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# WiMAX Evolution

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## Emerging Technologies and Applications

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# Foreword

## **Mobile WiMAX: the Enabler for the Mobile Internet Revolution**

The Internet has become one of 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 e-commerce. There have been profound social impacts from increased 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  
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# 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 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 led 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

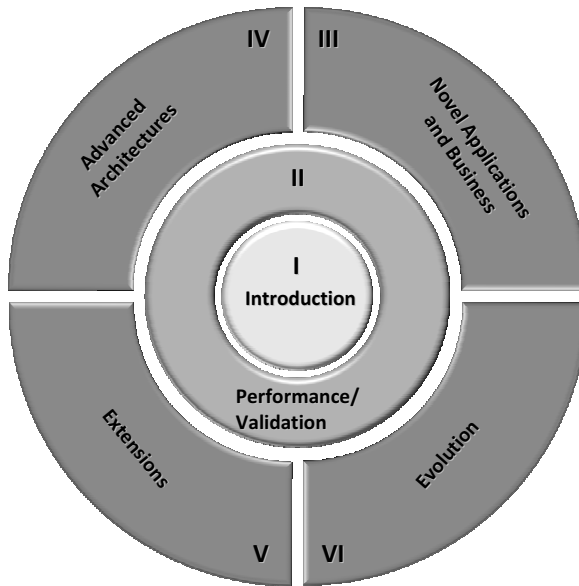


Figure 1 WiMAX evolution: organization of the book.

to create concrete supportive links between the presented concepts and future metropolitan communication systems, discussing technical solutions as well as novel identified scenarios, business applications and visions that are likely to become integral parts of the future WiMAX. Thus, this book tries to answer questions including the following. Which are the emerging WiMAX technologies that are being developed? What are the new scenarios for deploying WiMAX? What are the most promising WiMAX applications and business? How are standards evolving? What are the visions of industry? What are the capabilities and measured performance of real (commercial) WiMAX systems?

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](mailto:wimaxeditor@es.aau.dk).

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Albert Schweitzer

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# List of Acronyms

<b><math>\mu</math>C</b> MicroController	<b>ASN</b> Access Service Network
<b>16-QAM</b> 16 Quadrature Amplitude Modulation	<b>ASN-GW</b> Access Service Network Gateway
<b>2G</b> 2nd Generation	<b>ATM</b> Asynchronous Transfer Mode
<b>3G</b> 3rd Generation	<b>AVC</b> Advanced Video Coding
<b>3GPP</b> 3rd Generation Partnership Project	<b>AWGN</b> Additive White Gaussian Noise
<b>3GPP2</b> 3rd Generation Partnership Project 2	<b>BD</b> Block Diagonalization
<b>4G</b> Fourth Generation	<b>BE</b> Best Effort
<b>A/V</b> Audio/Visual	<b>BER</b> Bit Error Rate
<b>AAA</b> Authentication, Authorization and Accounting	<b>BF</b> Beamforming
<b>AAS</b> Adaptive Antenna System	<b>BGP</b> Border Gateway Protocol (routing)
<b>AC</b> Admission Control; Antenna Circulation	<b>BLER</b> Block Error Rate
<b>ACIR</b> Adjacent Channel Interference Ratio	<b>BOM</b> Bill Off Materials
<b>ACK</b> Acknowledgement	<b>bps</b> Bits Per Second
<b>ACR</b> Absolute Category Rating	<b>BPSK</b> Binary Phase Shift Keying
<b>ADSL</b> Asymmetric Digital Subscriber Line	<b>BS</b> Base Station
<b>AG</b> Antenna Grouping	<b>BSID</b> Base Station Identifier
<b>AMC</b> adaptive modulation and coding	<b>BWA</b> Broadband Wireless Access
<b>AMR</b> Adaptive Multi-Rate	<b>C/I</b> Carrier to Interference Ratio
<b>AMS</b> Adaptive MIMO Switching	<b>CAPEX</b> Capital Expenditures
<b>AP</b> Access Point	<b>CATV</b> Cable Television
<b>APD</b> Adaptive Power Distribution	<b>CBC</b> Cipher Block Chaining
<b>APFR</b> Adaptive Power Fixed Rate	<b>CBF</b> Coordinated Beamforming
<b>API</b> Application Programming Interface	<b>CBR</b> Constant Bit Rate
<b>APMC</b> Adaptive Power, Modulation and Coding	<b>CC</b> Chase Combining; Convolutional Code; Coordination Center
<b>AQ</b> Assessed QoS	<b>CCF</b> Call Control Function
<b>ARP</b> Address Resolution Protocol	<b>CCP2P</b> Cellular Controlled Peer to Peer
<b>ARQ</b> Automatic Repeat Request	<b>CDF</b> Cumulative Distribution Function
<b>AS</b> Antenna Selection	<b>CDL</b> Clustered Delay Line

<b>CDMA</b> Code Division Multiplex Access	<b>DMTBR</b> Dynamic Multiple-Threshold Bandwidth Reservation
<b>CELP</b> Code Excited Linear Prediction	<b>DNS</b> Domain Name System
<b>CH</b> Compressed Header	<b>DNS-SD</b> Dynamic Name System Service Discovery
<b>C/I</b> Carrier-to-Interference Ratio	<b>DPT</b> Dirty Paper Theory
<b>CID</b> Connection Identifier	<b>DRR</b> Deficit Round Robin
<b>CI-STBC</b> Coordinate Interleaved Space-Time Block Code	<b>DRX</b> Discontinuous Reception
<b>CMIP</b> Client Mobile IP	<b>DS-CDMA</b> Direct Sequence Code Division Multiple Access
<b>CN</b> Correspondent Node	<b>DSL</b> Digital Subscriber Line
<b>CN</b> Core Network	<b>DSLAM</b> Digital Subscriber Line Access Multiplexer
<b>CNL</b> VTT Converging Networks Laboratory	<b>DWRR</b> Deficit Weighed Round Robin
<b>CNR</b> Channel-to-Noise Ratio	<b>EAP</b> Extensible Authentication Protocol
<b>CoA</b> Care-of-Address	<b>ECMP</b> Equal Cost Multi-Path
<b>CODEC</b> Compression/Decompression	<b>EDF</b> Earliest Deadline First
<b>COST</b> European Cooperation in the Field of Scientific and Technical Research	<b>EpBR</b> Energy per Bit Ratio
<b>COTS</b> Commercial Off The Shelf	<b>ertPS</b> Extended Real-Time Polling Service
<b>CP</b> Cyclic Prefix	<b>ERT-VR</b> Extended Real-Time Variable Rate
<b>CPE</b> Customer Premises Equipment	<b>ESP</b> Encapsulating Security Payload
<b>CPS</b> Common Part Sublayer	<b>ETX</b> Expected Transmission Count
<b>CPU</b> Central Processing Unit	<b>EVD</b> Eigenvalue Decomposition
<b>CQI</b> Channel Quality Indicator	<b>EVRC</b> Enhanced Variable Rate Codec
<b>CQICH</b> Channel Quality Indicator Channel	<b>FA</b> Foreign Agent
<b>CRC</b> Cyclic Redundancy Check	<b>FBSS</b> Fast Base Station Switching
<b>CS</b> Convergence Sublayer	<b>FCH</b> Frame Control Header
<b>C-SAP</b> Control Service Access Point	<b>FDD</b> Frequency-Division Duplex
<b>CSG</b> Closed Subscriber Group	<b>FDM</b> Frequency Division Multiplexing
<b>CSI</b> Channel State Information	<b>FEC</b> Forward Error Correction
<b>CSN</b> Connectivity Services Network	<b>FER</b> Frame Error Rate
<b>CTS</b> Clear to Send	<b>FFMS</b> Forest Fire Monitoring Station
<b>DAS</b> Distributed Antenna System	<b>FFT</b> Fast Fourier Transform
<b>DCA</b> Dynamic Channel Allocation	<b>FIFO</b> First In First Out
<b>DCD</b> Downlink Channel Descriptor	<b>FP</b> Framework Programme
<b>DCF</b> Discounted Cash Flow	<b>FPAR</b> Fixed Power Adaptive Rate
<b>DES</b> Data Encryption Standard	<b>FPGA</b> Field-programmable Gate Array
<b>DFB</b> Distributed Feedback	<b>FTP</b> File Transfer Protocol
<b>DHCP</b> Dynamic Host Configuration Protocol	<b>FUSC</b> Fully Used Subcarriers
<b>DL</b> Downlink	<b>GA</b> Generic Adapter

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

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

<b>PEP</b> Performance Enhancing Proxy	<b>rt</b> real-time
<b>PER</b> Packet Error Rate	<b>RTP</b> Real-time Transport Protocol
<b>PHB</b> Per Hop Behavior	<b>rtPS</b> Real-Time Polling Service
<b>PHY</b> Physical Layer	<b>RTS</b> Request to Send
<b>PLC</b> Packet Loss Concealment	<b>RTT</b> Round Trip Time
<b>PLR</b> Packet Loss Rate	<b>RT-VR</b> Real-Time Variable Rate
<b>PMIP</b> Proxy Mobile IP	<b>Rx</b> Receive
<b>PMP</b> Point to Multipoint	<b>SA</b> Specific Adapter
<b>PN</b> Pseudorandom Noise	<b>SAF</b> Service Availability Forum
<b>POF</b> Plastic Optical Fiber	<b>SAMPDA</b> Simple Adaptive Modulation and Power Adaptation Algorithm
<b>PQ</b> Perceived QoS	<b>SAP</b> Service Access Point
<b>PSTN</b> Public Switched Telephone Network	<b>SBS</b> Serving Base Station
<b>PTMP</b> Point-to-Multipoint	<b>SC</b> Serra do Carvalho
<b>PTP</b> Precision Time Protocol	<b>SCM</b> Spatial Channel Model
<b>PTP</b> Point-to-point	<b>SCR</b> Spare Capacity Report
<b>PU2RC</b> Per-User Unitary and Rate Control	<b>SCTP</b> Stream Control Transmission Protocol
<b>PUSC</b> Partially Used Subcarrier; Partially Used Subchannelization	<b>SCW</b> Single Codeword
<b>QAM</b> Quadrature Amplitude Modulation	<b>SDMA</b> Spatial Division Multiple Access
<b>QoE</b> Quality of Experience	<b>SDU</b> Service Data Unit
<b>QoS</b> Quality of Service	<b>SE</b> Spectral Efficiency
<b>QPSK</b> Quadrature Phase-Shift Keying	<b>SF</b> Service Flow
<b>RADIUS</b> Remote Authentication Dial-In User Service	<b>SFDR</b> Spurious Free Dynamic Range
<b>RAN</b> Radio Access Network	<b>SFM</b> Service Flow Management
<b>RAU</b> Remote Antenna Unit	<b>SID</b> Silent Insertion Descriptor
<b>RB</b> Resource Block	<b>SINR</b> Signal-to-Interference + Noise Ratio
<b>RF</b> Radiofrequency	<b>SIP</b> Session Initiation Protocol
<b>RFC</b> Request for Comments (IETF standard document)	<b>SISO</b> Single Input Single Output
<b>RMF</b> Resource Management Function	<b>SL</b> Serra da Lousã
<b>RMS</b> Root Mean Square	<b>SLA</b> Service Level Agreement
<b>RoF</b> Radio-over-Fiber	<b>SM</b> Spatial Multiplexing
<b>ROHC</b> Robust Header Compression	<b>SMF</b> Singlemode Fiber
<b>RRM</b> Radio Resource Management	<b>SMS</b> Short Message Service
<b>RS</b> Relay Station	<b>SNMP</b> Simple Network Management Protocol
<b>RSS</b> Received Signal Strength	<b>SNR</b> Signal-to-Noise Ratio
<b>RSSI</b> Received Signal Strength Indicator	<b>S-OFDMA</b> Scalable Orthogonal Frequency Division Multiple Access
	<b>SOHO</b> Small Office/Home Office
	<b>SON</b> Self-Organized Network

<b>SP</b> Synchronization Pattern	<b>VBR</b> Variable Bit Rate
<b>SRA</b> Simple Rate Adaptation	<b>VCEG</b> Video Coding Experts Group
<b>SRD</b> System Requirement Document	<b>VCSEL</b> Vertical Cavity Surface Emitting Laser
<b>SS</b> Subscriber Station	<b>VDT</b> Virtual Drive Test
<b>SSL</b> Secure Socket Layer	<b>VLSI</b> Very-Large-Scale Integration
<b>STBC</b> Space Time Block Coding	<b>VoD</b> Video on Demand
<b>STC</b> Space-Time Coding	<b>VoIP</b> Voice over Internet Protocol
<b>SUI</b> Stanford University Interim	<b>VP</b> Vector Perturbation
<b>SW</b> Software	<b>VR</b> Virtual Router
<b>TBS</b> Target Base Station	<b>VRRP</b> Virtual Router Redundancy Protocol
<b>TCP</b> Transmission Control Protocol	<b>W3GPP</b> third generation partnership project
<b>TDD</b> Time Division Duplex	<b>WAC</b> Wireless Access Controller
<b>TDM</b> Time Division Multiplexing	<b>WDM</b> Wavelength Division Multiplexing
<b>TDMA</b> Time Division Multiple Access	<b>WEIRD</b> WiMAX Extension to Isolated Research Data Networks
<b>TEM</b> Telecommunications Equipment Manufacturer	<b>WEP</b> Wired Equivalent Privacy
<b>TETRA</b> Terrestrial Trunked Radio	<b>WiFi</b> Wireless Fidelity
<b>TTI</b> Transmission Time Interval	<b>WiMAX</b> Worldwide Interoperability for Microwave Access
<b>TTP</b> Trusted Third Party	<b>WINNER</b> Wireless World Initiative New Radio
<b>TWG</b> Technical Working Group	<b>WLAN</b> Wireless Local Area Network
<b>Tx</b> Transmit	<b>W-LSB</b> Windowed Least Significant Bits
<b>UC</b> University of Coimbra	<b>WMAN</b> Wireless Metropolitan Area Network
<b>UCD</b> Uplink Channel Descriptor	<b>WMN</b> Wireless Mesh Network
<b>UDP</b> User Datagram Protocol	<b>WNC</b> Wireless Network Coding
<b>UGS</b> Unsolicited Grant Service	<b>WNEA</b> WiMAX Network Element Advertisement
<b>UL</b> Uplink	<b>WPAN</b> Wireless Personal Area Network
<b>UMB</b> Ultra Mobile Broadband	<b>WRR</b> Weighted Round Robin
<b>UMTS</b> Universal Mobile Telecommunications System	<b>WSN</b> Wireless Sensor Network
<b>UMTS-LTE</b> Universal Mobile Telecommunications Systems – Long Term Evolution	<b>WT</b> WiMAX Terminal
<b>VAD</b> Voice Activity Detection	<b>WWRF</b> Wireless World Research Forum
	<b>ZFBF</b> Zero-Forcing Beamforming