Hybrid Strategies for Link Adaptation Exploiting Several Degrees of Freedom in WiMAX Systems

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WiMAX Evolution
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Foreword

Mobile WiMAX: the Enabler for the Mobile Internet Revolution

The Internet has become one the most important assets for the growth of economies across the globe. More than a billion people use the Internet at their workplace and in their daily lives for business interactions, social interactions and entertainment. The Internet has had a profound effect on the economy of developed and developing nations having made economic activity more efficient, accessible and affordable. Most of the productivity gains in today’s economies are thanks to the Internet and ecommerce. There have been profound social impacts from increased the access to valuable information and social interaction between the masses. The impact is at many socioeconomic levels: business productivity, energy savings, healthcare delivery, improved government functions, education, improved citizen interactions (locally and globally), etc. Despite the benefits of the Internet, today only about 20% of the World's population have access to the Internet. In particular, the emerging countries that could benefit greatly are seriously deprived of this valuable asset. There are a number of reasons for the small number of users in the emerging countries: lack of infrastructure, affordability of personal computers, unaffordable access fees, etc.

The next big step in the evolution of the Internet is ubiquitous availability enabled through mobile Internet. This revolutionary step is poised to increase the value of the Internet enormously as it will create a fundamental shift in the use of the Internet by bringing the Internet to the users as opposed to users having to go to the Internet. For this vision to become a reality, a number of requirements need to be met. First and foremost, affordable and ubiquitous mobile Internet access needs to be provided using the mobile cellular concept. This is poised to be fulfilled thanks to mobile WiMAX. Secondly, affordable and low-power mobile Internet devices and mobile PCs are needed. This is also happening with the computer industry making huge strides in making these devices more affordable. The low-cost netbook category with examples such as the ASUS Eee PC and variety of small mobile PCs or Mobile Internet Devices (MIDs) are now available and will undoubtedly become even more affordable in the near future.

Mobile WiMAX has been designed with the purpose of enabling mobile Internet from the physical layer to the network layer. The physical layer design relies on Orthogonal Frequency Division Multiple Access (OFDMA) and Multiple Input Multiple Output (MIMO) as the two key technologies to optimize coverage and spectral efficiency. In addition, sophisticated techniques for link adaptation and error control provide improved performance and robustness. Mobile WiMAX technology includes many other important aspects such as security
and power-saving methods, provisions for location-based services, support for hierarchical deployments, quality-of-service, and open Internet user and network management schemes, which are essential in enabling deployment and consumer adoption of the technology.

The Internet is dynamic by nature and is evolving rapidly on the application level and creating ever-increasing demands on connectivity. Studies indicate that Internet traffic has been doubling roughly every two years. Mobile Internet will undoubtedly change the Internet as we know it today and may create even more traffic than ever anticipated. Mobile WiMAX needs to evolve constantly to keep up with the growth of mobile Internet. The WiMAX industry has already been working on the next technology in IEEE 802.16m to build the basis for the next generation of mobile Internet.

This book provides the material that is essential to understand the underlying concepts for mobile WiMAX and it also provides an overview of technologies that will enable the evolution of the technology in the future. I sincerely hope that the book will further motivate researchers and developers to create innovative ideas and techniques that will help fulfill the promise of the new era of mobile Internet.

*Siavash M. Alamouti*, Intel Fellow
Chief Technology Officer, Mobile Wireless Group
Preface

The remarkable development of wireless and mobile communications in the last two decades is a unique phenomenon in the history of technology. Even the most optimistic predictions on penetration of mobile subscribers and capabilities of wireless devices have been surpassed by reality. In a quarter of a century the number of mobile subscribers soared from a few to half the world population (in 2008), and according to some forecasts by 2010 the number of mobile users will exceed the number of toothbrush users (four billion). The Wireless World Research Forum (WWRF) envisions that by year 2017 there will be seven trillion wireless devices serving seven billion people. Two main development directions in untethered communications can be identified, wide-area communications, with the omnipresent cellular systems as the most representative example, and short-range communications, involving an array of networking technologies for providing wireless connectivity over short distances, for instance Wireless Local Area Networks (WLANs), Wireless Personal Area Networks (WPANs), Wireless Body Area Networks (WBANs), Wireless Sensor Networks (WSNs), Bluetooth, etc. Recent years have witnessed an enormous growth in interest in the metropolitan wireless networks. This should not be a surprise, as in 2008, for the first time in history more than half of the world population lives in urban areas, according to the United Nations Population Fund. WiMAX (Worldwide Interoperability for Microwave Access) is the most representative worldwide initiative focusing on metropolitan communications. WiMAX, based on the IEEE 802.16 standard, defines wireless networks combining key characteristics of wide-area cellular networks as well as short-range networks, namely mobility and high data throughput. IEEE 802.16 is a very active and rapidly evolving standard that serves as the fundamental basis for WiMAX systems. Several amendments are currently being developed addressing particular technical aspects or capabilities, including 802.16g, 802.16h, 802.16i, 802.16j, 802.16k and 802.16m. There are already several books dealing with WiMAX technology, describing mostly the basic operating principles, current standards and associated technical solutions. The current vertiginous developments in the WiMAX arena have lead the Editors to conceive of this book, taking over where most of the published WiMAX volumes left off, that is, looking in future directions. Leading research scientists and engineers from key WiMAX industry, academia and research centers worldwide have contributed to this book with their ideas, concepts, concrete technical suggestions and visions.

As WiMAX as a whole encompasses a very broad area, it is impossible to find a single author able to write in detail about a large array of advanced concepts and solutions applicable at different system levels of WiMAX: the Editors have thus invited specialists in the field to contribute with their ideas in different chapters. The goal of this book is
Figure 1 WiMAX evolution: organization of the book.

As shown in Figure 1, this book has been organized into six independent parts, covering different aspects of WiMAX technology and its evolution. Part One overview of the current state of WiMAX technology, serving as an introduction to WiMAX. Part Two presents measurements and validation results carried out on real state-of-the-art WiMAX testbeds (fixed and mobile), providing unique results on the achievable capabilities of commercial equipment operating in real scenarios. Novel scenarios and business cases for WiMAX are considered in Part Three. In Part Four new promising architectures for WiMAX are discussed, including wireless sensor networks, mesh and cooperative networking as well as femtocells. Part Five discusses several extensions to the current WiMAX, that is, new solutions that can be used in conjunction with the current WiMAX standard. Finally, Part Six looks into technical developments beyond the immediate WiMAX future, including PHY and MAC evolution, prospects and visions, emerging technologies, evolution of standards, etc.

WiMAX Evolution: Emerging Technologies and Applications is a book intended for research, development and standardization engineers working in industry, as well as for scientists in academic and research institutes. Graduate students conducting research in
WiMAX and next generation mobile communications will also find in this book relevant material for further research. The Editors think that this book provides novel views and detailed technical solutions, foreseeing future WiMAX while being a stimulating source of inspiration for further advanced research in the field.

The Editors welcome any suggestions, comments or constructive criticism on this book. Such feedback will be used to improve forthcoming editions. The Editors can be contacted at wimaxeditor@es.aau.dk.

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Frank H.P. Fitzek  
_Aalborg University, Denmark_

September 2008
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At times, our own light goes out, and is rekindled by a spark from another person. Each of us has cause to think with deep gratitude of those who have lighted the flame within us.

Albert Schweitzer

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<td>MicroController</td>
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<tr>
<td>16-QAM</td>
<td>16 Quadrature Amplitude Modulation</td>
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<td>2G</td>
<td>2nd Generation</td>
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<td>3G</td>
<td>3rd Generation</td>
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<td>3GPP</td>
<td>3rd Generation Partnership Project</td>
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<tr>
<td>3GPP2</td>
<td>3rd Generation Partnership Project 2</td>
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<td>4G</td>
<td>Fourth Generation</td>
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<tr>
<td>A/V</td>
<td>Audio/Visual</td>
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<td>AAA</td>
<td>Authentication, Authorization and Accounting</td>
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<tr>
<td>AAS</td>
<td>Adaptive Antenna System</td>
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<tr>
<td>AC</td>
<td>Admission Control; Antenna Circulation</td>
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<tr>
<td>ACIR</td>
<td>Adjacent Channel Interference Ratio</td>
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<tr>
<td>ACK</td>
<td>Acknowledgement</td>
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<tr>
<td>ACR</td>
<td>Absolute Category Rating</td>
</tr>
<tr>
<td>ADSL</td>
<td>Asymmetric Digital Subscriber Line</td>
</tr>
<tr>
<td>AG</td>
<td>Antenna Grouping</td>
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<tr>
<td>AMC</td>
<td>adaptive modulation and coding</td>
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<tr>
<td>AMR</td>
<td>Adaptive Multi-Rate</td>
</tr>
<tr>
<td>AMS</td>
<td>Adaptive MIMO Switching</td>
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<tr>
<td>AP</td>
<td>Access Point</td>
</tr>
<tr>
<td>APD</td>
<td>Adaptive Power Distribution</td>
</tr>
<tr>
<td>APFR</td>
<td>Adaptive Power Fixed Rate</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>APMC</td>
<td>Adaptive Power, Modulation and Coding</td>
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<tr>
<td>AQ</td>
<td>Assessed QoS</td>
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<tr>
<td>ARP</td>
<td>Address Resolution Protocol</td>
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<tr>
<td>ARQ</td>
<td>Automatic Repeat Request</td>
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<tr>
<td>AS</td>
<td>Antenna Selection</td>
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<tr>
<td>ASN</td>
<td>Access Service Network</td>
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<tr>
<td>ASN-GW</td>
<td>Access Service Network Gateway</td>
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<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
</tr>
<tr>
<td>AVC</td>
<td>Advanced Video Coding</td>
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<tr>
<td>AWGN</td>
<td>Additive White Gaussian Noise</td>
</tr>
<tr>
<td>BD</td>
<td>Block Diagonalization</td>
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<tr>
<td>BE</td>
<td>Best Effort</td>
</tr>
<tr>
<td>BER</td>
<td>Bit Error Rate</td>
</tr>
<tr>
<td>BF</td>
<td>Beamforming</td>
</tr>
<tr>
<td>BGP</td>
<td>Border Gateway Protocol (routing)</td>
</tr>
<tr>
<td>BLER</td>
<td>Block Error Rate</td>
</tr>
<tr>
<td>BOM</td>
<td>Bill Off Materials</td>
</tr>
<tr>
<td>bps</td>
<td>Bits Per Second</td>
</tr>
<tr>
<td>BPSK</td>
<td>Binary Phase Shift Keying</td>
</tr>
<tr>
<td>BS</td>
<td>Base Station</td>
</tr>
<tr>
<td>BSID</td>
<td>Base Station Identifier</td>
</tr>
<tr>
<td>BWA</td>
<td>Broadband Wireless Access</td>
</tr>
<tr>
<td>C/I</td>
<td>Carrier to Interference Ratio</td>
</tr>
<tr>
<td>CAPEX</td>
<td>Capital Expenditures</td>
</tr>
<tr>
<td>CATV</td>
<td>Cable Television</td>
</tr>
<tr>
<td>CBC</td>
<td>Cipher Block Chaining</td>
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<tr>
<td>CBF</td>
<td>Coordinated Beamforming</td>
</tr>
<tr>
<td>CBR</td>
<td>Constant Bit Rate</td>
</tr>
<tr>
<td>CC</td>
<td>Chase Combining; Convolutional Code; Coordination Center</td>
</tr>
<tr>
<td>CCF</td>
<td>Call Control Function</td>
</tr>
<tr>
<td>CCP2P</td>
<td>Cellular Controlled Peer to Peer</td>
</tr>
<tr>
<td>CDF</td>
<td>Cumulative Distribution Function</td>
</tr>
<tr>
<td>CDL</td>
<td>Clustered Delay Line</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<td>---------</td>
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<tr>
<td>CDMA</td>
<td>Code Division Multiplex Access</td>
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<tr>
<td>CELP</td>
<td>Code Excited Linear Prediction</td>
</tr>
<tr>
<td>CH</td>
<td>Compressed Header</td>
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<tr>
<td>C/I</td>
<td>Carrier-to-Interference Ratio</td>
</tr>
<tr>
<td>CID</td>
<td>Connection Identifier</td>
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<tr>
<td>CI-STBC</td>
<td>Coordinate Interleaved Space–Time Block Code</td>
</tr>
<tr>
<td>CMIP</td>
<td>Client Mobile IP</td>
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<td>CN</td>
<td>Correspondent Node</td>
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<td>CNL</td>
<td>VTT Converging Networks Laboratory</td>
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<tr>
<td>CNR</td>
<td>Channel-to-Noise Ratio</td>
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<tr>
<td>CoA</td>
<td>Care-of-Address</td>
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<tr>
<td>CODEC</td>
<td>Compression/Decompression</td>
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<tr>
<td>COST</td>
<td>European Cooperation in the Field of Scientific and Technical Research</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial Off The Shelf</td>
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<tr>
<td>CP</td>
<td>Cyclic Prefix</td>
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<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
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<tr>
<td>CPS</td>
<td>Common Part Sublayer</td>
</tr>
<tr>
<td>CPU</td>
<td>Central Processing Unit</td>
</tr>
<tr>
<td>CQI</td>
<td>Channel Quality Indicator</td>
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<tr>
<td>CQICH</td>
<td>Channel Quality Indicator Channel</td>
</tr>
<tr>
<td>CRC</td>
<td>Cyclic Redundancy Check</td>
</tr>
<tr>
<td>CS</td>
<td>Convergence Sublayer</td>
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<tr>
<td>C-SAP</td>
<td>Control Service Access Point</td>
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<tr>
<td>CSG</td>
<td>Closed Subscriber Group</td>
</tr>
<tr>
<td>CSI</td>
<td>Channel State Information</td>
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<tr>
<td>CSN</td>
<td>Connectivity Services Network</td>
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<tr>
<td>CTS</td>
<td>Clear to Send</td>
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<tr>
<td>DAS</td>
<td>Distributed Antenna System</td>
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<tr>
<td>DCA</td>
<td>Dynamic Channel Allocation</td>
</tr>
<tr>
<td>DCD</td>
<td>Downlink Channel Descriptor</td>
</tr>
<tr>
<td>DCF</td>
<td>Discounted Cash Flow</td>
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<tr>
<td>DES</td>
<td>Data Encryption Standard</td>
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<tr>
<td>DFB</td>
<td>Distributed Feedback</td>
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<td>DHCP</td>
<td>Dynamic Host Configuration Protocol</td>
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<tr>
<td>DL</td>
<td>Downlink</td>
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<tr>
<td>DMTBR</td>
<td>Dynamic Multiple-Threshold Bandwidth Reservation</td>
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<tr>
<td>DNS</td>
<td>Domain Name System</td>
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<tr>
<td>DNS-SD</td>
<td>Dynamic Name System Service Discovery</td>
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<tr>
<td>DPT</td>
<td>Dirty Paper Theory</td>
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<tr>
<td>DRR</td>
<td>Deficit Round Robin</td>
</tr>
<tr>
<td>DRX</td>
<td>Discontinuous Reception</td>
</tr>
<tr>
<td>DS-CDMA</td>
<td>Direct Sequence Code Division Multiple Access</td>
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<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
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<tr>
<td>DSLAM</td>
<td>Digital Subscriber Line Access Multiplexer</td>
</tr>
<tr>
<td>DWRR</td>
<td>Deficit Weighted Round Robin</td>
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<td>EAP</td>
<td>Extensible Authentication Protocol</td>
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<tr>
<td>ECMP</td>
<td>Equal Cost Multi-Path</td>
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<tr>
<td>EDF</td>
<td>Earliest Deadline First</td>
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<tr>
<td>EpBR</td>
<td>Energy per Bit Ratio</td>
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<tr>
<td>ertPS</td>
<td>Extended Real-Time Polling Service</td>
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<td>ERT-VR</td>
<td>Extended Real-Time Variable Rate</td>
</tr>
<tr>
<td>ESP</td>
<td>Encapsulating Security Payload</td>
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<tr>
<td>ETX</td>
<td>Expected Transmission Count</td>
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<td>EVD</td>
<td>Eigenvalue Decomposition</td>
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<td>EVRC</td>
<td>Enhanced Variable Rate Codec</td>
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<td>FA</td>
<td>Foreign Agent</td>
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<td>FBSS</td>
<td>Fast Base Station Switching</td>
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<td>FCH</td>
<td>Frame Control Header</td>
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<td>FDD</td>
<td>Frequency-Division Duplex</td>
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<td>FDM</td>
<td>Frequency Division Multiplexing</td>
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<td>FEC</td>
<td>Forward Error Correction</td>
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<td>FER</td>
<td>Frame Error Rate</td>
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<td>FFMS</td>
<td>Forest Fire Monitoring Station</td>
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<td>FFT</td>
<td>Fast Fourier Transform</td>
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<td>FIFO</td>
<td>First In First Out</td>
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<td>FP</td>
<td>Framework Programme</td>
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<td>FPAR</td>
<td>Fixed Power Adaptive Rate</td>
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<td>FPGA</td>
<td>Field-programmable Gate Array</td>
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<td>FTP</td>
<td>File Transfer Protocol</td>
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<td>FUSC</td>
<td>Fully Used Subcarriers</td>
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<td>GA</td>
<td>Generic Adapter</td>
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LIST OF ACRONYMS

GIS Geographic Information Systems
GIST General Internet Signaling Transport
GMH Generic MAC Header
GoS Grade of Service
GPRS General Packet Radio Service
GPS Global Positioning System
GRE Generic Routing Encapsulation
GSM Global System for Mobile Communications
GTP GPRS Tunneling Protocol
GUI Graphical User Interface
GW Gateway
HA High Availability; Home Agent
HARQ Hybrid Automatic Repeat Request
HD High Definition
HFC Hybrid Fiber Coaxial
HFDD Half-duplex Frequency Division Duplex
HFR Hybrid Fiber Radio
HHO Hard Handover
HO Handover
HSDPA High Speed Data Packet Access
HSPA High Speed Packet Access
HSRP Hot Standby Router Protocol
HTTP Hyper Text Transfer Protocol
HW Hardware
ICMP Internet Control Message Protocol
ICT Information and Communication Technologies
ID Identification
IETF Internet Engineering Task Force
IFFT Inverse Fast Fourier Transform
IMDD Intensity Modulation, Direct Detection
IMS IP Multimedia Subsystem
IMT International Mobile Telecommunications
IP Internet Protocol
Ipsec Internet Protocol Security
IPTV Internet Protocol Television
IPv4 Internet Protocol version 4
IPv6 Internet Protocol version 6
IQ Intrinsic QoS
IQA Instrumental Quality Assessment
IRR Internal Rate of Return
ISD Inter-site Distance
IST Information Society Technologies
ITU International Telecommunications Union
kbps kilobits per second (1000 bits s⁻¹)
KPI Key Performance Indicator
L1 Layer 1 (Physical Layer)
L2 Layer 2 (Data Link Layer)
L2TP Layer 2 Tunneling Protocol
LA Link Adaptation
LACP Link Aggregation Control Protocol
LAG Ling Aggregation
LAN Local Area Network
LBC Load Balancing Cycle
LBS Location Based Services
LDAP Lightweight Directory Access Protocol
LLA Low Level Agent
LLL Lenstra–Lenstra–Lovász
LOS Line-of-Sight
LPC Linear Predictive Coding
LPM Loss Packet Matrix
LSB Least Significant Bit
LTE Long Term Evolution
LU Lenstra–Lenstra–Lovász
MAC Medium Access Control
MAN Metropolitan Area Network
MAP Medium Access Protocol; Mobile Application Part
MBAC Measurement Based Admission Control
MBB Make Before Break
MBMS Multimedia Broadcast Multicast Service
Mbps Megabits per second (1 000 000 bits s⁻¹)
MBS Mesh Base Station; Multicast and Broadcast Service
MCBCS Multicast and Broadcast Service
MCS Modulation and Coding Scheme
**LIST OF ACRONYMS**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCW</td>
<td>Multi Codeword</td>
</tr>
<tr>
<td>MDHO</td>
<td>Macro Diversity Handover</td>
</tr>
<tr>
<td>MeSH</td>
<td>IEEE 802.16-2004 Mesh Mode</td>
</tr>
<tr>
<td>MIB</td>
<td>Management Information Base</td>
</tr>
<tr>
<td>MICS</td>
<td>Media Independent Command Service</td>
</tr>
<tr>
<td>MIES</td>
<td>Media Independent Event Service</td>
</tr>
<tr>
<td>MIH</td>
<td>Media Independent Handover</td>
</tr>
<tr>
<td>MIHF</td>
<td>Media Independent Handover Function</td>
</tr>
<tr>
<td>MIHO</td>
<td>Mobile Initiated Handover</td>
</tr>
<tr>
<td>MIHU</td>
<td>Media Independent Handover User</td>
</tr>
<tr>
<td>MIIS</td>
<td>Media Independent Information Service</td>
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<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
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<tr>
<td>MIP</td>
<td>Mobile Internet Protocol</td>
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<tr>
<td>ML</td>
<td>Maximum Latency</td>
</tr>
<tr>
<td>MLD</td>
<td>Maximum Likelihood Decoder</td>
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<td>MLI</td>
<td>Modulation Level Information</td>
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<tr>
<td>MM</td>
<td>Mobility Management</td>
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<tr>
<td>MMF</td>
<td>Multimode Fiber</td>
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<tr>
<td>MMR</td>
<td>Mobile Multihop Relay</td>
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<tr>
<td>MMSE</td>
<td>Minimum Mean Square Error</td>
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<tr>
<td>MN</td>
<td>Mobile Node</td>
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<tr>
<td>MOS</td>
<td>Mean Opinion Score</td>
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<tr>
<td>MPEG</td>
<td>Moving Picture Experts Group</td>
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<tr>
<td>MRC</td>
<td>Maximum Ratio Combining</td>
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<tr>
<td>MRT</td>
<td>Maximum Ratio Transmission</td>
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<tr>
<td>MRTR</td>
<td>Minimum Reserved Traffic Rate</td>
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<tr>
<td>MS</td>
<td>Mobile Station</td>
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<tr>
<td>M-SAP</td>
<td>Management Service Access Point</td>
</tr>
<tr>
<td>MSB</td>
<td>Most Significant Bit</td>
</tr>
<tr>
<td>MSDU</td>
<td>MAC Service Data Unit</td>
</tr>
<tr>
<td>MSE</td>
<td>Mean Square Error</td>
</tr>
<tr>
<td>MSID</td>
<td>Mobile Subscriber ID</td>
</tr>
<tr>
<td>MSTR</td>
<td>Maximum Sustained Traffic Rate</td>
</tr>
<tr>
<td>MTBF</td>
<td>Mean Time Between Failures</td>
</tr>
<tr>
<td>MTU</td>
<td>Maximum Transmission Unit</td>
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<tr>
<td>NACK</td>
<td>Negative Acknowledgement</td>
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<tr>
<td>NAI</td>
<td>Network Access Identifier</td>
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<tr>
<td>NC</td>
<td>Network Coding</td>
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<tr>
<td>NCMS</td>
<td>Network Control and Management System</td>
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<tr>
<td>NDCQ</td>
<td>Nondegenerate Constraint Qualification</td>
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<tr>
<td>NE</td>
<td>Network Element</td>
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<tr>
<td>NET</td>
<td>Network Layer</td>
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<tr>
<td>NGMN</td>
<td>Next-Generation Mobile Network</td>
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<td>NGN</td>
<td>Next Generation Network</td>
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<td>NIHO</td>
<td>Network Initiated Handover</td>
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<td>NLOS</td>
<td>Non-Line-of-Sight</td>
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<td>NMS</td>
<td>Network Management System</td>
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<tr>
<td>NPV</td>
<td>Net Present Value</td>
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<td>NRM</td>
<td>Network Reference Model</td>
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<tr>
<td>nrt</td>
<td>Non-real-time</td>
</tr>
<tr>
<td>nrtPS</td>
<td>Non-real-time Polling Service</td>
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<tr>
<td>NSIS</td>
<td>Next Steps in Signaling</td>
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<tr>
<td>NSLP</td>
<td>NSIS Signaling Layer Protocol</td>
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<tr>
<td>NTLP</td>
<td>NSIS Transport Layer Protocol</td>
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<tr>
<td>NTP</td>
<td>Network Time Protocol</td>
</tr>
<tr>
<td>NWG</td>
<td>Network Working Group</td>
</tr>
<tr>
<td>O&amp;M</td>
<td>Operations and Management</td>
</tr>
<tr>
<td>OFDM</td>
<td>Orthogonal Frequency Division Multiplexing</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency Division Multiple Access</td>
</tr>
<tr>
<td>OGBF</td>
<td>Orthogonal Beamforming</td>
</tr>
<tr>
<td>OMC</td>
<td>Operation and Maintenance Center</td>
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<tr>
<td>OMF</td>
<td>Operation and Maintenance Function</td>
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<td>OPEX</td>
<td>Operational Expenditures</td>
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<tr>
<td>OSPF</td>
<td>Open Shortest Path First</td>
</tr>
<tr>
<td>P2P</td>
<td>Peer to Peer</td>
</tr>
<tr>
<td>PA</td>
<td>ITU Pedestrian A</td>
</tr>
<tr>
<td>PB</td>
<td>ITU Pedestrian B</td>
</tr>
<tr>
<td>PAN</td>
<td>Personal Area Network</td>
</tr>
<tr>
<td>PAPR</td>
<td>Peak to Average Power Ratio</td>
</tr>
<tr>
<td>PBE</td>
<td>Perfect Bayesian Equilibrium</td>
</tr>
<tr>
<td>PC</td>
<td>Paging Controller; Power Control</td>
</tr>
<tr>
<td>PCM</td>
<td>Pulse Code Modulation</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assistant</td>
</tr>
<tr>
<td>PDU</td>
<td>Protocol Data Unit</td>
</tr>
</tbody>
</table>
LIST OF ACRONYMS

PEP Performance Enhancing Proxy
PER Packet Error Rate
PHB Per Hop Behavior
PHY Physical Layer
PLC Packet Loss Concealment
PLR Packet Loss Rate
PMIP Proxy Mobile IP
PMP Point to Multipoint
PN Psedorandom Noise
POF Plastic Optical Fiber
PQ Perceived QoS
PSTN Public Switched Telephone Network
PTMP Point-to-Multipoint
PTP Precision Time Protocol
PTP Point-to-point
PU2RC Per-User Unitary and Rate Control
PUSC Partially Used Subcarrier; Partially Used Subchannelization
QAM Quadrature Amplitude Modulation
QoE Quality of Experience
QoS Quality of Service
QPSK Quadrature Phase-Shift Keying
RADIUS Remote Authentication Dial-In User Service
RAN Radio Access Network
RAU Remote Antenna Unit
RB Resource Block
RF Radiofrequency
RFC Request for Comments (IETF standard document)
RMF Resource Management Function
RMS Root Mean Square
RoF Radio-over-Fiber
ROHC Robust Header Compression
RRM Radio Resource Management
RS Relay Station
RSS Received Signal Strength
RSSI Received Signal Strength Indicator
rt real-time
RTP Real-time Transport Protocol
rtPS Real-Time Polling Service
RTS Request to Send
RTT Round Trip Time
RT-VR Real-Time Variable Rate
Rx Receive
SA Specific Adapter
SAF Service Availability Forum
SAMPDA Simple Adaptive Modulation and Power Adaptation Algorithm
SAP Service Access Point
SBS Serving Base Station
SC Serra do Carvalho
SCM Spatial Channel Model
SCR Spare Capacity Report
SCTP Stream Control Transmission Protocol
SCW Single Codeword
SDMA Spatial Division Multiple Access
SDU Service Data Unit
SE Spectral Efficiency
SF Service Flow
SFDR Spurious Free Dynamic Range
SFM Service Flow Management
SID Silent Insertion Descriptor
SINR Signal-to-Interference + Noise Ratio
SIP Session Initiation Protocol
SISO Single Input Single Output
SL Serra da Lousã
SLA Service Level Agreement
SM Spatial Multiplexing
SMF Singlemode Fiber
SMS Short Message Service
SNMP Simple Network Management Protocol
SNR Signal-to-Noise Ratio
S-OFDMA Scalable Orthogonal Frequency Division Multiple Access
SOHO Small Office/Home Office
SON Self-Organized Network
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>SP</td>
<td>Synchronization Pattern</td>
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<tr>
<td>SRA</td>
<td>Simple Rate Adaptation</td>
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<td>SRD</td>
<td>System Requirement Document</td>
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<td>SS</td>
<td>Subscriber Station</td>
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<td>SSL</td>
<td>Secure Socket Layer</td>
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<td>STBC</td>
<td>Space Time Block Coding</td>
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<tr>
<td>STC</td>
<td>Space-Time Coding</td>
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<tr>
<td>SUI</td>
<td>Standford University Interim</td>
</tr>
<tr>
<td>SW</td>
<td>Software</td>
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<td>TBS</td>
<td>Target Base Station</td>
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<td>TCP</td>
<td>Transmission Control Protocol</td>
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<td>TDD</td>
<td>Time Division Duplex</td>
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<td>TDM</td>
<td>Time Division Multiplexing</td>
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<td>TDMA</td>
<td>Time Division Multiple Access</td>
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<tr>
<td>TEM</td>
<td>Telecommunications Equipment Manufacturer</td>
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<tr>
<td>TETRA</td>
<td>Terrestrial Trunked Radio</td>
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<tr>
<td>TTI</td>
<td>Transmission Time Interval</td>
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<td>TTP</td>
<td>Trusted Third Party</td>
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<td>TWG</td>
<td>Technical Working Group</td>
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<tr>
<td>Tx</td>
<td>Transmit</td>
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<td>University of Coimbra</td>
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<td>UCD</td>
<td>Uplink Channel Descriptor</td>
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<td>UDP</td>
<td>User Datagram Protocol</td>
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<td>UGS</td>
<td>Unsolicited Grant Service</td>
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<td>UL</td>
<td>Uplink</td>
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<td>UMB</td>
<td>Ultra Mobile Broadband</td>
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<td>UMTS</td>
<td>Universal Mobile Telecommunications System</td>
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<tr>
<td>UMTS-LTE</td>
<td>Universal Mobile Telecommunications Systems – Long Term Evolution</td>
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<td>VAD</td>
<td>Voice Activity Detection</td>
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<td>VBR</td>
<td>Variable Bit Rate</td>
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<td>VCEG</td>
<td>Video Coding Experts Group</td>
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<td>VCSEL</td>
<td>Vertical Cavity Surface Emitting Laser</td>
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<td>VDT</td>
<td>Virtual Drive Test</td>
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<td>VLSI</td>
<td>Very-Large-Scale Integration</td>
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<td>VoD</td>
<td>Video on Demand</td>
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<td>VoIP</td>
<td>Voice over Internet Protocol</td>
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<td>VP</td>
<td>Vector Perturbation</td>
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<td>VR</td>
<td>Virtual Router</td>
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<td>VRRP</td>
<td>Virtual Router Redundancy Protocol</td>
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<td>W3GPP</td>
<td>third generation partnership project</td>
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<td>WAC</td>
<td>Wireless Access Controller</td>
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<td>WDM</td>
<td>Wavelength Division Multiplexing</td>
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<td>WEIRD</td>
<td>WiMAX Extension to Isolated Research Data Networks</td>
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<td>WEP</td>
<td>Wired Equivalent Privacy</td>
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<tr>
<td>WiFi</td>
<td>Wireless Fidelity</td>
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<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
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<td>WINNER</td>
<td>Wireless World Initiative New Radio</td>
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<td>WLAN</td>
<td>Wireless Local Area Network</td>
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<td>W-LSB</td>
<td>Windowed Least Significant Bits</td>
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<td>WMAN</td>
<td>Wireless Metropolitan Area Network</td>
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<td>Wireless Mesh Network</td>
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<td>WNC</td>
<td>Wireless Network Coding</td>
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<td>WNEA</td>
<td>WiMAX Network Element Advertisement</td>
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<td>WPAN</td>
<td>Wireless Personal Area Network</td>
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<td>WRR</td>
<td>Weighted Round Robin</td>
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<td>WSN</td>
<td>Wireless Sensor Network</td>
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<td>WT</td>
<td>WiMAX Terminal</td>
</tr>
<tr>
<td>WWRF</td>
<td>Wireless World Research Forum</td>
</tr>
<tr>
<td>ZFBF</td>
<td>Zero-Forcing Beamforming</td>
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</table>