference created by the cognitive radios and networks. For example, within the next two years, FCC will carry out measurements and assessments in order to learn what are the interference levels and patterns that will be created by the cognitive radio operation allowed under the current regulation. In this context, this projects aims at investigate the communication scenarios and assess the worst-case and average-case interference and performance degradation experienced by the incumbent users when cognitive users are active.
More in detail, the main focus and objective of this project will be:
- To get familiar with IEEE 802.22 and the FCC Second report and order
- To provide taxonomy of the important parameters in the envisioned systems: network/device types, power levels, localization/database requirements, expected density, etc.
- To evaluate the interference by using a combined analytical/simulation approach
- To study the effects of realistic fading models
- To assess the existing spectrum sensing techniques regarding their applicability to the interference scenarios in the 700 MHz band, as well as propose new spectrum sensing techniques
- To define and analyze specific spectrum sensing scenarios for 700 MHz

This student project is within a framework of industrial collaboration with Agilent Technologies, a leading company in designing and supplying measurement equipment for radio communications. The project will leverage on a master project that has been completed in the Spring 2009, with possibility to reuse the simulator developed in that project.

Requirements
Basic knowledge about PHY/MAC protocols for wireless networks and programming skills in MATLAB.

References
[3] IEEE 802 LAN/MAN Standards Committee 802.22 WG on WRANs (Wireless Regional Area Networks), http://www.ieee802.org/22/
8: Practical Retransmission schemes for MIMO Systems

Project duration: 9th and 10th semester (long project)

Main supervisor: Elisabeth de Carvalho (edc xx es.aau.dk), Co-supervisor: Petar Popovski (petarp xx es.aau.dk)

PROJECT DESCRIPTION

In current wireless standards, the data to be sent to a user is organized into blocks. The blocks are sent one after another. At the end of each block, a Cyclic Redundancy Check (CRC) is appended. At the receiver, the CRC is used to check if errors have been made in the detection of each block. If the decoding is erroneous, the data contained in the packet has to be retransmitted. Retransmission can be done in various ways; this topic has been mainly covered for the case where the transmitter and the receiver have a single antenna (SISO system).

In Multiple Input Multiple Output (MIMO) communications, both the transmitter and receiver have several antennas. With MIMO systems, it is possible to send several packets simultaneously, provided that the propagation channel has some good properties. Hence, MIMO systems provide an increased throughput compared to SISO systems, without increasing the transmit power or the system bandwidth. This is the reason why MIMO is considered as a major enabling technology to reach the throughputs targeted for the next generation of wireless systems.

The goal of this project is to design practical retransmission schemes for MIMO systems adapted to current wireless standards such as Wimax or LTE.

Here is an example of retransmission design specific to MIMO system. Let us consider a MIMO system with 2 transmit and 2 receive antennas. A packet X1 is sent from the first antenna and a packet X2 is sent from the second antenna. Retransmission schemes have to be designed for 2 following cases:

- both packets are erroneously decoded and both need to be retransmitted
- only 1 packet out of 2 is decoded erroneously and only 1 packet needs to be retransmitted from one of the antennas while a new packet can be transmitted from the other antenna.

The main difference with the SISO case is that MIMO systems provide with an additional degree of freedom: the antennas. Hence, retransmitted packets can be reallocated to different antennas. For example, if X1 is not correctly decoded, it can be retransmitted from either the first antenna or the second antenna.

project outline:
- Identification of retransmission schemes adapted to current wireless standards (Wimax or LTE).
- study of different practical MIMO modes as used in WImax/LTE
- Simulator for Wimax/LTE communication chain
- Evaluation of the selected methods

Requirements for the students:

The students are expected to be familiar with the following topics:

- Linear algebra
- Communication systems

Through the project the students are expected to build knowledge about:

- MIMO systems
- Automatic Repeat Request (ARQ) scheme
- Estimation theory: zero-forcing, MMSE estimation
- Advanced linear algebra
9: Multi Antenna terminal System investigation; towards the antenna of the future (small, efficient and tuneable)

Supervisors:
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Mauro Pelosi A6-207, mp@es.aau.dk
In corporation with:
Mikael B. Knudsen, Infineon Technologies Denmark A/S. Mikael.Knudsen@infineon.com

The project can be adapted to be a single semester (9) or long project (9+10) depending on the students proposals

Traditionally the HW blocks in a mobile terminal, typical a mobile phone has been designed independent of the other blocks based on a defined interface. The interface between the transmitter + receiver and the antenna has been considered to be one of the simplest to specify, namely just a 50 Ohm interface. During the recent years it has been more and more clear that with today’s small and complex terminals the simple 50 Ohm interface assumption significantly limiting the overall performance and new possibilities such as multi antenna systems. Today most of the transceiver is in one packed made by the chip manufacture and not the mobile phone manufacture and to win the market the chip manufacture need to investigated and implement all possible new features to ensure best overall performance. Therefore new ideas have attracted the largest chip manufacture for mobile phones and we are now proposing a project to research into the new ideas.

Motivation:
The mobile communication industry is more and more facing the demand of high data rate application like e.g. videophone etc. to compete with wired systems. So standards like HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access) are being developed within the UMTS (Universal Mobile Telecommunications System) mobile phone standard. Higher Data rates in general require better signal quality both the terminal and the base station. For a mobile terminal at the edge of a cell the signal quality is limited by thermal noise and the noise figure of the receiver, as well as the channel quality (fading) limiting a reliable data transfer. With half the distance to the base station, the signal quality improves by 6dB. As a matter of fact the area with feasible high data transfer is limited closer to the base station. One possible solution to widen the active area for high data would be to increase the number of base stations to minimize the distance to the terminal. Another solution to expand the range of high data rate is to increase the signal quality at the mobile terminal by using a second receiver chain. This is called diversity receiver. Given a specific network system (GSM, UMTS) and radio environment the gain of using antenna diversity relative to a single antenna is dependent on:

a) Combing algorithm (ex. selection diversity, maximum ratio combining)
b) Outage level
c) Branch power ratio
d) Correlation (CC between 0 and 1)
Where a), b) is related to BB processing and c), d) is related to the combined effect of the radio environment and the antennas. Each antenna in an antenna diversity system need also to be optimized according to the single antenna requirements, because the individual antennas performance sets the reference level for the diversity system performance. Hence, the performance of diversity antennas can be split into single antenna requirement and some additional requirements that are related to the diversity performance as listed below.

**Single antenna requirements:** Efficiency, VSWR, TRP and TIS, SAR, MEG

**Additional antenna diversity requirements:** Correlation, Branch power ratio, Mutual coupling (antenna isolation)

The branch power ratio is a measure of the MEG (mean effective gain) of one antenna relative to the other antenna, where MEG is the mean signal level received from each antenna. The MEG values contain the mutual effect of the radio environment and the radiation patterns of the Antennas. The correlation coefficient is a measure of independency between the signals received from each antenna. The correlation coefficient can vary between zero and one, one meaning that total dependency exist. When two antennas are positioned near each other, and one or both of them are excited, some energy end up at the other antenna. This interchange of energy is called mutual coupling or antenna isolation. The mutual coupling do not contain the effect of the radio environment, but given a specific radio environment and radiation pattern of the antennas there is a direct relation between the correlation and the mutual coupling in such a way that the lower the mutual coupling the lower the correlation. Hence, an antenna design optimized for low mutual coupling is for everything else being equal optimum for the diversity gain. The mutual antenna coupling will also influence the TRP (total radiated power) of a diversity handset. Part of the energy transmitted from one antenna will be absorbed in the second antenna. The amount of TX power absorbed in the second antenna is directly related to the mutual coupling, so a low mutual coupling result in a low absorption of transmitted power in the second antenna [1]. It is, however, very difficult for multiband mobile diversity terminals with a small form factor to obtain a low mutual coupling, especially at low frequencies (f.ex. UMTS at 900MHZ). Moreover, the user interference change the mutual coupling of two antennas dynamically [1], [2], which makes it difficult to have one set of fixed antennas optimum for all user position (freespace, talk, on table, etc.) [3].

**Aim:** This project should investigate the potential of a mutual antenna decoupling system that can adapt itself to changing frequencies and user positions.

**Expected content:** Investigation of the antenna configuration by numerical methods, for example using the FDTD code available at the APNet group. The investigation can also partly be experimental. The investigation should lead to knowledge on typical values of the isolation and ways to arrange the antennas optimally on a future mobile terminal.

**Prerequisites:**
Good theoretical background in communication, antennas and electromagnetics.
Suggest the project to a group of 2 or 3 students.

**References**
Available at: http://kom.aau.dk/~mp/

Supervisors: Boyan Yanakiev (by@es.aau.dk; AAU/Molex), Gert F. Pedersen (gfp@es.aau.dk; AAU) and Morten Christensen (morten.christensen@molex.com; Molex)

Introduction

The growing number of wireless devices, and more importantly their convergence to all in one multimedia devices, poses a serious challenge to the antenna engineer. The ever increasing throughput demand is nowadays met by the implementation of Multiple Input, Multiple Output (MIMO) systems. Typical examples are all of the newest wireless technologies like 802.11n, WiMax, LTE (4G), DVB-SH etc. Classical MIMO theory deals primarily with throughput increase seen from the perspective of information theory. The requirements towards the antennas (the inputs and outputs) are related to low correlation between the links, which leads to the usually quoted requirement of half-wavelength spacing of the antennas. On small, portable devices however, this is enough to make it a huge implementation challenge.

Looking into the current state of the art for SISO systems (eg. GSM), one can conclude that small devices are already pushing the limits of what is possible in terms of efficient antenna design. It has been shown (1), (2), (3), (4), (5), (6), (7) that there is a fundamental limit to the achievable antenna size, performance and bandwidth and a tradeoff must be found between the three. Currently, mobile phone antennas are designed so that the whole phone acts as an antenna (8), (9), especially for the low frequency bands. This to some extend compensates for the otherwise small volume available. The problem is most severe at the low GSM850 and GMS900 frequencies, because of the much larger wavelength. DVB-H suffers most from this, since the specified frequency is down to 470 MHz. The biggest challenge is to balance between customer expectation of a multifunctional and converged device, which is still small, fashionable and trendy. External antennas are not well accepted although they can be made high performing.

Adding additional antennas for the purposes of MIMO systems complicates things even further. A number of additional issues arise: antenna coupling, signal correlation, antenna spacing etc. Simply put since the user expects the same phone that simply does more and faster, while an increase in size, weight and so on is not acceptable. As of today the problem is only easily solved for 802.11n, where the terminals are Laptops or Wireless Access Points and not small portable devices and therefore the size required to meet MIMO theory requirements is available. Mobile phones with WiMax or LTE are still to come.

Problem Description

So far antenna performance has been determined by the Total Radiated Power (TRP) and Total Isotropic Sensitivity (TIS) parameters of a phone, measured in an anechoic chamber. These parameters alone however are inadequate for MIMO systems. Therefore, it has been already decided that the performance of the new 4G systems will be measured through the achieved capacity of the MIMO link. This is however a parameter depending not only on the individual antenna performance (TRP/TIS) but also on the interaction between them (ex. correlation), as well as non antenna related factors such as the radio channel and source coding. This project will focus on investigating the influence of various radio related factors on the achieved capacity including but not limited to the following:
- Antenna spacing within the phone
- Antenna coupling
- Correlation due to coupling
- Correlation due to user influence
- Correlation due to the radio channel
- Antenna efficiency
- Antenna polarization

The main tool used will be the AAU parallel supercomputer and the 3D FDTD simulator running on it. Student will have the opportunity to participate in real measurements in the middle of the semester and compare measurement results with simulation. Cooperation with industry (Molex – Antenna Business Unit, Aalborg) will give further insights on the practical limitations when designing mobile phone antennas that have to go into
products. Furthermore this project will be a part of the AAU/Molex contribution to the Converged Advanced Mobile Media Platform (CAMMP) project funded by Højteknologi Fonden http://www.cammp.aau.dk/

**Prerequisites**

- Wireless communications fundamentals
- Good understanding of statistical channel description
- Basic antenna theory
- Good Matlab (or any other) programming language skills

**Outcome**

The expected outcome of the project is a standard AAU project report as well as a paper publishable at the IEEE student conference at AAU.

**References**


11: Mobile distributed wireless stereo

Proposers: Morten V. Pedersen, Janus Heide and Frank H.P. Fitzek
email:ff@es.aau.dk, office A6-212 and Mobile Devices lab A5-206

Motivation:
This project aims to develop and implement an application that enables several mobile devices to distribute and play multimedia content in a synchronized fashion. In this system one node acts as a source for media, while several other devices act as sinks, the media could be audio or video. One example is that you have a song on a device that you would like to play for a group of your friends, in this case the application would allow to stream the content to each of your friends personal devices this would allow the devices form one large speaker. The key issue is to develop a protocol that can ensure that synchronization is maintained during playback.

The synchronization should be realized by lower protocol layer information.

Content:
- Synchronization requirements and issues in 802.11
- Considerations regarding reliability and real-time.
- Network protocol design, analysis and implementation
- Service discovery implementation
- Optionally: Cooperation and/or coding

The system should be implemented on laptops on Internet tablets (Nokia N810) or smart phones. Implementation should be done in C/C++/Qt or Python.

References