WiMAX
A WAY FORWARD
IN INDIA

WiMAX FORUM®

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Acronyms

BWA	Broadband Wireless Access
WMF	WiMAX Forum
FFR	Fractional frequency reuse
ICIC	Inter-cell interference coordination
HARQ	Hybrid ARQ
Tx, Rx	Transmit, Receive
TDD	Time-division duplexing
P2P	Point-to-point
ASN	Access Service Network
ASN-GW	ASN Gateway
PA	Power amplifier
TMA	Tower Mounted Amplifier
BS	Base station
CPE	Customer premises equipment
MS	Mobile station
DL	Downlink
UL	Uplink
LTE	3GPP Long Term Evolution
eNB	Evolved NodeB (LTE base station)
UE	User equipment (LTE terminal)
DoT	Department of Telecom
OMA-DM	Open Mobile Alliance – Device Management

1 Introduction

India is a huge market for broadband wireless services and offers immediate and enormous potential for growth. WiMAX is the only 4G broadband technology compatible with the 2.3 GHz BWA spectrum in India that today enjoys widespread global deployment along with a mature ecosystem of vendors, devices and applications. It offers Indian consumers both fixed and mobile high speed access to all internet services. WiMAX already powers a wide array of terminal devices today, from notebooks, dongles, CPEs, handhelds, and home/business VoIP gateways to the latest Smartphone's, personal hotspots, and machine to machine devices.

WiMAX has commercial networks in 149 countries today including Clearwire – Sprint in USA; KT and SKT in Korea; UQ in Japan; Imagine in Europe; VMAX and Vee in Taiwan; Yota -Scartel and Comstar in Russia; Packet One in Malaysia; and Wateen in Pakistan to name just a few. WiMAX networks offer coverage to 630 million people today and are projected to reach over 800 million by the end of 2010. Mobile WiMAX subscriptions have reached 10 million globally today and are projected to grow to 130 million subscribers by 2014.

Figure 1. Worldwide WiMAX deployments as of May 2010 (blue dots denote IEEE Std 802.16e deployment)

The WiMAX silicon, terminal and BS vendor ecosystem is comparable to 3G with more than 300 WiMAX Forum-certified devices. Leading vendors such as HTC, Motorola, Lenovo, Toshiba and Sony have launched WiMAX products. Strong vendor competition has already resulted in rapid price maturity that is

unprecedented in previous mobile technologies. Open Patent Alliance also provides a low IPR burden, thus driving prices much lower and much faster than for 3G and 3GPP-LTE. WiMAX employs a flat network architecture and all-IP protocols that allow vendors to offer simple and low cost core networks. CAPEX cost is projected to be as low as Rs. 600 per subscriber.

The Indian government has completed auctioning 2 slots of 20 MHz each (TDD) for broadband in the 2.3 GHz band. One 20 MHz slot in the 2.5 GHz slot is already assigned to BSNL. Another slot in the 2.5 GHz band will be auctioned for private operators when inter-working issues with satellite services are cleared, which may happen in late 2010. The two 20 MHz slots in the 2.3 GHz band are as close as 2.5 MHz in some circles and as far as 20 MHz in other circles.

This white paper is targeted to the Indian broadband operators and aims to provide recommendations for optimal deployment of WiMAX. The recommendations include:

(a) Deployment options in a 20 MHz slot,

(b) Radio coexistence in the 2.3 GHz BWA allocation,

(c) WiMAX Release 1 enhancements, and

(d) Migration from WiMAX Release 1 profile to Release 2 profile.

2 Deployment Options in 2.3 GHz BWA Spectrum

With 20 MHz allocated to each operator, it is recommended that the 20 MHz slot be channelized as two adjacent channels of 10 MHz each (identified as c1 and c2).

This section focuses on the deployment options rather than explicitly addressing co-existence. Please refer to Section 3 for more on co-existence considerations.

2.1 Sector and Frequency Plans

Either three-sector or four-sector BS may be used. Each deployment option has advantages and disadvantages.

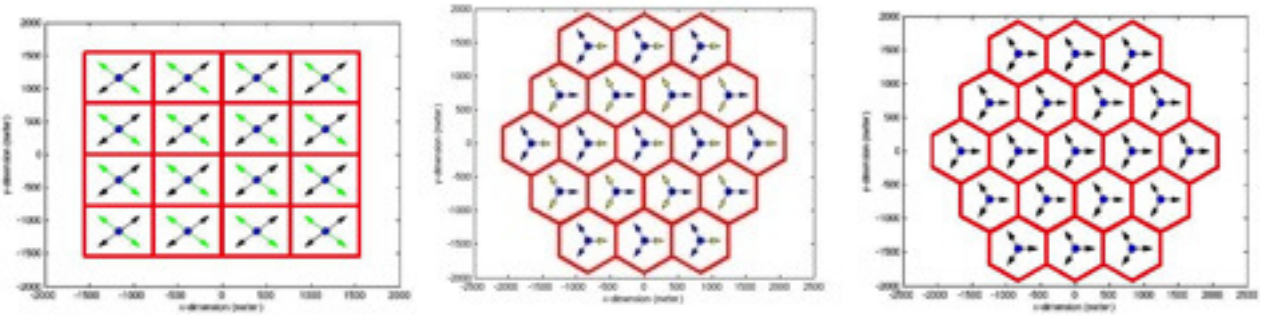
We recommend an initial deployment with a single radio channel per sector. The corresponding Tx-Rx antenna and PA configurations can be used as outlined in Section 2.3. As user demand for data grows, operators may wish to move to two radio channels per sector that offers a higher capacity, but which may incur some additional cost if additional radio units are required. Migration from one radio channel to two radio channels per sector can be carried out on a cell-by-cell basis. However, higher interference may be experienced in the transition period at the boundary cells.

We recommend three reuse options as follows:

Option A (1x4x2): A four sector deployment with one radio channel per sector. Two sectors use c1 and the other two sectors use c2. See Fig. 2A.

Option B (2x3x2): A three sector deployment with one radio channel per sector. One sector uses radio channel c1 and the other two sectors use c2 (dominant). Cells can interleave c1 and c2 dominance to balance interference. See Fig. 2B. An alternative configuration can let all three sectors within a cell use radio channel c1 (or c2). Cells can interleave c1 and c2 to balance inter cell interference.

Option C (1x3x1): A three sector deployment with two radio channels per sector. Both radio channels (c1 or c2) are used. This is a two-layer scheme. All cells use the uniform channel structure. The initial deployment could be done with one radio channel per sector and with the second radio channel turned on either selectively or globally through the network to increase capacity as needed. The two radio channels may be provided by one or two radio units per sector depending on the transmit power requirements and individual base station vendor's offerings. See Fig. 2C.



(2A) (2B) (2C)

Figure 2. (A) 4-Sector – 1x4x2, (B) 3-Sector – 2x3x2 (C) 3-Sector – 1x3x1

Simulation results for the average site (cell) throughput, cell edge user throughput and spectrum efficiency for each of the options are shown in Table 1. The underlying system level assumptions and methodology are those contained in [1] and [2]. It is noted that 10 users per sector are assumed for each configuration as defined in [1] and [2].

Options A and C have the highest average site throughput amongst the deployment scenarios. Option A has an advantage over Option C in terms of the cell edge user throughput. On the other hand, Option C has an advantage over Option A in terms of the average sector capacity. It should be noted that slightly different interpretations of assumptions underlying system-level simulations is inevitable, and therefore it is extremely difficult to arrive at identical simulation results across multiple vendors. The results in Table 1 are presented as a range of numbers to capture such variations.

Table 1. Average Site and Cell edge user throughput for different deployment configurations. Simulation based on the IMT-Advanced Urban Microcell [1] and IEEE 802.16m Pedestrian-B 3 km/hr [2] evaluation methodology

Configuration	Average Site Throughput (Mbps)		Cell Edge User Throughput (Kbps)		Cell Spectral Efficiency (b/sec/Hz)	
	IMT-Adv Urban Micro	IEEE 802.16m EVM	IMT-Adv Urban Micro	IEEE 802.16m EVM	IMT-Adv Urban Micro	IEEE 802.16m EVM
4-Sector (Option A) 1x4x2	57.2 (56.6-57.8)	43.0 (42.1-43.9)	545 (534.1-555.9)	344 (337.12-337.1)	4.64 (4.59-4.69)	3.48 (3.41-3.55)
3-Sector (Option B) 2x3x2	44.9 (44.5-45.3)	34.0 (33.3-34.7)	565 (560-570)	358 (350.8-365.2)	3.64 (3.6-3.8)	2.76 (2.7-2.82)
3-Sector (Option C) 1x3x1 (2 layers)	58.4 (57.8-58.9)	43.2 (42.3-44.1)	294 (291-297)	181 (177.4-184.6)	4.73 (4.69-4.76)	3.5 (3.43-3.57)

Overall, the c1 and c2 radios may operate in the same sector (in a two-layer deployment) or in adjacent sectors. We recommend coordinated deployment within the same geographic area. Coordination recommendations include: (a) Both radios must be time and frequency locked to GPS, (b) DL: UL symbol boundaries ratio must be aligned, (c) DL Tx powers must be aligned within 3 dB, (d) Control and data zones must be aligned, (e) Segmentation schemes (via FFR) must be coordinated.

2.2 Solutions for Reuse-1 with WiMAX

Several methods may be employed to optimize reuse 1 with WiMAX systems for both 3 sector (often Option C is used for this configuration) and 4 sector deployments. These methods are described in the next sections.

2.2.1 Fractional Frequency Reuse (FFR)

FFR is a technique which allows segmentation in control and data zones that can vary between zones. FFR is best used in 1/3, 1/3, 1/3 segmentation with corresponding FCH vectors 110000, 001100 and 000011. These binary vectors are a representation of the major groups used in each segment. A value of 1 means that the major group is used, otherwise it is set to 0. For 10 MHz bandwidth there are 6 major groups. Three of the major groups contain 6 subchannels and the others contain 4 subchannels.

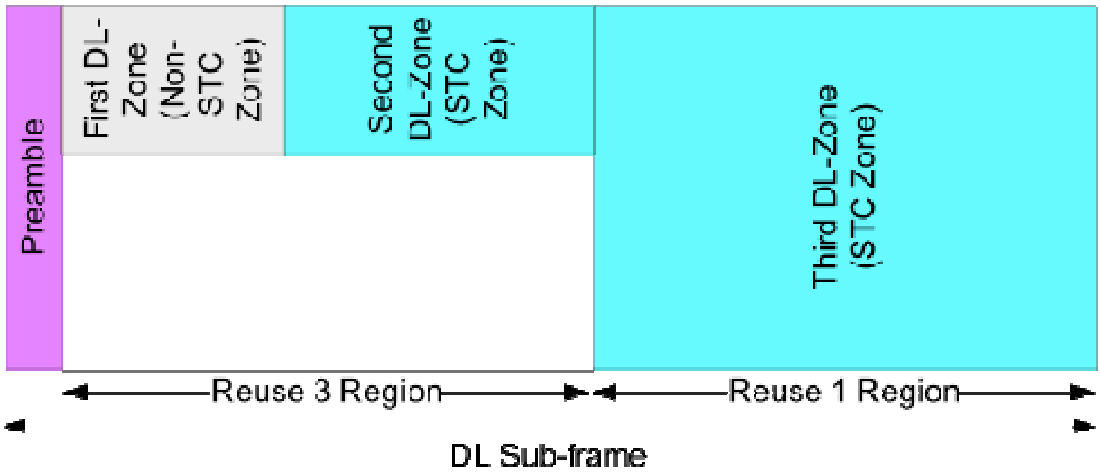


Figure 3. Example of FFR frame structure

The use of FFR depends on local deployment morphology. In general, segmentation of DL MAP is found to be mostly beneficial. Data zones can be both segmented and non-segmented as shown in Figure 3. Segmentation can improve the user throughput at cell edge. It can be used for MAP, DL data, UL control, and UL data. Segmentation also improves area reliability, i.e. percentage of the cell area where the link is reliable, when outages are caused by high interference. However, segmentation may lower cell average throughput and spectral efficiency.

2.2.2 Inter-Cell Interference Coordination (ICIC)

ICIC refers to a coordination of operations of adjacent cells, targeting reduction of interference between adjacent cells. ICIC can improve cell edge throughput and area reliability. Service providers may consider using FFR / segmentation and ICIC to fine-tune their network performance.

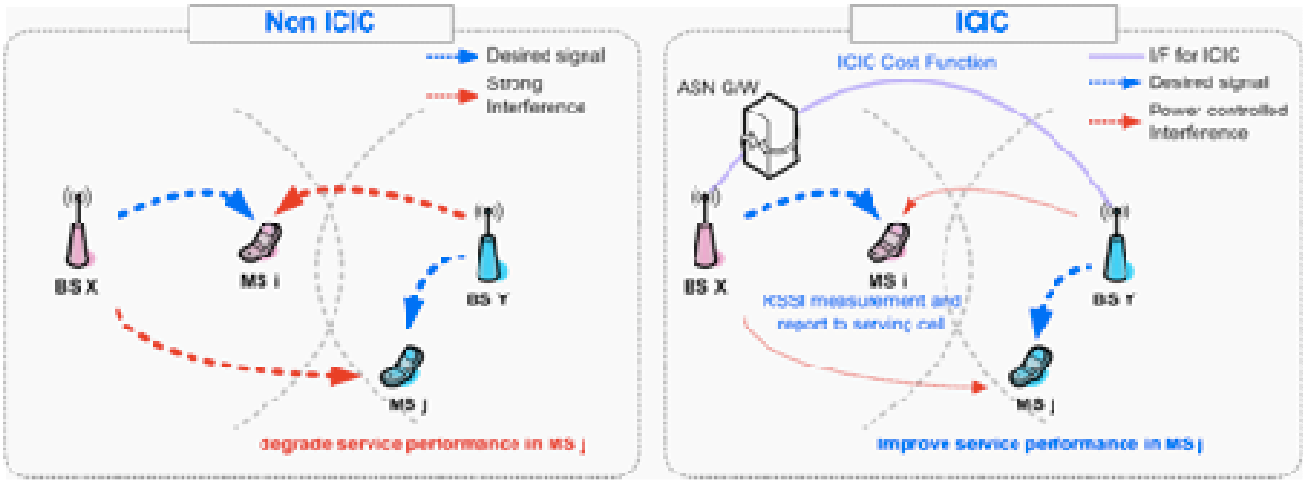


Figure 4. Illustration of ICIC scheme

ICIC improves frequency resource utilization. This is done by the exchanging of information between neighbor cells and by the BS adapting traffic power level accordingly. That is to say, BS configures its DL TX power of the DL burst for each MS based on some information shared between neighbor BSs. TX power adaptation may be targeting at maximizing edge user capacity. Since this procedure is transparent to the MS, there is no need of additional overhead for the MS.

2.2.3 Interference Mitigation

Interference mitigation techniques may be used in the BS to enable reuse 1 in both 3-sector and 4-sector configurations. These techniques may include advanced receivers in the BS combined with multi-antenna transmission techniques.

2.3 BS Power Amplifier (PA) Configuration

PAs constitute a major fraction of the BS cost, and their optimum use can improve network economics. Transmit power values discussed here are measured at the input to the antenna, therefore the actual PA rating must take into account any cable losses. There are several antenna configurations deployed in WiMAX with 2, 3 and 4 antennas per sector. The antennas are usually shared by the BS Tx and Rx chains. In some configurations, the number of transmit chains (hence PAs) are less than the Rx chains.

Like in all broadband wireless systems, cell coverage in WiMAX is usually limited by the UL. Therefore, the DL power can be reduced without affecting network performance. Though the BS Tx PA rating is usually 40 dBm, the Tx power per chain per 10 MHz channel can be reduced to 37 dBm or lower depending on the DL:UL link balance. Given that PAs are rated at 40 dBm, we can usually allow two 10 MHz Release 1 channels to use a single 40 dBm PA. Likewise, one 20 MHz Release 2 channel can use a single 40 dBm PA. The assessment of DL:UL link balance and consequently the required PA rating depends on a number of factors including the number of Tx versus Rx chains and the UL Tx power of the terminals.

2.4 Parameter Coordination

In order to ensure coexistence, operations of sectors, cells and allocation of frequency channels within a geographic service area should be coordinated.

3 Coexistence Issues

This section provides recommendations for the co-existence of WiMAX systems deployed in the 2.3 GHz BWA band in India. The current licenses auctioned in India consist of two 20 MHz blocks in 22 regions. The minimum frequency gap between allocated blocks is 2.5 MHz in 10 of these regions. The spectrum mask for

WiMAX equipment is based on Recommendation ITU-R M.1457. The spectrum allocation raises the issue of inter-operator coexistence between adjacent frequency blocks. Furthermore, in some regions, the 2.3 GHz band is shared with Point-to-Point (P2P) Fixed Services (FS). The following coexistence scenarios are identified:

1. Coexistence between WiMAX Release 1 deployments in the 20 MHz BWA slots and P2P radios on BWA deployments in the 2.3GHz band- The P2P radio nodes are characterized by having directional and high gain antennas. The deployment of P2P radio systems in the 2.3GHz band in India is geographically sparse and mostly deployed in areas with low population density. It is therefore anticipated that no serious co-existence issues will exist, since the probability of collision between these P2P systems and WiMAX deployments is very low. Because of the low-density nature of the Point-to-Point (P2P) radios, no additional guard band within the 20 MHz allocations, other than the inherent protection provided by guard tones, are recommended for co-existence consideration with the Point-to-Point (P2P) Fixed Services (FS).
2. Coexistence of WiMAX operators in two adjacent 20 MHz blocks within the same geographic area- We recommend coordinated deployment within the same geographic area between operators to support coexistence and they should meet the following requirements: (a) Both radios must be time slot and frequency locked to GPS, (b) DL:UL symbol boundaries ratio must be aligned, (c) DL TX powers must be aligned within 3 dB.
3. WiMAX can easily coexist with other TDD technologies in the adjacent carriers, e.g. TDD-LTE- Using the proper frame configuration of downlink and uplink symbols, WiMAX and TDD-LTE can be made coexist by aligning the uplink and downlink frame durations for the two systems. There is minimal loss to either system when they coexist. Details of the coexistence is the subject of a separate white paper.

4 Release 1 Enhancements

WiMAX Forum is developing enhancements to the currently deployed Release 1 profile (see [5] and [6] for more detail). The release is consistent with the WiMAX Forum Open Retail Model[1] and Certification Version Signaling (CVS), which allows operators to automatically identify the subscriber device and review its feature-by-feature certification test records during the network entry request. This process empowers the operator to automatically enforce policies properly based on certified capabilities to prevent devices from disrupting efficient network operation.

[1] Another important element of Open Retail is OMA DM device management, as specified by the Open Mobile Alliance. The OMA DM will allow operators' networks to automatically configure and maintain Open Retail devices over the air throughout the device life cycle.

Release 1 enhancement is offering advancements, through enablement of a set of features, in various areas including UL performance both during network entry and uplink data transmission mode, higher average and peak UL and DL throughputs through H-ARQ Category 5 and 6 and reduction for H-ARQ round trip delay, greater coverage reliability under both interference and noise limited conditions and finally, enabling load balancing across radio channels. The final timelines for formalizing the enhancement release is Q4 2010.

Release 1 enhancement upgrades on the MS can be of various types including software upgrade over the air or manufacturer software or hardware upgrades. Indian operators can deploy these enhancements as and when their selected infrastructure and MS vendors become ready. For the rest of the document Release 1 terminals will include Release 1 with enhancements.

5 Migration from WiMAX Release 1 to WiMAX Release 2

The WiMAX ecosystem is accelerating its development efforts to produce Release 2 profile equipment based on the IEEE 802.16m specification. The new release will offer significant coverage and capacity improvements over Release 1. The development timelines for Release 2 is targeted for early engineering trials by mid 2011, WiMAX Forum certification of equipment and early commercial availability by mid 2012 and general commercial availability with rich device offerings in 2013. Release 2 is designed for both low cost and seamless migration from Release 1, and Release 2 BS will provide full support for legacy terminals already deployed in the field.

This section provides the overall migration strategy from Release 1 to Release 2, assuming the operator has to migrate within the existing single 20 MHz slot.

5.1 Network Planning Recommendations

WiMAX Release 2 technology will have at least a similar cell size as Release 1. There will be no need to revise network planning elements, such as BS location and antenna height. Also, BS hardware such as TMAs, antennas, PAs may be fully reusable with minor or no change for Release 2. Also, core network elements such as servers and ASN GWs can be reused with Release 2. The main change will be to swap the channel cards and perform some software upgrades in certain units. We expect no more than 5% incremental CAPEX for migrating from Release 1 to Release 2.

The Release 2 network will use the same 20 MHz channels in every sector and cell, i.e., full reuse. FFR and segmentation functionality will be implemented by Release 2 subchannelization mechanism. Release 2 can be used in both 3- and 4-sector configurations.

No new WiMAX inter-operator (Release 2 – Release 2, or Release 1 – Release 2) co-existence issues will arise as long as sensible coordination of parameters between operators is maintained similar to Release 1 deployments.

5.2 Support of Release 1 Terminals

A variety of Release 1 terminals will be widely deployed. Some of these Release 1 terminals may be capable of supporting one or more radio access technologies (RATs) such as WiFi, 2G, 3G, EVDO, CDMA and 3GPP-LTE. We do not expect new inter-RAT issues related to the migration from Release 1 to Release 2. All such Release 1 terminals will operate in the new Release 2 network without any performance degradation.

Operators may have deployed their Release 1 network according to the recommendations in Section 2. Therefore, in a Release 1 network, terminals are allocated in either one of the two 10 MHz channels, sometimes switching between the two channels for load balancing reasons. In the Release 2 network, Release 2 terminals will use the entire 20 MHz channel, with Release 1 terminals being supported in one 10 MHz channel only. Operators should be aware of this constraint during migration to their Release 2 network. Use of flexible Release 1 or Release 2 terminal chipsets is expected to avoid potential issues from the terminal operation point of view.

The terminals entering the new network can be classified into three categories:

- Cat 1: Supports Release 1 functionality only (but can work in Release 2 network)
- Cat 2: Can be configured to support either Release 1 or Release 2 functionality
- Cat 3: Can support only Release 2 mode

5.3 Transition Process

Operators can start cutting over existing Release 1 BS to Release 2 BS. This cut over can be done one BS at a time. Both Release 1 and Release 2 BSs can coexist in the same network during the cut over process. Release 2 BSs are configured to support Cat 1, Cat 2 and Cat 3 terminals.

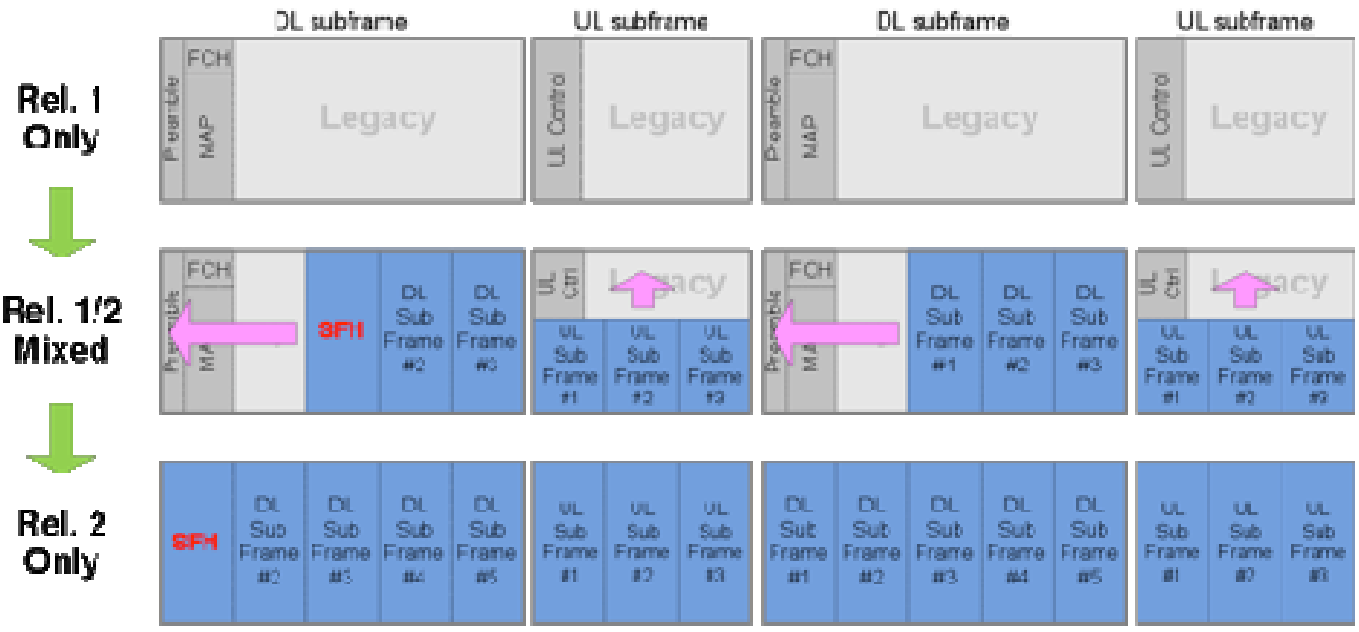
Cut over to Release 2 can be done with minimum down time. In most cases, the only change will be swapping a Release 1 channel card with a Release 2 channel card. All other equipment should be reusable without any or with minor changes. Cat 1 terminals will naturally hand over to the legacy zone of the BS. Cat 2 terminals would be in the Release 1 mode prior to cut over and will be signaled to move to Release 2 mode. Cat 3 terminals can now be introduced for the first time.

Cat 1 and Cat 2 terminals can handover and roam freely across the hybrid Release 1 and Release 2 networks. Cat 3 terminals cannot roam into Release 1 areas.

Once the BS segment of the network has fully transitioned to Release 2, Cat 1 terminals should be slowly phased out and the network will move to Cat 2 or 3 terminals only. Once all Cat 1 terminals are phased out, the network should be re-tuned to a pure Release 2 operation.

Figure 5. Same carrier migration (mixed mode)

Figure 5 shows the transition from a pure Release 1 to a pure Release 2 with intermediate support for both Release 1 and Release 2 terminals. The resource partitioning is done to match the mixture of load from different classes of terminals. During the mixed mode stage, the BS needs to use the same Release 1 UL PUSC sub-channelization across Release 1 and Release 2 zones.



Varying partitioning of Release 1 and Release 2 zones would result in changes in the system capacity. Figure 6 shows the relative DL performance of the average sector throughput, peak sector throughput, and 5%-tile cell edge throughput. As the Release 2 zone expands, the system performance will increase accordingly. For

example, compared to Release 1 only case, a 2:3 Release 1:Release 2 mix would bring over 20%/40%/60% improvements in performance of average/peak/edge throughputs, respectively. Likewise, pure Release 2 mode will see a 60%/80%/130% improvement over a pure Release 1 mode.

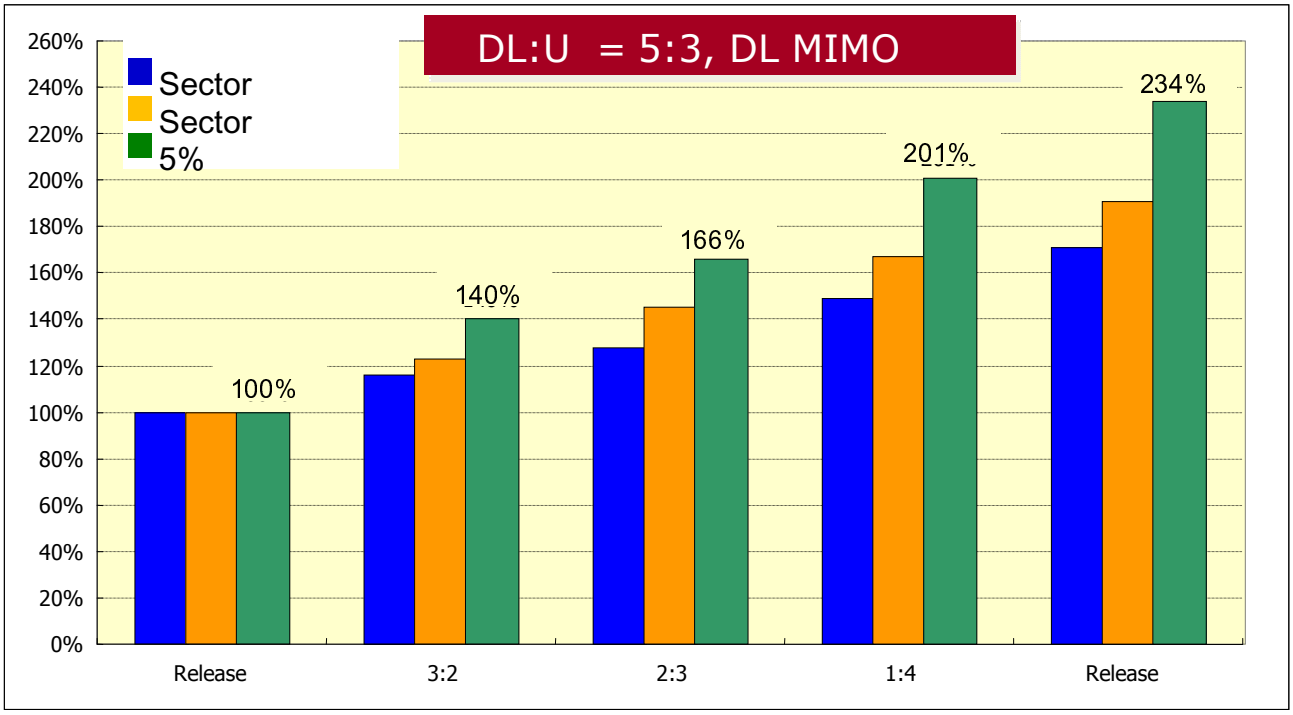


Figure 6. Mixed mode performance of Release 1 and Release 2

6 Concluding Remarks

In summary, WiMAX technology is well suited for India in the 2.3 GHz band with 20 MHz per operator. WiMAX has a proven field performance with nearly 10 million devices deployed today. WiMAX also has very attractive equipment pricing today with continuing price reductions. The WiMAX ecosystem has a firm roadmap to continued Release 1 enhancements and significant performance increases with the next generation Release 2 technology, with only a minor investment to upgrade the infrastructure segment while fully supporting legacy terminals. WiMAX is the only choice today and the right choice for the future of Indian wireless broadband.

7 References

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[2] IEEE 802.16m -08/004r5 Evaluation Methodology Document (EMD), http://ieee802.org/16/tgm/core.html#08_004, 2009-01-15.

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[4] IEEE P802.16m/D6, DRAFT Amendment to IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems 2010-04-22.

[5] DRAFT-T23-001-R010v09-B,WiMAX Forum™ Mobile System Profile, Working Group Approved Revision, 17 May 2010.

[6] DRAFT-T24-002-R010v01-H, WiMAX Forum™ Air Interface Trait Packages Open Retail 1, Working Group Approved Draft Specification, 27 April 2010.