Table of contents

BAS on
IP and ATM Convergence*
Sheraton Hotel, Tuesday Afternoon, Room Gavea A

Proposer: Paulo T. de Sousa, European Comission

IP and ATM Convergence 1660
Paulo T. de Sousa, European Commission

Symposium on Global Internet: Application and Technology (V03)

SESSION MM-GI01
Resource Management for Wireless Networks
10:45-11:25, Sheraton, Room Ipanema

Chair: Ramon Caceres, AT&T Research

1 **Adaptive Inverse Multiplexing for Wide-Area Wireless Networks** 1665
Alex Snoeren, Massachusetts Institute of Technology, USA

2 **Fair Allocation of Elastic Traffic for a Wireless Base Station** 1673
György Miklós, Ericsson Research; Sándor Molnár, Technical University of Budapest, Hungary

SESSION MM-GI02
Routing Algorithms
11:25-12:30, Sheraton, Room Ipanema

Chair: Christophe Diot, Sprint Labs

1 **The Use of IP-Anycast for Building Efficient Multicast Trees** 1679
Dina Katabi, Massachusetts Institute of Technology, USA

2 **A Distributed Algorithm for Multipath Computation** 1689
Srinivas Vutukury and J.J.Garcia-Luna-Aceves, University of California, USA

3 **A Randomized Algorithm for Finding a Path Subject to Multiple QoS Constraints** 1694
Turgay Korkmaz and Marwan Krunz, University of Arizona, USA

SESSION MA-GI03
Analyzing TCP
14:45-16:20, Sheraton, Room Ipanema

Chair: Erich Nahum, IBM Watson

1 **Analysis of a Method for Differential TCP Service** 1699
Panos Gevros, Fulvio Risso, and Peter Kirstein, University College London, United Kingdom

2 **Analysis of TCP with Several Bottleneck Nodes** 1709
Chadi Barakat and Eitan Altman, INRIA, France

3 **The Window Distribution of Multiple TCPs with Random Loss Queues** 1714
Archan Misra and Teunis Ott, Telcordia Technologies; John Baras, University of Maryland, USA

4 **Detecting and Measuring Asymmetric Links in an IP Network** 1727
Wenyu Jiang, Columbia University; Timothy F. Williams, Network Peripherals Inc., USA

SESSION MA-GI04
Buffer Management Mechanisms
16:40-18:15, Sheraton, Room Ipanema

Chair: Jennifer Rexford, AT&T Research

1 **Class-Based Buffer Management using Early Fair Drop** 1732
John Bruno, Banu Ozden, Abraham Silberschatz, and Taroon Mandhana, Lucent Technologies, USA

2 **On the Provision of Integrated QoS Guarantees of Unicast and Multicast Traffic in Input-Queued Switches** 1742
Ge Nong and Mounir Hamdi, The Hong Kong University of Science and Technology, Hong Kong

3 **Random Early Marking for Internet Congestion Control** 1747
David Lapsley, Melbourne Information Technologies; Steven Low, The University of Melbourne, Australia
4 **Flow-valve: Embedding a Safety-valve in RED** 1753
Kenjiro Cho, Sony Computer Science Laboratories, Inc., Japan

SESSION TM-GI05
Application Level Services
9:30-10:40, Sheraton, Room Ipanema

Chair: Dinesh Verma, IBM Watson

1 **Integrating WWW Caches and Search Engines** 1763
Wagner Meira Jr., Rodrigo Fonseca, Marcio Cesario, and Nivio Ziviani, Federal University of Minas Gerais, Brazil
2 **En Passant: Predicting HTTP/1.1 Traffic** 1768
Balachander Krishnamurthy and Jennifer Rexford, AT&T Labs Research, USA
3 **Comparison of Scalable Key Distribution Schemes for Secure Group Communication** 1774
Lakshminath Dondeti, University of Nebraska-Lincoln; Sarit Mukherjee, Panasonic Technologies, Inc.; Ashok Samal, University of Nebraska-Lincoln, USA

SESSION TM-GI06
Differentiated Services
11:00-12:30, Sheraton, Room Ipanema

Chair: Edmundo A. de Souza e Silva, Federal University of Rio de Janeiro

1 **A Two-Tier Resource Management Model for the Internet** 1779
Andreas Terzis, Lan Wang, Jun Ogawa, and Lixia Zhang, University of California at Los Angeles, USA
2 **Bandwidth Assurance Issues for TCP flows in a Differentiated Services Network** 1792
Nabil Seddigh, Biswajit Nandy, and Peter Pieda, Computing Technology Labs-Nortel Networks, Canada
3 **Supporting Best-Effort Traffic With Fair Service Curve** 1799
T. S. Eugene Ng, Carnegie Mellon University; Donpaul C. Stephens, Carnegie Mellon University/Lucent Technologies; Ion Stoica and Hui Zhang, Carnegie Mellon University, USA
4 **A Quantitative Study of Differentiated Services for the Internet** 1808
Sambit Sahu, Don Towsley, and Jim Kurose, University of Massachusetts, USA

SESSION TA-GI07
Support for Multimedia Traffic
14:30-16:05, Sheraton, Room Ipanema

Chair: Bengt Ahlgren, SICS

1 **A TCP-Friendly Congestion Control Scheme for Real-time Packet Video Using Prediction** 1818
Yeali Sun and Fu-Ming Tsou, National Taiwan University; Meng Chang Chen, Academia Sinica; Zsehong Tsai, National Taiwan University, Taiwan
2 **A Smoothing Proxy Service for Variable-Bit-Rate Streaming Video** 1823
Jennifer Rexford, AT&T Labs Research; Subhabrata Sen, University of Massachusetts; Andrea Basso, AT&T Labs Research, USA
3 **Efficient Mechanisms for Recovering Voice Packets in the Internet** 1830
Daniel Ratton Figueiredo and Edmundo de Souza e Silva, Federal University of Rio de Janeiro, Brazil
4 **Measuring Internet Telephony Quality: Where Are We Today?** 1838
Olof Hagsand, SICS; Kjell Hanson, Ericsson Business Networks; Ian Marsh, SICS, Sweden

SESSION TA-GI08
Internet Traffic Characterization
16:25-18:00, Sheraton, Room Ipanema

Chair: Sugih Jamin, University of Michigan, USA

1 **Investigating the Scaling Behavior, Crossover and Anti-persistence of Internet Packet Delay Dynamics** 1843
Qiong Li and David L. Mills, USA
2 **Inference of Internal Loss Rates in the Mbone** 1853
Ramón Cáceres and N.G. Duffield, AT&T Labs Research; Sue B. Moon and Don Towsley, University of Massachusetts, USA
3 **Inter-AS Traffic Patterns and Their Implications** 1859
Wenjia Fang and Larry Peterson, Princeton University, USA

4 The Current State and Likely Evolution of the Internet 1869
Andrew Odlyzko, AT&T Labs Research, USA

Symposium on Enterprise Application and Services (V03)

SESSION MM-EN01

WEB Based Management

10:45-12:30, Sheraton, Room Vidigal B + C

Organiser: John Buford
Chair: Pradeep Ray

1 Next Generation Computing [Invited Talk]
Michael Broodie, GTE Labs, USA

2 Agent and Web-Based Technologies in Network Management 1877
Matthew J. Wren and Jairo A. Gutiérrez, The University of Auckland, New Zealand

3 A Scalable, Web-based Architecture for Hierarchical Network Management 1882
Jiahai Yang, Peiyu Wang e Jianping Wu, Tsinghua University, China

4 Distributed Network Management by HTTP-Based Remote Invocation 1889
Hwa-Chun Lin and Chien-Hsing Wang, National Tsing Hua University, China

5 Web-based Customer Service Management System for a Virtual Private Network Service Based on Semi-permanent Connections 1894
S. De Smit, K. Daenen, and W. Van Leekwijck, Alcatel Corporate Research Center, Belgium

SESSION MA-EN02

Enterprise Network Design, Implementation and Operation

14:45-18:15, Sheraton, Room Vidigal B + C

Chair:Masayoshi Ejiri
Organiser: Giovanni Pau

1 Topological Design Comparison for Multicast Network 1899
Takumi Miyoshi and Yoshiaki Tanaka, Waseda University/Telecommunications Advancement Organization of Japan; Kaoru Sezaki, University of Tokio, Japan

2 Modeling, Simulation, and Verification of an Enterprise Network 1905
Jonathan Felten, Özgür Gürbüz, and Henry Owen, Georgia Institute of Technology, USA;
Thomas Grossmann, Gerd Kussman, and Werner Schröck, DeTeSystem Deutsche Telekom Systemlösungen, Germany

3 Analysis and Implementation of a Transparent Priority Mechanism for LAN Internet Access 1910
A. Giovanardi and G. Mazzini, University of Ferrara, Italy

4 Interfaces for Interworking among Intelligent Networks, Computer Telephony, and Voice over IP Systems 1916
Ryo Takeuchi, Kazuhiro Nagayama, Akira Miura, and Hiroki Tanaka, NTT Information Sharing Platform Laboratories, Japan

5 Active TCP Control by a Network 1921
Arata Koike, NTT Information Sharing Platform Laboratories, Japan

6 A Transactional Approach for Cross-Organizational Cooperation 1926
M. Munier, K. Benali, and C. Godart, LORIA, France

7 The Evolution Towards the Information Society, A Market Driven Perspective from the Convair Project in ACTS 1932
P. Briggs and B. Hopwood, Marconi Communications; E. Garetti, CSELT; P. Polese, ETIC A.I/Alcatel), Belgium

SESSION TM-EN03

Enterprise Applications and Network Management

9:30-12:30, Sheraton, Room Vidigal B + C

Organiser: Simon Kerridge
Chair: Lundy Lewis

1 On Workflow and Agent Technologies on the Internet/Intranet 1937
Geng-Sheng (G. S.) Kuo and Howard Y. Cheng, National Central University, Taiwan

2 The COO Operator to Support and Improve the Flexibility of Adaptive Workflows 1942
O. Perrin and C. Godart, LORIA-INRIA, France

3 **Using the Internet to Communicate Software Metrics in a Large Organization** 1947
Tony Jokikyyny, Ericsson Research; Casper Lassenius, Helsinki University of Technology, Finland

4 **A Study on Efficient Information Searchers with Agents for Large-Scale Networks** 1954
Shinji Sugawara, Katsunori Yamaoka, and Yoshinori Sakai, Tokyo Institute of Technology, Japan

5 **A Web Ontology Description Language** 1959
Hicham Ouahid and Ahmed Karmouch, University of Ottawa, Canada

6 **BDI-Oriented Agents for Network Mangement** 1964
Morsy M. Cheikhrouhou, Institut Eurécom, France

7 **Security Management Against Cloning Mobile Phones** 1969
Mirela Sechi Moretti Annoni Notare, Federal University of Santa Catarina, Brazil; Azzedine Boukerche, University of North Texas, USA; Fernando A. da S. Cruz, Bernardo G. Riso, and Carlos B. Westphall, Federal University of Santa Catarina, Brazil

SESSION TA-EN04
Enterprise Service and System Management
14:30-18:00, Sheraton, Room Vidigal B + C

Organiser: G. S. Kuo
Chair: Samir Chatterjee

1 **Service Level Management: Definition, Architecture, and Research Challenges** 1974
Lundy Lewis, Cabletron Systems, USA; Pradeep Ray, University of New South Wales, Australia

2 **Cooperative Service Management Over Enterprise Networks: A Case Study in Healthcare Environments** 1979
Pradeep Ray, Westmead Hospital; Gamini Weerakkody, University of New South Wales, Australia

3 **A Pricing and Accounting Architecture for QoS Guaranteed Services on a Multi-domain Network** 1984
Mitsuhiro Nakamura, Fujistu Ltd., Japan; Masakazu Sato, TAO, Japan; Takeo Hamada, Fujitsu Laboratories of America, USA

4 **Efficient Agent-Based Negotiation for Telecommunications Services** 1989
George D. Stamoulis, Dimitrios Kalopsikakis, Anna Kirikoglou, and Costas Courcoubetis, University of Crete, Greece

5 **Managing Users, Applications and Resources with RMON2** 1997
L. P. Gaspary, Federal University of Rio Grande do Sul/Vale do Rio dos Sinos University; L. R. Tarouco, University of Rio Grande do Sul, Brazil

6 **Broadband connectivity Management Service for Multi-domain ATM and SDH Networks** 2002
Alex Galis, University College London, United Kingdom

7 **Enterprise Directory Support for Future SNMPV3 Network Management Applications** 2010
S. Omari, University of Versailles, France; R. Boutaba, University of Toronto, Canada; O. Cherkaoui, UQAM University, Canada

Symposium on Multimedia Services and Technology Issues (V04)

SESSION WM-MM01
Multimedia: State of the Art [Invited Session]
9:30-12:30, Intercontinental, Room Agata

1 **Content Adaptation Framework: Bringing the Internet to Information Appliances** 2015
Rakesh Mohan, John R. Smith and Chung-Sheng Li, IBM T.J. Watson Research Center, USA

2 **Audio and Video Compression on Programmable Chips for Mobile Communication** 2022
Takao Nishitani and Ichiro Kuroda, NEC Corporation, Japan

3 **Video Communication Advances and Applications** 2030
Bernd Girod, University of Erlangen-Nuremberg, Germany

4 **Advances in Color Image Segmentation** 2038
Luca Lucchese and S. K. Mitra, University of California, USA

5 **High Quality Audio for Multimedia: Key Technologies and MPEG Standards** 2045
P. Noll, Technical University of Berlin, Germany

6 **The Voice User Interface** 2051
Joseph P. Olive, Lucent Technologies, USA

SESSION WA-MM02
Multimedia Applications and Systems
14:30-16:05, Intercontinental, Room Agata

Organizer: Nelson Fonseca, State University of Campinas, Brazil
Chair: Jeff H. Derby, IBM Corporation

1 **The Video Conference Service in an Intelligent Broadband Network: Design, Load Balancing and Performance Analysis in the Control Plane** 2056
F. Cuomo and M. Listanti, University of Rome "La Sapienza", Italy

2 **Quality of Perception to Quality of Service Mapping Using a Dynamically Reconfigurable Communication System** 2061
G. Ghinea, J. P. Thomas, and R. S. Fish, University of Reading, United Kingdom

3 **Overview of Risks in Multimedia Broadband Upgrades** 2066
Kjell Stordahl, Telenor; Nils Kristian Elnegaard, Tele Denmark; Leif Aarthun Ims and Borgar Tørre Olsen, Telenor, Norway

4 **A Stream Relationship Monitor for Adaptive Multimedia Document Retrieval** 2071
Eduardo Carneiro da Cunha, Luiz Fernando Rust da Costa Carmo, and Luci Pirmez, Federal University of Rio de Janeiro, Brazil

SESSION WA-MM03
Multimedia Services Access and Control
16:25-18:00, Intercontinental, Room Agata

Organizer: Nelson Fonseca, State University of Campinas, Brazil
Chair: Otto Carlos M. B. Duarte, Federal University of Rio de Janeiro, Brazil

1 **Threshold-Based Admission Policies for Video Services** 2076
S.-H. Gary Chan, Hong Kong University of Science and Technology, Hong Kong; Fouad A. Tobagi, Stanford University, USA

2 **Performance Evaluation of an Adaptive Access Control Scheme in an Integrated Voice/Video/Data CDMA System** 2081
Seung Sik Choi and Dong-Ho Cho, Korea Advanced Institute of Science and Technology, Korea

3 **Resource Reservation Admission Control Algorithm with User Interactions** 2086
F. Sallabi and A. Karmouch, University of Ottawa, Canada

4 **FEC-PSD: A FEC-aware Video Packet Drop Scheme** 2091
Ahmed Mehaoua, University of Versailles, France; Sijing Zhang, University of Cambridge, United Kingdom; Raouf Boutaba, University of Toronto, Canada

Symposium on Advanced Signal Processing for Communications (V04)

SESSION MA-SP01
Antenna and Array Processing
14:45-18:15, Intercontinental, Room Quartzo B

Organisers: Tomohiko Taniguchi, Fujitsu, USA; Naohisa Ohta, Sony, Japan
Chair: Horst Bessai, University of Siegen, Germany

1 **Downlink Beamforming for Frequency Division Duplex Systems** 2097
Klaus Hugl, Juha Laurila, and Ernst Bonek, Technische Universität Wien, Austria

2 **Field Measurements of High Speed QAM Wireless Transmission Using Equalization and Real-Time Beamforming** 2102
Jean-François Frigon and Babak Daneshrad, University of California at Los Angeles, USA

3 **Distribution Analysis of SIR in Adaptive Antenna Arrays under Rayleigh Correlated Channels** 2107
Alime (Yanartas) Özyildirim and Yalçin Tanik, Middle East Technical University, Turkey

4 **Reducing Capture Effects in Despread-Respread Multi-Target Adaptive Arrays in CDMA Systems** 2112
Francisco R. P. Cavalcanti, Federal University of Ceará; João M. T. Romano, State University of Campinas-UNICAMP, Brazil

5 **Space-Time Iterative MMSE Multiuser Detection in Frequency Selective Coded CDMA Wireless Mobile Channels** 2117
Joseph Thomas and Evaggelos Geraniotis, University of Maryland, USA

6 **Bandwidth-Efficient Pilot Symbol Aided Technique with Diversity Reception in Land Mobile Satellite Fading Channels** 2122
M. H. Ng and S. W. Cheung, The University of Hong Kong, Hong Kong

7 **Implementation of Mobile User Tracking System** 2127
Ramin Baghaie and Petri Karttunen, Helsinki University of Technology, Finland

8 Fractional Lower-Order Statistics for Efficient Adaptive Temporal and Spatial Methods in Non-Gaussian Environment 2132
M. Rupi and E. Del Re, University of Florence, Italy

SESSION TM-SP02
Equalisation and Channel Estimation
9:30-12:30, Intercontinental, Room Quartzo B

Organiser: Bin Qiu, Monash University, Australia
Chair: João Marcos Romano, State University of Campinas, Brazil

1 On a New Multilayer Blind Equalizer 2137
João B. Destro Filho, State University of Campinas-UNICAMP, Brazil; Gérard Favier, CNRS/UNSA, France; João M. Travassos Romano, State University of Campinas-UNICAMP, Brazil

2 Information Rate Maximizing FIR Transceivers: Filterbank Precoders and Decision-Feedback Equalizers for Block Transmissions over Dispersive Channels 2142
Anastasios Stamoulis, Wei Tang, and Georgios B. Giannakis, University of Minnesota, USA

3 New Results on Second-Order Statistics-Based Blind Identification and Equalization of S.I.M.O. Channels 2147
Jitendra K. Tugnait, Auburn University, USA

4 Comparison of Equalization Techniques in a Wavelet Packet Based Multicarrier Modulation DS-CDMA System 2152
Yifeng Zhang, Philips Semiconductors; Jeffrey Dill, Ohio University, USA

5 Non Linear Channel Estimation in Fading OFDM Systems 2157
Fernando D. Nunes and José M. N. Leitão, Instituto Superior Técnico, Portugal

6 Channel Estimation with Superimposed Pilot Sequence 2162
Peter Hoeher, University of Kiel, Germany; Fredrik Tufvesson, Lund University, Sweden

7 A Reduced-State Viterbi Algorithm for Blind Sequence Estimation of DPSK Sources 2167
Tongtong Li, Auburn University; Zhi Ding, University of Iowa, USA

SESSION TA-SP03
Communication Signal Processors
14:30-18:00, Intercontinental, Room Quartzo B

Organiser: Jaafar Elmirghani, University of Northumbria, Newcastle, United Kingdom
Chair: Naohisa Ohta, Sony Japan

1 A High-Speed Processor for Rectangular-to-Polar Conversion with Applications in Digital Communications 2172
Dengwei Fu and Alan N. Willson, Jr., University of California at Los Angeles, USA

2 Data-Aided ML Parameter Estimators of PSK Burst Modems and Their Systolic VLSI Implementations 2177
Yimin Jiang, Farhad B. Verahrami, and Wen-Chun Ting, Hughes Network Systems, Inc.; Robert L. Richmond and John S. Baras, University of Maryland, USA

3 Radial Basis Function Decision Feedback Equaliser Assisted Burst-by-burst Adaptive Modulation 2183
M. S. Yee and L. Hanzo, University of Southamptom, United Kingdom

4 Multiple Access Over Digital Subscriber Loops Using Optimal FIR Transmit Filter Bank 2188
Ahmed F. Shalash, New Jersey Design Center; Mohammed Nafie, University of Minnesota, USA

5 Analysis of a Partial Decorrelator in a Multi-cell DS/CDMA System 2193
Mohammad Saquib, LSU; Roy Yates, Rutgers University, USA

6 Optimal Perceptual Binary Allocation for AAC Audio Coder 2198
Marcos Perreau Guimaraes, Madeleine Bonnet, and Nicolas Moreau, Université René Descartes, France

7 Non-Intrusive Whitening of Speech Using Least Mean Square and Divergence Detection Technique 2203
Wai Pang Ng, Jaafar M.H. Elmirghani, R.A. Cryan, and Simon Broom, University of Northumbria, United Kingdom

8 Hierarchical Image Transmission System for Telemedicine Using Segmented Wavelet Transform and Golomb-Rice Codes 2208
Masayuki Hashimoto, Atsushi Koike, and Syuichi Matsumoto, KDD R&D Laboratories, Japan

SESSION WM-SP04
Interference Cancellation
9:30-12:30, Intercontinental, Room Quartzo B

Organisers: Trevor Clarkson, Kings College London; Jaafar Elmirghani, University of Northumbria, Newcastle, United Kingdom
Chair: Yeheskel Bar-Ness, New Jersey Institute of Technology, USA

1 Interference Cancellation in W-CDMA Cellular Structures Using Statistical Processing 2213
M. R. Shikh-Bahaei and A. H. Aghvami, King's College London, United Kingdom

2 Fast Adaptive Interference Cancellation In Chirp Spread Spectrum Systems 2218
Martin Brandl, Alfred Pohl, and Franz Seifert, University of Technology of Viena, Austria; Leo Reindl, Siemens Corporate Research, Germany

3 Multistage Symbol-by-Symbol Bayesian Interference Cancellation for UMTS-CDMA Links Affected by Severe Multipath 2223
R. Cusani and M. Di Felice, University of Rome "La Sapienza", Italy; J. Mattila, Helsinki University of Technology, Finland

4 Receive-Filtering for GSM Receivers in Interference Limited Environments 2228
Gunnar Fock, Jens Baltersee, and Heinrich Meyr, Aachen University of Technology, Germany; Lihbor Yiin, Lucent Technologies, USA

5 Interference Cancellation for Downlink TDMA Systems Using Smart Antenna 2233
Christian Ibars and Yeheskel Bar-Ness, New Jersey Institute of Technology, USA

6 Noise Reduction Based on Local Linear Representation Using Artificial Neural Networks 2238
A. Müller and J. M. H. Elmirghani, University of Northumbria, United Kingdom

7 Direct Carrier Frequency Compensation in Burst Mode Satellite Communication 2244
S. Thao and M. Bellanger, CNAM; A. Marguinaud and T. de Couasnon, Alcatel, France

SESSION WA-SP05

Detection

14:30-18:00, Intercontinental, Room Quartzo B

Organisers: Trevor Clarkson, Kings College London, United Kingdom; Bin Qiu, Monash University, Australia
Chair: Jaafar Elmirghani, University of Northumbria, United Kingdom

1 Progressively Powerful Multiuser Detectors for Rapidly Time-varying Multipath Environments 2249
Tamer A. Kadous and Akbar M. Sayeed, University of Wisconsin-Madison, USA

2 Adaptive Blind MIMO Channel Estimation and Multiuser Detection in DS-CDMA Systems 2254
I-Tai Lu and Jaeyoung Kwak, Polytechnic University, USA

3 Prediction-Based Decision Feedback Differential Detection for MDPSK 2259
Robert Schober and Wolfgang H. Gerstacker, University of Erlangen-Nuremberg, Germany

4 Differential Detection of Multilevel Continuous Phase Modulation for Radio Applications 2264
Bernhard Spinnler and Berthold Lankl, Siemens AG; Johannes Huber, University of Erlangen, Germany

5 Polyhedral Methods for Blind Deterministic Separation of Binary Co-Channel Signals 2269
João Xavier and Victor Barroso, Instituto Superior Técnico, Portugal

6 Fast, Accurate and Simple Carrier Acquisition Algorithm for OFDM Systems 2274
Zulfiquar Sayeed, Lucent Technologies, USA

7 Analysis Of OFDM/OQAM Systems Based On The Filterbank Theory 2279
Pierre Siohan and Nicolas Lacaille, CNET/DMR, France

8 Asynchronous Communication and Symbol Synchronization in Multipoint-to-Point Multicarrier Systems 2285
Ravi Chandran, Mark J. Patton, Peter J. W. Melsa, and Daniel J. Marchok, Tellabs Research Center, USA

Symposium on Communication Theory (V05)

SESSION MM-CT01

Equalization

10:45-12:30, Intercontinental, Room Agua Marinha

Chair: Hikmet Sari, Alcatel, France

1 Fractionally-Spaced Prefiltering for Reduced State Equalization 2291
Michael Schmidt and Gerhard P. Fettweis, Dresden University of Technology, Germany

2 A Novel Reduced-Complexity MAP Equalizer Using Soft-Statistics For Decision-feedback ISI Cancellation 2296
E. Baccarelli and A. Fasano, University of Rome "La Sapienza", Italy; S. Galli, Telcordia Technologies, USA; A. Zucchi, University of Rome "La Sapienza", Italy

3 Blind Spatio-Temporal Decision Feedback Equalization: A Self-Adaptive Approach 2301
J. Labat and C. Laot, ENST, France

4 Delay Processing vs. Per Survivor Techniques for Equalization with Fading Channels 2306
Shan Gao, University of Melbourne; Iain B. Collings, University of Sidney, Australia

5 Per Tone Equalization for DMT Receivers 2311
Katleen Van Acker, Geert Leus, and Marc Moonen, Catholic University of Leuven; Olivier van de Wiel and Thierry Pollet, Alcatel-Corporate Research Centre, Belgium

SESSION MM-CT02
Multiple-Antenna Systems
10:45-12:30, Intercontinental, Room Onix

Chair: Len Cimini, AT&T, USA

1 Multiple Antennas in Cellular CDMA Systems: Transmission, Detection and Spectral Efficiency 2316
Howard Huang, Harish Viswanathan, and G. J. Foschini, Lucent Technologies, USA

2 New Spread-Spectrum Techniques for Multiple Antenna Transmit Diversity 2321
Dinesh Rajan, Elza Erkip, and Behnaam Aazhang, Rice University, USA

3 Power Control Schemes for TDD Systems with Multiple Transmit and Receive Antennas 2326
Raymond Knopp, Swiss Federal Institute of Technology, Switzerland; Giuseppe Caire, Institut Eurécom, France

4 Exact Error Probability Expressions for MRC in Correlated Nakagami Channels with Unequal Fading Parameters and Branch Powers 2331
Moe Z. Win and Jack H. Winters, AT&T Labs-Research, USA

5 Turbo Coded Modulation for Systems with Transmit and Receive Antenna Diversity 2336
Andrej Stefanov and Tolga M. Duman, Arizona State University, USA

SESSION MA-CT03
Turbo Codes & Iterative Decoding I
14:45-18:15, Intercontinental, Room Agua Marinha

Chair: Max Costa, State University of Campinas, Brazil

1 A Capacity-Approaching Hybrid ARQ Scheme Using Turbo Codes 2341
R. Mantha and F. R. Kschischang, University of Toronto, Canada

2 Performance of Trellis Coded CPM with Iterative Demodulation and Decoding 2346
Krishna r. Narayanan, Texas A&M University; Gordon L. Stüber, Georgia Institute of Technology, USA

3 Semi-Random Interleaver Design Criteria 2352
Christine Fragouli and Richard D. Wesel, University of California at Los Angeles, USA

4 Adapted Iterative Decoding of Product Codes 2357
Annie Picart and Ramesh Pyndiah, ENST-Bretagne, France

5 Turbo Codes for Continuous Hidden Markov Channels with Unknown Parameters 2363
Javier Garcia-Frias, University of Delaware; John D. Villasenor, University of California at Los Angeles, USA

6 Adaptive Iterative Detection for Turbo Codes with Carrier-Phase Uncertainty 2369
Achilleas Anastasopoulos, University of Michigan; Keith M. Chugg, University of Southern California, USA

7 Serial Encoding and Iterative Detection of Continuous Phase Modulations 2375
Christophe Brutel, Matra Nortel Communications; Joseph Boutros, ENST; Fabrice Belvèze, Matra Nortel Communications, France

SESSION MA-CT04
Multiuser Communications
14:45-18:15, Intercontinental, Room Onix

Chair: Yeheskel Bar-Ness, New Jersey Institute of Technology, USA

1 Orthogonal Waveform Multiple Access with Sequential Resource Sharing 2380
Hikmet Sari, Alcatel, France

2 Joint Adaptive Channel Gain Estimator and Multiuser Detector for Asynchronous CDMA Time-Variant Multipath Channels 2385
N. J. M. van Waes and Y. Bar-Ness, New Jersey Institute of Technology, USA

3 Capture Effect in Rician Fading Channels with Application to Slotted ALOHA 2390
Jaime Sanchez, CICESE, Mexico; David R. Smith, The George Washington University, USA

4 Low Complexity Space-Frequency MLSE for Multi-User COFDM 2395
Michael Speth, Andreas Senst, and Heinrich Meyr, Aachen University of Technology, Germany

5 Joint Multiuser Detection and Frequency Offset Correction for Downlink MC-CDMA 2400
Matthijs A. Visser and Yeheskel Bar-Ness, New Jersey Institute of Technology, USA

6 **Performance of Multiuser MMSE Decision Feedback Receiver with Convolutional Codes and Trellis Coded Modulation** 2405
Slavica Marinkovic, Branka S. Vucetic, and Wen Feng, The University of Sidney, Australia

7 **Asymptotic Performance Analysis of Linear Multiuser Receivers in Multipath Fading Channels** 2411
Jamie S. Evans, University of Sidney, Australia; David N. C. Tse, University of California, USA

8 **Wireless Multicasting using CDMA and Multiuser Detection** 2417
Chandrasekar Sankaran and Anthony Ephremides, University of Maryland, USA

SESSION TM-CT05

Source & Channel Coding

9:30-12:30, Intercontinental, Room Agua Marinha

Chair: Giuseppe Caire, Institut Eurecom, France

1 **Estimation of Bit Error Probabilities Using a Priori Information** 2422
M. Kaindl and T. Hindelang, Munich University of Technology, Germany

2 **Improved Tight Performance Bounds on Concatenated Codes** 2427
Rupert Herzog and Cristian Weib, Munich University of Technology, Germany

3 **Coding For Privacy with Burst Adaptive Permutations** 2432
Valdemar C. da Rocha Jr., Federal University of Pernambuco, Brazil

4 **BER Bounds on Parallel Concatenated Single Parity Check Arrays and Zigzag Codes** 2436
Xiaoling Huang and Nam Phamdo, State University of New York at Stony Brook, USA; Li Ping, City University of Hong Kong, Hong Kong

5 **Error Statistics of Constrained Codes on Non-Renewal Burst Channels** 2441
Cecilio Pimentel, Federal University of Pernambuco, Brazil

6 **Symbol-MAP-Based Trellis Vector Quantization** 2446
Tariq Haddad and Abbas Yongaçoglu, University of Ottawa, Canada

7 **Soft-Decoding Combined Trellis-Coded Quantization/Modulation** 2451
Keang-Po Ho and Kwok Hung Chei, The Chinese University of Hong Kong, Hong Kong

SESSION TM-CT06

CDMA

9:30-12:30, Intercontinental, Room Onix

Chair: Valdemar Cardoso, Federal University of Pernambuco, Brazil

1 **CDMA System Design Through Asymptotic Analysis** 2456
Giuseppe Caire, Eurécom, France; Giorgio Taricco and Ezio Biglieri, Politecnico di Torino, Italy

2 **Forward-Link Performance of Satellite CDMA with Linear Interference Suppression and One-step Power Control** 2461
Weimin Xiao and Michael L. Honig, Northwestern University, USA

3 **Subspace-Based Adaptive Multiuser Interference Cancellation for CDMA System** 2467
Ammar Chkeif, Karim Abed-Meraim, and Ghassan Kawas Kaleh, ENST Paris, France

4 **Effect of Circular-Cell Approximation on the Forward-Link BER Performance of a Power-Controlled CDMA System** 2472
Ser W. Oh and Kwok H. Li, Nanyang Technological University, Singapore

5 **An Improved Power-Control Law for Forward-Link Cellular DS-CDMA Systems** 2477
Ser W. Oh and Kwok H. Li, Nanyang Technological University, Singapore

6 **Analysis of a Pipelined Successive Interference Cancellation Scheme for a DS/CDMA System with Various Tentative Decision Strategies** 2482
Dae-Ki Hong and Tae-Yoon Kim, Yonsei University; Young-Hwan You, Korea Electronic Technology Institute; Chang-Eon Kang, Yonsei University, Korea

7 **On DPSK Demodulation of DS/CDMA Signals** 2487
George N. Karystinos and Dimitris A. Pados, State University of New York at Buffalo, USA

SESSION TA-CT07

Modulation & Demodulation

14:30-18:00, Intercontinental, Room Agua Marinha

Chair: Umberto Mengali, University of Pisa, Italy

1 **Maximum Likelihood Detection of Nonlinearly Distorted Multicarrier Symbols by Iterative Decoding** 2493
José Tellado, Gigabit Wireless; Louise M. C. Hoo and John M. Cioffi, Stanford University, USA

2 **Robust and Improved Channel Estimation for OFDM Systems in Frequency Selective Fading Channels** 2499
Baoguo Yang, Tsinghua University, China; K. B. Letaief and Roger S. Cheng, The Hong Kong University of Science & Technology; Zhigang Cao, Tsinghua University, China

3 **Feedback Frequency Synchronization for OFDM Applications** 2504
M. Morelli, A. N. D'Andrea, U. Mengali, University of Pisa, Italy

4 **Joint Impulse Response Shortening for Discrete Multitone Systems** 2508
Bo Wang and Tülay Adali, University of Maryland, USA

5 **Symbol Timing Recovery for Wavelet-Based Linear Modulations** 2513
Marco Luise, Marco Marselli, and Ruggero Reggiannini, University of Pisa, Italy

6 **Noncoherent Trellis Coded Amplitude-Phase Modulation** 2518
Avi Ben-Zur and Dan Raphaeli, Tel Aviv University, Israel

7 **Linear MMSE Channel Estimation for GSM** 2523
Jens Baltersee, Gunnar Fock, and Heinrich Meyr, Aachen University of Technology, Germany; Lihbor Yiin, Lucent Technologies, USA

8 **New Analytical Expressions for Probability of Error for Classes of Orthogonal Signals in Rayleigh Fading** 2528
Xiaodai Dong and Norman C. Beaulieu, Queen's University, Canada

SESSION WM-CT08
Fading Channels
9:30-12:30, Intercontinental, Room Agua Marinha

Chair: Moe Win, AT&T, USA

1 **Pilot-aided Joint Data And Channel Estimation In Flat Correlated Fading** 2534
Christos Komninakis and Richard D. Wesel, University of California at Los Angeles, USA

2 **Coded Modulation for DPSK on Fading Channels** 2540
L. H.-J. Lampe, R. F. H. Fischer, S. Calabrò, and S. H. Müller-Weinfurtner, University of Erlangen-Nuremberg, Germany

3 **Optimal Precoding For Transmissions Over Linear Time-varying Channels** 2545
Sergio Barbarossa, University of Rome "La Sapienza", Italy; Anna Scaglione, University of Minnesota, USA

4 **Transmission Over Fading Channels with Channel Side Information and Delay Constraint** 2550
Rohit Negi and John M. Cioffi, Stanford University, USA

5 **Impact of Modulation and Coding on the Outage Probability for Mobile Radio Systems over Block Fading Channels** 2555
M. Chiani and A. Conti, University of Bologna, Italy

6 **The Effect of Dynamic Range on an Open-loop Power Controlled CDMA System** 2561
Ai Yu and Jiangzhou Wang, The University of Hong Kong, Hong Kong

SESSION WA-CT09
Turbo Codes & Iterative Decoding II
14:30-18:00, Intercontinental, Room Agua Marinha

Chair: Giorgio Taricco, Politecnico di Torino, Italy

1 **Generalized Fixed Points of Permutations With Application To Estimation of Minimum Distance of Turbo Codes** 2566
Fred Daneshgaran, California State University, USA; Marina Mondin, Politecnico di Torino, Italy

2 **Upper Bounds on the State Complexity of Trellis Diagrams for Turbo Codes** 2571
Toshihiko Okamura, NEC, Japan

3 **Exploiting Time and Frequency Diversity by Iterative Decoding in OFDM-CDMA Systems** 2576
Armin Dekorsy, Volker Kühn, and Karl-Dirk Kammeyer, University of Bremen, Germany

4 **A Turbo Trellis Coded Discrete Multitone Transmission System** 2581
Joseph P. Lauer, Broadcom Corporation; John M. Cioffi, Stanford University, USA

5 **Performance of Turbo Codes with Quantized Channel Measurements** 2586
Jean Au and Peter J. McLane, Queen's University, Canada

6 **The SPC Technique and Low Complexity Turbo Codes** 2592
Li Ping, City University of Hong Kong, China

7 **Improved Turbo Decoding Through Belief Propagation** 2597
Saejoon Kim and Stephen B. Wicker, Cornell University, USA

8 Iterative Decoding of Product Codes with a Priori Information over a Gaussian Channel for Still Image Transmission 2602
Abdessamad Elbaz, Ramesh Pyndiah, Basel Solaiman, and Omar Ait Sab, ESNT, France

Symposium on Future Wireless Communication Systems (V05)

SESSION MM-FW01
Signal Processing and Communications Systems
10:45-12:30, Intercontinental, Room Quartzo B

Chair: Michael Yacoub, State University of Campinas

1 A Novel DAB Technique Using Code Combining, Packet Combining and Iterative Decoding (TURBO CODE) 2607
Byung K. Yi and Raymond Pickholtz, George Washington University, USA
2 New DSPs for Next Generation Mobile Communications 2615
Ulrich Walther, Falk Tischer, and Gerhard P. Fettweis, Dresden University of Technology, Germany
3 CEM Modulation & Per-Symbol Detection for High-Data-Rate Multicode DS-CDMA Systems 2620
Dong In Kim, University of Seoul, Korea
4 LMDS from High Altitude Aeronautical Platforms 2625
D. Grace, N. E. Daly, T. C. Tozer, and A. G. Burr, University of York, United Kingdom
5 Performance Evaluation and Link Budget Analysis for 42 GHZ Local Multipoint Distribution Systems 2630
G. Redaelli and S. Marsili, CEFRIEL; G. Coppola and G. Girola, Philips Research Monza, Italy

PANEL MM-FW02
Executive Panel on 3G Wireless Technology, Business and Policy Issues
10:45-12:30, Intercontinental, Room Quartzo A

Organizer: Chih-Lin I, AT&T
Moderator: Jesse Russell, AT&T
Jesse Russell, Chairman, Wireless Communications Division, TIA VP, Advanced Communications, AT&T
William Lee, VP & Chief Scientist, Global Technology, Vodafone AirTouch
Bosco Fernandes, Chairman, Information Communications Technologies, UMTS VP & Global Key Account, Siemens
Akio Sasaki, Director, ARIB (Association of Radio Industries and Businesses) VP, NTT-DoCoMo
Shihe Li, Chairman, China Academy of Telecomm Tech Chairman, Beijing Xinwei Telecom Tech Co.
Mark Epstein, Senior VP, Development, QUALCOMM Chairman, International Standards Coordinating Subcommittee, TIA
George Zysman, CTO and VP, Wireless Comm, Lucent

SESSION MA-FW03
Radio Link Scheduling for Multimedia
14:45-18:15, Intercontinental, Room Quartzo A

Chair: Takeshi Hattori, Sophia University

1 The Delay Decrement Method for Voice/Data Traffic Service in Mobile System 2637
Young-il Kim and Duck-bin Lim, Electronics and Telecommunications Research Institute, Korea
2 Performance of VBR Video with Equalization on Wireless Fading Channels 2642
F. Freiha and K. Chandra, University of Massachusetts Lowell; V. Mehta, Lucent Technologies; C. Thompson, University of Massachusetts Lowell, USA
3 Analysis of the Hybrid HOL/PBS Queuing Scheme for Multiclass Calls in Multimedia PCS 2648
Dong Chun Lee, Howon University; Hyo Young Shin, Kyungbok College; JooSeok Song, Yonsei University, South Korea
4 Downlink Scheduling in CDMA Data Networks 2653
Anand Bedekar, University of Washington; Sem Borst, Kavita Ramanan, and Phil Whiting, Lucent Technologies; Edmund Yeh, Massachusetts Institute of Technology, USA
5 MAC Scheduler Using Polling with Priorities for Future Wireless Multimedia Networks 2658
Nikolaos Georganopoulos and A. H. Aghvami, Kings College London, United Kingdom
6 Wireless ATM MAC Layer Protocol Using WDWEDF and Two-Phase Scheduling Algorithm 2663
Sungwon Lee, Samsung Electronics, Inc.; Young-Jae Song, Kyunghee University; Dong-Ho Cho, Korea Advanced Institute of Science and Technology;
Yong-Bae Dhong and Jung-Won Yang, Korea Electronics Technology Institute, Korea

7 Adaptive Modulation and Scheduling for Fading Channels 2668
Nilo Casimiro Ericsson, Uppsala University, Sweden

8 A Variable Bit Rate Resource Allocation Algorithm for Wireless ATM 2673
Jean-François Frigon, Henry C. B. Chan, and Victor C. M. Leung, The University of British Columbia, Canada

SESSION TM-FW04
IMT2000 Systems
9:30-12:30, Intercontinental, Room Quartzo A

Chair: Hery L. Bertoni, Polytechnic University

1 Performance Analysis of Separate/Combined Air Interface Protocol Structure for IMT2000 System 2678
Sang-Min Jin, Korea Thrunet Co.; Sung-Soo Park, Electronic and Telecommunications Research Institute; Dong-Ho Cho, Korea Advanced Institute of Science and Technology; Pyeong-jung Song, Korea Thrunet Co., Korea

2 The UTRA Concept, Europe's Proposal to IMT-2000 2683
Werner Mohr, Siemens AG, Germany

3 Analysis of Mutual Interference in UMTS/IMT-2000 Mixed-Mode Scenarios 2689
Peter Seidenberg and Marc Peter Althoff, Aachen University of Technology; Egon Schulz, Günther Herbster, and Meik Kottkamp, Siemens AG, Germany

4 The Design and Performance Evaluation of High-Speed Packet Data MAC Protocol for CDMA based IMT2000 2694
Sungwon Lee, Samsung Electronics; Young-Jae Song, Kyunghee University; Dong-Ho Cho, Korea Advanced Institute of Science and Technology; Hyunsuk Lee, Su-Dong Park, and Youngky Kim, Samsung Electronics, Korea

5 ESA Satellite Wideband CDMA Radio Transmission Technology for the IMT-2000/UMTS Satellite Component: Features & Performance 2699
R. De Gaudenzi, European Space Agency, The Netherlands; G. Gallinaro, Space Engineering, Italy; G. Caire, Politecnico di Torino, Italy; R. Lyons, Square-Peg Communications, Canada; M. Ruggieri, University of Rome Tor Vergata, Italy; A. Vernucci, Space Engineering, Italy, H. Widmer, Ascom Systec, Switzerland

6 Comparison of Different Turbo Decoder Realizations for IMT-2000 2704
J. Vogt, K. Koora, A. Finger, and G. Fettweis, Dresden University of Technology, Germany

7 IP Telephony GSM Interworking 2709
Jussi Lemiläinen and Henry Haverinen, Nokia Wireless Business Communications, Finland

SESSION TA-FW05
Capacity and QoS in Advanced Wireless Systems
14:45-18:15, Intercontinental, Room Quartzo A

Chair: Chih-Lin I, AT&T

1 Dual Polarization Waves Reuse Scheme in Cross Polarization Channel 2714
Jungshown Wu and Shan-An Yang, National Taiwan University, Taiwan

2 Performance Enhancement by Narrow-Beam Quad-Sector Cell and Interleaved Channel Assignment in Wireless Networks 2719
Li-Chun Wang and Kin K. Leung, AT&T Labs-Research, USA

3 Load Balancing in Multiband CDMA 2725
Lachlan L. H. Andrew, University of Melbourne, Australia

4 On Call Level QoS Guarantees Under Heterogeneous User Mobilities in Wireless Multimedia Networks 2730
Jelena Misic and Tam Yik Bun, Hong Kong University of Science and Technology, Hong Kong

5 A QoS-Based and Enforceable Burst-level Reservation Protocol for VBR-type Wireless ATM Traffic 2737
Yin-Jieh Chen, National Central University; Jin-Fu Chang, National Taiwan University, Taiwan

6 PRAS: a MAC Protocol for Wireless ATM Networks 2743
Luigi Fratta, Politecnico di Torino; Paolo Giacomazzi, University of Messina; Luigi Musumeci, Politecnico di Torino, Italy

7 Implementation of the Multiclass Priority Fair Queuing (MPFQ) Algorithm for Extending Quality of Service in Existing Backbones to Wireless Endpoints 2752
Jay R. Moorman and John W. Lockwood, University of Illinois at Urbana-Champaign, USA

8 Management of Wireless ATM Networks Loaded by Mobile ABR Source Traffic 2758
A. Lombardo, S. Palazzo, and G. Schembra, University of Catania, Italy

Table of contents

SESSION WM-FW06

Network Access and Handoff

9:30-12:30, Intercontinental, Room Quartzo A

Chair: Werner Mohr, Siemens AG

1 Connection Admission Control for a High Capacity Multimedia Satellite Communication System 2763
Yi Qian, Rose Hu, Hosame Abu-Amara, and Payam Maveddat, Nortel Networks, USA

2 Exact Tracking Performance Analysis of Land Mobile Satellite Channel 2768
H. Besbes, Laboratoire de Systèmes de Télécommunications/Sup'Com; J. Ezzine, Laboratoire d'Analyse et Commande de Systèmes/ENIT; M. Jaidane-Saidane, Laboratoire de Systèmes de Télécommunications/ENIT, Tunisia

3 FS-ALOHA++, A Collision Resolution Algorithm with QoS Support for the Contention Channel in Multiservices Wireless LAN 2773
D. Vázquez Cortizo, University of A Coruña, Spain/University of Antwerp, Belgium; C. Blondia, University of Antwerp, Belgium; J. García, Polytechnic University of Catalunya, Spain

4 Optimal Power Allocation Based on Qos Balance for a Multi-rate Packet CDMA System with Multi-media Traffic 2778
Lin Wang and A. Hamid Aghvami, University of London, United Kingdom

5 Handoff Procedure for Heterogeneous Wireless Networks 2783
M. Ylianttila, R. Pichna, J. Vallström, and J. Mäkelä, University of Oulu, Finland; Ali Zahedi, P. Krishnamurthy, and Kaveh Pahlavan, Worcester Polytechnic Institute, USA

6 Routing and Handoff Support for a Novel Wireless Broadband Access Network (UniNet) 2788
Qiang Gao and Anthony Acampora, University of California at San Diego, USA

7 Soft Handoff on the Quick Paging Channel 2794
Sandip Sarkar, Brian Butler, and Edward Tiedemann, Qualcomm, USA

(*) The BAS papers did not follow the review process

Achieving High Data Rates in CDMA Systems Using BLAST Techniques

Howard Huang, Harish Viswanathan, and G. J. Foschini
Bell Labs, Lucent Technologies; 791 Holmdel-Keyport Rd.; Holmdel, NJ 07030
{hchuang, harishv gjf} @ lucent.com

***Abstract-* We evaluate the capacity of a downlink cellular CDMA system where the transmitters use multiple antennas and the receivers use space-time multiuser detection. We discuss a family of transmission techniques which combine transmit diversity and multicode transmission for achieving high data rates. Higher system spectral efficiencies (greater than one) can potentially be achieved if the same spreading code is used on different antennas to transmit independent substreams. In this case multiple antennas at the receiver distinguish the signals based only on their spatial characteristics. In general, the receivers employ an extension of the BLAST (Bell Labs Layered Space-Time) receiver architecture for wideband CDMA signals. Accounting for shadowing and frequency-selective Rayleigh fading, we develop a novel technique for evaluating the capacity of systems with CDMA BLAST detectors and show that the resulting capacities offer significant improvement over conventional single antenna systems.**

I. INTRODUCTION

High-speed data services will be a major application of future wireless networks. Provisions such as multicode transmission and transmit antenna diversity have been recommended for third generation CDMA systems to provide such services. However, using conventional single-antenna matched filter receivers, the overall system capacities are limited.

In reference [1], high spectral efficiencies were demonstrated for a narrowband point-to-point system with multiple antennas at the transmitter and receiver. In this work, we extend these ideas to study the downlink of a cellular CDMA system. High spectral efficiencies are achieved using multiple antennas and multiuser detection at the receivers. In Section II, we investigate a family of transmission techniques using multiple antennas and orthgonal codes. The received signal at the high-speed mobiles is given in Section III. As described in Section IV, these receivers use multiple antennas and a generalization of the V-BLAST algorithm [2] to account for multiacess interference.

We then determine the resulting spectral efficiency (the number of information bits per chip per sector) from the number of high-speed data users which can be supported in a sector at a given error rate and outage rate. In Section V, we develop a technique based on [3] for determining the system capacity for a multiple antenna system with multiuser detectors, and in Section VI we apply the technique to demonstrate the potential spectral efficiency gains achievable by these enhancements.

II. TRANSMISSION TECHNIQUES

The base station transmitter has three resources: spreading codes, antennas, and power. Our goal is to allocate the resources efficiently among K high-speed data users in a manner that minimizes interference and maximizes the system capacity. We assume that there are M transmit antennas at the base station indexed by $m = 1 \ldots M$. High-speed data transmissions are achieved by demultiplexing a single data stream into G substreams, each with rate R. In general, a substream's power can be arbitrarily distributed and transmitted over space (transmit antennas) and time. However in order to be compatible with current CDMA proposals, we assume that a substream is spread by a length N code and transmitted over one or more antennas (more antennas to achieve transmit diversity). If the same substream is simultaneously transmitted from more than one antenna, different codes are used to spread the data onto each antenna since, otherwise, there would be no gain from transmit diversity. On the other hand, different substreams could be transmitted from up to M antennas using either the same code or different codes. If the same code is used, the receiver would distinguish the substreams based only on their spatial characteristics. If different codes are used, the receiver would use both spatial and code information.

To illustrate the coupling between data substreams, spreading codes and transmit antennas, Figs. 1A – 1D show four assignment options for a given data user's G substreams. Each row represents a transmit antenna ($m = 1,\ldots, M$; $M = 4$), and each column represents a unique orthogonal code.

- Fig. 1A shows the assignment for same code, no transmit diversity ($M_t = 1$) transmission for $G = 8$ substreams. Substreams 1 - 4 are transmitted, respectively, from antennas 1 - 4 using the same code. Substreams 5 - 8 are transmitted, respectively, from antennas 1 - 4 using a different code, so a total of $G/M = 2$ codes is used.
- Fig. 1B shows the assignment for different code, no transmit diversity transmission. The antenna assignments for the substreams is the same as before, but now each substream is assigned a unique code so that a total of $G = 8$ codes is used.
- Fig. 1C shows the assignment for same code transmission with transmit diversity order $M_t = 2$. Each substream is now transmitted twice using different antennas and codes. For the first transmission, the code and antenna assignments are the same as in Fig. 1A. For the second transmission, the antenna assignments are cyclically shifted so that the m_tth transmission ($m_t = 1 \ldots M_t$) of the gth ($g = 1 \ldots G$) substream is through antenna

  $$m = (m_t + g - 2) \bmod M + 1 \qquad (1)$$

  A total of $GM_t / M = 4$ codes is used.
- Fig. 1D shows the assignment for different code transmission with transmit diversity order $M_t = 2$. The antenna assignment is the same as in the corresponding same-code case (using (1)), but now each substream is assigned a unique code so a total of $GM_t = 16$ codes is used.

0-7803-5796-5/99/$10.00 © 1999 IEEE

m	A	B
1	1	5
2	2	6
3	3	7
4	4	8

Code A B

Fig. 1A. Same-code transmission, $M_t = 1$

m	A	B	C	D	E	F	G	H
1	1				5			
2		2				6		
3			3				7	
4				4				8

Code A B C D E F G H

Fig. 1B. Different-code transmission; $M_t = 1$

m	A	B	C	D
1	1	5	4	8
2	2	6	1	5
3	3	7	2	6
4	4	8	3	7

Code A B C D

Fig. 1C. Same-code transmission, $M_t = 2$

m	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	1				5				4				8			
2		2				6				1				5		
3			3				7				2				6	
4				4				8				3				7

Code A B C D E F G H I J K L M N O P

Fig. 1D. Different-code transmission; $M_t = 2$

III. RECEIVED SIGNAL MODEL AND ASSUMPTIONS

We consider the complex baseband received signal at the kth high-speed user's receiver. Each high-speed data user has a P antenna receiver for demodulating its G substreams. The KG data substreams are transmitted out of M antennas, where the antenna assignment for a user's substream is given by (1). The substreams are each spread by a length N code. The multipath channel induces L resolvable multipath components, and the complex fading coefficient among all antennas and multipath components are uncorrelated. The delay spread is small compared to the symbol period so that intersymbol interference can be ignored. Following a chip matched filter, the discrete-time complex baseband received signal for a mobile user at its pth ($p = 1 \ldots P$) antenna during a given symbol period can be written as a complex N-vector:

$$\mathbf{r}_p = \mathbf{S}\tilde{\mathbf{C}}_p\mathbf{A}\mathbf{b} + \mathbf{n}_p \tag{2}$$

where $\mathbf{S}$ is the real N-by-KGM_tL code matrix defined by

$$\begin{aligned}\mathbf{S} \triangleq [&\mathbf{s}_{1,1,1,1}\cdots\mathbf{s}_{1,1,1,L}\cdots\mathbf{s}_{1,1,M_t,1}\cdots\mathbf{s}_{1,1,M_t,L}\cdots\\ &\mathbf{s}_{1,G,1,1}\cdots\mathbf{s}_{1,G,1,L}\cdots\mathbf{s}_{1,G,M_t,1}\cdots\mathbf{s}_{1,G,M_t,L}\cdots\\ &\mathbf{s}_{K,1,1,1}\cdots\mathbf{s}_{K,1,1,L}\cdots\mathbf{s}_{K,1,M_t,1}\cdots\mathbf{s}_{K,1,M_t,L}\cdots\\ &\mathbf{s}_{K,G,1,1}\cdots\mathbf{s}_{K,G,1,L}\cdots\mathbf{s}_{K,G,M_t,1}\cdots\mathbf{s}_{K,G,M_t,L}]\end{aligned}$$

and where $\mathbf{s}_{k,g,m_t,l}$ corresponds to the code sequence of the kth user's gth substream's transmission over the antenna for the m_tth transmission and lth multipath component. For $l = 1$, unique codes (depending on the transmission technique) are independent and binary-valued. The chips values are $\pm 1/\sqrt{N}$, each with probability 1/2. For a given code, its resolvable multipath components $l = 1 \ldots L$ can likewise be modeled as random, binary-valued, and mutually independent codes. Matrix $\tilde{\mathbf{C}}_p$ is a block diagonal KGM_tL-by-KGM_t matrix $diag(\mathbf{C}_p, \cdots, \mathbf{C}_p)$ where $\mathbf{C}_p$ is the complex GM_tL-by-GM_t channel matrix defined by

$$\mathbf{C}_p \triangleq diag\left(\begin{bmatrix}\mathbf{c}_{m(1,1),p}\\ \vdots\\ \mathbf{c}_{m(1,M_t),p}\end{bmatrix}, \ldots, \begin{bmatrix}\mathbf{c}_{m(G,1),p}\\ \vdots\\ \mathbf{c}_{m(G,M_t),p}\end{bmatrix}\right)$$

where in turn $\mathbf{c}_{m(g,m_t),p}$ is the complex L-vector corresponding to the multipath channels between transmit antenna m and the receive antenna p: $\mathbf{c}_{m(g,m_t),p} \triangleq \left[c_{m,p,1} \cdots c_{m,p,L}\right]^T$. The transmit antenna assignment m is given by (1). The channel amplitudes are independent, zero-mean proper complex Gaussian random variables with normalized variance:

$$E\left(c^*_{m_1,l,p_1} c_{m_2,l,p_2}\right) = \begin{cases}0 & \text{if } m_1 \neq m_2 \text{ or } p_1 \neq p_2\\ 1 & \text{if } m_1 = m_2 \text{ and } p_1 = p_2\end{cases} \tag{3}$$

where * denotes the complex conjugate. Matrix $\mathbf{A}$ is a KG-by-KG diagonal matrix of amplitudes defined by $\mathbf{A} \triangleq diag\left(A_{1,1} \cdots A_{1,G} \cdots A_{K,1} \cdots A_{K,G}\right)$. Vector $\mathbf{b}$ is the real KG binary data vector defined by $\mathbf{b} \triangleq \left[b_{1,1} \cdots b_{1,G} \cdots b_{K,1} \cdots b_{K,G}\right]^T$. Vector $\mathbf{n}_p$ is the zero-mean complex (circularly symmetric) Gaussian noise N-vector with i.i.d. components whose real and imaginary components each have variance σ^2.

Note that all the substreams corresponding to a given data user have the same transmit power. We determine the system capacities assuming that the total base station power is fixed. The channel is assumed to be fixed over the duration of the symbol and assumed to be known at the receiver. In other words, we assume that the detectors will have perfect estimates of $c_{m,l,p}$. Channel (and timing) estimates can be obtained from auxiliary pilot channels (one for each transmit antenna), but these are not explicitly accounted for in (2). However, one could interpret $\mathbf{r}_p$ in (2) as an enhanced received signal where the pilot signals have been removed after channel estimation.

IV. DETECTION TECHNIQUE

The jointly optimum detector is the maximum likelihood space-time multiuser detector which jointly detects all *KG* data substreams [4]. Because the complexity of this detector is exponential with respect to the number of substreams, we develop a suboptimal detector based on an extension of the V-BLAST receiver [2] to CDMA spread signals. Shown in Figure 2, the receiver acquires a sufficient statistic vector from the received signal (2) by performing a space-time matched filtering with respect to the codes and channel coefficients [5]. Since the data is binary valued, we then take the real component of each element to obtain the sufficient statistic vector. Letting y be the *KG*-dimensional sufficient statistic vector, we can write

$$\mathbf{y} = \operatorname{Re}\left[\sum_{p=1}^{P} \tilde{\mathbf{C}}_p^H \mathbf{S}^T \mathbf{r}_p\right] = \mathbf{RAb} + \mathbf{n} \tag{4}$$

where $\mathbf{R} \triangleq \sum_{p=1}^{P} \operatorname{Re}\left[\tilde{\mathbf{C}}_p^H \mathbf{S}^T \mathbf{S} \tilde{\mathbf{C}}_p\right]$ is the *KG* -by- *KG* space-time code correlation matrix, where the vector **n** is a real *KG*-dimensional Gaussian noise vector with covariance $\sigma^2\mathbf{R}$, and where the real operator on vectors and matrices is defined by $\operatorname{Re}(\mathbf{x}) \triangleq (\mathbf{x} + \mathbf{x}^*)/2$. Assuming non-orthogonal space-time codes, each component of **y** is corrupted by multiaccess interference from the $G-1$ other substreams destined for that user and the $(K\text{-}1)G$ substreams for the other users. The interuser interference is eliminated using a group decorrelating detector [6], and the remaining intrauser interference is eliminated using the V-BLAST algorithm. For each remaining substream, this algorithm detects the strongest substream using a decorrelator, removes the reconstructed estimate of the strongest (post-decorrelator) substream's signal, and then repeats the process until all *G* substreams are detected. We initialize $\mathbf{X}_p(1) = \mathbf{S}\tilde{\mathbf{C}}_p$ for the *p*th antenna on the first iteration. On successive iterations, $\mathbf{X}_p(j)$ is derived from $\mathbf{X}_p(j-1)$ by striking out the column corresponding to the strongest remaining substream, designated by the index *g*(*j*). Defining $\mathbf{R}(j) \triangleq \sum_{p=1}^{P} \operatorname{Re}\left[\mathbf{X}_p^H(j)\mathbf{X}_p(j)\right]$ and defining $\tilde{\mathbf{R}}(j) \triangleq \left[\mathbf{R}^{-1}(j)_{[1:M-j+1,1:M-j+1]}\right]$ to be upper-left (*M-j*) -by- (*M-j*) submatrix of $\mathbf{R}^{-1}(j)$, the conditional bit error rate for the *g*th substream of user 1, assuming the desired substream's data bit is one, is

$$P_{1,g(j)}(\sigma) = Q\left(\frac{\left[\tilde{\mathbf{R}}^{-1}(j)\sum_{p=1}^{P}\mathbf{X}_p^H(j)\Gamma(j)\right]_{(g(j))}}{\sigma\sqrt{\left[\tilde{\mathbf{R}}^{-1}(j)\right]_{(g(j),g(j))}}}\right) \tag{5}$$

where $\Gamma(j) \triangleq \mathbf{S}\tilde{\mathbf{C}}_p\mathbf{Ab} - \sum_{i=1}^{j-1}\mathbf{S}_{1,g(i)}\begin{bmatrix}\mathbf{c}_{m(g(i),1),p}\\ \vdots \\ \mathbf{c}_{m(g(i),M_t),p}\end{bmatrix}A_1\hat{b}_{1,g(i)}$, where $\hat{b}_{1,g(j)}$ is the bit estimate for the user's *g*(*j*)th bit, and where $[\mathbf{x}]_k$ denotes the *k*th component of the vector **x**. Since the linear transformation $\mathbf{R}^{-1}$ requires the knowledge of all *KG* substream codes, this information could be transmitted to the receiver on an auxiliary control channel.

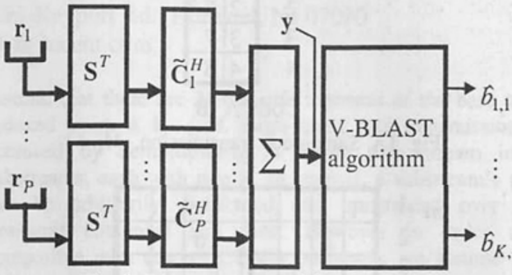

Fig. 2. Block diagram of the space-time decorrelating detector

V. SPECTRAL EFFICIENCY ANALYSIS

In this section we describe the technique for determining capacity in terms of the number of users per sector the system can support. The spectral efficiency is given by the total data throughput per sector divided by the bandwidth. The capacity analysis is based on the approach in [3] for voice, but with suitable modifications to account for multiple transmit and receive antennas and the fact that a decorrelating detector at the front-end of the receiver is used. The capacity analysis consists of two parts: the outage curves and the BER curves.

The outage curves are obtained by randomly distributing a given number of users in each sector of a multiple cell system (we use a 19 cell system with 2 tiers of cells) and then determining the probability that the received Eb/No does not meet the Eb/No requirement for all users. We assume that the cells are divided into three 120 degree sectors, that there is perfect sectorization at the base station (no sidelobe energy), and that there is no soft handoff. The received Eb/No (following the code matched filters and channel combiner but prior to antenna combining) is given by

$$\left(\frac{E_b}{N_o}\right)_{rx} = \frac{\beta S\phi_k\gamma_{k,1}N}{\sum_{b=2}^{19} S\gamma_{k,b} + N_o W} \tag{6}$$

where S is the maximum transmit power available at each base station, $\gamma_{k,b}$ is the shadow fading and path loss from base station b to user k which is communicating with cell 1 (the center cell), ϕ_k is the fraction of the total power available in base station 1 to each substream of user k, N_o is the AWGN spectral density, W is the signal bandwidth, N is the spread factor, β is the fraction of the base station power available for information, and $1-\beta$ is the fraction devoted to the pilot. The denominator term includes the interference and noise terms. The interference term consists only of the out-of-cell interference. Unlike the voice capacity analysis in [3], since a decorrelator detector is used, the in-cell interference is ignored in the outage analysis since it is considered in the BER analysis to derive the target Eb/No. Note that the above equation is independent of the number of transmit and receive antennas since the received Eb/No is measured prior to combining among the *P* receive antennas. Since all the substreams of a given user are demodulated at the same location, each one requires the same transmit power level. Hence the total transmit power to user k for G substreams is $G\phi_k$.

For successful decoding of the received signal the received Eb/No has to be larger than the Eb/No required to meet the target BER. The base station can choose the power fractions $G\phi_k$ to each user just sufficiently large to meet the Eb/No requirement so as to support as many users as possible subject to the total power constraint $\sum_{k=1}^{K} G\phi_k \le 1$. Note that this assumption amounts to having perfect power control in our capacity calculations. An outage event is said to occur if for a given number of users K, it is not possible for all the users to meet their Eb/No requirement, i.e., to satisfy the condition $(E_b/N_0)_{rx} = (E_b/N_0)_{req}$. From (6) this yields

$$\phi_k = \frac{(E_b/N_o)_{req}}{\beta N}\left(\sum_{b=2}^{19}\frac{\gamma_{k,b}}{\gamma_{k,1}} + \frac{N_o W}{S\gamma_{k,1}}\right), \qquad (7)$$

and the outage probability is thus $\Pr\left\{\sum_{k=1}^{K} G\phi_k > 1\right\}$.

This is a probability averaged over the shadow fading and the random user locations. For a fixed Eb/No, we plot the outage probability versus the number of users K. Then for a fixed outage probability, we can plot the measured Eb/No versus K as shown in Fig. 3, using N=128, $\beta = 0.8$, G=1, and activity factor of 1.

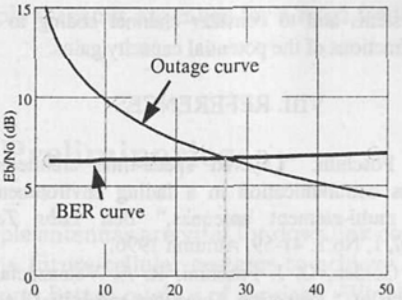

Fig. 3. Determining the number of users from the outage and BER curves

The BER curves determine the required Eb/No to achieve the target BER. As a function of Eb/No, they are generated for a given K, M, M_t, L, and P using the received signal model (2) and BER expression (5). In this context the Eb/No corresponding to (6) is given as $A^2/2\sigma^2$. This is the signal-to-noise ratio after despreading, multipath combining and transmit diversity combining but prior to receive diversity combining. Hence a required Eb/No value obtained from the BER curves can be directly applied in equation (7) to obtain the appropriate outage curve. The additive noise $\mathbf{n}_p$ in BER calculation plays the role of out-of-cell interference and thermal noise. Note that in the case of a decorrelation type detector the BER does not depend on the received power levels of the interfering users. Hence the calculation of the BER can be independent of the power control scheme used. After plotting the BER versus Eb/No for various values of K, then for a fixed BER, we can plot the required Eb/No versus K as shown in Figure 3 (L = 2, M = 1, P= 4, N = 128, using same code transmission).

The resulting system capacity corresponds to the intersection of the outage and BER curves, and given this capacity C in terms of the number of users, the spectral efficiency is the total sector throughput per bandwidth: $SE = CGR/W = CG/N$. The units are given in bits per second per Hertz per sector.

VI. NUMERICAL RESULTS

Fig. 4 shows the system spectral efficiency versus the number of receive antennas. The top three graphs are for same-code transmission, and the bottom three are for different-code transmission. The columns of graphs correspond to different numbers of transmit antennas (M = 2, 4, 8), and the curves in each graph are parameterized by the transmit diversity order (M_t =1, 2, 4). We fix the number of substreams per data user to be G = 8 and consider the spectral efficiency as M, P, and M_t are varied. Assuming the data rate of a single substream is 9.6 Kbps, each data user receives a rate of 76.8Kbps. We assume a spreading factor of N = 128 and L = 2 resolvable multipath components.

We observe that the spectral efficiency increases linearly with the number of receive antennas P. This is because, roughly speaking, the required pre-antenna-combining Eb/No decreases linearly with P; hence for a fixed base station transmit power, increasing the number of antennas results in a corresponding increase in spectral efficiency. Note however that the capacity eventually becomes saturated when the set of orthogonal codes is exhausted. For same-code transmission, the number of codes used is GM_t/M. Hence if the spreading factor is N, the maximum number of users is $(NM)/(GM_t)$, and the maximum spectral efficiency is M/M_t. For different-code transmission, the number of codes used is GM_t, and the maximum spectral efficiency is $1/M_t$. Therefore while both different-code transmission and transmit diversity improve the link performance, the tradeoff is a lower achievable spectral efficiency. It follows that if P is large, we would opt to use same-code transmission and no transmit diversity to achieve the highest spectral efficiency. From Fig. 4 we see that with P = 12, the code limited spectral efficiency of 4 bps/Hz per sector is achieved with M = 4 and M_t = 1. The capacity improvement with M = 8 is negligible considering the additional transmitter and receiver complexity.

If P is small, we would use different-code transmission and as much transmit diversity as possible (without running out of codes) to improve the link performance. With P = 2, the spectral efficiency is maximized (0.32 bps/Hz per sector) using M = 2 antennas, M_t = 2, and different code transmission.

For comparison, we use Monte Carlo simulations to evaluate a voice-only system which uses single antennas at the transmitter and receivers. With a fixed required Eb/No of 7dB and voice activity factor 3/8, this system can support 20 users, resulting in a spectral efficiency of 20/128 = 0.16 bps/Hz per sector.

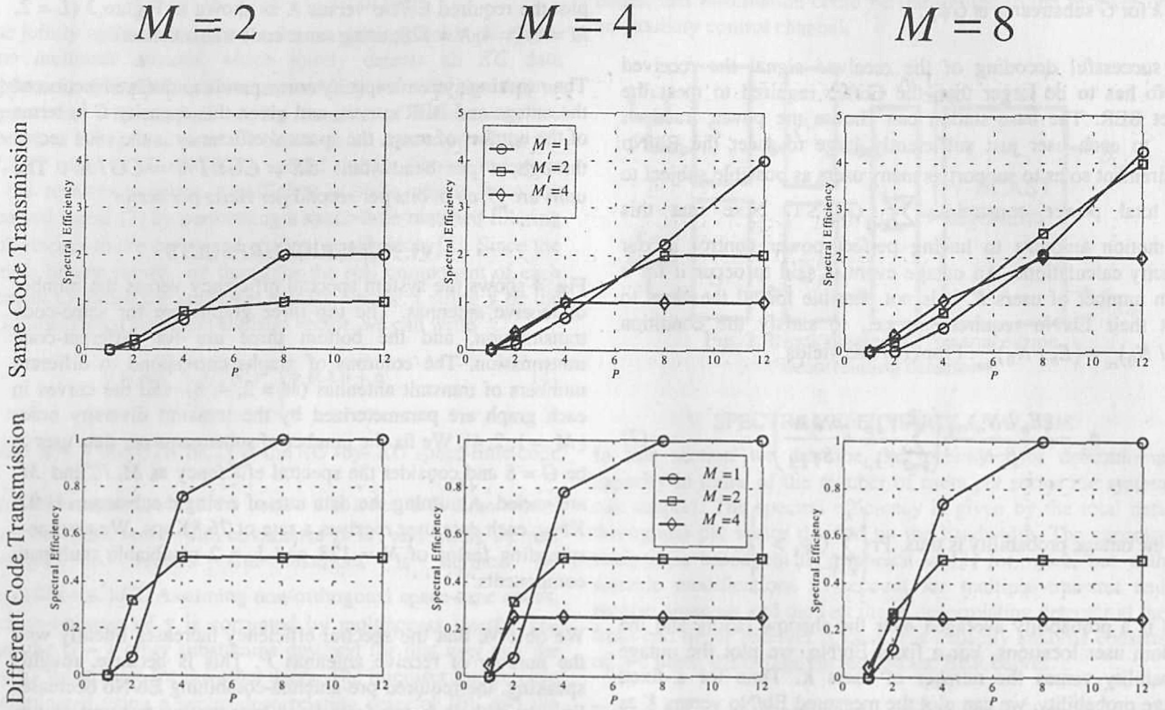

Figure 4. System spectral efficiency

VII. CONCLUSIONS

We studied a high-speed downlink CDMA system which uses multiple antenna transmit diversity, multicode transmission, and space-time detectors. Using a novel technique for evaluating the system capacity, we showed that significant capacity improvements could be achieved. The transmission method which yields the highest system spectral efficiency depends on the number of antennas P at the receivers. If P is small so that the maximum potential spectral efficiency is less than one, we would use the codes liberally to provide signal separation via different code transmission and to improve the link performance via transmit diversity. On the other hand, if P is larger so that the spectral efficiency is potentially greater than one, we would achieve this capacity by conserving codes with same-code transmission and less transmit diversity.

For the range of parameters we considered, the maximum spectral efficiency (4.0 bps/Hz per sector) was achieved using same-code transmission with $M = 4$ transit, $P = 12$ receive antennas, and no transmit diversity.

While we have demonstrated that there is potential for significant capacity gains from using multiple transmit and receive antennas in CDMA systems, the results were based on assumptions such as perfect power control, perfect channel estimation and complex processing at the receiver. It remains for future work to study the effect of non-idealities that occur in practical systems and to consider channel coding to achieve significant fractions of the potential capacity gains.

VIII. REFERENCES

[1] G. J. Foschini, "Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," *Bell Labs Technical Journal*, 1, No.2: 41-59, Autumn 1996.

[2] G. D. Golden, G. J. Foschini, R. A. Valenzuela, P. W. Wolniansky, " Detection Algorithm and Initial Laboratory Results Using V-BLAST Space-Time Communication Architecture," *Electronic Letters*, No. 17, Nov. 1998.

[3] K. S. Gilhousen, I. M. Jacobs, R Padovani, A. J. Viterbi, L. A Weaver Jr., C. E. Wheatley III, "On the Capacity of a Cellular CDMA System," *IEEE Trans. on Vehicular Technology*, Vol. 40, No.2: 303-312, May 1991.

[4] R. Kohno, N. Ishii, and M. Nagatsuka, "A spatially and temporally optimal multi-user receiver using an array antenna for DS/CDMA," *Proc. IEEE Int. Symp. on Personal, Indoor and Mobile Radio Communications*, 3:950-954, Sept. 1995

[5] H. Huang and C. Papadias, "Linear space-time multiuser receivers for wireless CDMA systems," *Proc. IEEE Int. Symp. on Personal, Indoor and Mobile Radio Communications*, Sept. 1998.

[6] M. Varanasi, "Group Detection for Synchronous Gaussian Code-Division Multiple-Access Channels," *Trans. Information Theory,* Vol. 4, No. 4: 1083-1095, July 1995.

```
LEADER 00000cam a2200421Ia 4500
001    44903024
003    OCoLC
005    20160530165108.0
008    000829t19991999njua     b    101 0 eng d
010    87640337
020    0780357965 (softbound)
020    0780357973 (casebound)
020    0780357981 (microfiche)
040    LHL|cLHL|dEEM|dUtOrBLW
049    EEME
090    TK5101.A1|bI146 1999
090    TK5101.A1|bI146 1999
111 2  IEEE Global Telecommunications Conference|d(1999 :|cRio de
       Janeiro, Brazil)|0http://id.loc.gov/authorities/names/
       n83146931
245 10 GLOBECOM 1999 :|bseamless interconntection for universal
       services : conference record, Global Telecommunications
       Conference, 5-9 December 1999, Rio de Janeiro, Brazil,
       Intercontinental and Sheraton Hotels /|csponsored by the
       IEEE Communications Society.
246 38 Seamless interconnection for universal services.
246 30 1999 IEEE GLobal Telecommunications Conference.
260    Piscataway, N.J. :|bIEEE Operations Center,|c[1999],
       ©1999.
300    5 volumes in 6 :|billustrations ;|c28 cm
336    text|btxt|2rdacontent
337    unmediated|bn|2rdamedia
338    volume|bnc|2rdacarrier
500    "IEEE catalog number: 99CH37042"
504    Includes bibliographical references and index.
505 0  v. 1a. General conference (Part A) -- v. 1b. General
       conference (Part B) -- v. 2. Symposium on Access
       Networking ; Symposium on High Speed Networks -- v. 3.
       Symposium on Global Internet: Application and Technology ;
       Symposium on Enterprise Applications and Services -- v. 4.
       Symposium on Multimedia Services and Technology Issues ;
       Symposium on Advanced Signal Processing for Communications
       -- v. 5. Symposium on Communication Theory ; Symposium on
       Future Wireless Communication System.
650  0 Telecommunication|vCongresses.|0http://id.loc.gov/
       authorities/subjects/sh2008112721
650  0 Data transmission systems|vCongresses.|0http://id.loc.gov/
       authorities/subjects/sh2008102044
650  0 Computer networks|vCongresses.|0http://id.loc.gov/
       authorities/subjects/sh2008101222
650  0 Broadband communication systems|vCongresses.|0http://
       id.loc.gov/authorities/subjects/sh2007102163
650  0 Artificial satellites in telecommunication|vCongresses.
       |0http://id.loc.gov/authorities/subjects/sh2007101479
710 2  IEEE Communications Society.|0http://id.loc.gov/
       authorities/names/n79018773
866  0 v. 1A-B, 2-5
994    E0|bEEM
```

LOCATION	CALL # (CLICK TO BROWSE SIMILAR ITEMS)	STATUS
MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.1a	AVAILABLE
MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.1b	AVAILABLE

MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.2	1 HOLD
MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.3	AVAILABLE
MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.4	AVAILABLE
MSU REMOTE STORAGE D	TK5101.A1 I146 1999 v.5	AVAILABLE