Program

P1: Poster Session 1

Chair: Norbert Görtz

Overhead Reduction of NR type II CSI for NR Release 16 1
Rana Ahmed, Filippo Tosato and Marco Maso
In Release 15, NR type II CSI feedback is promising significant performance gain over previous LTE codebooks, more than 30% throughput enhancement in some cases [1]. However, this gain comes at the expense of significant increase in (uplink) UL overhead [2] That is why in Release 16, overhead reduction of existing Type II CSI is studied. In this extended abstract, we present results for overhead reduction of type II CSI using frequency domain compression. We also compare the performance against a simple extension of type II CSI that uses frequency domain interpolation.

Computationally Efficient Limited Feedback for Codebook-Based FD-MIMO Precoding 6
Mariam Mussbah, Stefan Pratschner, Stefan Schwarz and Markus Rupp
Massive multiple input multiple output (MIMO) is one of the key technologies that was introduced in the fifth generation (5G) mobile communication systems for keeping pace with the ever increasing demand for higher data rates. Full-dimension MIMO (FD-MIMO) is a special case of massive MIMO, where the base station is equipped with a uniform planar array. FD-MIMO supports beamforming in the horizontal and vertical domain. Channel state information at the transmitter is crucial for achieving gains through FD-MIMO. Since for frequency division duplex transmission channel reciprocity cannot be exploited, precoding matrix indicator (PMI) feedback is required for codebook based spatial processing. In this paper, we present a computationally efficient limited feedback scheme for calculating the PMI. We exploit the separable structure of the standardized 5G codebook and split the PMI into a horizontal and vertical indicator. The complexity for the PMI calculation is reduced by adapting the reporting interval for the vertical precoder, according to the performance achieved with the calculated PMI. The trade off between performance and computational efficiency is investigated.

Time Shifting - Effective Reporting of Channel State Information in mobile Radio Systems 11
Wolfgang Zirwas
Currently, 3GPP new radio (NR) discusses in the NR Release 16 massive MIMO study item Type II enhancements for more efficient reporting of channel state information. Type II CSI feedback is based on a covariance approach over suitably chosen frequency subbands. Simulations indicate that the achievable performance in typical massive MIMO scenarios is quite high with about 30~percent gain over Type I CSI feedback. At the same time, for more advanced multi transmission point (TRP) scenarios with higher number of channel components, further improvements will be needed. Especially, free cell concepts - potentially including joint transmission precoding over multiple sites - will require more accurate transmit-sided channel knowledge as well as channel prediction as main enablers. Compressed sensing is known to allow for effective reporting of channel state information. Here, we propose as alternative to the conventional OMP algorithm a so called time shifting approach, which has benefits with respect to the complexity as well as the overall feedback overhead, as it can be applied to the discrete time sampled channel impulse response without oversampling.

Energy Efficiency Analysis of Scheduling in M2M Communication Over Rayleigh Fading Channels 19
Moses Torkudzor, Stefan Schwarz, Martin Klaus Müller, Markus Rupp and Jamal-deen Abdulai
Machine-to-Machine (M2M) Communication technology, which enables remote human and machine interaction with physical, chemical and biological systems, is envisaged to generate significant revenues for network operators in mobile communication systems. M2M communication has a wide range of applications such as intelligent transportation systems, health care, smart metering and public safety. Often the employed devices are battery limited. Scheduling of M2M traffic is a challenging task, due to varying QoS characteristics, energy consumption constraints and the massive number of M2M devices. In this paper, we present an energy efficiency analysis of round robin, max throughput and proportional fair scheduling algorithms in the uplink of gateway-assisted M2M communications. Results indicate that the max throughput algorithm is the most energy efficient followed by the proportional fair algorithm and the round robin algorithm.

Power Allocation for NOMA with CSI Uncertainties and Imperfect Successive Interference Cancellation 25
Yasser Naguib
Non-orthogonal multiple access (NOMA) employing multiple-input single-output (MISO) is considered as one of the disruptive technologies introduced in the 5G systems to offer higher data rate. The performance of such

techniques is heavily dependent on the availability of channel state information (CSI). Perfect CSI assumed in the current NOMA literature is difficult to realize, thus only high resolution CSI can be obtained at the base station (BS). In this paper we give a closed form optimal power allocation scheme that considers erroneous CSI with imperfect successive interference cancellation (SIC). Numerical results validate the derived expressions, showing that the proposed method outperforms conventional power allocation schemes that do not take into account the practical constraints of MISONOMA.

A Fair Comparison Between Spatial Modulation and Antenna Selection in Massive MIMO Systems 30

Bernhard Gäde, Ali Bereyhi, Saba Asaad and Ralf R. Müller

Both antenna selection and spatial modulation allow for low-complexity MIMO transmitters, when the number of RF chains is much lower than the number of transmit antennas. In this extended abstract, we present a quantitative performance comparison between these two approaches by taking into account implementational restrictions, such as antenna switching. We consider a band-limited MIMO system, for which the pulse shape is designed, such that the outband emission satisfies a desired spectral mask. The bit error rate is determined for this system, considering antenna selection and spatial modulation. The results depict that for any array size at the transmit and receive side, antenna selection outperforms spatial modulation, as long as the power efficiency is smaller than a certain threshold level. By passing this threshold, spatial modulation starts to perform superior. Our investigations show that the threshold takes smaller values, as the number of receive antennas grows large. This indicates that spatial modulation is an effective technique for uplink transmission in massive MIMO systems.

Coordinated Jamming: A Privacy Preserving Method for C-RAN with Untrusted Radios 36

Omid Taghizadeh, Tianyu Yang and Rudolf Mathar

In this work, we study the uplink (UL) of a cloud radio access network (C-RAN), under the consideration of information privacy. In particular, we consider a system where the UL communication takes place with the presence of idle users (IUs), which act as the undesired information receivers. Moreover, the central processing unit (CU) utilizes remote radio units (RU)s belonging to the same operator, i.e., the trusted RUs, as well as the RUs belonging to other operators or private owners, i.e., the untrusted RUs. In order to preserve information privacy, we propose a coordinated jamming strategy, where the trusted RUs are enabled with full-duplex (FD) capability and transmit a coordinated jamming signal towards the exotic RUs and the IUs, while receiving and forwarding UL signal to the CU. An optimization problem is then formulated to maximize the sum uplink private information rate by jointly designing the fronthaul compression, as well as the information and jamming transmission strategies. Due to the intractability of the resulting mathematical problem, an iterative solution is proposed with convergence to a point satisfying the Karush-Kuhn-Tucker (KKT) optimality conditions. Numerical simulations illustrate a notable gain obtained via the proposed sharing mechanism under the consideration of information privacy.

S1: Detection and Receivers

Chair: Andrea M Tonello

Constrained Tensor Decompositions for Semi-blind MIMO Detection 42

Liana Khamidullina, Yao Cheng and Martin Haardt

In this paper we introduce a complex valued PARAFAC2 tensor decomposition to perform a semi-blind data detection and channel estimation in MIMO communication systems. We represent the received data in the form of a three-way tensor, with receive antennas on the first mode, data symbols in each packet on the second, and packets on the third mode. Factorizing the resulting received data tensor via the proposed complex valued PARAFAC2 decomposition enables a simultaneous estimation of the channel and transmitted data. Moreover, the use of a few training symbols allows to solve the permutation and scaling ambiguities.

Efficient Initialization of Iterative Linear Massive MIMO Uplink Detectors by Binary Jacobi Synthesis 48

Pascal Seidel, Daniel Gregorek, Steffen Paul and Jochen Rust

In this paper, we propose a decentralized feedforward initialization approach for iterative equalization methods, that decomposes a massive MIMO system into multiple smaller subsystems, where successively combining pairs of these systems and their solutions using the Jacobi method results in a high quality initial estimate for a following iterative detection method. In contrast to existing methods, this approach allows a computation of an initial estimate while the Gram matrix and matched filter output vector is not fully available. The BER performances show the effectiveness of this initialization method compared to approaches like maximum-ratio combining at high basestation-to-client antenna ratios.

Approximate Message Passing for Joint Activity Detection and Decoding in Non-orthogonal CDMA 53
Stefan Birgmeier and Norbert Görtz
In Compressive Sensing, the knowledge of an unknown vector's statistical properties together with a small number of linear measurements makes it possible to reconstruct the vector with high accuracy in terms of minimum mean-squared error. A popular statistical property is sparsity of the unknown vector. The model can thus be applied to multi-user systems, where only a small number of users is active at a given time. In this paper, we show how the properties of the users' channel code and approximate knowledge of the fraction of active users can be used to simultaneously detect user activity and the transmitted codeword, when the users' code-symbols are transmitted by non-orthogonal spreading sequences. The main goal is to provide a unified framework (based on compressed-sensing techniques) in which to describe and solve the joint detection-and-decoding problem by a single computationally highly efficient algorithm.

Closed-form performance analysis of linear MIMO receivers in general fading scenarios 58
Giuseppa Alfano, Mario Kieburg, Gernot Akemann and Giuseppe Caire
Linear precoding and post-processing schemes are ubiquitous in wireless multi-input-multi-output (MIMO) settings, due to their reduced complexity with respect to optimal strategies. Despite their diffusion, performance analysis of linear MIMO receivers is mostly not available in closed form, apart for the canonical (uncorrelated Rayleigh fading) case, while for more general fading conditions only bounds thereof are provided. This lack of results is motivated by the complex dependence of the output signal-to-interference and noise ratio (SINR) at each branch of the receiving filter on both the squared singular values as well as the (typically right) singular vectors of the channel matrix. While the explicit knowledge of the statistics of the SINR can be circumvented for some fading types in the analysis of the Linear Minimum Mean-Squared Error (LMMSE) receiver, this does not apply to the less complex and widely adopted Zero-Forcing (ZF) scheme. This work provides the first-to-date closed-form expression of the probability density function (pdf) of the output ZF and MMSE SINR, for a wide range of fading laws, encompassing, among others, channel models typical of the last two generations of mobile wireless systems.

S2: Localization and Direction Estimation

Chair: Martin Haardt

Cooperative Localization by Set-theoretic Estimation 65
Jochen Fink, Daniel Schäufele, Martin Kasparick, Renato L. G. Cavalcante and Slawomir Stanczak
Among the vast variety of sensor localization techniques, set-theoretic estimation methods are especially appealing for large-scale networks with low-cost devices. Firstly, these methods usually exhibit comparatively low complexity. Secondly, the design of both centralized and distributed fixed-point algorithms for set-theoretic estimation problems is usually straightforward. Existing set-theoretic algorithms for range-based localization usually relax the spheric constraint sets to convex balls, which may lead to poor localization performance even if the range measurements are exact. In this paper, we formulate the spheric cooperative localization problem as a convex feasibility problem in a product Hilbert space. In this way, it is accessible by the multiplicity of existing solution strategies for such problems. In particular, we propose a cooperative localization technique that exploits the bounded perturbation resilience of a fixed-point algorithm for the spheric convex feasibility problem. We make use of a semidefinite programming formulation of the problem to define perturbations that steer the iterates of this algorithm towards a solution to the semidefinite program. Moreover, we show that the localization accuracy can be improved with low effort by heterogeneous sensor measurements.

DoA Estimation in Multipath Channels for Packet Transmission Communication Systems 73
Daniele Inserra, Andrea M Tonello and Wen Guangjun
This manuscript deals with the problem of direction of arrival (DoA) in multipath wireless channels with a line-of-sight (LOS) component. A cyclic prefixing (CP) orthogonal frequency division multiplexing (OFDM) transmission technique is herein considered to show how the proposed methodology can be easily integrated into a data transmission system. The method basically consists of three steps: a frame synchronization and a channel estimation (which are shared with the data processing path), and finally the DoA estimation. The proposed procedure is general and does not rely on a particular synchronization mechanism or a specific channel estimation algorithm. A comparison between the use of two different DoA estimation methodologies (a low complexity DoA estimator applied to the first arrival path and a super-resolution algorithm using smooth-MUSIC) is described in this work to serve as a guideline for the appropriate method selection according to the specific application requirements.

Multi-Node RSS-based Localization with the Aid of Compressed Sensing: An l1-localization Approach 79
Ehsan Zandi and Rudolf Mathar
In this work try we try to estimate the positions of multiple co-channel wireless nodes along with the unknown transmit power of them. The propagation channel is assumed to be log-normal shadowing model. We propose

an unbiased estimator. The underlying complicated optimization problem has a combinatorial nature that selects the best grid points as the location of the targets. We then convert the combinatorial problem to a convex form by means of ` 1 -minimization, or precisely a technique which is inspired by the theory of compressed sensing (CS). The performance of the estimator is justified to be good using simulations.

LTE Uplink TOA Opportunistic Measurement Based on DM-RS 87

Alessandro Pin, Roberto Rinaldo, Andrea M Tonello, Chris Marshall, Alessandro Biason and Marco Driusso
This paper studies the possibility of performing radio localization by measuring the time-difference-of-arrival (UTDOA) using the uplink demodulation reference signal (DM-RS) in 4G Long Term Evolution (LTE) cellular networks. The main problem of the Global Navigation Satellite System (GNSS) is the poor performance in indoor and urban canyon environments, which suffer from high signal attenuation and severe multipath propagation. With the increase of services based on the accurate location of the user, new techniques that cooperate with GNSS are necessary. The current release of the 3rd Generation Partnership Project (3GPP) LTE specification supports a UTDOA localization technique based on the Sounding Reference Signal (SRS). A Local Measurement Unit (LMU) uses knowledge of the SRS to perform the time difference measure. In this paper, an UTDOA technique that uses the DM-RS is proposed. We point out the advantages of our proposal and evaluate its feasibility by means of simulations.

S3: Modeling and Experimentation

Chair: Luis Castedo

Conducted Beamforming Testing in the Millimeter Wave Spectrum 93

Joachim Wehinger, Andre Janßen, Guillaume Monghal and Svante Widell
The advent of millimeter wave (mmW) communications in standards like 3GPP-New Radio (NR) and IEEE802.11ad mandates the use of analog beam-forming mechanisms to overcome the path-loss challenge introduced at carrier-frequencies higher than 8 GHz. Since the expression of the beam-pattern becomes an essential part of the overall wireless channel it must be included during end-to-end system performance testing. However, the antenna arrays required to perform active beamforming at mmW can require many elements and a tight integration with RF components. This renders the testing of performance at mmW with active beamforming using a traditional RF fader essentially impossible. As a result, the only vehicle to test an end-to-end mmW system with active beamforming is an over-the-air (OTA) chamber including both transmitter and receiver. This, however, comes with two issues. First of all, only very simple wireless channels can be tested in a single OTA chamber, while literature shows that mmW channel can have non-trivial fading characteristics w.r.t. delay-spread and directivity as demonstrated in e.g. [1]-[3]. Secondly, due to the necessity to test mmW systems in far-field distance OTA chamber may be very large and costly to scale. In the present paper we describe a novel approach that we call "New Fader". The presented methodology allows to shift large parts of OTA-based-testing to a conducted testing where algorithmic and performance behavior can be analyzed more efficiently. The resulting setup allows for end-to-end mmW performance testing of 5G-NR or WiGig in a conducted fashion as it was done in cellular phone systems like GSM, UMTS, and LTE. The heart of the proposed arrangement is the "New Fader". It absorbs the functionality of the 3D spatial propagation channel, the beamforming on gNodeB (gNB)- as well as User-Equipment (UE)-side, and the movement models.

Hybrid Ray Tracing Method for Millimeter Wave Propagation Simulation in Large Indoor Scenarios 99

Han Niu, Diego Dupleich, Robert Müller, Sergii Skoblikov, Christian Schneider, Giovanni Del Galdo and Reiner S. Thomä
In this paper, a novel three dimensional (3D) hybrid ray tracing (HRT) method for wave propagation simulation in large indoor and urban micro cell environment is proposed. HRT combines two ray tracing (RT) methods: 'standard' ray tracing (i.e. image ray tracing) simulating rays encountered three basic propagation mechanisms (i.e., reflection, transmission, and diffraction) and 'intelligent' ray tracing (i.e., effective roughness model) estimating rays related to diffuse scattering. To establish the accuracy of HRT, HRT simulation results were compared with millimeter wave (mmWave) wide-band measurements in a large indoor scenario for different positions in different visibility conditions. It shows that good predictions can be obtained by HRT in many aspects, such as received power and path loss model parameters, temporal characteristics and dispersion, spatial consistency, etc. Meanwhile, some differences can be observed and be further analyzed as well.

Experimental Evaluation of the Influence of Fast Movement on Virtual Antenna Arrays 105

Daniel Schützenhöfer, Erich Zöchmann, Martin Lerch, Stefan Pratschner, Herbert Groll, Sebastian Caban and Markus Rupp
Virtual antenna arrays are employed on the roof of high-speed trains to sound the channel between a train and a fixed base station. Because high-speed trains are moving fast during such a measurement, high Doppler shifts

are experienced. In this paper, we evaluate the influence of fast movement on measurements with virtual antenna arrays if algorithms for static scenarios are employed. We have built a laboratory setup to test common algorithms such as the Bartlett beamformer. Our laboratory setup allows to compare the performance of algorithms at standstill to the performance of the same algorithms at different velocities. We show that the estimated power angular spectrum changes up to 20 dB in magnitude if we apply the same algorithm as in the static scenario. The Doppler effect also causes an angular shift. We experience that the difference in circular variance is 7.4 %. The measurement results show that DOA estimation algorithms that do not consider Doppler are not consistent anymore at fast movement.

Properties of Measured Massive MIMO Channels using Different Antenna Geometries 110
Maximilian Arnold and Stephan ten Brink
With a significant increase in data throughput, massive MIMO has become an enabling technology for fifth generation (5G) wireless mobile communication systems. Evaluating achievable throughputs in massive MIMO propagation environments using actual channel measurements is an important task. In this paper we characterize three measurement scenarios over four key channel parameters in typical urban environments. We show that different antenna geometries result in different dominating channel properties due to angular resolution and diversity, leading to antenna geometries favoring particular scenarios. A good compromise in antenna geometry is the unconventional ``L"-structure for separating channels even in near proximity of the basestation. It is shown that the performance for a practical system in a Rician fading environment can be better approximated with the average K factor and channel order rather than the commonly assumed i.i.d. Gaussian channel model. Moreover, we show that the ``L"-array structure increases spectral efficiency and user throughput in the measurement scenarios studied.

P2: Poster Session 2

Chair: Christoph F Mecklenbräuker

Investigation of Wraparound Techniques for the Simulation of Wireless Cellular Networks 115
Agnes Fastenbauer, Martin Klaus Müller and Markus Rupp
A common approach to obtain analytical results for the performance of wireless cellular networks relies on assuming an infinite amount of interferers. For simulations with finite dimensions, interference is often inadequately represented for users in the border region. These border effects can be circumvented by a wraparound that allows signals that leave the region of interest on one side to reappear on the opposite side, thus mirroring the missing interferers beyond the scenario boundary. In this paper, we determine a minimal network size for which the simulation with wraparound strategy approximates the infinitely stretched out network. We compare this strategy to the interference region strategy, for which dummy interferers are placed outside of the simulated network. The effects of the chosen network size and path loss exponent on the accuracy of the two strategies are discussed.

Random Graph Modeling of Foliage Influence on Millimeter-wave Propagation Channels..... 121
Lin Yang, Xuefeng Yin, José Rodríguez-Piñeiro, Nanxin Wang and YU Ziming
In this paper, we propose a novel graph modeling method for analyzing the impact of foliage on propagation channels by utilizing spherically distributed scatters to characterize trees influence. Traditional graph modelling always uses rectangular or squared surfaces to simulate the real world objects, hence it fails to reflect foliage scattering structures accurately. By introducing the sphere, the original shape of environmental elements can be better modeled, resulting in a better explanation of the foliage influence on millimeter-waves(mm-waves) propagation. By comparing simulation results with measurements, we appreciated slight mismatches. With the aim of minimizing the mismatches found in our first approach, the proposed graph model is improved by using multilayer nested spheres, and the results obtained are more consistent with the measurement ones. The evaluation of the proposed method is conducted by comparing the simulated foliage loss characteristics and the real-environment measured data in directional domain.

How Wireless Dumb Devices Could Attain High Data Rates Thanks to Smart Massive MIMO Networks..... 126
Dinh-Thuy Phan-Huy, Stefan Wesemann and Philippe Sehier
For the first time, we have presented and evaluated a communication system between a dumb device and a smart massive multiple input multiple output (M-MIMO) antenna at the network side. The dumb device simply transmits and receives a single carrier waveform. A simple single tap receiver is used. No channel coding is used. On the network side, a transmit space-time matched filter is used to deliver the data to the device through a nearly single tap channel and a receive space-time matched filter is used to receive the data. A performance evaluation study based on indoor and outdoor M- MIMO channel measurements show that antenna arrays of 64 antenna elements are smart enough to deliver at least 18 Mbits/s and up to 72 Mbits/s, with a BER lower

than 10-4, to dumb devices in both uplink and downlink directions. Future works will focus on the challenges in implementation of such devices and antennas.

The OpenAirInterface 5G New Radio Implementation: Current Status and Roadmap 134
Florian Kaltenberger, Guy De Souza, Raymond Knopp and Hongzhi Wang
OpenAirInterface (OAI) is an open-source project that implements 3GPP technology on general purpose x86 computing hardware and off-the-shelf software defined radio cards like the USRP. At its base OAI implements 4G LTE, but recently we have also started implementing 5G New Radio (NR). In this paper we describe the OAI 5G NR project, the current state of its development, and the roadmap for the future. 5G NR is much more demanding on both processing power, latency, and radio capabilities compared to 4G LTE. At the time of writing, we implemented all the necessary functions to support basic downlink functionality at both gNB and UE showing the feasibility to run 5G NR in real-time on a software defined radio platform. The roadmap is to have a fully standard compliant implementation of 5G NR that is inter-operable with commercial equipment by the end of 2019.

On Delay Diversity in OQAM/FBMC Based Transmission Schemes 139
Wenfeng Liu, Stefan Schwarz, Da Chen, Markus Rupp and Tao Jiang
Offset quadrature amplitude modulation based filter bank multicarrier (OQAM/FBMC) is a spectrally efficient alternative to the conventional orthogonal frequency division multiplexing (OFDM) due to its feature of time-frequency localization. However, in presence of the intrinsic interference, it is not as straightforward as OFDM for OQAM/FBMC to benefit from the gains of incorporating multiple-input multiple-output processing, especially for the spatial diversity technique. In this paper, we propose a low-complexity delay diversity (DD) scheme for OQAM/FBMC system, which is formed by transmitting delayed versions of the same signal on multiple transmit antennas. The associated channel estimation and equalization are also developed for the OQAM/FBMC system with DD. Simulation results verify the effectiveness of the proposed channel estimation method and demonstrate that the proposed DD scheme obtains significant improvement in bit error rate performance.

Parallel Data Reduction Method for an Industrial Massive MIMO Detector using "Tall Skinny QR" Decomposition. 144
Daniel Gregorek, Pascal Seidel, Jochen Rust and Steffen Paul
We propose a "Tall Skinny QR" approach for massive MIMO to enable data reduction while baseband data is forwarded through a QRD tree. A 1.46 speedup for the uplink baseband processing of a 128x8 MIMO system is achieved. This improves the applicability and scalability for actual hardware implementations, especially for an industrial context when requiring very low-latency and jitter.

Assessment and comparison of multicarrier waveforms under nonlinear conditions 148
Kiril Kirev and Stefan Schwarz
Power Amplifiers (PAs) are inherently nonlinear devices for which power efficiency and amplifier linearity are a trade-off recourse. On one hand, poor power efficiency reduces the battery life of a mobile device, or is accompanied by a significant financial burden in the case of a base station. On the other hand, driving the amplifier above the linear regime to increase power efficiency distorts the amplified signal in a nonlinear fashion. This distortion not only deteriorates the transmission quality, but also introduces interference in adjacent frequency channels. Multicarrier systems, in which the signal bandwidth is shared among multiple pulses are particularly vulnerable to Out-Of-Bound (OOB) interference. Robustness against such interferences caused by nonlinear amplification is to be considered when choosing the right modulation scheme. In this paper, the following modulation waveforms are compared: OFDM, FOFDM, WOLA, UFMC, FBMC-OQAM and block-spread FBMC OQAM, and their sensitivity towards nonlinear distortions is assessed. For this purpose, the Vienna 5G Link Level Simulator is used, which allows for a fair comparison of the waveforms on a unified platform.

S4: Channel Estimation

Chair: Roman Marsalek

Oversampling based Channel Estimation for 1-bit Large-Scale Multiple-antenna Systems 153
Zhichao Shao, Lukas T N Landau and Rodrigo C. de Lamare
In this paper, we propose an oversampling based low-resolution aware least squares channel estimator for large-scale multiple-antenna systems with 1-bit analog-to-digital converters on each receive antenna. To mitigate the information loss caused by the coarse quantization, oversampling is applied at the receiver, where the sampling rate is faster than the Nyquist rate. We also characterize analytical performances, in terms of the deterministic Cram´er-Rao bounds, on estimating the channel parameters. Based on the correlation of the filtered noise, both the Fisher information for white noise and a lower bound of Fisher information for colored noise

are provided. Numerical results are provided to illustrate the mean square error performances of the proposed channel estimator and the corresponding Cram´er-Rao bound as a function of the signal-to-noise ratio.

Maximum Likelihood Channel Estimation for Millimeter-Wave MIMO Systems with Hybrid Beamforming 158
Fazal-E- Asim, Josef A. Nossek, Felix Antreich, Charles Casimiro Cavalcante and André de Almeida
In a millimeter-wave massive multiple-input-multiple-output system, the accurate estimation of the angle of departure is crucial to benefit from a high array gain. In this paper, a novel algorithm is proposed for maximum likelihood estimation angle of departure estimation. The proposed approach is based on discrete Fourier transform beamforming vectors to estimate the angle of departure. The discrete Fourier transform matrix can efficiently be implemented in the analog domain by a so-called Butler matrix.

Evaluation of Neural-Network-Based Channel Estimators Using Measurement Data 164
Christoph Hellings, Aymen Dehmani, Stefan Wesemann, Michael Koller and Wolfgang Utschick
In multiantenna communication systems, side knowledge about the structure of the possible channel realizations can be exploited to improve the accuracy of the channel estimates and to reduce the computational complexity of the channel estimation procedure. To this end, it has been proposed to train a neural network based on channel realizations from the considered scenario such that the resulting estimator is specialized in the estimation of channel realizations that might occur in this particular scenario. While existing work has evaluated the performance of this approach only based on artificially generated channel realizations from a 3GPP channel model, we train and test the neural-network-based channel estimator with realistic channel realizations from a measurement campaign. The results indicate that the good performance observed in the model-based simulations carries over to more realistic experiments with measured data.

Low-Complexity Millimeter Wave CSI Estimation in MIMO-OFDM Hybrid Beamforming Systems 169
Khaled Ardah, André de Almeida and Martin Haardt
Channel state information (CSI) estimation in hybrid analog-digital (HAD) millimeter-wave (mmWave) massive MIMO systems is a challenging problem due to the high channel dimension and reduced number of radio-frequency chains. The problem becomes even harder when we consider wideband channels with higher frequency selectivity than the narrowband channels. Fortunately, by exploiting the sparse scattering nature of the mmWave channels and by adopting a simple setup at the transmitter, it was shown that the received signal can be organized into a third-order tensor that admits a Canonical Polyadic decomposition. Therefore, the channel parameters can be simply recovered once the decomposed factor matrices are estimated, e.g., using an alternating least square (ALS) method. However, ALS has a high computational complexity and a slow convergence rate. To resolve this issue, we propose a low-complexity algorithm to recover the channel parameters without need to estimate the decomposed factor matrices by utilizing a compressed sensing technique and tensor algebra. Simulation results are provided to evaluate the effectiveness of the proposed algorithm.

S5: Hybrid and Massive MIMO

Chair: Wolfgang Utschick

Investigation of Hybrid-MIMO Configurations for Office Docking in the 60 GHz Band..... 174
Felix Fellhauer, Stephan ten Brink and Nabil Loghin
This work focuses on comparison of physical layer performance for 60GHz wireless local area network (WLAN) systems, when advancing from single-input single-output (SISO) systems to multiple-input multiple-output (MIMO). Simulation results of 60GHz indoor hybrid-MIMO (H-MIMO) channels for the specific application of office docking are presented. Three different transceiver configurations are investigated: A SISO configuration consisting of a single analog precoder, antenna array and radio frequency (RF) chain; second, a H-MIMO configuration with two RF chains, each feeding an analog precoder and a single antenna array; and third, a configuration with two spatially separated antenna arrays each connected to a dedicated analog precoder and RF chain. Simulations are conducted based on the IEEE 802.11ay (11ay) channel model featuring a ray-tracing based quasi deterministic (QD) approach. For analog precoding and combining, a codebook based low complexity algorithm is used that is well aligned to the two stage beamforming scheme defined in 11ay. All configurations are compared with respect to achievable mutual information and scenario specific parameters like device position and orientation. Results show that H-MIMO increases the mean rates by up to ~62.9 % with spatial separation when compared to the SISO case.

Practical Hybrid Beamforming Schemes in Massive MIMO 5G NR Systems 179
Xiaoguang Zhao, Elena Lukashova, Florian Kaltenberger and Sebastian Wagner
Massive MIMO systems in mmWave band rely on beamforming techniques to focus transmit energy in a specific direction. Hybrid beamforming, which typically includes analog wideband and digital subband components, is designed as a compromise between affordable but low precision fully analog schemes and energy-

consuming, expensive fully digital approaches. In this paper, we apply a practical approach to hybrid beamforming for Single User 5G Massive MIMO Systems. In the 5G NR simulator, we implement and experimentally validate dual-stage hybrid beamforming approaches based on Singular Value Decomposition of the channel matrix and Zero-Forcing, while fully digital scheme is taken as a baseline. We quantify gain offered by partially and fully connected structures, various number of RF chains and transmit antennas, in terms of throughput and Block Error Rate. Varying the number of phase shifters, we investigate the performance-complexity trade-off for resolution of the phase shifters. To adequately reflect propagation environment, the simulations were run with CDL-A channel model with angle scaling.

Beam Allocation based on Spatial Compatibility for Hybrid Beamforming C-RAN Networks 187
László Costa, Yuri C. B. Silva, Francisco Rafael Marques Lima and Anja Klein
In this extended abstract, we consider the problem of beam allocation in hybrid beamforming (HBF) cloud radio access networks (C-RANs). The problem is formulated for the joint precoding scenario, assuming a codebook-based analog beamforming at the remote radio heads (RRHs) and digital beamforming at the baseband unit (BBU). Differently from previous works, we assume that a given user equipment (UE) can be served by multiple beams, without being specifically associated to a given RRH, and propose a low-complexity correlation-based beam allocation algorithm, which is shown to provide a reasonable performance/complexity trade-off. For the final version of this paper, further simulation results will be presented and another algorithm will be proposed, which takes into account the impact of both channel gain and correlation.

TDD and FDD Massive MIMO: Channel Coherence and Operation Region..... 193
Xiaojie Wang, Maximilian Arnold and Stephan ten Brink
We analyze the achievable rates of time division duplex (TDD) and frequency division duplex (FDD) operations in massive MIMO systems depending on the coherence time and bandwidth of the underlying channel. In particular, an interlaced FDD (IFDD) scheme is considered due to its simplicity and low pilot overhead. We establish the operational region of TDD and IFDD schemes for channels with different properties in the time and frequency domain. We prove that IFDD performs well when the channel has large coherence bandwidth while TDD performs better if the channel has large coherence time. Furthermore, we evaluate the performance of TDD and IFDD systems for time-varying and frequency-selective channels via numerical simulations, showing that IFDD is an attractive alternative in high speed scenarios.

S6: Coding and Multicarrier Modulation

Chair: Robert F.H. Fischer

Binary Multilevel Coding over Eisenstein Integers for MIMO Broadcast Transmission 198
Sebastian Stern, Daniel Rohweder, Juergen Freudenberger and Robert F.H. Fischer
It is well known that signal constellations which are based on a hexagonal grid, so-called Eisenstein constellations, exhibit a performance gain over conventional QAM ones. This benefit is realized by a packing and shaping gain of the Eisenstein (hexagonal) integers in comparison to the Gaussian (complex) integers. Such constellations are especially relevant in transmission schemes that utilize lattice structures, e.g., in MIMO communications. However, for coded modulation, the straightforward approach is to combine Eisenstein constellations with ternary channel codes. In this paper, a multilevel-coding approach is proposed where encoding and multistage decoding can directly be performed with state-of-the-art binary channel codes. An associated mapping and a binary set partitioning are derived. The performance of the proposed approach is contrasted to classical multilevel coding over QAM constellations. To this end, both the single-user AWGN scenario and the (multiuser) MIMO broadcast scenario using lattice-reduction-aided preequalization are considered. Results obtained from numerical simulations with LDPC codes complement the theoretical aspects.

Location-guided Precoded OFDM for Asynchronous Uplink Access 206
Saeed Afrasiabi-Gorgani and Gerhard Wunder
The reduction of signaling overhead in order to increase the efficiency, for instance in massive Machine Type Communications (mMTC), does not allow a closed-loop coordination of the transmission timing between the base station and the user equipments in uplink direction. Consequently, considerable multi-user interference occurs due to the asynchronicity in the uplink transmission, which is desired to be handled at the waveform level. In addition, the recent developments in 5G demand transparency of user's transmitted waveform to the CP-OFDM receiver. Following this constraint, a waveform design is proposed that can inherently maintain nearly equal signal quality for all users regardless of their location. In an LTE-conformable setting, a considerably small variance in Signal to Interference plus Noise (SINR) of randomly located users is shown at the price of having a lower peak SINR.

On PAPR in Single-Carrier Massive MIMO Systems 212
Hela Jedda and Josef A. Nossek
This work analyzes the Peak-to-Average-Power Ratio (PAPR) of single-carrier modulation in massive Multi-User (MU) Multiple-Input Multiple-Output (MIMO) systems while using the Root-Raised Cosine (RRC) filter for pulse shaping. Simulation results show that the PAPR at the transmit antennas increases with the number of transmit antennas and the number of served users. An RRC pulse shaper with roll-off factor around 0.4 is optimal in terms of minimal PAPR.

Energy Efficient Full Duplex Massive MIMO Multi-carrier Bidirectional Communication with Hardware Impairments 217
Vimal Radhakrishnan, Omid Taghizadeh and Rudolf Mathar
In this paper, we address the power allocation problem for a bi-directional communication system, where a full duplex (FD) massive multiple-input-multiple-output (mMIMO) multi-carrier (MC) node communicates with multiple FD MC single antenna nodes. We consider orthogonal frequency division multiplexing (OFDM) as our MC strategy. The impact of hardware distortions resulting in residual self-interference and inter-carrier leakage, and also imperfect channel state information (CSI) are jointly taken into account. We formulate a joint sub-carrier and power allocation problem to maximize the spectral efficiency (sum rate maximization) and an iterative optimization method is proposed, which follows successive inner approximation (SIA) framework to reach the convergence point that satisfies the Karush-Kuhn-Tucker (KKT) conditions. Then, we extend it to an energy efficiency (EE) maximization problem which is solved using a two stage iterative algorithm which follows the SIA and Dinkelbach algorithm. Numerical results show the significance of distortion aware design for such systems and also the significant gain in terms of sum rate and energy efficiency compared to its half duplex (HD) counterpart.

P3: Poster Session 3

Chair: Markus Rupp

Multi-Step Knowledge-Aided Iterative MUSIC for Direction Finding using Nested Arrays 225
Silvio Bernardes, Pinto and Rodrigo C. de Lamare
In this work, we propose a subspace-based algorithm for direction-of-arrival (DOA) estimation using nested sensor arrays, referred to as multi-step knowledge-aided iterative nested MUSIC method (MS-KAI-MUSIC). Differently from existing knowledge-aided methods applied to uniform linear arrays (ULAs), which make use of available known DOAs to improve the estimation of the covariance matrix of the input data, the proposed MS-KAI-MUSIC employs knowledge of the structure of the augmented sample covariance matrix, which is also obtained by exploiting a difference co-array structure, and the gradual incorporation of prior knowledge, which is obtained on line. Simulations show that MS-KAI-MUSIC significantly outperforms existing techniques.

Wideband Triple-Mode Patch Antenna Array for Millimeter-Wave Applications 230
Jia-Tian Weng, Qing-Xin Chu, Yi-Ting Chen and Rui Wu
A wideband antenna fed by substrate integrated waveguide (SIW) is presented, after introducing two pairs of metallic vias inside the SIW and placing two rectangular resonators beside the conventional patch antenna, three resonated modes can be achieved. By moving these two higher frequency modes close to the resonated mode of the patch antenna, bandwidth is broadened. Base on the triple-mode antenna element, we develop a antenna array which consists of 4 elements and a SIW feeding network. The 2x2 array can be designed and fabricated with single-layer printed-circuit board(PCB). The measured -10dB impedance bandwidth of the antenna array is 18.2 % (40.9-49.1GHz) with peak gain of 10.4-14.0dBi and the cross-polarization level of better than 20 dB.

Blind Adaptive Array by Constant Modulus with Variable Step Size for Multi-beam Massive MIMO 234
Kentaro Nishimori, Kazuki Maruta and Takefumi Hiraguri
Multi-beam massive MIMO configuration has been proposed that utilizes the beam selection with high power in an analog part and blind algorithm such as constant modulus algorithm (CMA) which does not need channel state information (CSI) in a digital part. However, when the Least Square - CMA (LS-CMA) is applied to Quadrature Amplitude Modulation (QAM) signal whose amplitude changes, the effect of interference cancellation decreases as the number of modulation order increases. In this paper, variable step size based CMA (VS-CMA), which modifies the step size of steepest descent CMA (SD-CMA) as the blind based adaptive algorithm instead of LS-CMA, is proposed. Moreover, the basic performance of VS-CMA and its applicable for the multi-beam massive MIMO transmission are verified via the computer simulation.

Multi-Target Signal Estimation with Sensor Networks under Imperfect CSI 240
Vimal Radhakrishnan, Ehsan Zandi, Omid Taghizadeh and Rudolf Mathar
This paper solves the problem of multi-target signal estimation with the aid of sensor networks, given the condition that the channel state information is imperfect. First, an unbiased estimator is proposed. Subsequently, the variance of the estimation error is minimized by optimal data the fusion at fusion center. Moreover, the power allocation to different sensors is optimized, in order to extend the lifespan of the network. The incentive to do so is that, we assume that the sensors are battery operated. This makes the optimal power allocation crucial for a prolonged lifespan.

Optimization of Distributed Quantizers Using an Alternating Information Bottleneck Approach 246
Steffen Steiner and Volker Kuehn
This paper considers a scenario with distributed nodes receiving statistically dependent signals. The nodes have to quantize these signals and forward them over capacity-limited links to a common receiver. As a joint vector quantization is assumed to be infeasible, individual scalar quantization is performed. However, these scalar quantizers have to be designed jointly. The optimization is based on the alternating Information Bottleneck method. The quantizers are optimized successively, keeping all other quantizers fixed and using their statistics as side-information. Following this approach, we fulfill given rate constraints and preserve more relevant information than using independently optimized scalar quantizers.

Comparison of Two Baseline AoA Estimation Methods in a EM Lens Assisted MAA System 252
Sarmad Ahmed Shaikh and Andrea M Tonello
The fifth generation (5G) of wireless systems will implement new groundbreaking technologies, for instance, massive multiple-input-multiple-output (MIMO) transmission. Such systems, by deploying massive antennas array (MAA), can enhance the data communication performance as well as offer precise radio localization based on angle of arrival (AoA) estimation. This paper considers two baseline AoA estimation techniques, namely complex conjugate AoA estimation and sum-difference patterns, when used in the electromagnetic (EM) lens assisted MAA system. Due to the property of the EM lens to focus the received signal on a small subset of antennas, these schemes can be implemented in the MAA system with reduced computational complexity using a fully digital or a mixed analog-digital structure. The presented techniques estimate the AoA of a received signal by exploiting two elements of the focused subset of antennas and alleviate the need of using high-resolution algorithms which form the high dimensional covariance and eigenvalue decomposition matrices. The obtained simulation results are comparable to the conventional algorithms without lens, despite significantly reducing the overall system complexity.

S7: Beamforming and Precoding

Chair: Josef A. Nossek

1-Bit Precoding in Massive MU-MISO-OFDM Downlink with Linear Programming 257
Ferhad Askerbeyli, Hela Jedda and Josef A. Nossek
Employing 1-bit quantization in the massive multiple-input-multiple-output (MIMO) systems, enhances the system power efficiency. Novel precoder designs like maximum safety margin (MSM) precoder are required to handle the distortions that are caused by the 1-bit quantization and deteriorate the bit-error-ratio (BER) performance. We extend the MSM precoder design to the 1-bit quantized downlink multi-user (MU) multiple-input-single-output orthogonal frequency division multiplexing (MISO-OFDM) system in which PSK modulation scheme is used. The transmit vector design is based on maximizing the margin of the received symbols to the decision thresholds of the PSK modulation schemes. The simulation results are compared with the zero-forcing (ZF) precoder.

Multibeam Transceiver with 4D Arrays Based on Single-Pole Multiple-Throw Switches 262
Roberto Maneiro-Catoira, Marc Bernice Angoue Avele, Julio C. Brégains, José A. García-Naya and Luis Castedo
Time-modulated Arrays (TMAs) use radio-frequency switches to perform beam steering, standing out as a simple and cost-effective alternative to standard arrays using variable phase shifters. In this work, we consider the utilization of single-pole multiple-throw (SPMT) switches to synthesize the pulses which modulate the excitations of a TMA. These pulses are approximations of time-delayed sine waves and allow for an efficient beam steering over the first positive harmonic while guaranteeing a certain threshold level for the undesired harmonics, making the proposed TMA architectures particularly suitable for the design of multibeam transceivers. Besides the cost, the main advantages of multibeam TMA structures based on SPMT switched are the use of a single radio-frequency front-end for a multibeam transmitter (receiver) chain; the phase resolution of the beam scanning; and the fact that the performance of the antenna feeding network is conditioned to the signal bandwidth rather than the carrier frequency.

Multi User Beam Selection Using Sequential Competition Test 267
Mostafa Khalili, Wolfgang Rave and Gerhard Fettweis
We present a novel sequential hypothesis test for multi user beam selection when knowledge about the SNR operating point of each user is not available. The proposed sequential test adaptively changes the test length (the number of observations) according to the SNR operating point to achieve the desired performance close to the ideal beam selector based on genie knowledge.

The Elimination Game or: Beam Selection based on M-ary Sequential Competition & Elimination 271
Wolfgang Rave and Mostafa Khalili
We study the properties of our recently proposed sequential competition test based on M observation sequences. This test solves the problem of deciding which among M unknown amplitude levels is the strongest one, when the SNR is not assumed known but needs to be estimated from the data. In this work we demonstrate that the average test length can be further reduced by eliminating stochastical paths during the competition. We also study how the termination and elimination thresholds should be set in order to fulfill a given rate constraint by parametrizing the test with an absolute SNR target value and SNR differences to which the instantaneous SNR estimates of each signal are compared.

Discrete One-Bit Precoding for Massive MIMO 279
Benedikt Fesl, Hela Jedda and Josef A. Nossek
Multi-User (MU) massive Multiple-Input-Multiple- Output (MIMO) systems are seen as one of the most promising ways to improve wireless communications. In order to prevent an excessive increase in power consumption, nonlinear one-bit precoding methods are gaining interest recently. In this work, we present a new nonlinear precoding technique, which miti- gates all quantization distortions in the example of Phase-Shift-Keying (PSK). The underlying optimization problem is based on maximizing the safety margin to the decision thresholds of the receiver constellation modulation. The resulting performance gain in comparison to state-of-the-art algorithms is shown in terms of the uncoded Bit Error Ratio (BER) over the transmit power for different number of constellation points and different ratios of antennas to users.