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Department 1 “Mini-Conference”

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Ecole Nationale Supérieure des Télécommunications

46 rue Barrault, Paris

Metro: Corvisart (line 6)

Room: E800

Program

9:45

Introduction

Phil Regalia

10:00

Orthogonal Frequency Division Multiplexing and Multicarrier Communications: An Overview, Issues and Knowledge Gaps

Hanna Bogucka, Poznań University of Technology

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a form of multicarrier transmission, in which a high-rate data stream is transmitted in a parallel manner over a number of low-rate orthogonal subcarriers. Thanks to advances in VLSI technology, high-speed, high-order FFT/IFFT chips which implement OFDM modulation have become commercially viable, thus making OFDM a candidate for many commercial applications. OFDM has been applied in high-speed digital subscriber lines (HDSL, ADSL, VDSL), in digital broadcasting systems (DAB, DVB), as well as wireless LANs (HIPERLAN/2, IEEE 802.11, IEEE 802.16), and is in consideration for other interesting applications, such as wireless ATM networks (Magic-WAND), and future broadband radio area networks. OFDM has many advantages, which are a consequence of low-rate data transmission on distinct subcarriers and the orthogonality of subcarriers. OFDM is robust against multipath fading, intersymbol interference and narrow-band interference. It is spectrally very efficient, does not require any side bandwidth for system operation, and allows for single-frequency network configuration. New promising techniques and technologies are being considered for the application with OFDM, which increases overall OFDM system effectiveness

even more; these include: adaptive modulation and coding, adaptive bit and power loading, adaptive subcarrier allocation, space-time processing, MIMO, smart antennas, multicarrier CDMA, and so on.

The major performance parameter in OFDM is the Peak-to-Average Power Ratio (PAPR) of the transmitted signal. High PAPR results in the clipping noise, caused by limited quantization levels, rounding and truncation, during the (I)FFT computations, and nonlinear distortion of power amplifiers. In addition to degrading the BER performance, clipping causes energy to spill into adjacent channels and induces intermodulation effects on the subcarriers, thereby warping of the signal constellation in each subchannel. PAPR reduction can be obtained by coding, windowing, reference signal subtraction, and more or less complicated signal manipulation, which requires transmission of some overhead information. Multicarrier systems are also inherently more susceptible to frequency offset and phase noise, which unless appropriately compensated, are sources of intercarrier interference. OFDM is already a mature technology, although the exploitation of its benefits and compensation of its drawbacks are still in the research phases of many experts world-wide.

10:30

Advanced Signal Processing Techniques for Wireless Communications

Erdal Panayırçı, ISIK

Abstract: Traditional wireless technologies are confronted with new challenges in meeting the ubiquity and mobility requirements of cellular systems. Hostile channel characteristics and limited bandwidths in wireless applications provide key barriers that future generation systems must cope with. Advanced signal processing methods, such as the expectation-maximization algorithm, the SAGE algorithm, the Baum-Welch algorithm, per-survivor processing, Kalman filters and their extensions, hidden Markov modeling, sequential Monte Carlo filters, stochastic approximation algorithms, and sphere decoding and convex relaxation techniques (semidefinite relaxations) for detection, in collaboration with inexpensive and rapid computing power provide a promising avenue for overcoming the limitations of current technologies. Applications of advanced signal processing algorithms mentioned above include, but are not limited to, joint/blind/sequence detection, decoding, synchronization, equalization as well as channel estimation techniques employed in advanced wireless communication systems such as OFDM/-OFDMA, Space-Time-Frequency Coding, MIMO, CDMA and with Multi User Detection, Time- and Frequency-Selective MIMO Channels. Especially, the development of suitable algorithms for wireless multiple-access systems in non-stationary and interference-rich environments presents major challenges to us. While considerable previous work has addressed many aspects of this problem separately, e.g., single user-channel equalization, interference suppression for multiple access channels and tracking of time varying channels, the problem of jointly combatting these impairments in wireless channels has only recently become significant. On the other hand, the optimal solutions often present a prohibitively high computational complexity, impeding thus their implementation. The statistical tools offered by the advanced signal processing techniques above have provided a promising new route for the design of low complexity signal processing

algorithms with performance approaching the theoretical optimum for fast and reliable communication in the highly severe and dynamic wireless environment.

11:00

Applications of Large Random Matrices to Performance Evaluation of Large Communication Systems

Philippe Loubaton, Université Marne-la-Vallée (CNRS)

Abstract: Signal and receiver design for (MC-) CDMA and MIMO systems requires evaluating as explicitly as possible the influence of various parameters on the performance. For (MC-) CDMA systems, important parameters include the loading factor, the distribution of the extra-cell interference, and the power allocation among users. For MIMO systems, the most critical factor is the channel distribution, in terms of correlations between transmit and/or receive antennas, line of sight components, in addition to frequency and/or time selectivity. Code matrices of multi-carrier CDMA systems are commonly modeled as realizations of certain kinds of random matrices (e.g., independent and identically distributed (i.i.d), Haar distributed, deterministic unitary matrices scrambled by an i.i.d. sequence, and so forth), while channel matrices of flat fading MIMO systems are usually modelled as complex Gaussian. In this context, the most common performance indices, such as Shannon capacity or signal to interference plus noise ratio, depend in a complicated way on the entries of these matrices. It turns out that when the dimensions of the matrices increase at the same rate, then the usual performance indices converge toward deterministic limits depending only on the statistical properties of the matrices, and not on their particular realizations. The evaluation of these limits, based on large random matrix theory, free probability theory and replica analysis, lends considerable insight into the influence of the various relevant parameters on overall performance.

Although some simple situations have been considered in the literature, important work remains to be done to cover more realistic situations such as multi-carrier CDMA and MIMO systems with correlated and/or Rician frequency selective channels, as well as to evaluate and compare the performance of advanced receivers such as multistage and/or iterative receivers. This talk provides an overview of the existing results, as well as some important open problems.

11:30

Wideband Signaling over Fading Multipath Channels

Erdal Arıkan, Bilkent University

Abstract: Médard and Gallager showed that spread-spectrum systems, which spread transmitted signals uniformly over time and frequency, fall far short of achieving the information-theoretic capacity of multi-path fading channels in the regime of extremely large bandwidths. By contrast, peaky signaling schemes, which concentrate the signal power in both time and frequency, can attain channel capacity. Similar results were proved by Tse and Telatar, and Subramanian

and Hajek. What lies behind this phenomenon is that each signaling scheme requires a specific set of channel parameters to be estimated (implicitly or explicitly) for successful detection of transmitted information. The only means of collecting channel state information is through expenditure of part of a user's energy for that purpose (by employing pilot signals or a blind method). Spread-spectrum systems, in particular CDMA, do not scale well when the bandwidth is increased, because they require estimation of such a large number of channel parameters that the task becomes impossible. This casts serious doubts on the usability of CDMA—the design choice for 3G systems—for systems beyond 3G.

Some knowledge gaps and directions for further research in this area appear to be the following. First, it is not entirely clear to what extent the above results will actually constrain the communication systems envisioned for 4G. It is unclear if the channel models used in these studies are representative of future 4G systems. Also, since the results are asymptotic in nature, it is unclear when the wideband regime kicks in. Second, there is need to take a more fundamental look at the notion of “peakiness,” for which several measures may be found in the literature. Some of these measures are not invariant under reversible transformations of the channel model, showing their ad-hoc nature. It is worth searching for a notion of peakiness that is fundamental in nature and hopefully lends itself to proving non-trivial coding theorems. For example, given a signal set, it would be nice to have a coding theorem stated in terms of the empirical cross-correlations of the signals. Third, there is need to develop coherent design methodologies for scalable signal sets, as potential alternatives to W-CDMA. Fourth, there is need to incorporate symbol synchronization into the problem formulation in the study of wideband signaling systems. The extremely peaky signal sets that achieve the capacity of fading channels assume that there is perfect synchronization at the receiver, which is clearly unrealistic. This is especially relevant in future wireless systems in which a growing fraction of traffic is expected to be very short IP acknowledgment packets, which will make synchronization overhead non-negligible. Related to the synchronization issue is the study of the trade-offs in using pilot signals vs. combined channel estimation and detection strategies adapted to peaky signals over wideband multi-path channels.

12:00

Lunch Break

Everyone

14:00

Turbo Codes for Short and Medium Block Lengths: The State of the Art

Claude Berrou, ENST-Bretagne (GET)

14:30

Iterative Multiuser Decoding

Ralf Müller, FTW

Abstract: Separating detection and decoding incurs severe performance losses if the detector's uncoded error probability degrades due to interference. In order to circumvent the prohibitive search complexity in a joint trellis of code laws and interference, multiuser decoding is performed iteratively. In analogy to iterative decoding of low-density parity check codes (LDPCs), the introduction of some irregularity is required to approach high spectral efficiency. For the additive white Gaussian noise (AWGN) channel, the optimization procedure (irregularization) is shown to be a linear program assigning a few different power levels to the user population.

This is joint work with the two NEWCOM researchers Giuseppe Caire (Eurecom) and Wolfgang Gerstacker (UEN), as well as Toshiyuki Tanaka (Tokyo Metropol. Univ., not in NEWCOM).

15:00

Advances in Efficient MMSE-based Turbo Decoding of Space-Time BICM over MIMO Block Fading ISI Channels with Imperfect CSIR

Antoine Berthet, SupElec

Abstract: Most of the studies about space-time coding assume perfect Channel State Information (CSI) at the receiver, even though severe performance is observed with mismatched channel estimates. The channel estimation problem is critical for Multiple-Input Multiple-Output (MIMO) systems, since the number of path gains to estimate increases linearly with the number of transmit antennas. The optimal trade-off between the number of pilot symbols and the system capacity has been investigated by Hochwald and Hassibi assuming classical training-based linear estimation algorithms. By extending this arena, sophisticated nonlinear channel estimation techniques may help to artificially reduce the number of pilot symbols, thus increasing the system capacity, with no performance penalty. Of course, this comes at the price of much higher computational burden at the receiver side.

As an instance of the so-called turbo principle, an attractive, and now widespread, idea consists in processing the different modules, i.e., channel estimation (path gains), channel equalization reducing both InterSymbol Interference (ISI) and MultiAntenna Interference (MAI), and outer decoding (assuming error control coding) separately and iteratively. This cooperative approach, albeit initially motivated by pragmatic interests such as complexity reduction and receiver design flexibility, raises quite complex theoretical issues such as the analysis of the behavior of turbo-processing when three “modules” or more are involved.

Considering the transmission over a MIMO block fading ISI channel with no CSIT and imperfect CSIR, this presentation examines the concept in the extreme: not only are channel estimation, equalization, and decoding functions decoupled, but also ISI equalization and MAI resolution. Derivations are done assuming Space-Time Bit-Interleaved Coded Modulation

(STBICM), which has been found attractive for such environments, but can be easily extended to other modulation-coding schemes. We examine the Minimum Mean Square Error (MMSE) criterion everywhere in the communication chain in order to obtain a complexity polynomial (at most cubic) in all system parameters. Only the outer decoding algorithm sticks to the Maximum A Posteriori (MAP) criterion. Monte-Carlo simulations highlight the remarkable potential of this strategy, provided that a sufficiently powerful outer error-correcting code is used (or equivalently that the system load is not too heavy). The outer MAP decoding helps all MMSE-based processors, i.e., ISI canceller, MAI detector/canceller, and channel estimator, to converge towards their respective MAP counterparts.

15:30

Symbol Estimation with Channel State Information

Emmanuel Boutillon, Université de Bretagne Sud (GET)

Abstract: In many communication problems (MIMO, MC-CDMA), the received signal is given by a linear combination of the data symbols corrupted by additive noise. The discrete received signal at instant k can be written as $Y = H \cdot X + B$, where Y is the received vector, H is a known $N_t \times N_r$ real channel transfer matrix (perfect Channel State Information) with real coefficients $h_{ij} \sim \mathcal{N}(0, 1)$, the symbols are binary ($X \in \{-1, +1\}^N$), and B is an additive white Gaussian noise vector.

From the received vector Y , the Maximum Likelihood (ML) decoder gives

$$\hat{X} = \arg \min_{X \in \{-1, +1\}^N} \|Y - HX\|^2.$$

Unfortunately, for many applications, such as MC-CDMA applications, or non-orthogonal Space Time MIMO codes, the ML decoding algorithm is NP-complete.

In this presentation, after the justification of our model, we present an overview of existing decoding methods for the $Y = H \cdot X + B$ problem. The proposed solutions can be divided into two families: decoding by relaxation (Zero Forcing, MMSE, Parallel Interference Canceller, Serial Interference Canceller) and decoding by evaluation (Sphere Decoding, ML). All these algorithms are compared in terms of complexity, performance and suitability for hardware implementation. Some results related to a new mixed method (relaxation and evaluation) named Hyperplane Intersection Selection (HIS) are also given.

16:00

Closing Remarks

Map:

