Advances in Cooperative Wireless Communications

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Abstract

In the early days of wireless communications the research community used to view multipath-induced dispersion as an undesirable propagation phenomenon, which could only be combated with the aid of complex channel equalizers. The longer the Channel Impulse Response (CIR) was, the more complex the channel equalizer became. However, provided that the complexity of a sufficiently high-memory channel equalizer was affordable, the receiver could benefit from the fact that the individual propagation paths faded independently. To elaborate a little further, even if one of the paths was experiencing a high attenuation, there was a good chance that some of the other paths were not, which led to a potential diversity gain.

However, if the channel does not exhibit several independently fading paths, techniques of artificially inducing diversity may have to be sought. A simple option is to employ a higher direct-sequence spreading factor, which results in a higher number of resolvable multipath components and hence in an increased diversity gain. Naturally, this is only possible if either the available bandwidth may be extended according to the spreading factor or the achievable bitrate is reduced by the same factor. A whole host of classic diversity combining techniques may be invoked then for recovering the original signal.

An alternative technique of providing multiple independently faded replicas of the transmitted signal is to employ relaying, distributed space-time coding or some other cooperation-aided procedure, which is the subject of this course. One could also view the benefits of decode-and-forward based relaying as receiving and then flawlessly regenerating and re-transmitting the original transmitted signal from a relay - provided of course that the relay succeeded in error-freely detecting the original transmitted signal.

This course reviews the current state-of-the-art and proposes a number of novel relaying and cooperation techniques. An important related issue is the availability or the absence accurate channel information, which leads to the concept of coherent versus non-coherent detection at the relays and at the destination. Similarly, the related initial synchronization issues also have to be considered.

Naturally, when using hard-decisions in the transmission chain, we discard valuable soft-information, which results in an eroded performance, albeit also reduces the complexity imposed. Hence the hard- versus soft-decoding performance trade-off will also be explored in the course, along with the benefits of interleaved random space-time coding invoked for multi-source cooperation.

Key Topics

1. Successive Relaying Aided Near-Capacity Irregular Distributed Space-Time Coding

An Irregular Distributed Space-Time (Ir-DST) coding scheme is studied in the context of a twin-relay aided network in which the successive relaying protocol is employed. A tight upper-bound of the successive relaying aided network's capacity is given. The distributed codes at the source and relays are jointly designed with the aid of EXtrinsic Information Transfer (EXIT) charts for the sake of high-integrity operation at Signal-to-Noise Ratios (SNRs) close to the corresponding network's capacity. Finally, it is shown that our proposed Ir-DST coding scheme is capable of near-capacity cooperative communications in the successive relaying aided network, which is an explicit benefit of our joint source-and-relay mode design.

2. Distributed Self-Concatenated Codes for Low-Complexity Power-Efficient Cooperative Communication

We study a Distributed Binary Self-Concatenated Coding scheme using Iterative Decoding (DSECCC-ID) for cooperative communications. The DSECCC-ID scheme is designed with the aid of binary Extrinsic Information Transfer (EXIT) charts. The source node transmits SECCC symbols to both the relay and the destination nodes during the first transmission period. The relay performs SECCC-ID decoding. It then re-encodes the information bits using a Recursive Systematic Convolutional (RSC) code during the second transmission period. The resultant symbols transmitted from the source and relay nodes can be viewed as the coded symbols of a three-component parallel-concatenated SECCC-ID encoder. At the destination node, three-component DSECCC-ID decoding is performed. It is shown that the performance of the DSECCC-ID exactly matches the EXIT chart analysis. The EXIT chart gives us an insight into operation of the distributed coding scheme which enables us to significantly reduce the transmit power of the system.

3. Resource-Optimized Differentially Modulated Hybrid AF/DF Cooperation Dispensing with Channel Estimation

In multi-user cellular uplinks cooperating mobiles may share their antennas in order to achieve transmit diversity by formig a virtual antenna array (VAA) in a distributed fashion. In this paper, based on the minimum BER criterion, we investigate cooperating-user-selection (CUS) and adaptive-power-allocation (APA) for two types of differentially modulated cooperative cellular uplinks requiring no channel state information (CSI) at the receiver, namely, for the differential-amplify-and-forward (DAF) and the selective differential-decode-and-forward (DDF) assisted systems. They both employ multiple-symbol differential sphere detection (MSDSD) to combat rapid-fading-induced performance degradation. More specifically, we investigate the cooperative-protocol-selection (CPS) of the uplink system in conjunction with a beneficial CUS as well as the APA scheme in order to further improve the achievable end-to-end performance, leading to a resource-optimized hybrid AF/DF cooperative system. Hence, a number of cooperating MSs may be adaptively selected from the available MS candidate pool and the cooperative protocol employed by a specific cooperating MS may also be adaptively selected in the interest of achieving the best possible BER performance.

4. Physical-layer Algebraic Network Coding and Superposition Coding for the Multi-Source Cooperation Aided Uplink

In this paper, we consider coding schemes designed for energy efficient multi-source cooperation. More explicitly, we propose both a powerful superposition coding scheme and a physical-layer algebraic network coding scheme. The concept of generalised network coding is introduced and the relation between superposition coding and network coding is revealed. Our simulation results demonstrate that both of the proposed schemes are capable of performing close to the outage probability bound at the lower end of the target transmit power range. Moreover, compared to the superposition coding scheme considered, the proposed algebraic network coding arrangement imposes a lower complexity at the cost of a slight performance degradation, while maintaining the same throughput and delay.

5. Cooperative Differential Space-Time Spreading for the Asynchronous Relay Aided CDMA Uplink Using Interference Rejection Spreading Code

A differential Space-Time Coding (STC) scheme designed for asynchronous cooperative networks, where neither channel estimation nor symbol-level synchronization is required at the cooperating nodes. More specifically, our system employs differential encoding during the broadcast phase and a Space-Time Spreading (STS)-based amplify-and-forward scheme during the cooperative phase in conjunction with interference rejection direct sequence spreading codes, namely Loosely Synchronized (LS) codes. Our simulation results demonstrate that the proposed Cooperative Differential STS (CDSTS) scheme is capable of combating the effects of asynchronous uplink transmissions without any channel state information, provided that the maximum synchronization delay of the relay nodes is within the width of IFW. It will be demonstrated that in the frequency-selective environment considered our CDSTS arrangement is capable of exploiting both space-time diversity and multi-path diversity with the aid of a RAKE combiner.

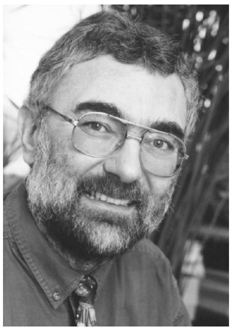
Intended Audience

Whilst this overview is ambitious in terms of providing a research-oriented outlook, potential attendees require only a modest background in wireless networking and communications. The mathematical contents are kept to a minimum and a conceptual approach if adopted. Postgraduate students, researchers and signal processing practitioners as well as managers looking for cross-pollination of their experince with other topics may find the coverage of the presentation beneficial. The participants will receive the set of slides as supporting material and they may find the detailed mathematical analysis in the above-mentioned books.

Course Notes: a copy of the slides will be made available for the participants.

The instructor presented short courses for example at the following IEEE conferences:

ICCS'94 in Singapore; ICUPC'95 in Tokyo; ICASSP'96 in Atlanta, USA; PIMRC'96 in Taipei, Taiwan; ICASSP'96 in Atlanta; ICCS'96 in Singapore; VTC'97 in Phoenix, USA; PIMRC'97 Helsinki, Finland; VTC'98, Ottawa, Canada; Globecom'98 Melbourne, Australia; VTC'99 Spring Houston, USA; EURASIP Conference'99, June, 1999, Krakow, Poland; VTC'99 Fall Amsterdam, The Netherlands; VTC'2000 Spring Tokyo, Japan; VTC'2001 Spring Rhodes, Greece; Globecom'2000 San Francisco, USA; Globecom'2001 San Antonio, USA; ATAMS'2001 Krakow, Poland; Eurocon'2001, Bratislava, Slovakia; VTC'2002 Spring Birmingham Alabama, USA; VTC'2002 Fall Vancouver, Canada; ICC'2002, New York, USA; Wireless'02, Calgary, Canada; WPMC'02 Honolulu, Hawaii; ATAMS'2002, Krakow, Poland; WCNC'03 New Orleans, USA; VTC'2003 Spring, Jeju Island, Korea; PIMRC'2003, Beijing, China; VTC'2003 Fall Orlando, USA; European Wireless Conference'2004, Barcelona, Spain; ICC'2004, Paris, France; EUSIPCO'2004, Vienna, Austria; VTC'2005 Spring Stockholm, Sweden; VTC'2005 Fall, Dallas, USA; WPMC'2005 Aalborg, Denmark; VTC'2006 Spring Melbourne, Australia; ICC'2006 Istanbul, Turkey; WCNC'2006, Las Vegas, USA; ISSSTA'2006, Manaus, Brazil; VTC'2006 Fall, Montreal; VTC 2007 Spring, Dublin; ICC 2007, Glasgow; IST' 2007, Budapest, Hungary; VTC 2007 Fall, Baltimore, USA; ColCom'2007, Bogota, Colombia; ICSPC'2007, Dubai; WCNC'2007, Hong-Kong, China; ICC'2008, Beijing, China; VTC'2008 Spring Singapore; WCNC'2008, Las Vegas; VTC'2008 Fall, Calgary, Canada; Globecom'2008, New Orleans, USA; VTC'2009 Spring, Barcelona, Spain; ICC'2009, Dresden, Germany; VTC'2009 Fall, Anchorage, USA; Globecom 2009, Hawaii, USA; Accepted: VTC 2010 Spring, Taipei; Pending decision: ICC 2010 Cape Town;



Bio of the Instructor

Lajos Hanzo received his first-class Master degree in electronics in 1976, his PhD in 1983 and his Doctor of Sciences (DSc) degree in 2004. He is a Fellow of the Royal Academy of Engineering (FREng). He co-authored 18 IEEE Press - John Wiley books totalling in excess of 10 000 pages on mobile radio communications, published in excess of 900 research papers, organised and chaired major IEEE conferences, and has been awarded a number of distinctions. Lajos is also an IEEE Distinguished Lecturer and a Fellow of both the IEE and IEEE. He is the Editor-in-Chief of the IEEE Press. He has in excess of 10 000 Harzing citations and 676 IEEE Xplore entries.For further information on research in progress and associated publications please refer to http://www-mobile.ecs.soton.ac.uk;