Roadmap and Standards for Continuing 3G Evolution

Sachin Bhatmuley
(for Dr. Tom O'Neill)
QUALCOMM International Inc.
Johannesburg, South Africa

ITU BDT Seminar on
Broadband Wireless Access for Africa
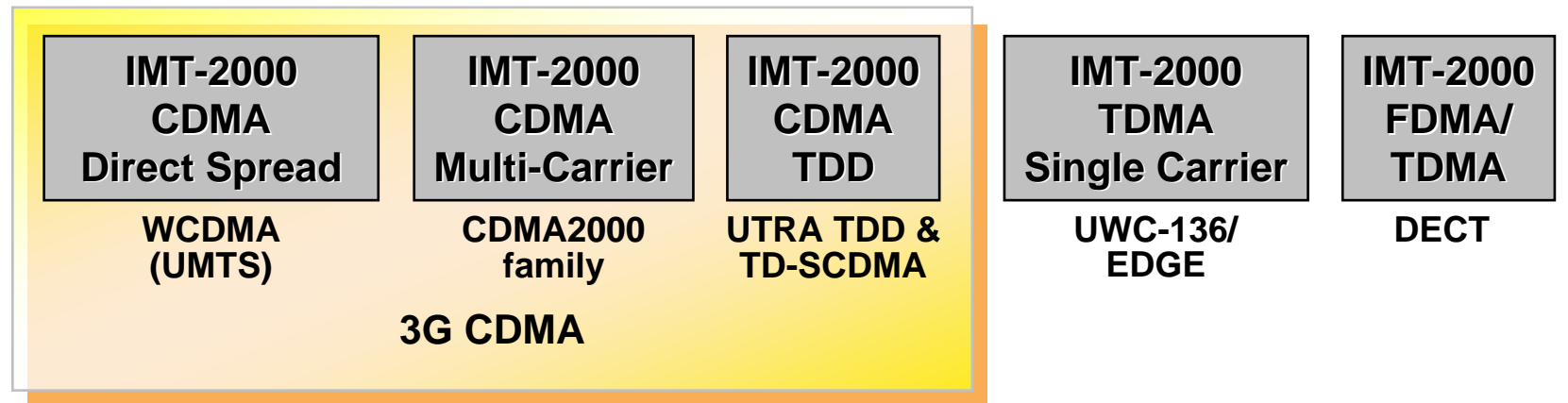
19 September 2006

IMT-2000 Radio Air Interfaces

- The ITU has approved five radio air interface standards (ITU-R Recommendation M.1457) and has identified multiple frequency bands for IMT-2000

I M T
ITU

IMT-2000 Terrestrial Radio Interfaces

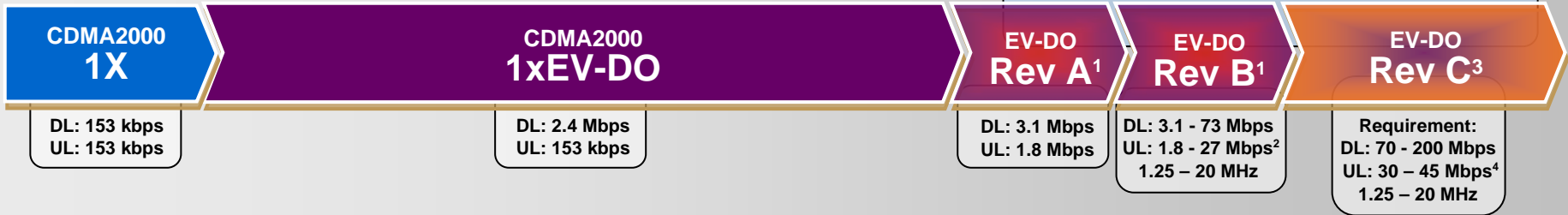| IMT-2000 CDMA Direct Spread	IMT-2000 CDMA Multi-Carrier	IMT-2000 CDMA TDD	IMT-2000 TDMA Single Carrier	IMT-2000 FDMA/ TDMA
WCDMA (UMTS)	CDMA2000 family	UTRA TDD & TD-SCDMA	UWC-136/ EDGE	DECT

3G CDMA

Although there are five terrestrial standards, most of the attention and energy in the industry has been toward the CDMA standards

3G Broadband Technology Evolution
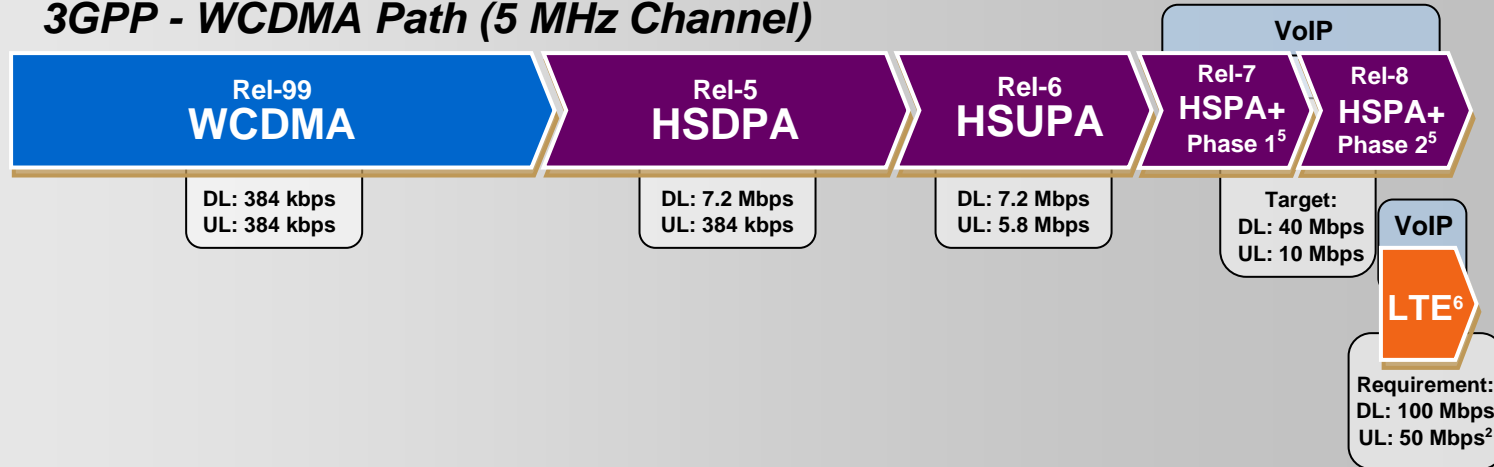
■ CDMA   **■ CDMA/TDM**   **■ OFDM**   **■ OFDMA**

3GPP2 - CDMA2000 EV-DO Path (1.25 MHz Channel)

VoIP

CDMA2000 1X	CDMA2000 1xEV-DO	EV-DO Rev A[1]	EV-DO Rev B[1]	EV-DO Rev C[3]
DL: 153 kbps UL: 153 kbps	DL: 2.4 Mbps UL: 153 kbps	DL: 3.1 Mbps UL: 1.8 Mbps	DL: 3.1 - 73 Mbps UL: 1.8 - 27 Mbps[2] 1.25 – 20 MHz	Requirement: DL: 70 - 200 Mbps UL: 30 – 45 Mbps[4] 1.25 – 20 MHz

3GPP - WCDMA Path (5 MHz Channel)

VoIP

Rel-99 WCDMA	Rel-5 HSDPA	Rel-6 HSUPA	Rel-7 HSPA+ Phase 1[5]	Rel-8 HSPA+ Phase 2[5]
DL: 384 kbps UL: 384 kbps	DL: 7.2 Mbps UL: 384 kbps	DL: 7.2 Mbps UL: 5.8 Mbps	Target: DL: 40 Mbps UL: 10 Mbps	

VoIP

LTE[6]

Requirement:
DL: 100 Mbps
UL: 50 Mbps[2]

2001 **2002** **2003** **2004** **2005** **2006** **2007** **2008** – – – – →

Note: timeline depicts initial commercial availability of each technology. Those introduced beyond 2008 are under standardization and are subject to variability

[1] EV-DO Rev A and Rev B incorporate OFDM for multicasting
[2] Data rates of 73 Mbps for the DL and 27 Mbps for the UL figures are based on a 2 x 20 MHz allocation
[3] May have multiple modes, with at least one mode being backwards compatible with EV-DO (all versions); will likely utilize CDMA/OFDM or a combination of OFDMA and CDMA; MIMO/SDMA; leverages EV-DO protocol stack
[4] Data rate dependant on level of mobility. Data rates of 73 Mbps for the DL and 27 Mbps for the UL figures are based on a 2 x 20 MHz allocation
[5] Release 7 and Release 8 introduce enhancements such as MIMO and VoIP
[6] Utilizes OFDMA on the DL and SC-FDMA on the UL; MIMO

3

EV-DO (3GPP2) Evolution
EV-DO Continues to Evolve as the Leading IP WAN Standard

EV-DO **Year Standardized**	**Rel 0** 2000		**Rev A** 2004		**Phase 1** **Rev B** 2006		**Phase 2** **Rev C** Est. 2007
Key Features	All-IP, High FL Data Rates	**+**	VoIP, QoS, low latency High RL Data Rates	**+**	Dynamic Multi Carrier allocations, Higher Performance per Carrier	**+**	Higher Spectral Efficiency OFDM/MIMO/ SDMA
Key Services	BE Downstream (http, VoD, MoD)	**+**	Low Latency Comm. (VT, VoIP, PTC, gaming)	**+**	Broadband Apps, concurrent services	**+**	Enhanced Broadband Apps

The evolution of EV-DO allows operators to continue to be the first to deliver advanced IP-based services affordably

EV-DO Rev. A

- **New peak rates for better user experience**
  - 3.1 Mbps peak data rate on forward link
  - 1.8 Mbps peak data rate on reverse link

- **Higher Spectral efficiency**
  - Increased rate quantization on both forward and reverse link enables more efficient use of air link resources
  - 1.2 times Rel 0 forward link sector capacity
  - 3.4 times Rel 0 reverse link sector capacity

- **Reduced latency and optimized QoS enables delay sensitive applications**
  - Support for delay sensitive applications such as Push to Talk, Video Telephony, Instant Multi-Media (IMM), VoIP and low-delay gaming

- **DO Platinum Multicast**
  - 1.5 Mbps capacity with > 98% coverage
  - Configurable based on market needs

- **Backward compatibility**
  - Continued support for existing Rel 0 devices

EV-DO Rev. B: Multi-Carrier

- **Rev B aggregates multiple EV-DO channels for higher performance**
  - Gradual upgrades to existing Rev A networks will support All-IP applications at broadband rates
  - Allows deployment in "hot-zones" with high data demand
- **Higher peak data rates**
  - Aggregate carriers for linear gains in peak rates
    - 2 RFs – 6.2 Mbps, 3 RFs – 9.3 Mbps
  - Likely configuration of 5 MHz (standard supports up 20 MHz)
- **Increased bandwidth**
  - Support for wider bandwidth to address portable data and visual centric devices
  - Existing applications supported at higher rates
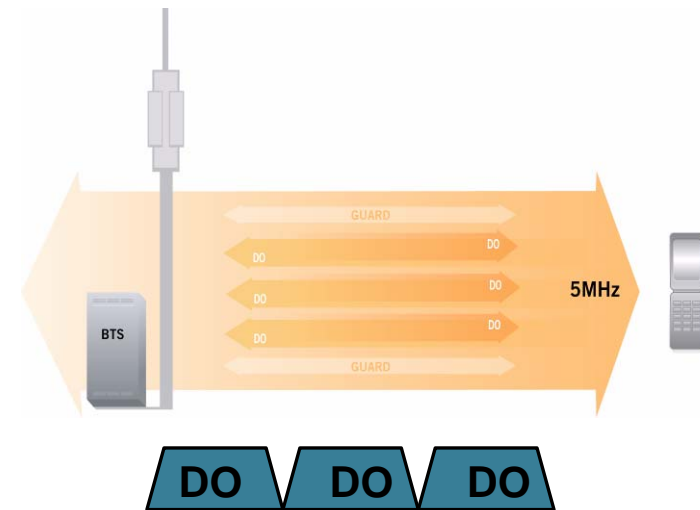- **Network flexibility**
  - Allocation of bandwidth for new devices depends on application needs and network availability
- **Higher capacity**
  - Improved spectral efficiency on both FL and RL due to Multi-carrier TX
- **Backward compatibility**
  - Continued support for existing Rev A devices
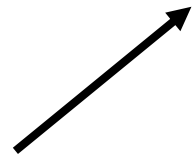 - DOrA channel cards can be utilized

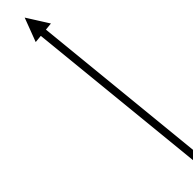**3 DO carriers with 5 MHz device**
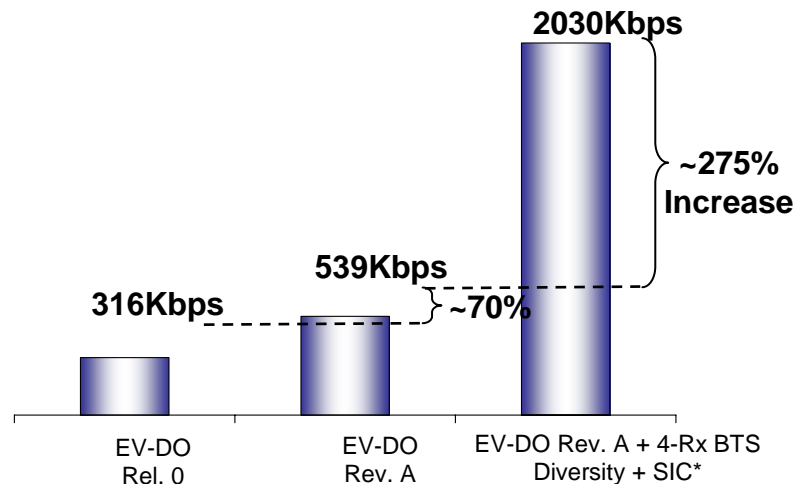
6

Continue to Drive Air Interface Improvements

EV-DO Rel 0, Rev A, Rx Diversity, Equalizer and Interference Cancellation Techniques

Forward Link
sector throughput gains

1500Kbps

~20% Increase

1240Kbps

~50%

830Kbps

EV-DO Rel. 0	Rel. 0 + 2-Rx Handset Diversity	Rev. A + 2-Rx Handset Diversity + Equalizer

Reverse Link
sector throughput gains

2030Kbps

~275% Increase

539Kbps

316Kbps

~70%

EV-DO Rel. 0	EV-DO Rev. A	EV-DO Rev. A + 4-Rx BTS Diversity + SIC*
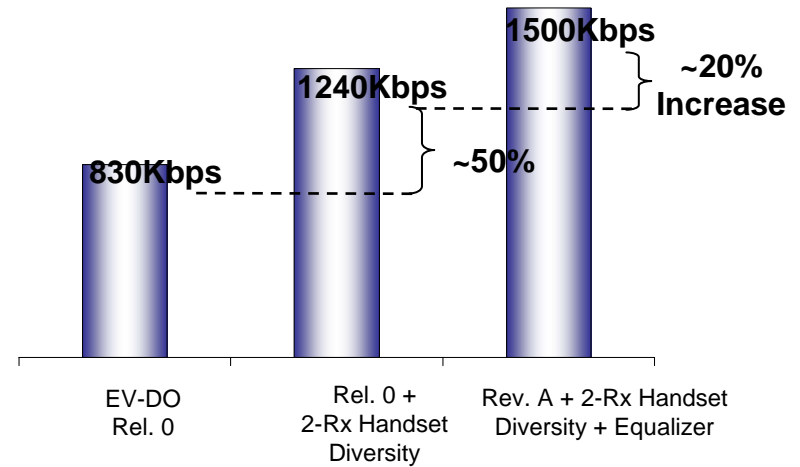
Figures are per sector for a single RF carrier.
*SIC: Successive Interference Cancellation.

QUALCOMM

Increasing Peak Data Rates and Throughput

Peak Data Rates Implemented

(Forward Link in 5MHz)

Kbps (in logarithmic scale)

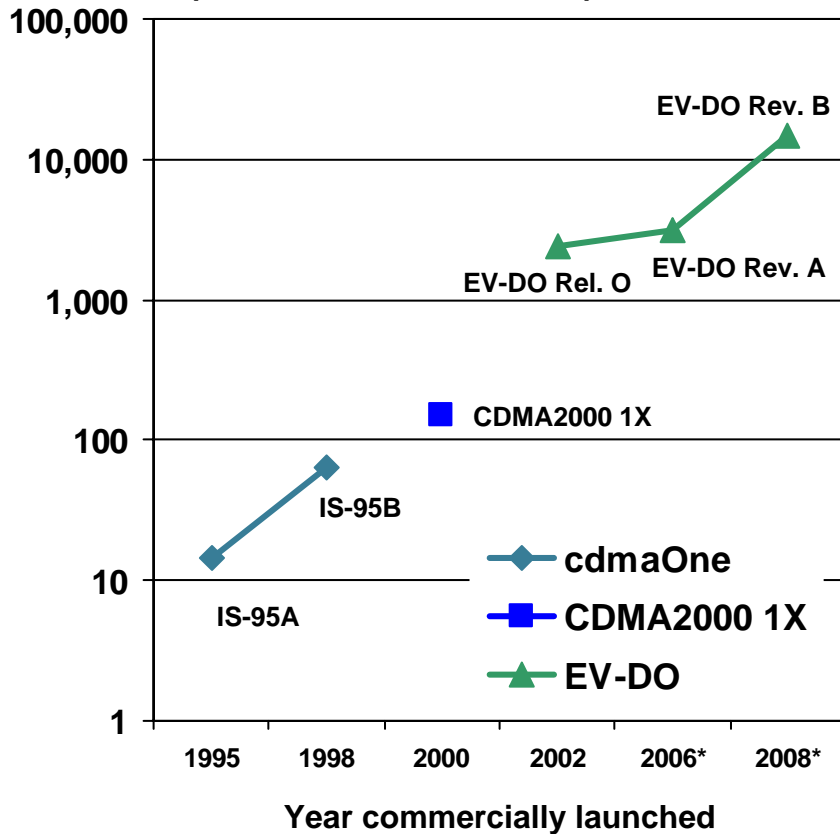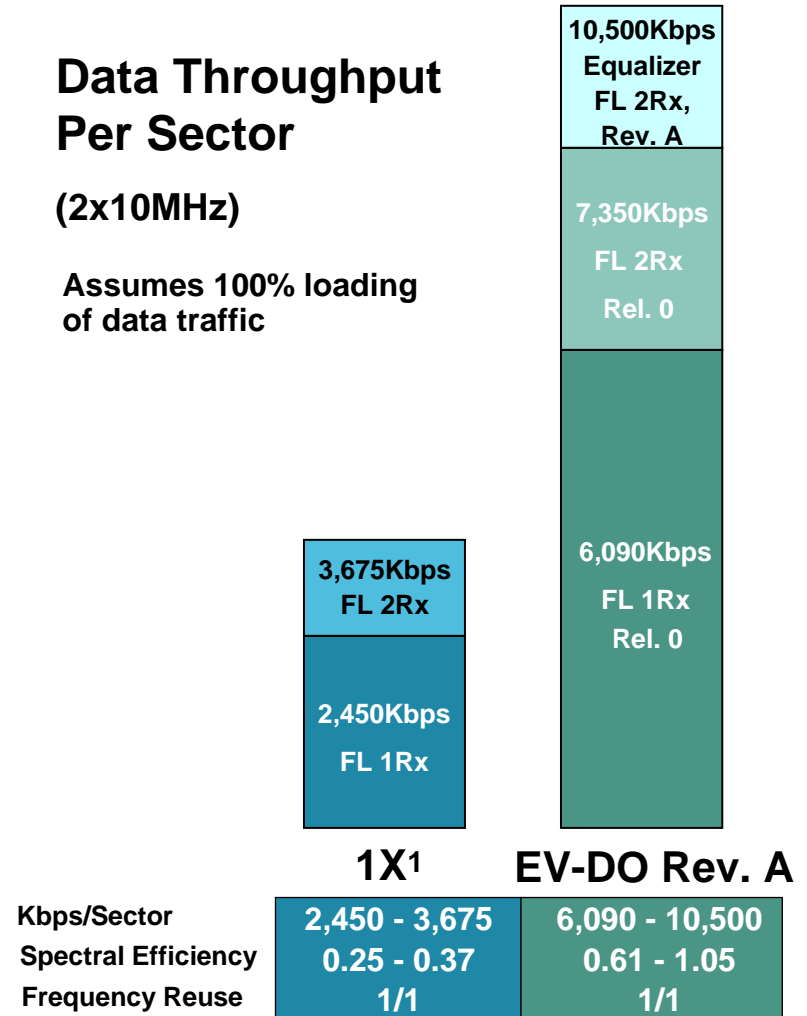- 100,000
- 10,000 — EV-DO Rev. B
- 1,000 — EV-DO Rel. O / EV-DO Rev. A
- 100 — CDMA2000 1X
- 10 — IS-95B / IS-95A
- 1

Legend:
- cdmaOne
- CDMA2000 1X
- EV-DO

Years: 1995, 1998, 2000, 2002, 2006*, 2008*

Year commercially launched

Data Throughput Per Sector

(2x10MHz)

Assumes 100% loading of data traffic

1X[1]
- 3,675Kbps FL 2Rx
- 2,450Kbps FL 1Rx

EV-DO Rev. A
- 10,500Kbps Equalizer FL 2Rx, Rev. A
- 7,350Kbps FL 2Rx Rel. 0
- 6,090Kbps FL 1Rx Rel. 0

	1X[1]	EV-DO Rev. A
Kbps/Sector	2,450 - 3,675	6,090 - 10,500
Spectral Efficiency	0.25 - 0.37	0.61 - 1.05
Frequency Reuse	1/1	1/1

1. CDMA2000 simulation methodology, 10 users per sector.
2. CDMA2000 simulation methodology, 10 users per sector, equalizer gain simulated. * Estimates.
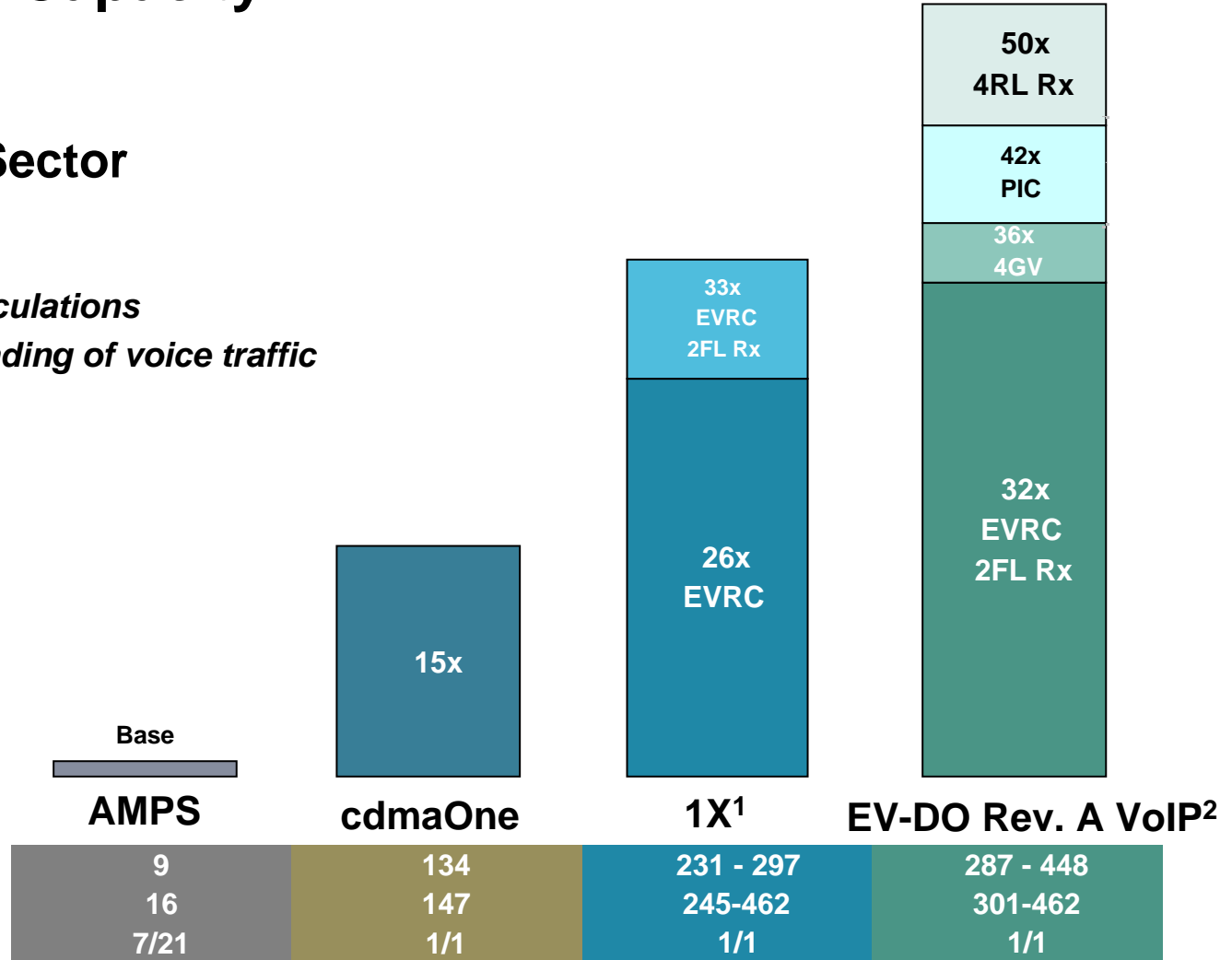
8

Growing Voice Capacity

Erlangs Per Sector

(2x10MHz)

2% GOS for all calculations
Assumes 100% loading of voice traffic

	50x 4RL Rx
	42x PIC
	36x 4GV
33x EVRC 2FL Rx	32x EVRC 2FL Rx
26x EVRC	
15x	
Base	

	AMPS	cdmaOne	1X[1]	EV-DO Rev. A VoIP[2]
Erlangs/Sector	9	134	231 - 297	287 - 448
Users/Sector	16	147	245-462	301-462
Frequency Reuse	7/21	1/1	1/1	1/1

1. "Further Capacity Improvements in CDMA Cellular Systems," QUALCOMM Inc., Roberto Padovani. Assumes two-way Rx Diversity at handset and four-way Rx Diversity at BTS. 4GV Capacity Operating Point 2.

2. QUALCOMM simulation, 4GV Capacity Operating Point 2.

9

EV-DO Rev. C: Objectives

- **Highly scalable evolution path of the EV-DO Rev 0, A and B standards**

- **Higher Peak Data Rates and System Capacity**

  - **Target peak data rates range from 70 Mbps to 200 Mbps, depending on mobility, for the FL and 30 Mbps to 45 Mbps for the RL**

  - **Application layer throughput 60/30 Mbps FL/RL**

- **Higher spectral efficiency (e.g., hot spots)**

- **Lower delay (10 ms latency)**

- **Higher mobility (up to 250 km/h)**

- **Enhanced VoIP capacity and user experience**

- **Support for bandwidth allocations up to 20 MHz in 1.25 MHz blocks**

- **Support flexible spectrum allocation options including possible operation on non-contiguous carriers**

- **Minimize control and signaling overhead**

- **Decrease terminal power consumption and improve battery life**

EV-DO Rev. C (3GPP2 Phase 2)
Going Beyond Rev B in 2GHz FDD

- **A Few modes in 3GPP2 for Phase 2 Evolution**

  1. **Full Backwards Compatible mode: UHDR-DO**
     - Inserts MBWA FL slots into DO FL
       - CDMA or OFDM + MIMO symbols
       - Relies on TDM frame structure
     - Improved battery life

  2. **Loosely Backwards Compatible modes: UHDR FDD/TDD**
     - FDD/TDD Modes of MBWA for 5 MHz and beyond
     - OFDMA FL, MIMO/SDMA
     - Quasi-orthogonal OFDMA RL
     - CDMA RL control channel
     - Leverages on DO Protocol Stack

- **Studies so far indicate all modes provide similar spectral efficiency**

  Note: UHDR – Ultra High Data Rate
  MBWA – Mobile Broadband Wireless Access

3GPP2 Summary

- **3GPP2 Evolution to offer highly enhanced next generation ubiquitous mobile broadband experience**

- **Ensures optimal utilization of time/frequency/spatial resources**

- **Targets high spectral efficiency and system capacity, low latency and improved VoIP capacity**

- **3GPP2 Phase 1 (Rev B) provides significant improvements through a SW upgrade in existing DO Rev A cards and potential enhancements with new channel cards for low risk migration**

- **3GPP2 Phase 2 (Rev C) provides a great competitive edge for CDMA operators over other next generation mobile wireless technologies**

- **Modes for strictly and loosely backwards compatibility with existing EV-DO networks to ensure smooth integration of CDMA with OFDMA mode**

- **Leverages existing DO technology and protocol stack to introduce OFDMA mode for new bands, and enables CDMA operators on the fast track.**

QUALCOMM®

WCDMA Evolution

WCDMA (UMTS)	HSDPA	HSUPA	Evolved 3G	
3GPP Release 99	*Release 5*	*Release 6*	*Release 7*	*Release 8 +*

▪ DL/UL: - 64 kbps CS - 384kbps (typical) - 2 Mbps (per std) ▪ MMS / LCS ▪ ATM Transport	▪ DL: -14 Mbps (standard) - 7.2Mbps (typical) ▪ IMS ▪ IP Transport ▪ WB-AMR	▪ UL: 1.4 - 5.8 Mbps ▪ MBMS ▪ WLAN-UMTS Inter-working ▪ IMS Services	▪ Enhanced support for real time services - IMS ▪ MIMO	▪ HSPA+ - Further enhance WCDMA in 5MHz ▪ LTE - Higher peak rates - Flexible bandwidth

All UMTS releases can be deployed in any of 10 specified bands including 2.1GHz, 1.7, 1.8 & 1.9 GHz, 850 & 900 MHz

WCDMA – A well established evolution path to broadband capabilities, while maintaining backward compatibility
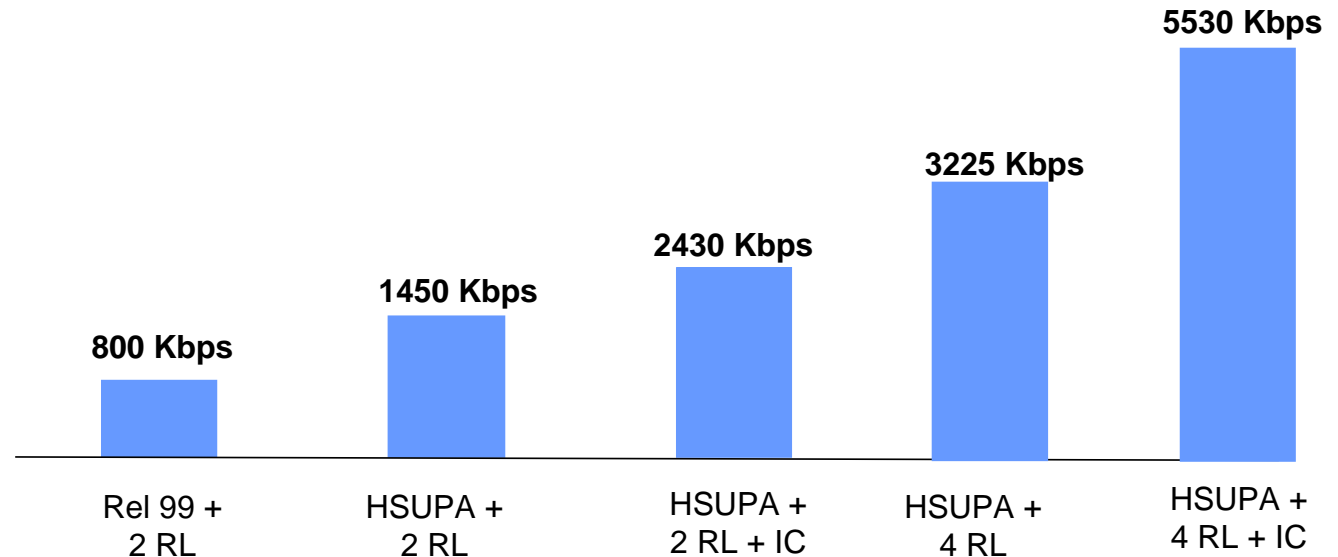
13

UMTS Evolution

- **Release 7, 8 & Beyond – Continued evolution of WCDMA in 5 MHz**
  - **Enhanced UE receiver performance requirements**
    - Inter-cell interference reduction for improved edge of cell performance
  - **Increased peak rate in high SNR scenarios - MIMO**
  - **Enhanced support for data services**
    - Reduced set-up times, enhanced support for real time services
    - Enhanced performance in "active state"
  - **HSPA+**
    - Enhanced IMS/IP services comparable to LTE (peak rates, delay, spectral efficiency)
    - Continued support for Rel. 99 and HSPA terminals
- **LTE**
  - **New air interface**
    - OFDMA in DL and SC-FDMA in UL
    - Same principles as HSPA+ : Link Adaptation, HARQ, MIMO, etc.
  - **High peak rates – 100 Mps DL/50Mbps UL in 20MHz**
  - **Flexible bandwidth and modes**
    - 1 – 20 MHz variable bandwidth
    - Flexible duplex modes -FDD, TDD and FDD half duplex
  - **Enhanced control of inter-cell interference and cell edge coverage**

QUALCOMM®

WCDMA Spectral Efficiency Summary

Sector Capacity in 5 MHz of spectrum

Downlink

800 Kbps	1200 Kbps	2400 Kbps	3600 Kbps	5200 Kbps
Rel 99 Single antenna	Rel 99 + 2-RX Handset	HSDPA + Single antenna	HSDPA + 2-RX handset	HSDPA + 2-RX handset + Equalizer

Uplink

800 Kbps	1450 Kbps	2430 Kbps	3225 Kbps	5530 Kbps
Rel 99 + 2 RL	HSUPA + 2 RL	HSUPA + 2 RL + IC	HSUPA + 4 RL	HSUPA + 4 RL + IC

15
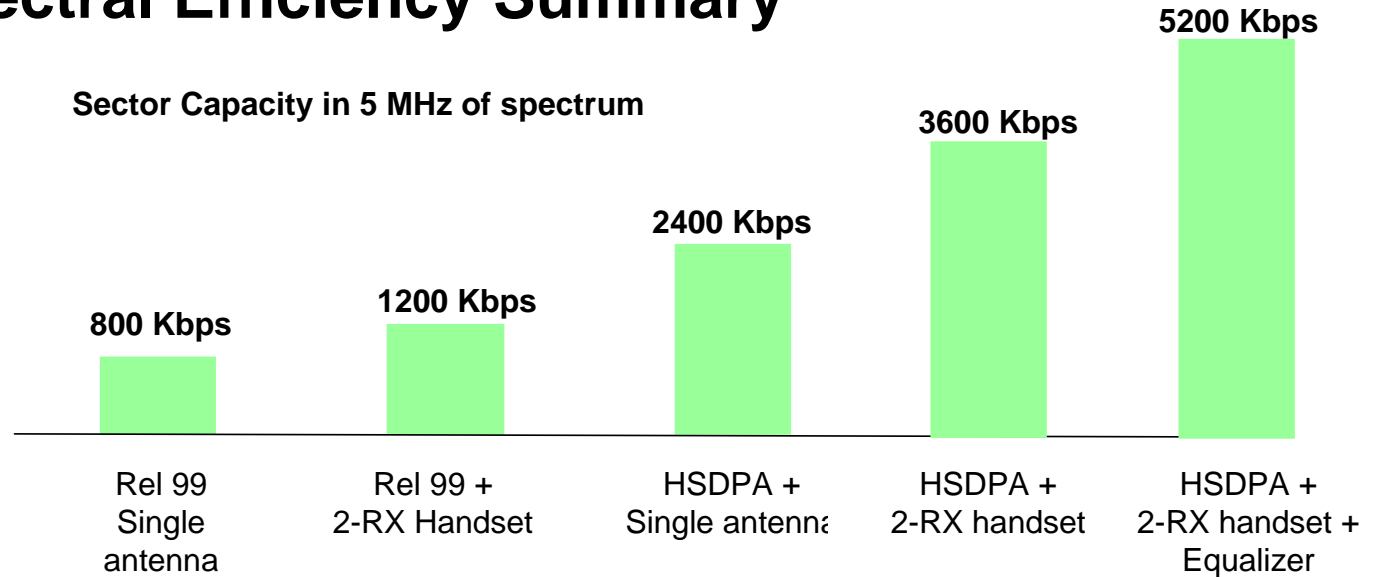
Mobile Broadband Vision
3G and Beyond

WPAN

CDMA2000, WCDMA, 802.20, FLO…

MPROC

GPRS, WLAN

GPS

DSP

3D Graphics

DSP

Video

Audio

Memory

Imaging

QUALCOMM
San Diego, CA
USA

WLAN
(802.11n)

Mobile MAN
(802.20, 3GPP2 Phase 2, LTE)

Relative Peak Rates

3G and Beyond Mobile WAN
(DOrA, DOrB, Flash-OFDM, HSDPA, HSUPA…)

Digital Mobile Broadcast
(FLO)

Relative Coverage

Best Connected Service:

- **Application-specific air interfaces**
- **New OFDM(A) Physical layers**
- **Common IP-based core network**
- **Integrated WAN / LAN services**
- **Multimode devices**

Illustrative only. Not drawn to scale.

16

QUALCOMM®

IEEE 802.20 Mobile Broadband Technology

- **MIMO optimized: Variety of advanced multiple antenna techniques supported**

- **FDD and TDD modes**

- **Supports RF channel bandwidths up to 20 MHz wide in licensed spectrum**
  - Peak data rates up to 260 Mbps
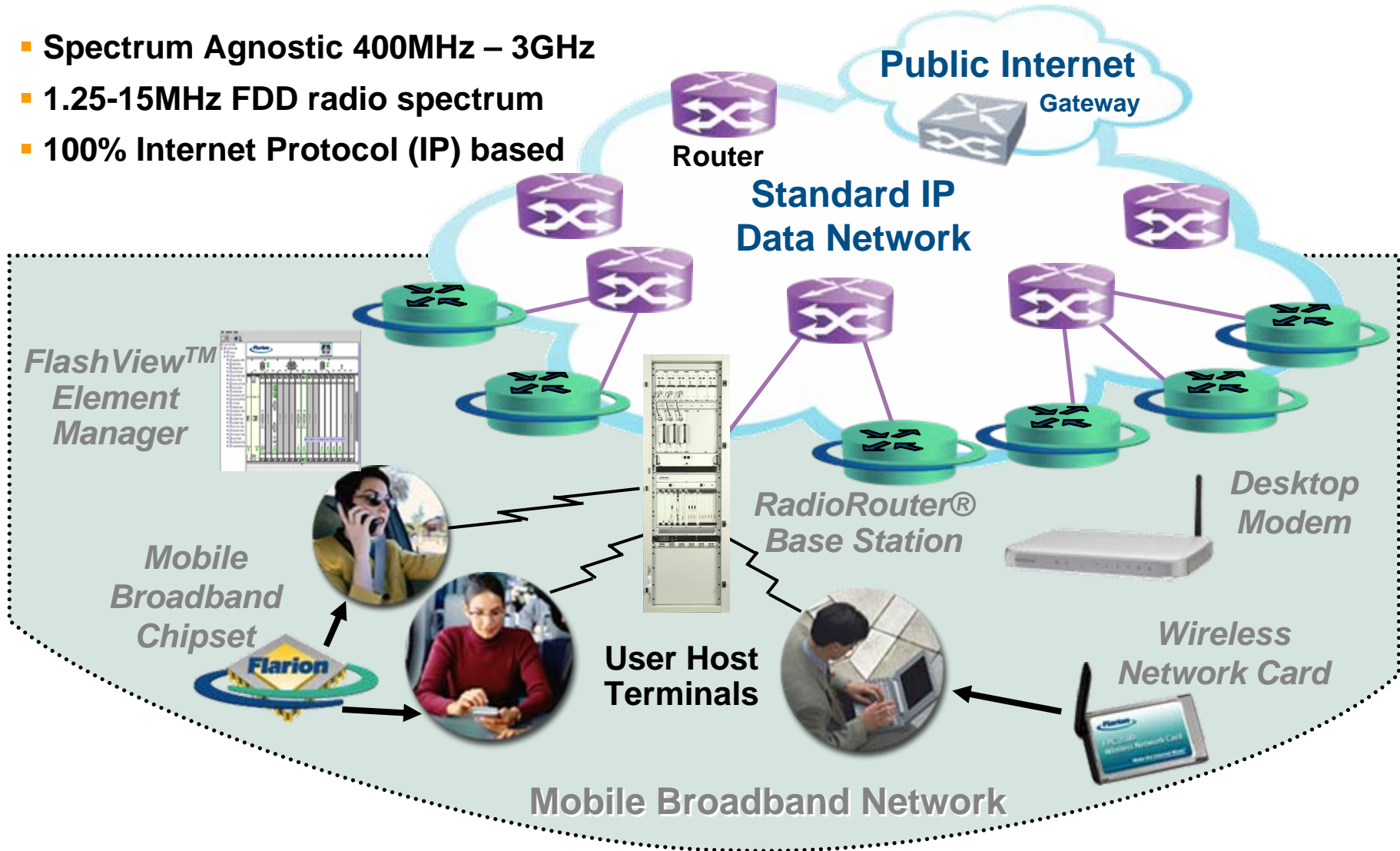 - Unparalleled spectral efficiency

- **System designed from ground up for mobile broadband**
  - Superior performance in macro-cellular and micro/picocell deployments
  - Flexible airlink resource management with efficient, low-overhead signaling

- **Advanced interference management**
  - Distributed power control
  - Fractional frequency re-use for cell edge performance

- **Superior mobility**
  - Proven/mature mobility mechanisms provide seamless, low latency handoffs
  - Fast sector selection using uplink CDMA control channels

QUALCOMM®

FLASH-OFDM® Mobile Broadband

- **Spectrum Agnostic 400MHz – 3GHz**
- **1.25-15MHz FDD radio spectrum**
- **100% Internet Protocol (IP) based**

Public Internet
Gateway

Router

**Standard IP
Data Network**

*FlashView™
Element
Manager*

*Mobile
Broadband
Chipset*

*RadioRouter®
Base Station*

*Desktop
Modem*

**User Host
Terminals**

*Wireless
Network Card*

Mobile Broadband Network

18

7 Years of Mobile OFDM Evolution

- **Five-Year Lead in Mobile OFDM Deployments**
- **System Concept 1998**
- **Four Years of Technical and Commercial Validation**
- **Market Trials 2004**
- **Commercial Launch 2005**

2006

2005

2004

2003

2001

1998

Early Commercial Deployment

Commercial Validation

Technical Validation

Innovation

19

FLASH-OFDM® Products

Network

3rd-party Solaris & Linux servers; 3rd party routers, Home Agent, etc.

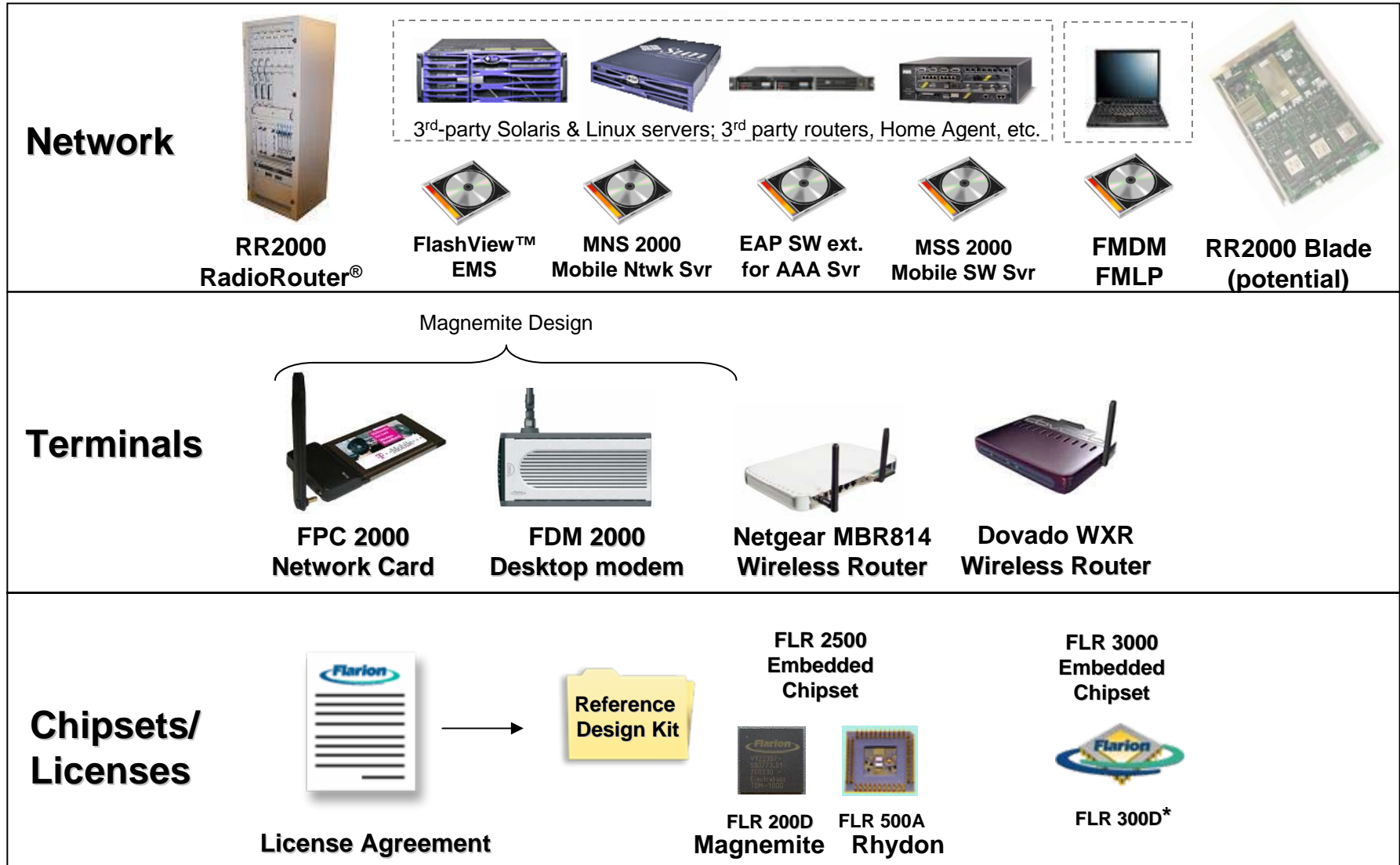| RR2000 RadioRouter® | FlashView™ EMS | MNS 2000 Mobile Ntwk Svr | EAP SW ext. for AAA Svr | MSS 2000 Mobile SW Svr | FMDM FMLP | RR2000 Blade (potential) |

Terminals

Magnemite Design

| FPC 2000 Network Card | FDM 2000 Desktop modem | Netgear MBR814 Wireless Router | Dovado WXR Wireless Router |

Chipsets/ Licenses

Flarion

Reference Design Kit

FLR 2500 Embedded Chipset

FLR 3000 Embedded Chipset

License Agreement

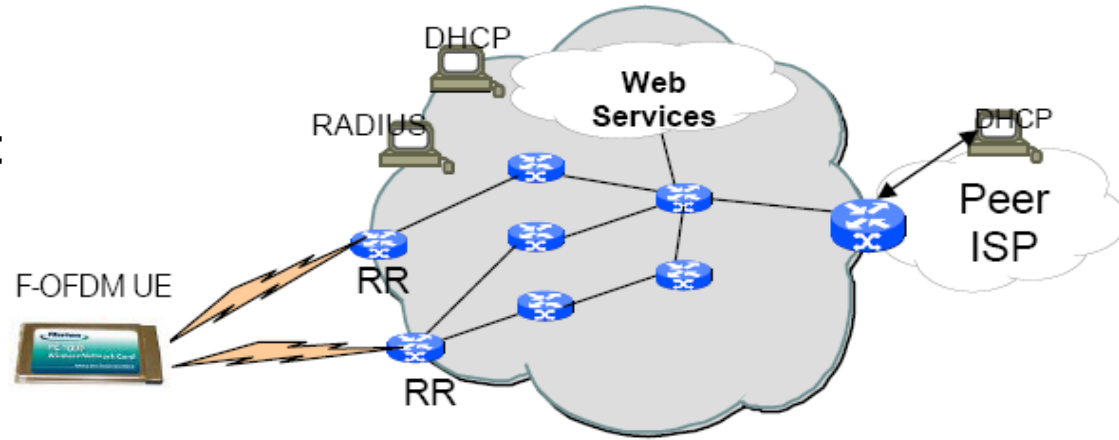FLR 200D **Magnemite**

FLR 500A **Rhydon**

FLR 300D*

Technical Performance

- RR1000 System Features:
  - **Low latency**
  - **High cell capacity**
  - **Tiered QoS**
  - **Simplified IP centric architecture**
  - **User experience close to wire-line DSL**
  - **Well suited for areas with low penetration of fixed line broadband**
  - **High user satisfaction**

DL peak data throughput	3.2	Mbps
DL average throughput**	1.5	Mbps
UL peak data throughput	0.9	Mbps
UL average throughput	0.5	Mbps
Average latency (RTT)	30	ms
Handoff success rate	99.2	%
VoIP cell capacity	31 active calls	

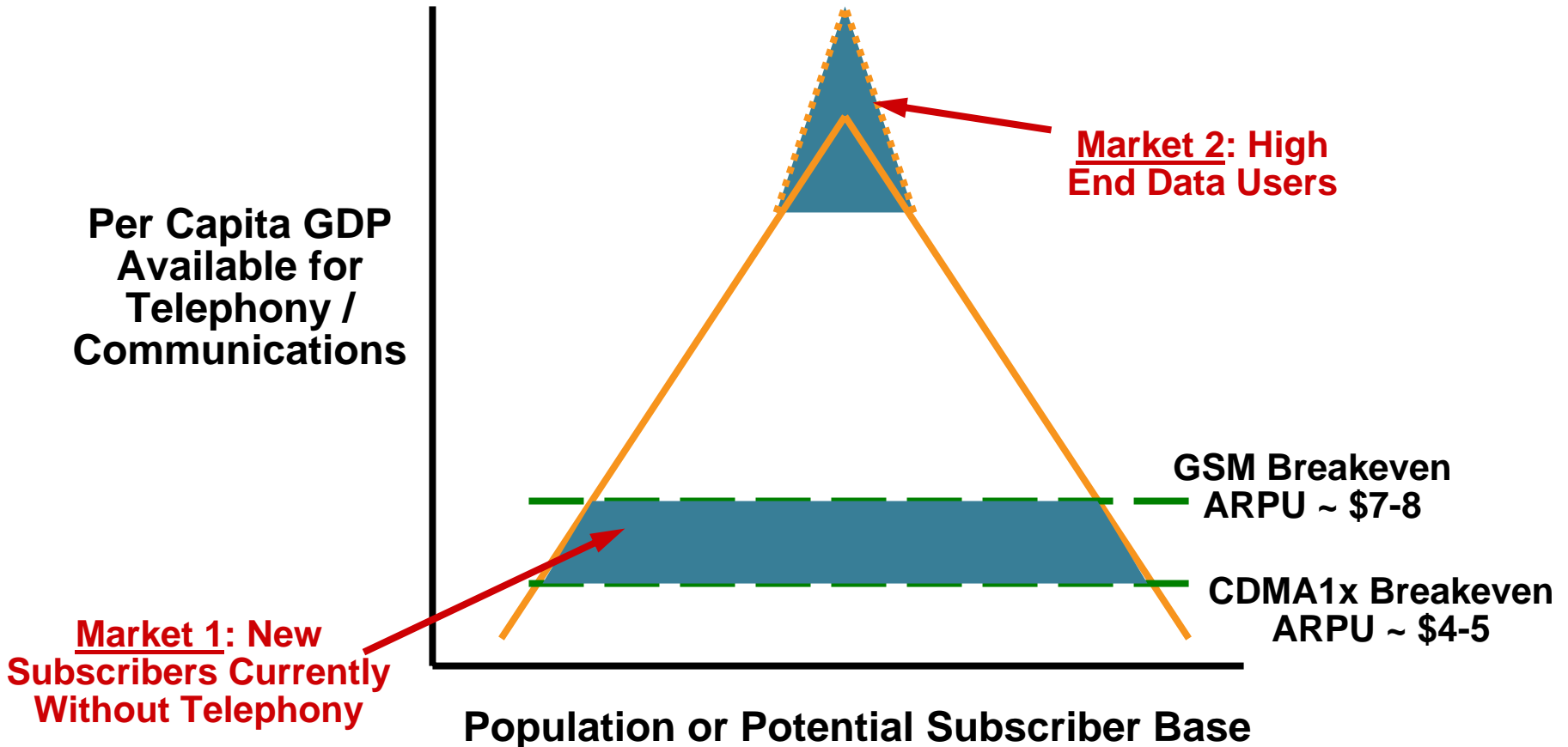**· · · · · · · T · · Mobile ·**

3G for Africa

3GCDMA Strengths:

- **<u>Designed for Spectral Efficiency</u>**

  - **Maximize users or data throughput in limited spectrum allocation**

  - **Metric: Shannon Limit**

  - **Interference Limited, and not Power Limited**

  - **Coverage dependent upon number of active users**

  - **Results in reduced CapEx/Sub for same service needs (Voice or Data).**

  - **Potential for Lower Tariffing to Subscribers; Better Competitive Technology for Network Operators**

- **<u>High Data Speeds</u>**

  - **Best Solutions for Wide-Area, Cellular coverage**

  - **Evolutionary Roadmaps, with scaleable bandwidth solutions**

  - **Very attractive for net connectivity in African context, at sub-GHz frequencies**

African Markets Addressed with CDMA:

Per Capita GDP Available for Telephony / Communications

Market 2: High End Data Users

GSM Breakeven ARPU ~ $7-8

CDMA1x Breakeven ARPU ~ $4-5

Market 1: New Subscribers Currently Without Telephony

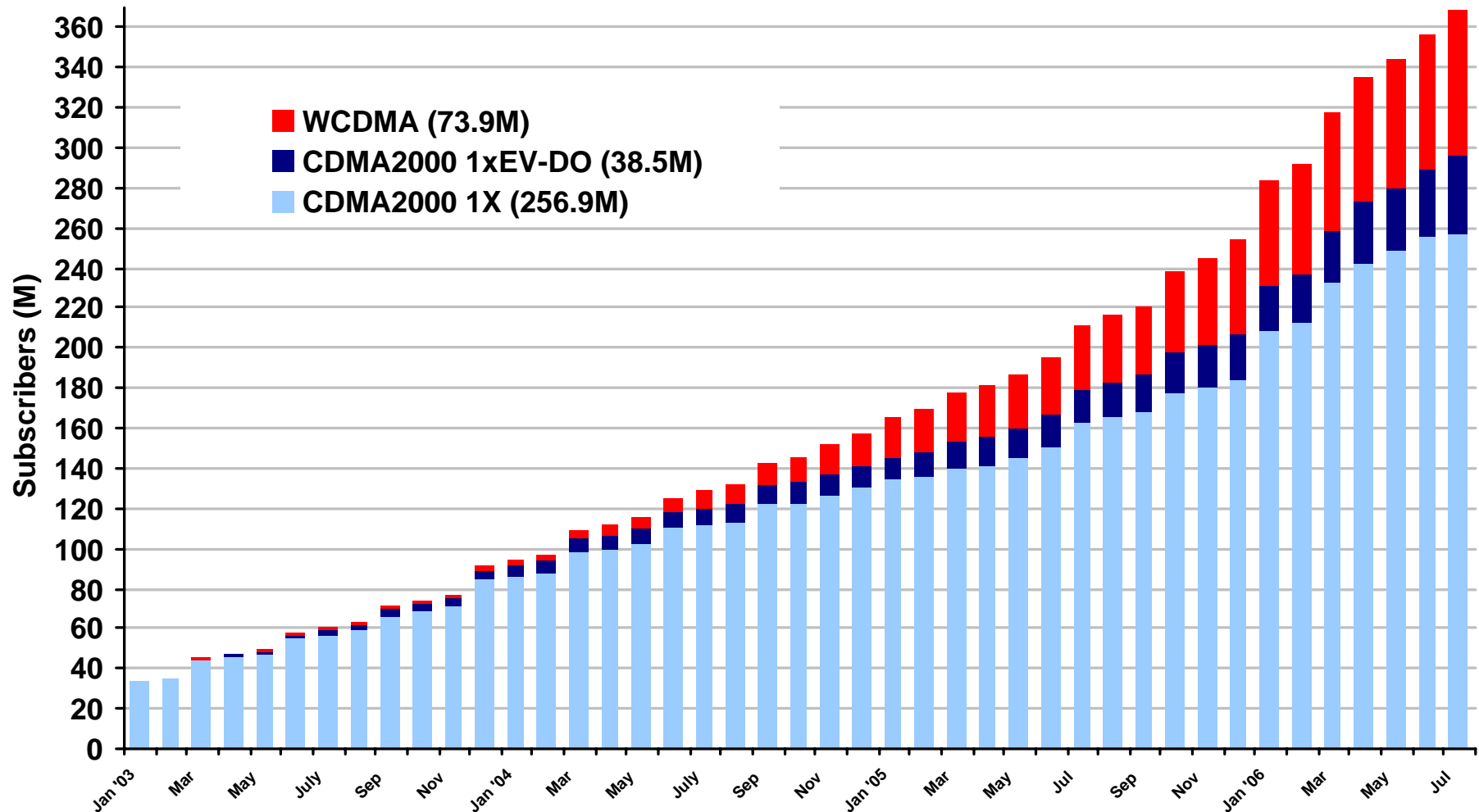**Population or Potential Subscriber Base**

CDMA Potential in Africa: Low-Cost Telephony, and High-Speed Data Services

24

QUALCOMM®

Over *369 Million* 3G CDMA Reported* Subscribers (Worldwide)
(Source: 3Gtoday.com, as of July31, 2006)

■ **WCDMA (73.9M)**
■ **CDMA2000 1xEV-DO (38.5M)**
■ **CDMA2000 1X (256.9M)**

Note: A number of 3G operators have yet to report 3G CDMA subscriber numbers.

Spectrum Allocations

Providing affordable, ubiquitous coverage is crucial in mobile communications

The benefits of the warmer (lower) licensed frequencies….

Greater range (larger coverage areas), fewer cell sites, reduced costs, better in-building penetration, better mobile performance, less power consumption, higher average data throughputs in an NLOS environment
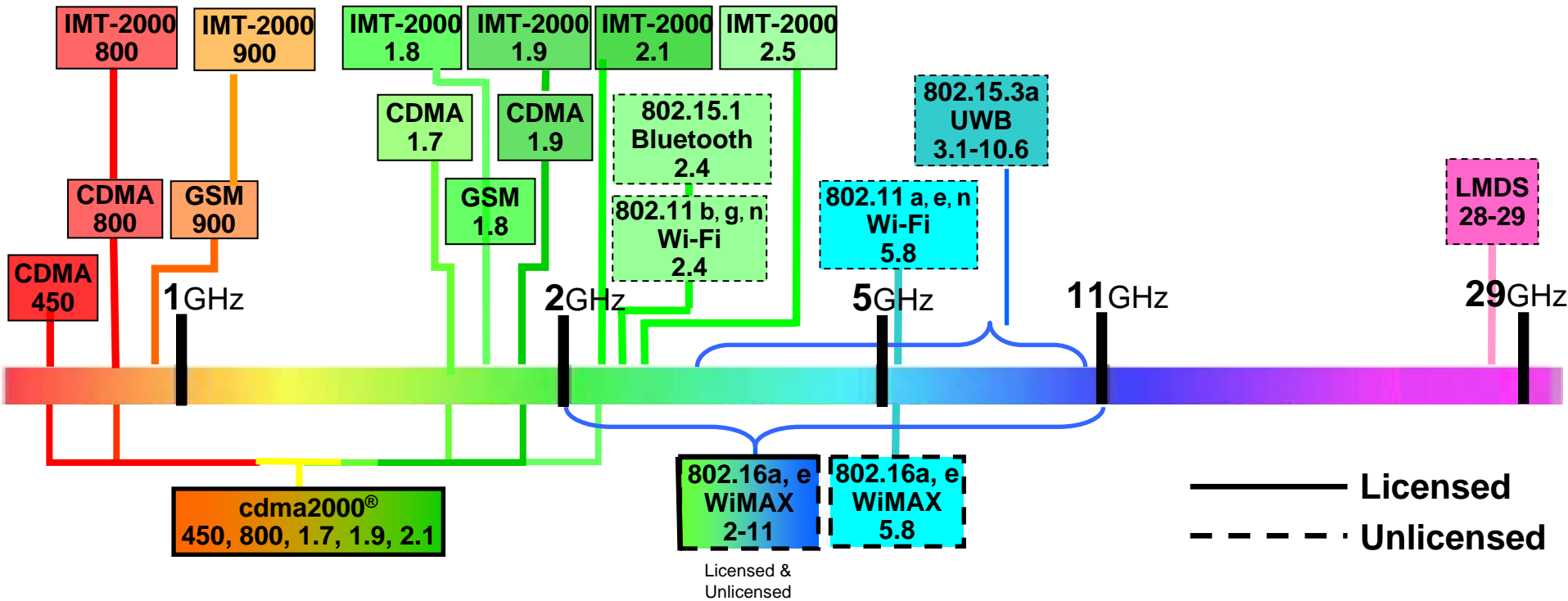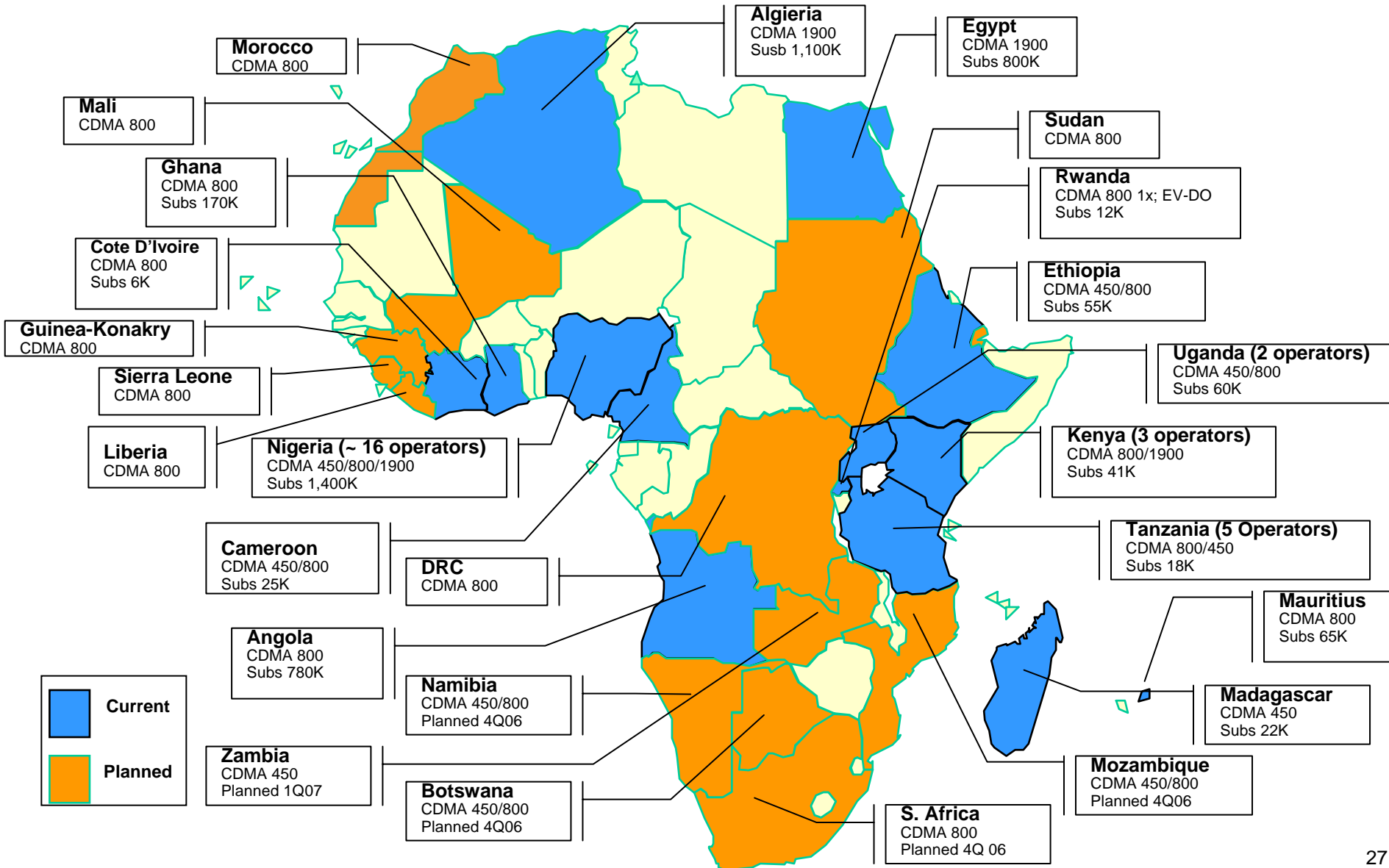

Using the lower frequency bands is preferable for providing
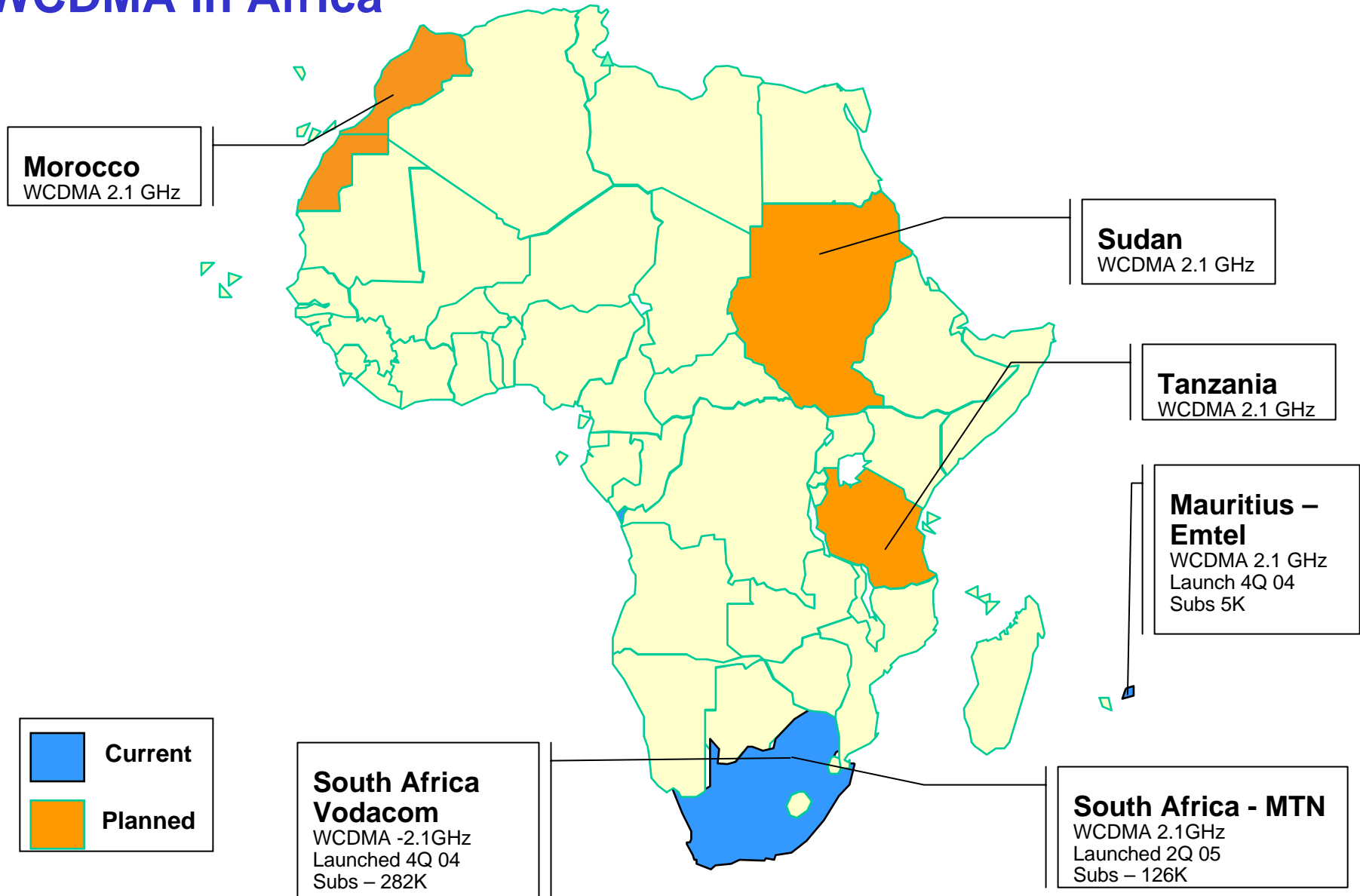*Universal Access for voice communications, Internet access & multimedia services*

26

CDMA2000 in Africa *from African CDMA Forum (www.3gafrica.org)*

Morocco
CDMA 800

Algieria
CDMA 1900
Susb 1,100K

Egypt
CDMA 1900
Subs 800K

Mali
CDMA 800

Ghana
CDMA 800
Subs 170K

Sudan
CDMA 800

Rwanda
CDMA 800 1x; EV-DO
Subs 12K

Cote D'Ivoire
CDMA 800
Subs 6K

Ethiopia
CDMA 450/800
Subs 55K

Guinea-Konakry
CDMA 800

Uganda (2 operators)
CDMA 450/800
Subs 60K

Sierra Leone
CDMA 800

Kenya (3 operators)
CDMA 800/1900
Subs 41K

Liberia
CDMA 800

Nigeria (~ 16 operators)
CDMA 450/800/1900
Subs 1,400K

Tanzania (5 Operators)
CDMA 800/450
Subs 18K

Cameroon
CDMA 450/800
Subs 25K

DRC
CDMA 800

Mauritius
CDMA 800
Subs 65K

Angola
CDMA 800
Subs 780K

Namibia
CDMA 450/800
Planned 4Q06

Madagascar
CDMA 450
Subs 22K

Current

Planned

Zambia
CDMA 450
Planned 1Q07

Botswana
CDMA 450/800
Planned 4Q06

Mozambique
CDMA 450/800
Planned 4Q06

S. Africa
CDMA 800
Planned 4Q 06

27

QUALCOMM

WCDMA in Africa

Morocco
WCDMA 2.1 GHz

Sudan
WCDMA 2.1 GHz

Tanzania
WCDMA 2.1 GHz

**Mauritius –
Emtel**
WCDMA 2.1 GHz
Launch 4Q 04
Subs 5K

Current

Planned

**South Africa
Vodacom**
WCDMA -2.1GHz
Launched 4Q 04
Subs – 282K

South Africa - MTN
WCDMA 2.1GHz
Launched 2Q 05
Subs – 126K

28

Challenges…

- ## Regulatory..

  - **The Largest Regulatory Challenge in Africa is Spectrum Utilization**

  - **Wireless 3G Voice and Data Services are needed <u>now</u> to leapfrog Africans to higher teledensity**

  - **Africa, although ITU Zone 1, doesn't heavily use 800 MHz for Broadcast ➔ Reallocate 800 MHz Spectrum for Cellular 3G Services, <u>NOW</u>**

- ## Ecosystem and Economies of Scale..

  - **Africa needs to adopt technologies and standards that enjoy widespread economies of scale ➔ Enjoy low cost access!**

  - **Need to ensure robust ecosystem ➔ Ready availability of Infrastructure and Handsets ➔ Quicker Time-to-Market**

Thank You!

Sachin Bhatmuley
sachinb@qualcomm.com

Dr. Thomas O'Neill
toneill@qualcomm.com

)