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WiMAX, LTE and UMB – Key Technical Features

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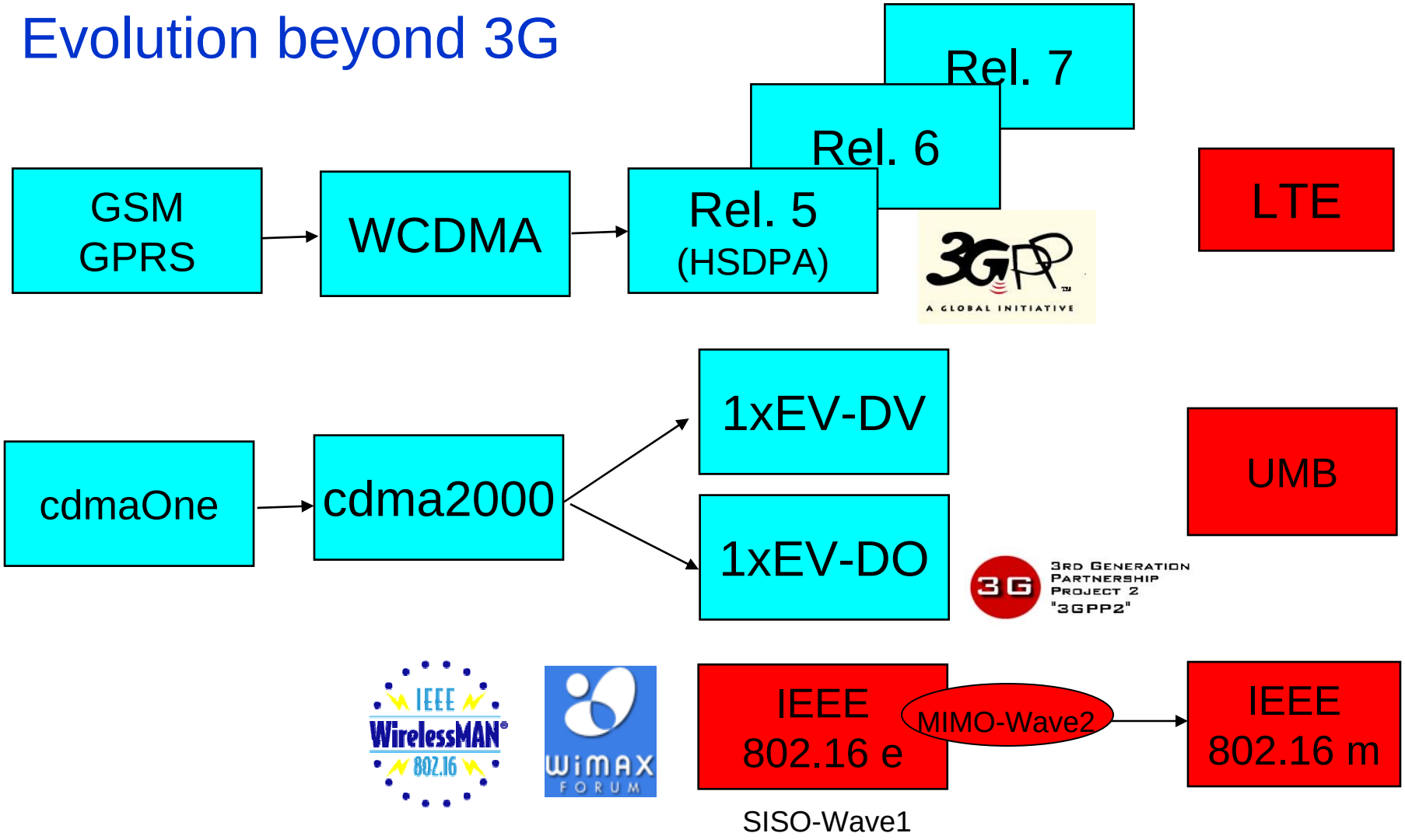
IMT Advanced

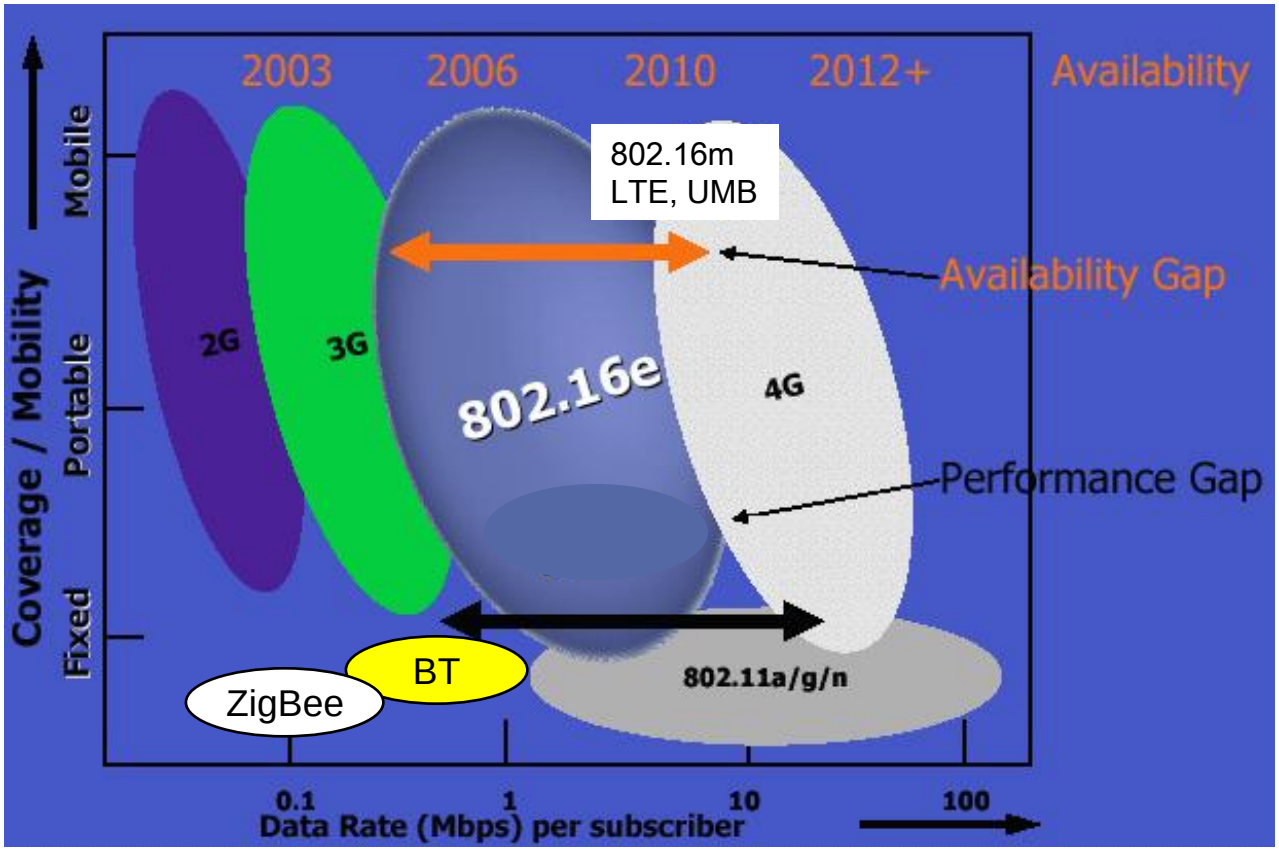
- ITU initiative (started 06/2003)
  - Development of systems beyond IMT-2000 (open and global standards)
- Enhanced IMT-2000 systems should support
  - Evolution of new applications, products, and services
  - Flexible spectrum allocation, FDD & TDD operation
- Aspects: Enhanced mobile access, Seamless networking
- Data rate requirements:
  - 100 Mbits/s for high mobility
  - 1 Gbits/s for low mobility (nomadic/local wireless) access
- Timeline:
  - Initial proposals for IMT-Advanced to be solicited mid-2008
  - Standardization mid 2008 - 2009
- Current global standards
  - IEEE 802.16m, 3GPP LTE, 3GPP2 UMB
  - All based on Orthogonal Freq. Division Multiple Access (OFDMA)

Evolution beyond 3G



Beyond 3.5G – OFDM(A) for high data rates, spectral efficiency

Wireless Broadband



Ref: A. Agrawal, WiMAX Workshop, New Delhi, Dec 2004

802.16e-2005 – Mobile WiMAX

Leading BWA Standards – 3GPP LTE, 3GPP2 UMB, IEEE 802.16m

Mobile WiMAX (802.16e) …

- IEEE 802.16e – part of ITU's IMT-2000 family
  - Name of standard – "IMT-2000 OFDMA TDD WMAN"
    - A specific profile developed by the WiMAX forum - IEEE 802.16e-2005
  - Sixth member of IMT-2000 family
  - Other members
    - IMT-Direct Sequence -Wideband CDMA (UTRA-FDD)
    - IMT-Multicarrier - cdma2000 (only 1x version being developed)
    - IMT-Time Division, TD-CDMA (UTRA TDD-HCR), TD-SCDMA (UTRA TDD-LCR)
    - IMT-Single Carrier – EDGE
    - IMT Frequency-Time – DECT
- Key aspects
  - Scaleability
    - Scaleable PHY - bandwidth 1.25 / 2.5 / 5 / 10 / 20 MHz
      - FFT Size: 128 / 256 / 512 / 1024 / 2048 (sub-carrier = 10.94 KHz)
      - QPSK / 16QM / 64QAM

Mobile WiMAX – Key Aspects …

- Key aspects
  - High data rates
    - Advanced Error Correction techniques (Conv Turbo Coding (CTC))
    - Adaptive modulation and coding, Hybrid ARQ
  - Advanced Antenna Techniques – 2x1, 2x2, other configurations
    - Full MIMO and beam-forming support
  - QoS - Supports different traffic types (5 categories)
  - Efficient MAC design
    - Fast and advanced scheduling (for DL and UL)
  - Mobility - Secure optimized handover with < 50 msec break time
    - Efficient power management - “Sleep mode” and “Idle Mode”
  - Security - Advanced authentication and encryption
  - End-to-end IP-based network
  - Flexible frequency reuse – facilitating network planning

IEEE 802.16m

- Amendment 802.16m approved December 2006
- Aim of project:
  - Develop an advanced air-interface
  - In cooperation with ITU-R and its members
- Stakeholders for the standard
  - Vendors developing IEEE 802.16 (WiMAX) products
  - Licensed carriers using IEEE 802.16 products
  - Members of the WiMAX Forum and ITU-R

Requirements

- State of the art wireless communications technology
  - Modulation (OFDMA - downlink and uplink), support smart antennas
- Peak useful data rates up to 100 Mbits/s for mobile users
- Up to 1 Gbits/s for stationary users
- Support a wide range of multimedia services, QoS
- Time line (from Workplan):
  - Finalize requirements, channel models, evaluation methodology by 2007
  - Finalize IMT proposal by 2008-09
  - Release 802.16m Dec 2009

802.16m Candidate System Requirements

Feature	Mobile WiMAX R1 (802.16e)	802.16m Requirements	
RF Bands	2.3 GHz, 2.5GHz, 3.3-3.8GHz	2.3 GHz, 2.5GHz, 3.3-3.8GHz	
Duplexing Modes	TDD	TDD, FDD/HFDD	
		Minimum	*Target*
Channel Bandwidths	5, 3.5, 7, 8.75, 10 MHz	5, 10, 20 MHz	
Peak Data Rates (per sector)	DL: 64 Mbps (2x2) @ 10MHz	DL: > 160 Mbps (2x2) @ 20MHz	DL: > 300 Mbps (4x4) @ 20MHz
	UL: 28 Mbps (2x2 collaborative MIMO) @ 10MHz	UL: > 56 Mbps (1x2) @ 20MHz	UL: > 200 Mbps (2x4) @ 20MHz
Mobility	Up to 60-120 km/hr	Up to 350 km/hr	Up to 500km/hr
Latency	Link-Layer Access: ~20ms Handoff: ~35-50ms	Link-Layer Access: <10ms Handoff: <20ms	
MIMO Configuration	DL: 2x2 MIMO	DL: 2x2 MIMO	DL: 2x4, 4x2, 4x4 MIMO
	UL: 1x2 MIMO	UL: 1x2 MIMO	UL: 1x4, 2x2, 2x4 MIMO
Peak Spectral efficiency (per sector)	DL 6.4 bps/Hz (2x2)	DL > 8 bps/Hz (2x2)	DL > 15 bps/Hz (4x4)
			DL > 9.8 bps/Hz (4x2)
	UL 2.8 bps/Hz (1x2)	UL > 2.8 bps/Hz (1x2)	UL > 4.7 bps/Hz (1x2)
Coverage (km)	1/5/30 km	1/5/30 km (Optimal at 5km)	
N... A...	~ 50 users/sector/FDD MHz	> 100 users/sector/FDD MHz (2x2)	

Advanced MIMO Schemes and high throughput MAC optimization techniques will be a significant focus for performance!

Source: J. Puthenkulam WiMAX Presentation (Intel)

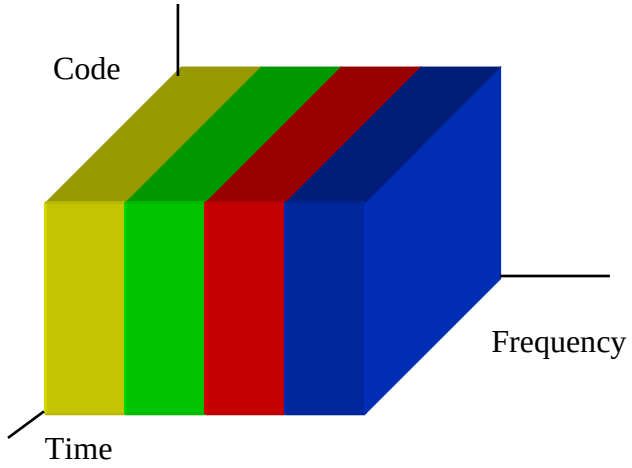
3GPP Long-Term Evolution

- 3GPP – Third Generation Partnership Project (UMTS)
  - LTE - feasibility study on UTRAN evolution in 2004
- Technical Report (TR) 25.913 provides detailed requirements
  - Downlink peak data rate of 100 Mb/s in 20 MHz
  - Uplink peak data rate of 50 Mb/s in a 20 MHz uplink
- At least 200 “active” users per cell supported in 5 MHz
- Mobility support – up to 120 km/h (optimized for low mobility)
- Spectrum flexibility and higher spectral efficiency
  - 1.25 MHz to 20 MHz and beyond (in steps of 200 KHz)
- Technical specifications:
  - Downlink uses Orthogonal Frequency Division Multiple Access (OFDMA)
  - Uplink uses Single Carrier – Frequency Division Multiple Access (SC-FDMA)
    - To minimize peak-to-average ration
- Key Aspects
  - Smart antenna techniques (MIMO, beamforming, Diversity)
  - FDD and TDD
- 3GPP LTE standardization is currently in progress

3GPP2 UMB

- UMB – Ultra Mobile Broadband
- 3GPP2 and CDMA Development Group (CDG) collaboration
- Evolution path for cdma2000 systems
- Systems Requirement Document (SRD) approved in May 2006
- Scalable bandwidths up to 20 MHz
- Peak data rates
  - Up to 300 Mbps (downlink) and 80 Mbps (uplink) in mobile environment
    - Using 20 MHz (FDD), 4x4 MIMO
- Improved spectral efficiency and coverage
- Flexible spectrum allocations
- OFDMA on the forward link, OFDMA + CDMA on reverse link
- Supports advanced antenna techniques
  - MIMO, SDMA, beam-forming
- Handoffs to 3G systems
- Time line:
  - Air interface specification expected in 2009 timeframe

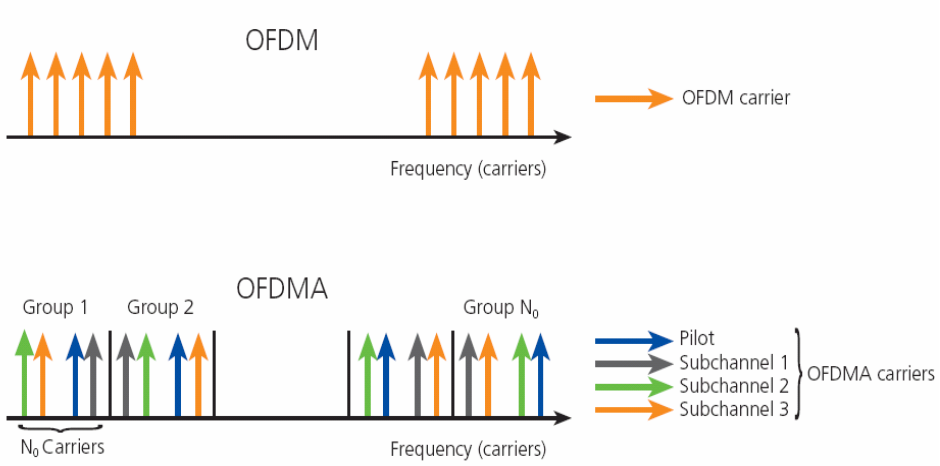
OFDM



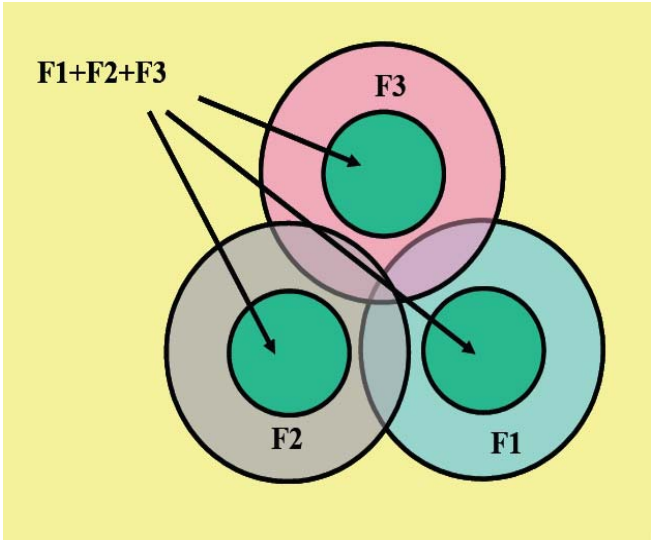
- Effect of Multipath
  - CDMA – loss of orthogonality
    - More severe if spreading factor is low
  - TDMA ⇒ need for complex equalization
    - More severe for higher baud rates
  - OFDM attractive for high speed data in multipath fading
- OFDM – Orthogonal Frequency Division Multiplexing (Multicarrier)
  - Narrow carriers ⇒ low baud rate ⇒ long symbol duration
  - An attractive candidate for broadband wireless
  - Efficient digital multicarrier implementation using DFT / IDFT
  - Opportunity to do optimized coding and modulation in each carrier
    - Maximize capacity utilization based on channel condition
    - A active area of research
  - Issues: High peak-to-average ratio, sensitivity to frequency & timing errors
- OFDM used for WLAN, WWAN, Digital Audio Broadcasting, 4G, …

OFDM Systems

- Technical focus
  - Adaptive modulation and coding (AMC)
  - MIMO, Transmit Diversity and Beamforming
    - Channel quality feedback
    - Pre-coding techniques, beamforming
    - 4TX MIMO, diversity
    - Downlink Multi-user MIMO
  - Reference signals (Pilot) – Downlink and Uplink
    - Optimal placement, minimal overhead
    - Sequence design, hopping RS
  - Control signaling
    - ACK/NACK, feedback, CQI
  - MAC
    - Major emphasis on OFDMA scheduler
  - Interference mitigation (due to 1/1 re-use)



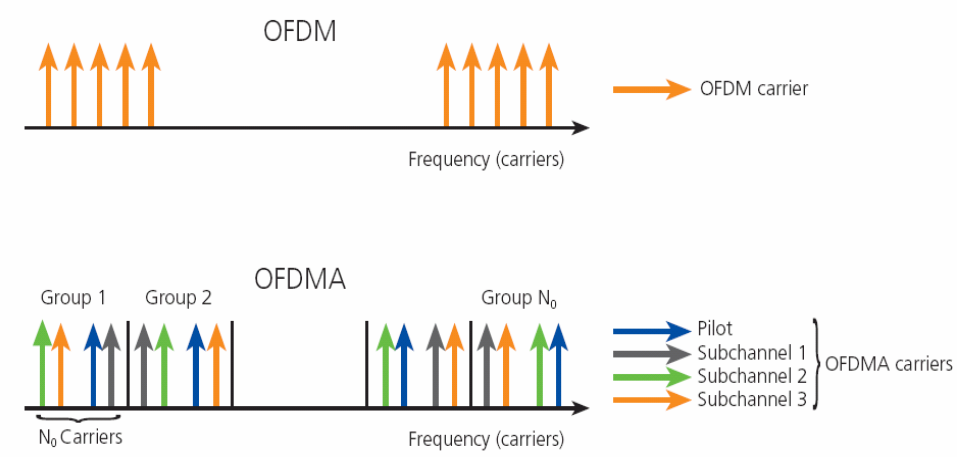
1/1 reuse

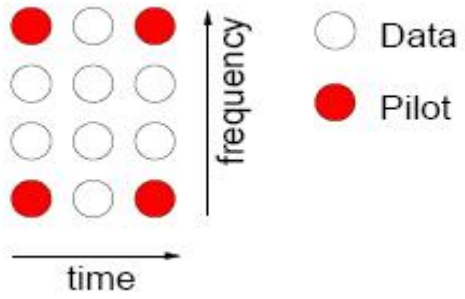


Fractional frequency reuse

OFDM Systems

- Sub-carrier allocation
  - Contiguous – Band AMC / Tile
    - Experience same fading channel
    - Select optimum AMC
    - Beam-forming
  - Diversity – Pseudo-random permutation
    - Achieves frequency diversity
    - Partially Used Sub-Carrier (PUSC)
    - Fully Used Sub-Carrier (FUSC)
- Challenges
  - Channel estimation
    - 1/1 re-use ⇒ SINR ~ 0 dB
  - Channel tracking
  - Interference mitigation





Market Segmentation and User Density

- Dense Urban (Case: Mumbai)
  - 70% of 16M people
    - In area of 600 sq Km
  - ~3733 households per sq km
    - Assuming 5 per household
  - ~ 50% wireless internet subscribers
  - ~ 1866 wireless internet/sq km
  - cell radius = 0.75 km
  - ~ 3300 subscribers/cell
  - Assuming 5 competitive operators in each area =>

    660 subscribers/operator/cell
- Urban (Case: Pune)
  - 70% of 4.2M people
    - In area of 400 sq Km
  - ~1470 households per sq km
    - Assuming 5 per household
  - ~ 60% wireless internet subscribers
  - ~ 882 wireless internet/sq km
  - cell radius = 1 km
  - ~ 2800 subscribers/cell
  - Assuming 5 competitive operators in each area =>

    ~560 subscribers/operator/cell

- In sub-urban and rural, higher % of subscribers for wireless broadband
  - Due to lack of wired infrastructure
- Typical scenarios evaluated by Indian operators
- Technology options for India must be very flexible and scaleable
- Synchronization of TDD systems is a key issue

CEWiT & BWCI

Goal: Put India on the global map for next generation wireless

- Centre of Excellence in Wireless Technologies (located in Chennai)
- Government of India initiative (started in 2004)
- A Public-Private Partnership - Academia / Industry / Government
- Leverage Indian market for mobile and fixed wireless
  - Participation in global wireless research and standardization
- Broadband Wireless Consortium of India (BWCI)
  - Provide a common national forum for broadband wireless
  - Involvement of all major stake holders of wireless broadband in India
  - Operators, Equipment manufacturers, Semiconductors, Technology Services, R&D
  - Participation in key global standards 3GPP, 3GPP2 and IEEE 802.16
  - Address needs of Indian market (including spectrum issues)
  - Four working groups (WG1-4) and related activities
- Strong emphasis on strategic IPR

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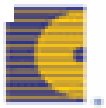
Summary

- Broadband wireless provides major technical challenges / opportunities
- Aggressive development and deployment of new technologies
  - HSPA, EV-DO, IEEE 802.16e (Mobile WiMAX)
- IMT Advanced presents a challenging set of requirements
  - Technology evolutions to meet IMT Advanced
  - LTE, UMB, IEEE 802.16m
  - Many common technical issues pertaining to OFDM(A) systems
- Role of CEWiT and BWCI – a carefully planned strategic initiative
  - Technology neutrality in Broadband wireless
  - Commercial focus
  - Strong technical collaboration between stake-holders
- India will be very large market
  - Can support multiple Broadband wireless technologies
- Indian operators will play a key role
- An opportunity to work together and make India a major player in broadband wireless



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My best wishes for the success of this IEEE Workshop and to each of you

Thank You !

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David Koilpillai Profile

Education

B.Tech, IIT Madras, MS, PhD Caltech, USA

Work Experience

IIT Madras (2002 – present)

- Professor, TeNeT Group, EE Department

CEWiT – Chief Scientist (Jan 2007 – present)

Ericsson Inc, USA (1990-2002)

- Director, Advanced Technologies, Research and Patents

(R&D team of 75 engineers, annual budget US $20 Million)

Professional

- Areas of expertise: Cellular, wireless systems, DSP
- 32 Issued US patents
- Publications: 10 Journal, 32 Conference
- Research Interests: DSP applications in Wireless
- Ericsson Inventor of Year Award 1999
- Fellow, Indian National Academy of Engineering