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Multiple access communications in future-generation wireless networks

Norman Abramson[1], Claudio Sacchi[2], Boris Bellalta[3*] and Alexey Vinel[4]

In June 1971, the first two-way wireless transmission of data packets within a computer network was achieved at the Manoa campus, University of Hawaii, Honolulu [1]. The ALOHANet was an experimental UHF radio network designed and implemented at the University of Hawaii at a time when the only other option for remote access to information resources was based upon the use of inflexible, slow, and unreliable telephone network connections.

The ALOHA System Research project began in September 1968, with the purpose of defining [2] "those situations where radio communications are preferable to conventional wire communications." The properties of the wireless medium led to the use of a new form of random access channel architecture, now known as an ALOHA channel. The commercial application of ALOHA channels in the 1970s was limited by the fact that suitable frequencies for terrestrial wireless transmission of packets were not generally available. Thus, the first two commercial uses of an ALOHA channel were in cable networks and then in satellite networks.

In 1973, Metcalfe demonstrated a cable-based application of ALOHA in the "Alto ALOHA Network" [3] at the Xerox Palo Alto Research Center. This network was later developed by Metcalfe into Ethernet.

In 1976, an ALOHA channel was used for the request channel in the Marisat (later Inmarsat) satellite network [4]. Over the last 30 years millions of small two-way earth stations using ALOHA channels have been implemented around the world. In the early 1980s, frequencies for mobile networks became available [5] and in 1985 frequencies suitable for what became known as WiFi were allocated [6] in the USA. ALOHA channels were used in a limited way in the 1980s in 1G mobile phones for signaling and control purposes [7]. In the 1990s, Matti Makkonen and others at Telecom Finland greatly expanded the use of ALOHA channels in order to implement SMS message texting in 2G mobile phones. In the early 2000s, additional ALOHA channels were added to 2.5G and 3G mobile phones with the widespread introduction of GPRS using a slotted ALOHA random access channel combined with a version of the Reservation ALOHA scheme first analyzed by a group at BBN [8]. It seems clear that the expanding use of smartphones and IP-based web traffic in developing 4G networks will lead to an even greater use of random access ALOHA channels in this decade. Metcalfe at Xerox [9] and Kleinrock and Tobagi at UCLA [10] added the use of Carrier Sense (CS) and Carrier Detection (CD) to an unslotted ALOHA channel to define the CSMA/CD protocol used in the original Ethernet 802.3 cable standard. The 802.11 WiFi wireless standard modified the CD part of the Ethernet standard to Collision Avoidance (CA) to define the CSMA/CA protocols adopted in 1997 for WiFi. Ironically, recent chatter on the web dealing with full duplex WiFi hints at further development of WiFi in the direction of the original ALOHA architecture. The theoretical foundations of ALOHA random access have been described in various ALOHA System technical papers [11,12]. Over the last 30 years research groups throughout the world have provided a deeper, more complete understanding of the multiple access channel, its limitations, and its possibilities. Many of these possibilities are dealt with in this Special Issue of the EURASIP Journal of Wireless Communications and Networking.

This Special Issue contains 21 selected articles, covering a significant number of hot topics in Multiple Access Communications such as new cooperative MAC protocols; spectrum sharing, and channel assignment techniques for cognitive radio networks; new results on PHY layer multiple access techniques; admission control, and radio resource management for multimedia traffic in WLANs, WIMAX, and LTE networks, as well as on general topics such as multiuser detection (MUD), cross layer, and quality of service.

* Correspondence: boris.bellalta@upf.edu
[3]Department of Information and Communication Technologies, Universitat Pompeu Fabra, Spain
Full list of author information is available at the end of the article

The article "*On the feasibility of a Channel-Dependent Scheduling for the SC-FDMA in 3GPP-LTE (Mobile Environment) based on a Prioritized-Bifacet Hungarian Method*" by Gerardo Agni Medina-Acosta and José Antonio Delgado-Penin applies the so-called "Prioritized-Bifacet Hungarian Method" to make up a decision about which part of the whole bandwidth is the most reliable to establish a communication by each of the users in the 3GPP-LTE uplink or SC-FDMA system. The benefits of the proposed dynamic scheduling against of the classic static scheduling and other known methods are demonstrated by means of a simulative study.

The article *"ZAP: A Distributed Channel Assignment Algorithm for Cognitive Radio Networks"* by Paulo Roberto Walenga Junior, Mauro Fonseca, Anelise Munaretto, Aline Carneiro Viana, and Artur Ziviani proposes an algorithm for the distributed channel assignment in cognitive radio networks, which, in contrast to related work, relies on a fully distributed approach based only on local (neighborhood) knowledge, while significantly reducing computational costs and the number of messages required for channel assignment. Simulations confirm the efficiency of ZAP in terms of (i) the performance tradeoff between different metrics and (ii) the fast achievement of a suitable assignment solution regardless of network size and density.

The article *"Carrier Frequency Offset Estimation for Multi-User MIMO OFDM Uplink Using CAZAC Sequences: Performance and Sequence Optimization"* by Yan Wu, J W M Bergmans, and Samir Attallah studies the carrier frequency offset (CFO) estimation in the uplink of multiuser multiple-input multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. Conventional maximum likelihood estimator requires computational complexity that increases exponentially with the number of users. To reduce the complexity, a suboptimal estimation algorithm is proposed using constant amplitude zero autocorrelation (CAZAC) training sequences. The complexity of the proposed algorithm increases only linearly with the number of users. In this algorithm, the different CFOs from different users destroy the orthogonality among training sequences and introduce multiple access interference (MAI). To reduce the effect of the MAI, the authors find the CAZAC sequence that maximizes the signal-to-interference ratio.

The article "*Hidden Node Aware Routing Method Using High Sensitive Sensing Device for Multi hop Wireless Mesh Network*" by Shamsad Parvin and Takeo Fujii proposes a routing method for wireless mesh networks that achieves a better performance compared with the conventional methods by avoiding the hidden node problem. Simulation study demonstrates that the proposed routing method improves the network throughput.

The article "*An efficient method for proportional differentiated admission control implementation*" by Vladimir Shakhov and Hyunseung Choo investigates the admission control mechanism inspired in the framework of proportional differentiated services. The article improves previous solutions of the problem and offers an efficient nonasymptotic method for implementation of proportional differentiated admission control.

The article "*Polarization Division Multiple Access With Polarization Modulation for LOS Wireless Communications*" by Bin Cao, Qin-Yu Zhang, and Lin Jin discusses a potential multiple access and modulation scheme based on polarized states of electromagnetic (EM) waves for Line-of-Sight (LOS) communications. Some theoretical analysis has been carried out to demonstrate the feasibility of the proposed scheme and the simulation results are presented to evaluate the performance of the proposed system.

The article "*Interference Aware Radio Resource Management for Local Area Wireless Networks*" by Pekka Markus Nikolai Jänis, Cássio B. Ribeiro, and Visa Koivunen proposes an interference-aware radio resource management scheme where receivers inform about their throughput, interference, and signal levels by means of broadcast messages tied to data reception. The presented results demonstrate that the proposed scheme enables fair and efficient wireless access in challenging interference scenarios, for example, multiple networks deployed in the same geographical area and sharing a common band.

The article "*Quality of Service Implications of Power Control and Multiuser Detection based Cross-Layer Design*" by Ulrike Korger, Christian Hartmann, Katsutoshi Kusume, and Joerg Widmer deals with MAI using physical layer techniques, such as MUD or power control by considering a joint physical layer (PHY) and medium access control (MAC) cross-layer design.

The article "*Performance Evaluation of Uplink Delay-Tolerant Packet Service in IEEE 802.16-based Networks*" by Zsolt Saffer, Sergey Andreev, and Yevgeni Koucheryavy provides an analytical model for efficient dynamic capacity allocation in IEEE 802.16 wireless metropolitan area network, where the non-real-time traffic can utilize the bandwidth unused by the real-time traffic. The analytical model is applied for investigating the influence of the real-time traffic on the delay of the non-real-time service flow. The article discusses also the determination of several traffic parameters under different constraints, which have potential applications in network control.

The article "*Coherence time Based Cooperative MAC Protocol for Wireless Ad hoc Networks*" by Murad Khalid,

Yufeng Wang, Ismail Butun, In-ho Ra, Ravi Sankar, and Hyung-jin Kim addresses the goal of achieving performance gains in wireless ad hoc networks under heavy-load and fast fading conditions. The authors develop a cooperative MAC protocol (termed as instantaneous relay-based cooperative MAC-IrcMAC) that uses channel coherence time and estimates signal-to-noise ratio (SNR) of source-to-relay, relay-to-destination, and source-to-destination links, to reliably choose between relay path or direct path for enhanced throughput and delay performances.

The article "*Efficient Control Channel Resource Allocation for VoIP in OFDMA-based Packet Radio Networks*" by Yong Fan and Mikko Valkama proposes an efficient control channel resource allocation approach to enhance the performance of voice-over-IP (VoIP) in orthogonal frequency division multiple access (OFDMA)-based next generation mobile communication systems. Its effectiveness is validated through large-scale radio system level simulations, and simulation results confirm that VoIP capacity with dynamic scheduling can be further enhanced with the proposed resource allocation approach.

The article "*Slotted Aloha with Multi-AP Diversity and Transmit Beamforming*" by Di Zheng and Yu-Dong Yao presents a theoretical contribution for the study of classical Slotted ALOHA random access algorithm for multi-access-point diversity case with omni-directional or beamforming antennas at transmission nodes. Mathematical framework for the throughput and mean packet delay is provided.

The article "*Towards a Collision-Free WLAN: Dynamic Parameter Adjustment in CSMA/E2CA*" by Jaume Barcelo, Boris Bellalta, Cristina Cano, Anna Sfairopoulou, Miquel Oliver, and Kshitiz Verma enhances previous studies of these authors and investigates further the efficiency of the improved CSMA/CA MAC protocol called CSMA/ECA. The idea of the improvement comes from the fact that if all the stations use the same deterministic backoff after successes, the system naturally converges to a collision-free operation in which the stations transmit in a round-robin deterministic fashion. In this article, a model that computes the number of slots required to reach this collision-free operation is presented and a modification that results in a shorter transitory is introduced.

The article "*Iterative Fusion of Distributed Decisions over the Gaussian Multiple Access Channel using Concatenated BCH-LDGM Codes*", by Javier Del Ser, Diana Manjarres, Pedro Crespo, Sergio Gil-Lopez, and Javier García-Frías investigates the performance of concatenated Low Density Generator Matrix-Bose, Ray-Chaudhuri, Hocquenghem (BCH-LDGM) codes for iterative data fusion of distributed decisions over the Gaussian MAC. The use of LDGM codes permits to efficiently exploit the intrinsic spatial correlation between the information registered by the sensors, whereas BCH codes are selected to lower the error floor due to the MAC ambiguity about the transmitted symbols. The new scheme significantly outperforms state-of-the-art coding schemes.

The article "*AWPP: A New Scheme for Wireless Access Control Proportional to Traffic Priority and Rate*" by Thomas Lagkas and Periklis Chatzimisios proposes an alternative for IEEE 802.11e MAC protocol which is shown to improve traffic differentiation as well as overall WLAN performance. Corresponding analytical model is developed.

The article "*Binary De Bruijn Sequences for DS-CDMA Systems: Analysis and Results*" by Susanna Spinsante, Stefano Andrenacci, and Ennio Gambi provides results about the evaluation of specific full-length binary sequences, namely, De Bruijn sequences, when applied as spreading codes in DS/CDMA schemes, and compares their performance to other families of spreading codes commonly used, such as m-sequences, Gold, OVSF, and Kasami sequences. Considering the similarity of De Bruijn sequences to random sequences, we investigate the performance resulting by applying them as spreading codes. The results herein presented suggest that binary De Bruijn sequences, when properly selected, may compete with more consolidated options.

The article "*Evaluating IEEE 802.15.4 for Cyber-Physical Systems*" by Feng Xia, Alexey Vinel, Ruixia Gao, Linqiang Wang, and Tie Qiu analyzes the performance of IEEE 802.15.4 standard operating in different modes. Extensive simulations have been conducted to examine how network QoS will be impacted by some critical parameters. The results are presented and analyzed, which provide some useful insights for network parameter configuration and optimization for cyber-physical systems (CPS) design. CPS is a new class of engineered systems that features the integration of computation, communications, and control.

The article "*A Comparative Survey of Adaptive Codec Solutions for VoIP over Multi-rate WLANs: a Capacity vs Quality performance Trade-off*" by Anna Sfairopoulou, Boris Bellalta, Carlos Macian, and Miquel Oliver surveys various codec adaptation mechanisms that have been proposed as a solution to enhance the performance of multi-rate WLANs with VoIP traffic. These solutions are presented, categorized according to the adaptation policy they implement, and evaluated at call-level in terms of the resulting blocking and dropping probabilities, as well as the perceived voice quality.

The article "*A Near-Optimum Multi-User Receiver for STBC MC-CDMA Systems based on Minimum Conditional BER Criterion and Genetic Algorithm-assisted*

Channel Estimation" by Leandro Dorazio, Claudio Sacchi, Massimo Donelli, Jérôme J. Louveaux and Luc Vandendorpe proposes near-optimum and computationally affordable algorithms for linear MUD (based on minimum conditional BER) and channel estimation (based on Genetic algorithms) targeted to the effective implementation of the baseband section of a multicarrier CDMA terminal exploiting MIMO diversity.

The article "*Performance Analysis for Linearly Precoded LTE Downlink Multiuser MIMO*" by Zihuai Lin, Pei Xiao, and Yi Wu provides a mathematical model for the SINR distribution and the average channel capacity for multiuser Space-Division-Multiplexed (SDM) MIMO systems with frequency domain packet scheduler, which provides a theoretical reference for the future version of the LTE standard and a useful source of information for the practical implementation of the LTE systems.

The article "*A Utility-Based Approach for Secondary Spectrum Sharing*" by Maxim Dashouk and Murat Alanyali provides a social welfare framework for coexistence of secondary users of spectrum in the presence of static primary users. A CS multiple access-based randomized channel selection technique and a measurement-based gradient ascent method are considered to reach the optimal system performance. Distributed versions of the method are discussed and shown to outperform previously published study in a variety of simulation scenarios that study effects of primary user presence, varying secondary user density, varying total channel availability.

We hope that the papers published in this Special Issue will inspire and promote further research in Multiple Access Communications in Future-Generation Wireless Networks. We would like to take this opportunity to thank all the authors who have contributed to this Special Issue and express our gratitude to all the anonymous reviewers for their efforts in providing valuable reviews and comments.

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Author details
[1]Department of Electrical Engineering, University of Hawaii, USA [2]Information Engineering and Computer Science Department, University of Trento, Italy [3]Department of Information and Communication Technologies, Universitat Pompeu Fabra, Spain [4]Saint-Petersburg Institute for Informatics and Automation, Russian Academy of Sciences, Russia

Competing interests
The authors declare that they have no competing interests.

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