Beceem Communications Inc.

Leading the Wireless Broadband Revolution

Mobile WiMAX

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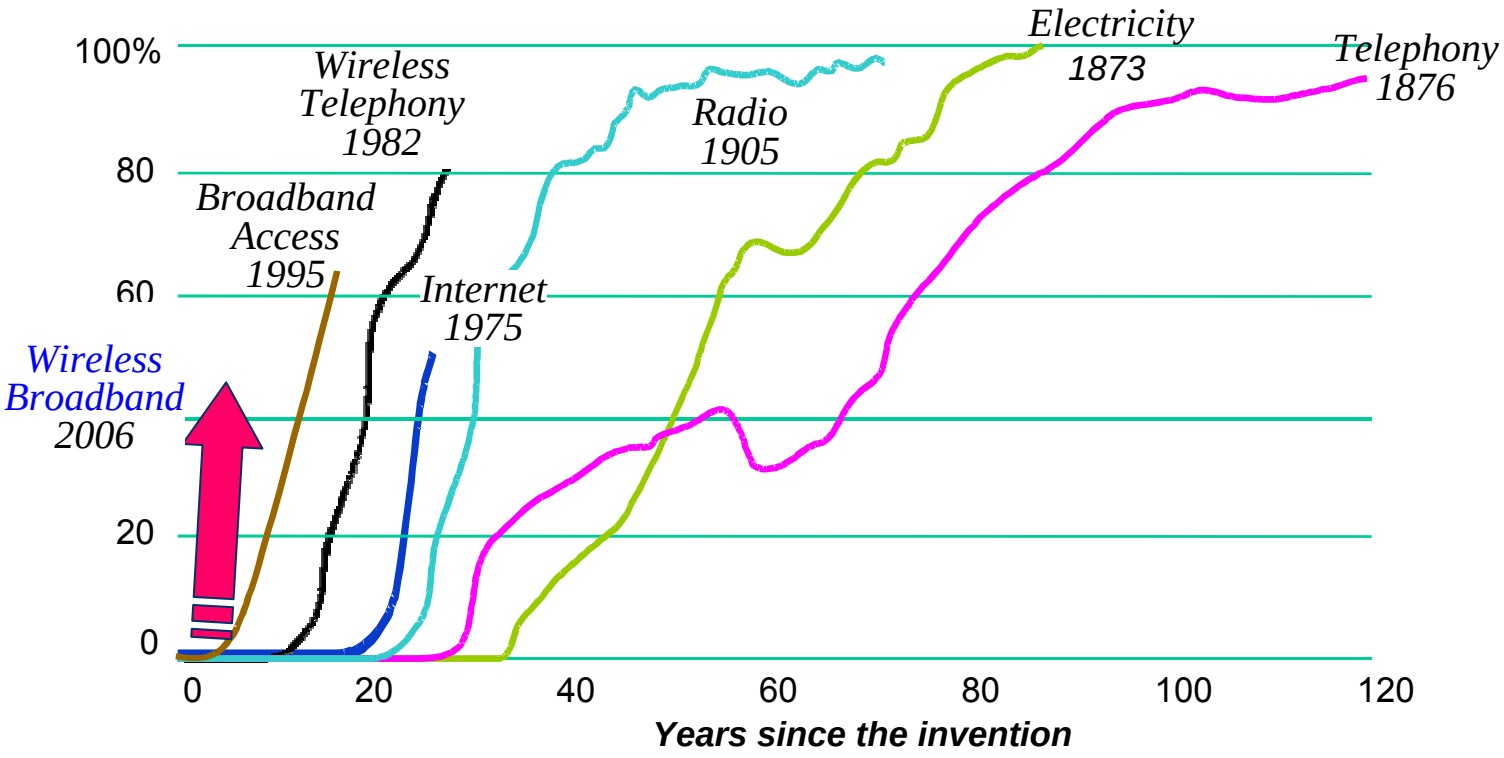
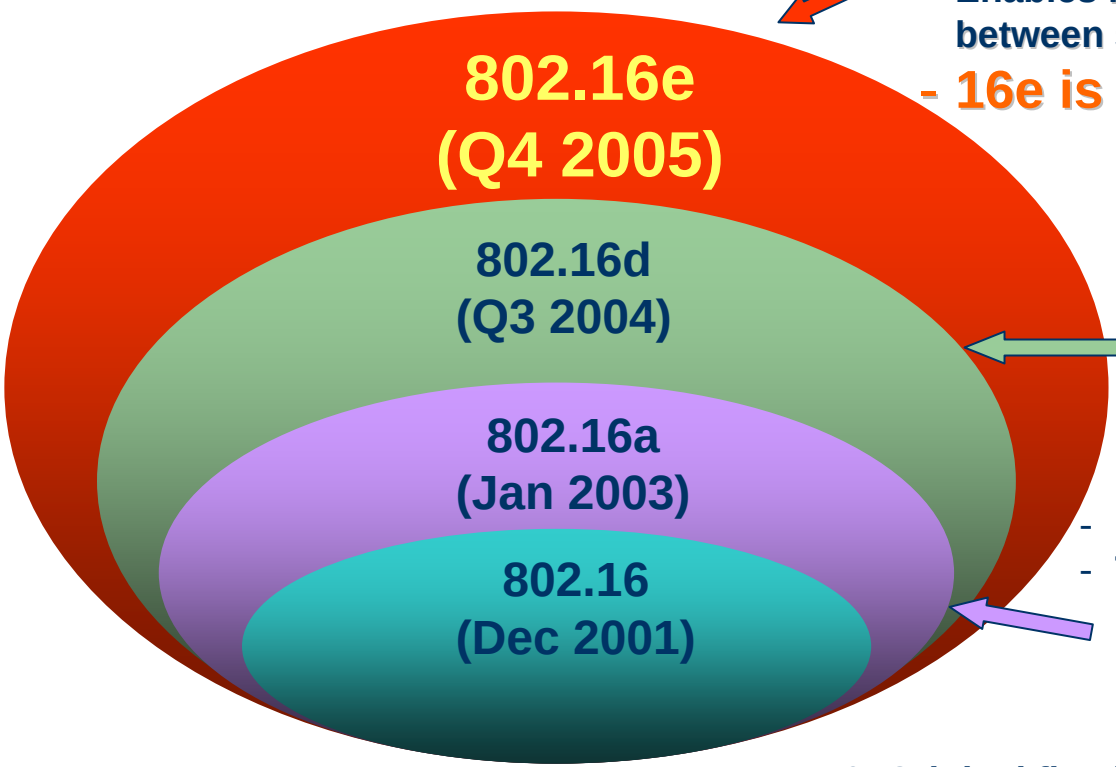
The Market Opportunity



Wireless Broadband has tremendous growth potential if ...

802.16 Standards



- .16e: Amendment for Mobile BW @vehicular speeds in licensed bands < 6 GHz
- Enables roaming for portable clients within & between service areas
- **16e is for fixed/portable/mobile**

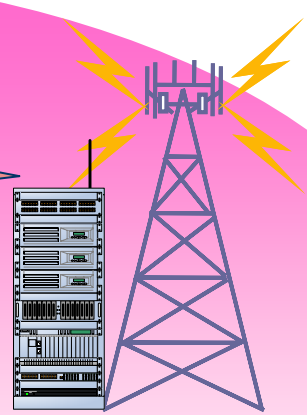
- .16d: Revision to 802.16a to add Errata, Enhancements and WiMAX System Profiles
- 16d is mainly for fixed application

- .16a: Amendment for 2-11 GHz
- Targeted for non line of sight, Point-to-Multi-Point applications like fixed last mile broadband access

- .16: Original fixed wireless broadband air Interface for 10 – 66 GHz
- Point-to-Point applications

802.16-2004 and 802.16e

BEST FIT
for Converged Fixed / Mobile
Multi-media Services

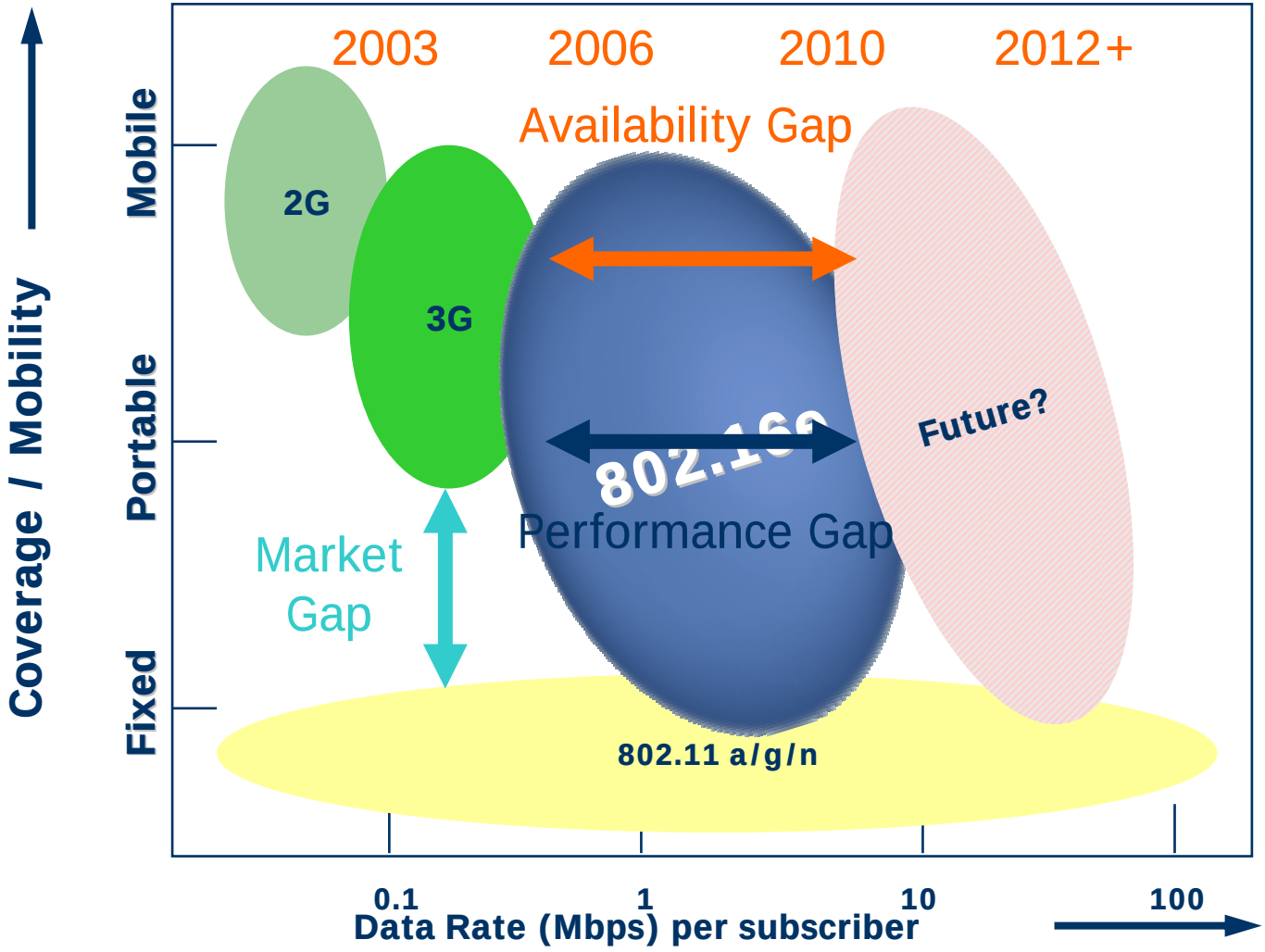


802.16-2004

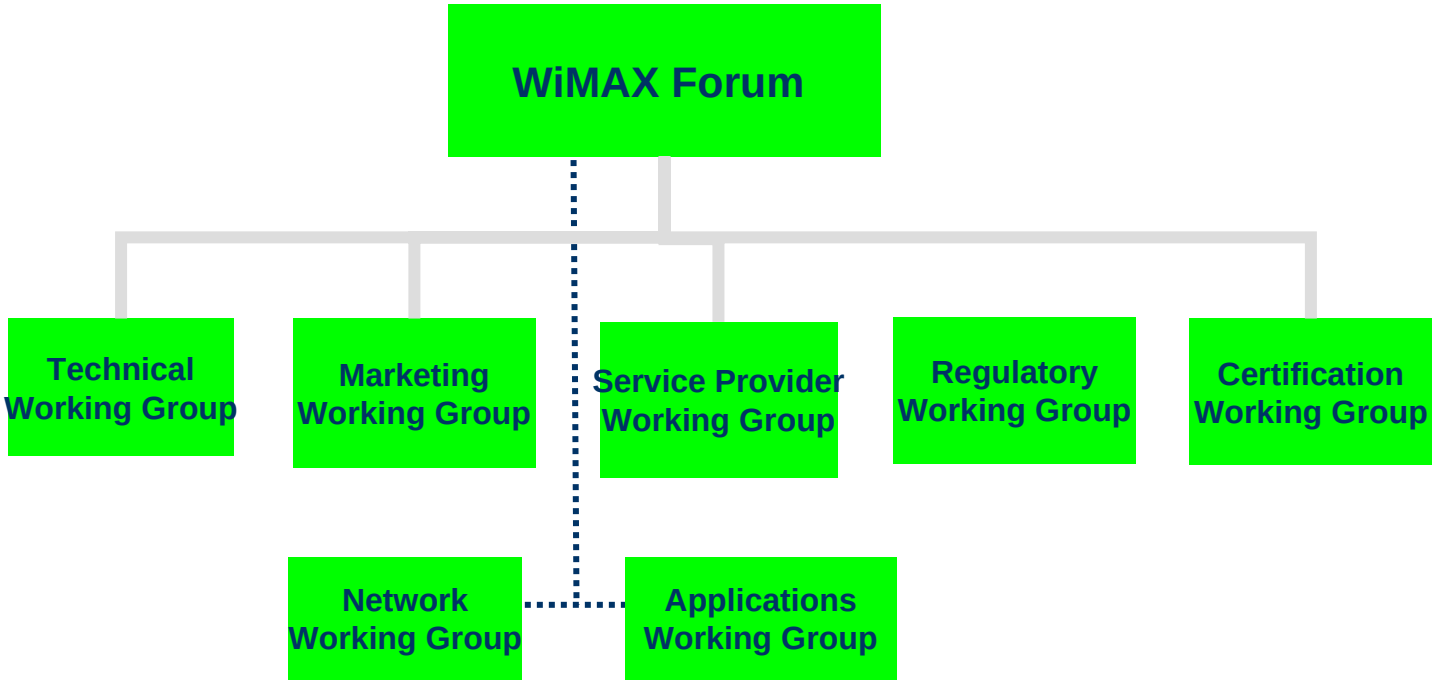
802.16e

Fixed Outdoor | Indoor unit | Portable unit | Mobile unit | Consumer Devices

Broadband Wireless 16e Fills a Market Opportunity

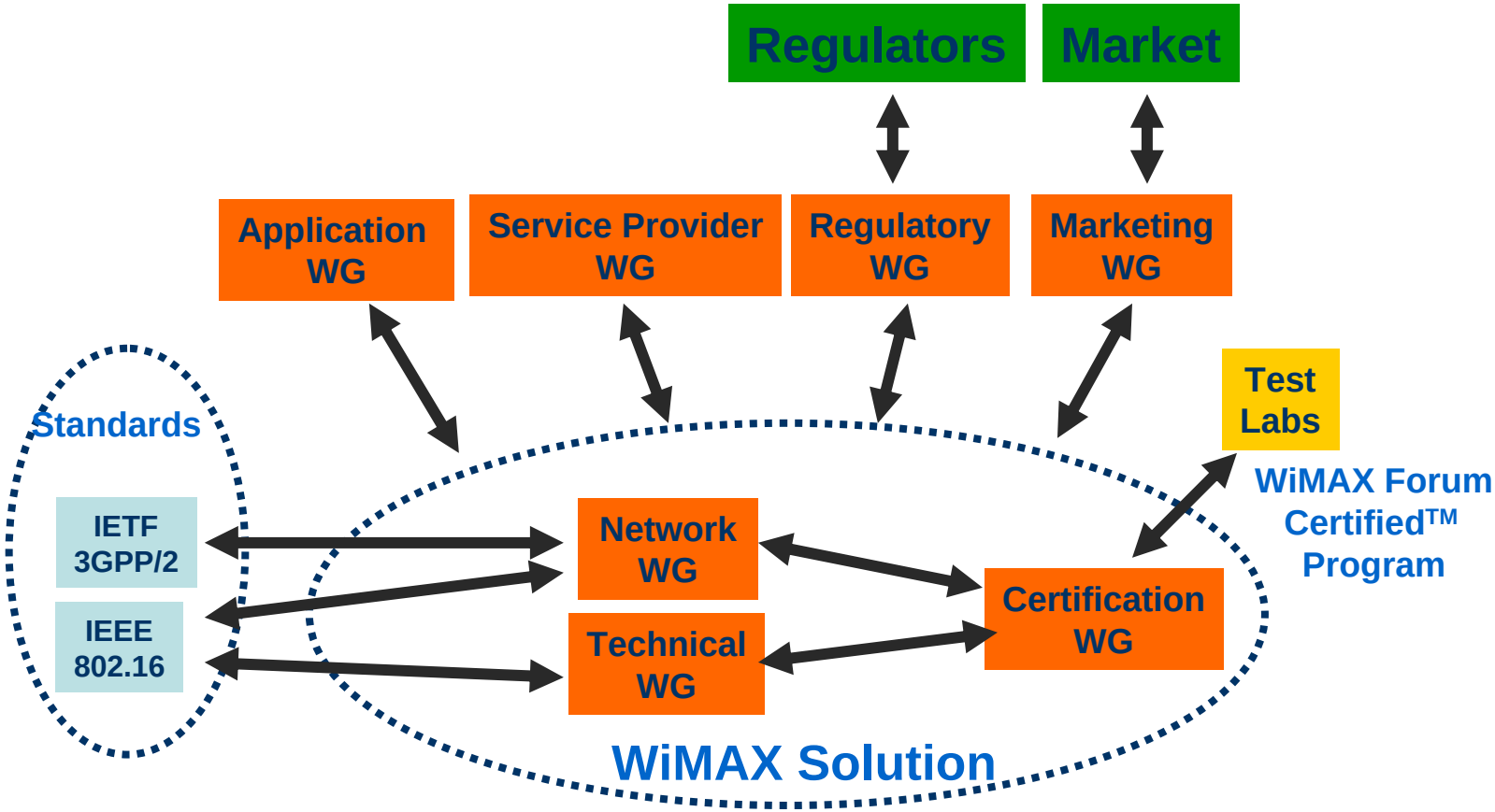


WiMAX Forum

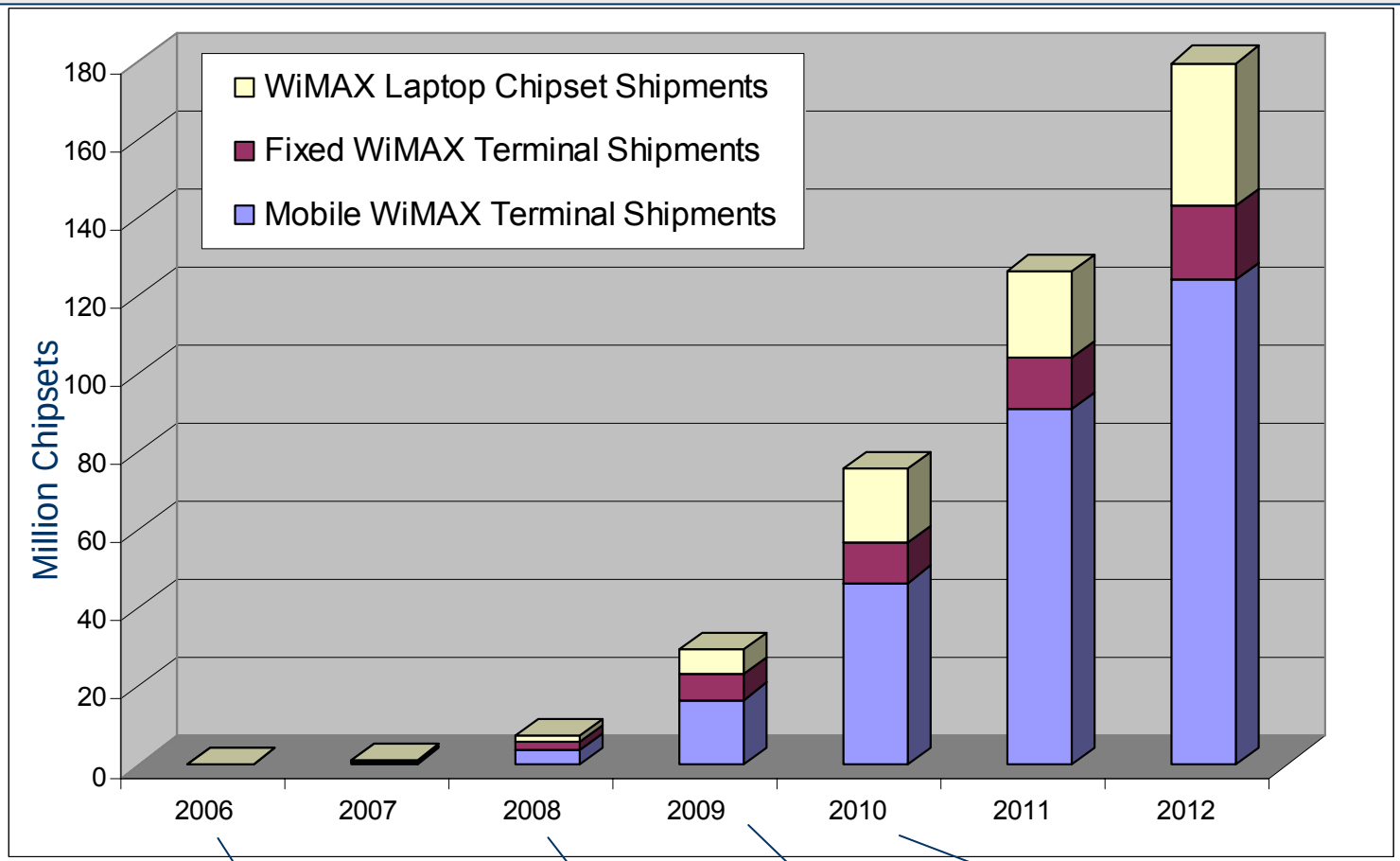


Promote and guide market position WiMAX
Establish global harmonization of WiMAX standards
Ensure products meet industry expectations
Secure Regulatory Commitments for global access to spectrum
Establish a Network Architecture framework for WiMAX ecosystem
Define and plan favorable services for WiMAX systems

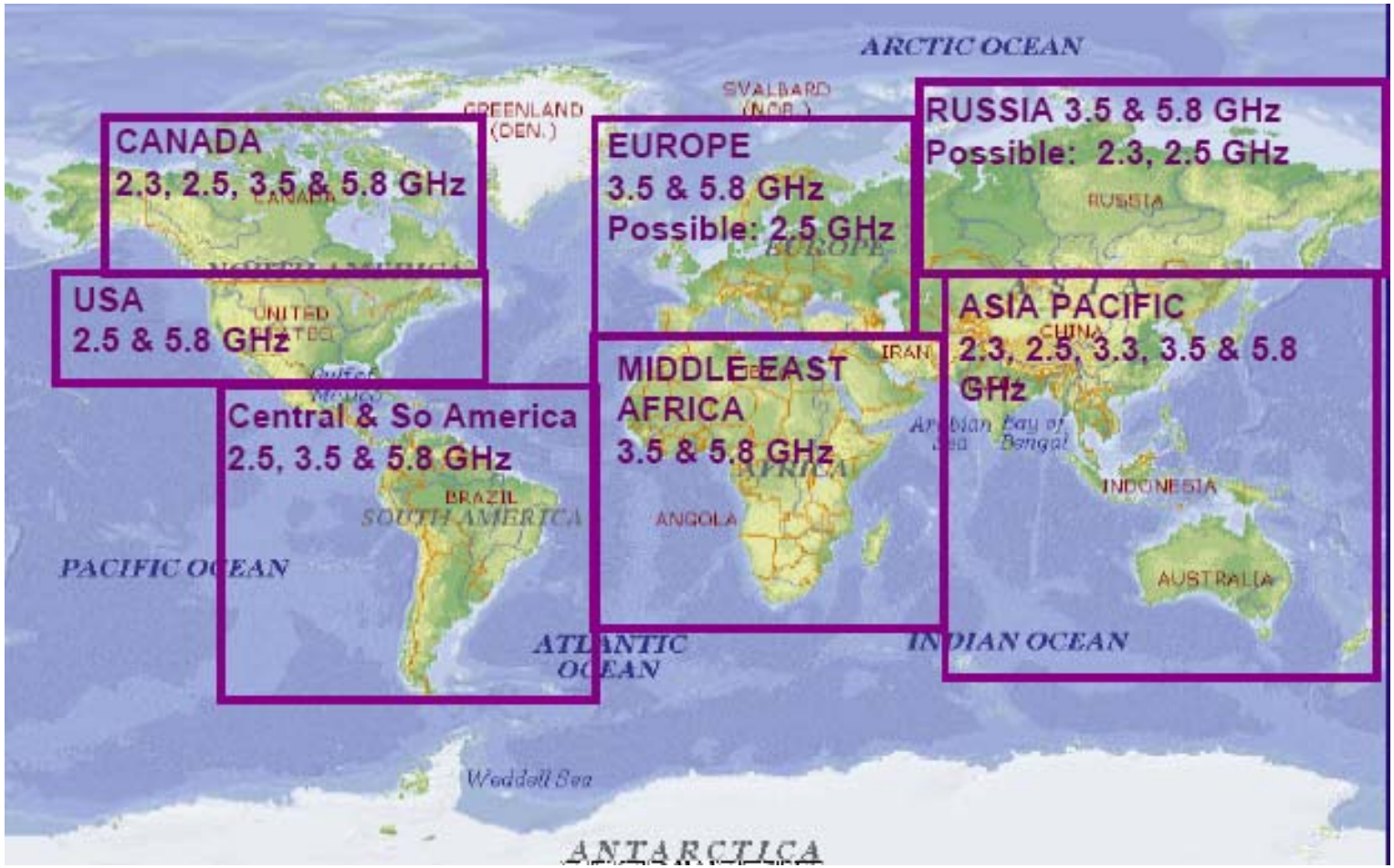
WiMAX Ecosystem



WiMAX Market Projections



WiMAX Spectrum Opportunities



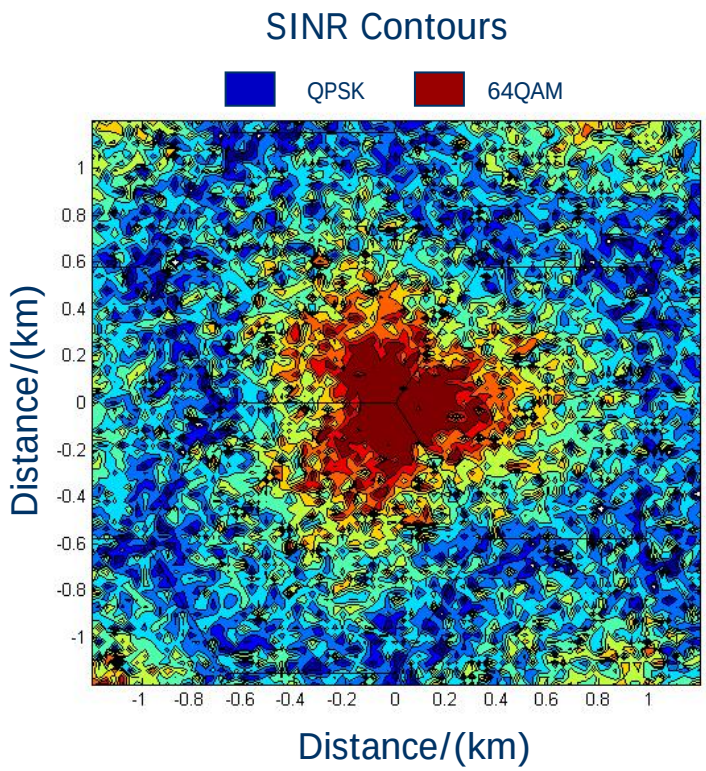
Source: Intel – LSG APEC Meeting April '05

Early Carrier Interest

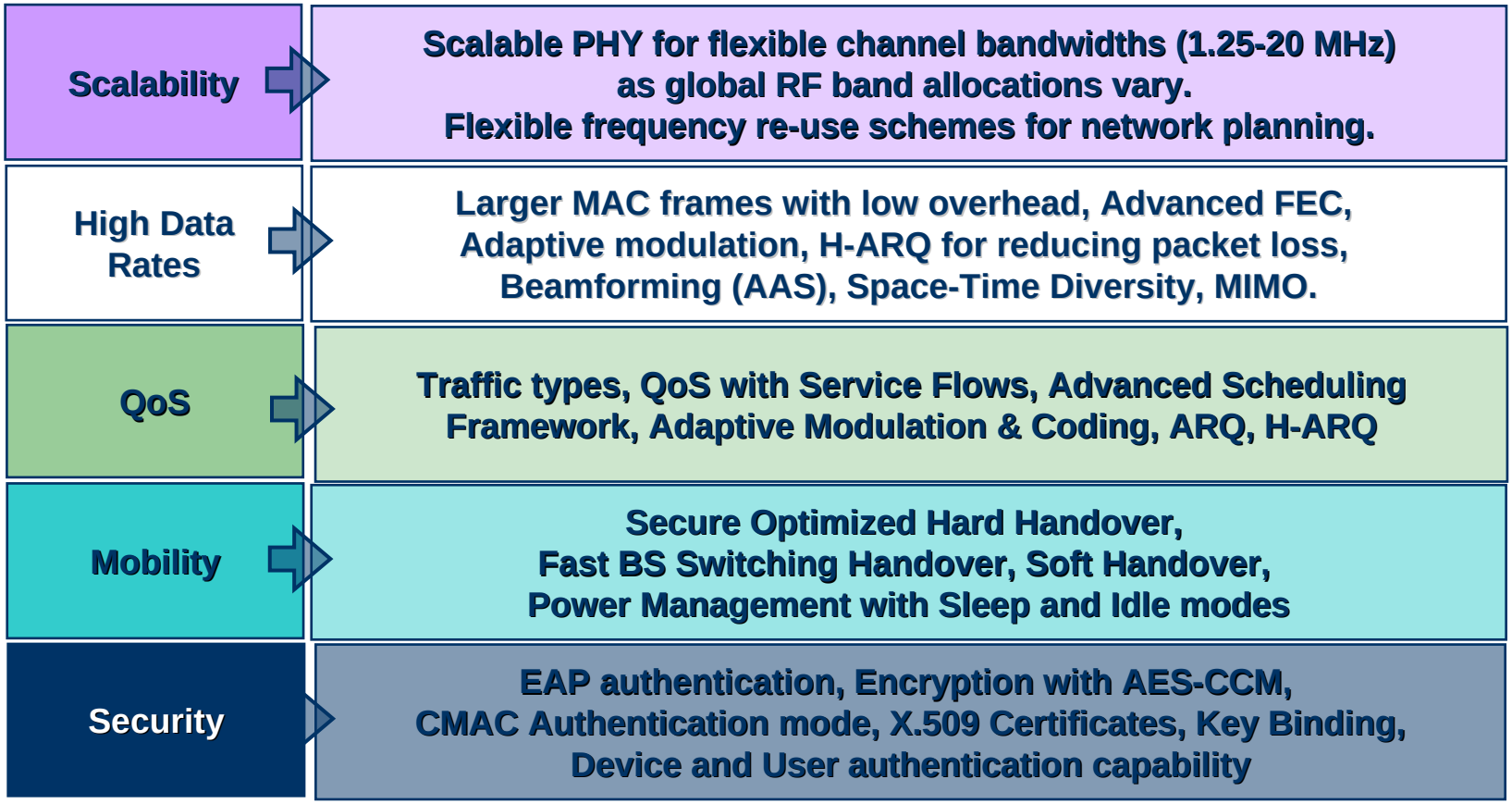
Country	Carriers	Comments
Korea	**KT, SKT**	KT is highly interested in wireless services to complement its wireline business.
US	**Sprint Nextel**	Sprint Nextel looking to increase market share using the BRS spectrum they own
India	**BSNL, Reliance, Tata, Bharti**	Lack of infrastructure creates a natural pull for standard based technology
UK	**BT**	Wireline carrier looking to expand into wireless business to become one stop shop
Japan	**KDDI**	Great interest in a high performance, low cost alternative to super 3G
China	**China Netcom**	Chinese government is putting more emphasis on WiMAX vs. 3G

Wireless Broadband isn't easy but it can be done!

- Data rate depends on signal quality
- Signal quality impacted by many factors
  - Signal degradation over distance
  - Multi-path (signal shift in time)
  - Doppler (signal shift in frequency)
  - Fading (time based channel changes)
  - Interference from other users
- 802.16e uses advanced techniques to maximize signal quality
  - Diversity
  - Opportunistic scheduling
  - Beamforming
  - MIMO



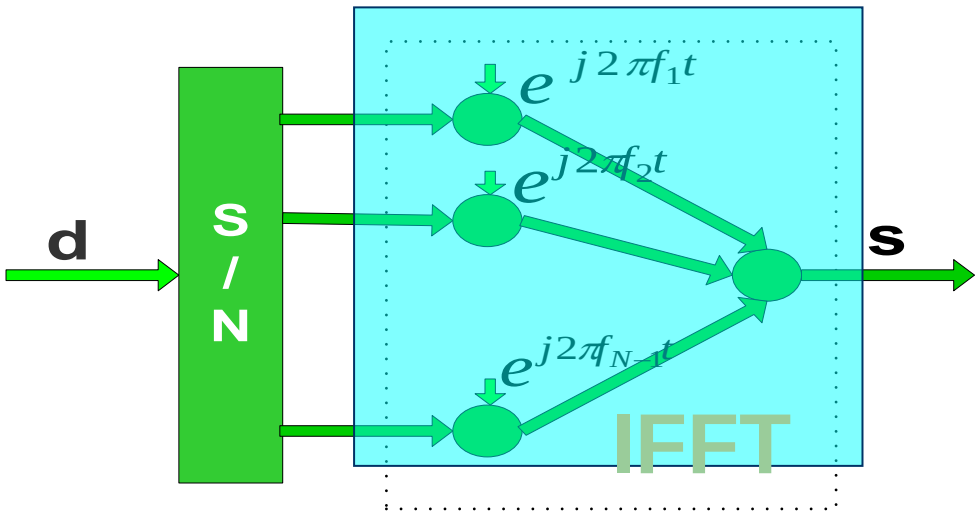
Mobile Standard Salient Features



Source: Intel

Why OFDM?

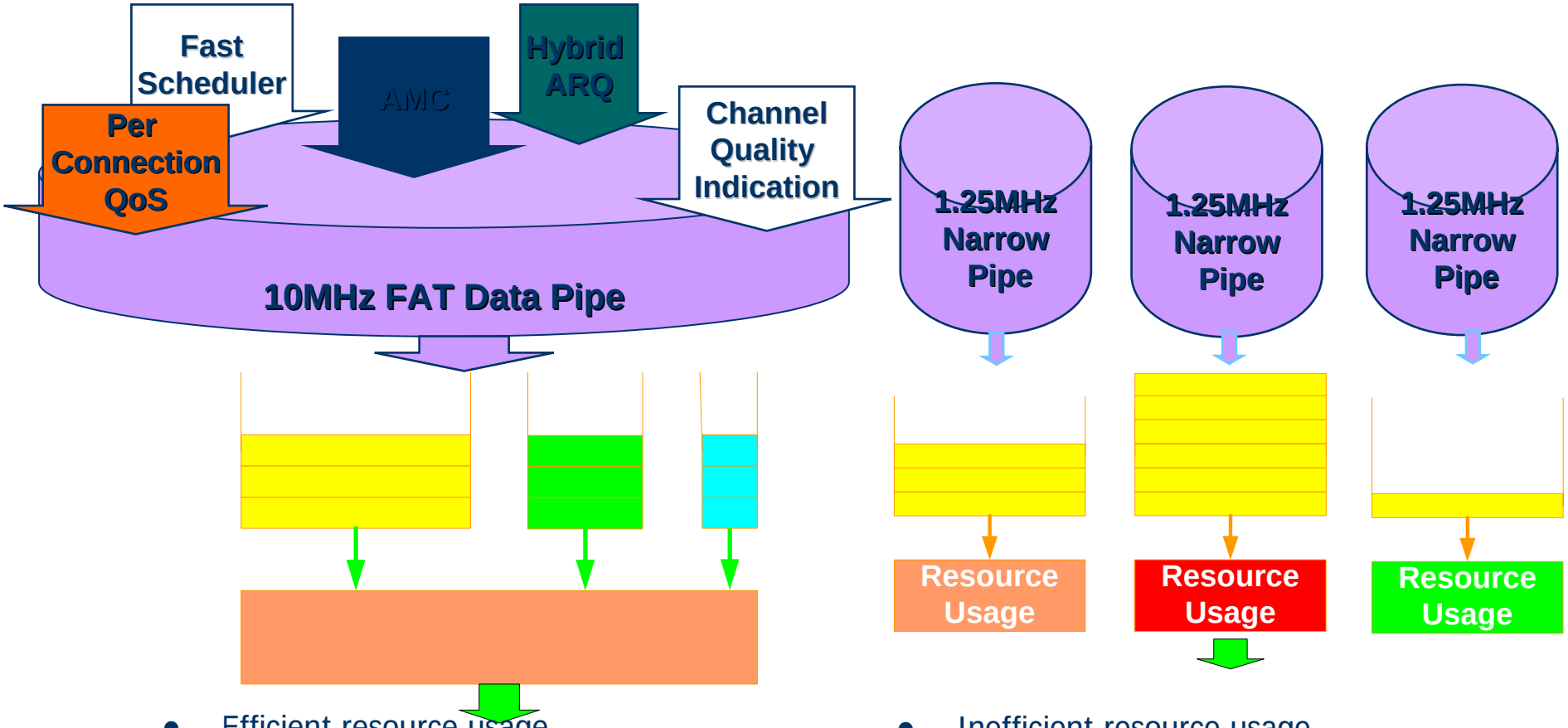
- TDMA and CDMA suffers in high delay spread channels
- How to combat frequency selective fading?
  - parallel orthogonal flat narrowband channels



- Orthogonal subcarriers → high spectral efficiency
- FFT fast algorithm → large number of subcarriers, efficient to implement
- Low data rate on each subcarrier → low ISI
- Combing with advanced FEC →reducing burst errors

Source: Intel

Quality of Service

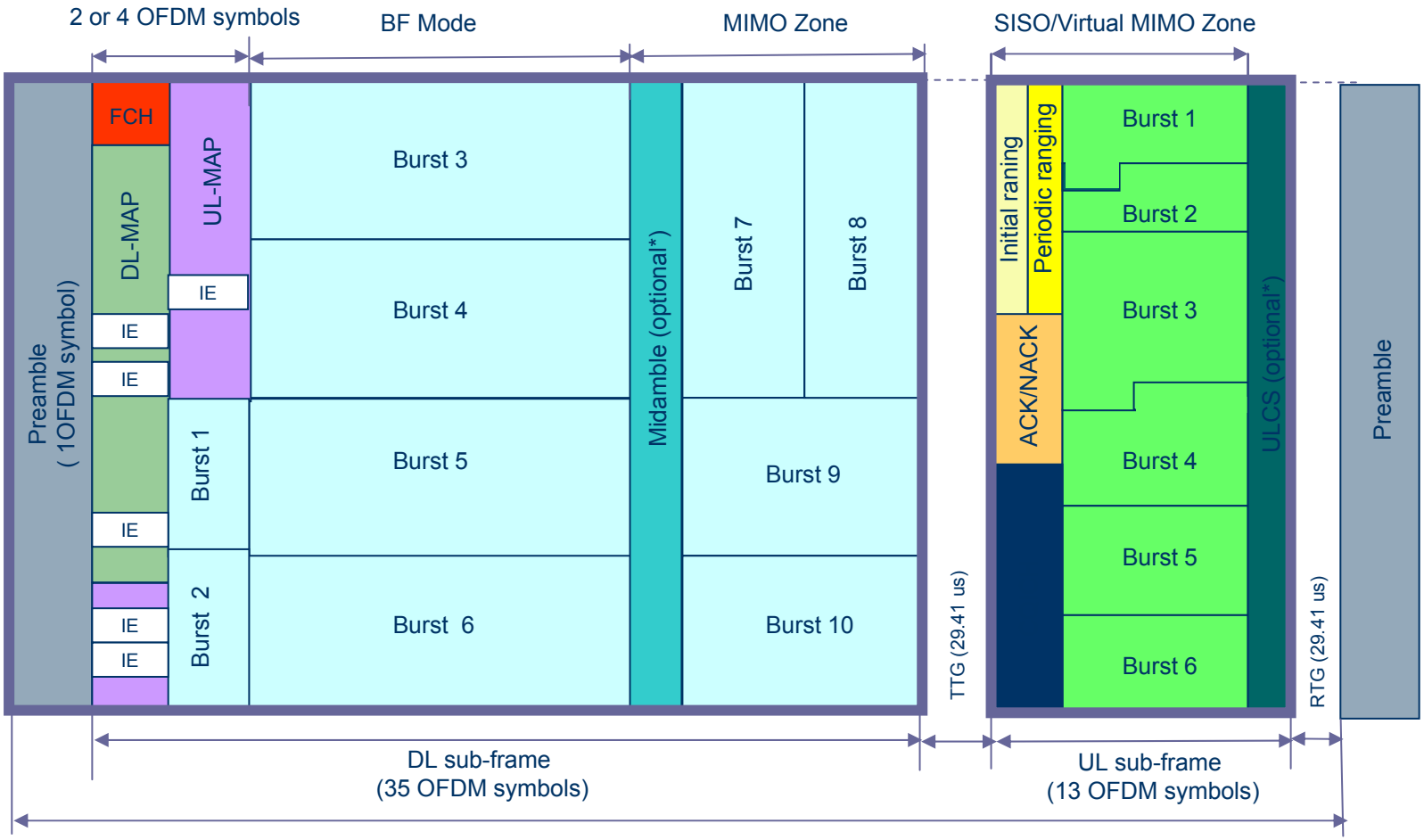


- Efficient resource usage
- Lower delay [$D=1/W(1-\rho)$]
- Triple play enabled

- Inefficient resource usage
- Higher delay
- Difficult to support fine QoS

Source: Intel

Frame Structure – zoomed in

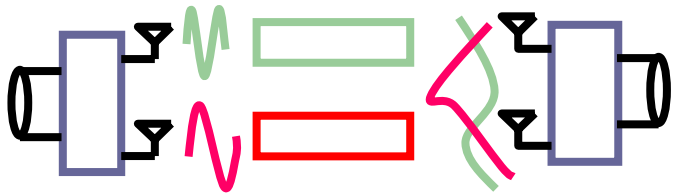


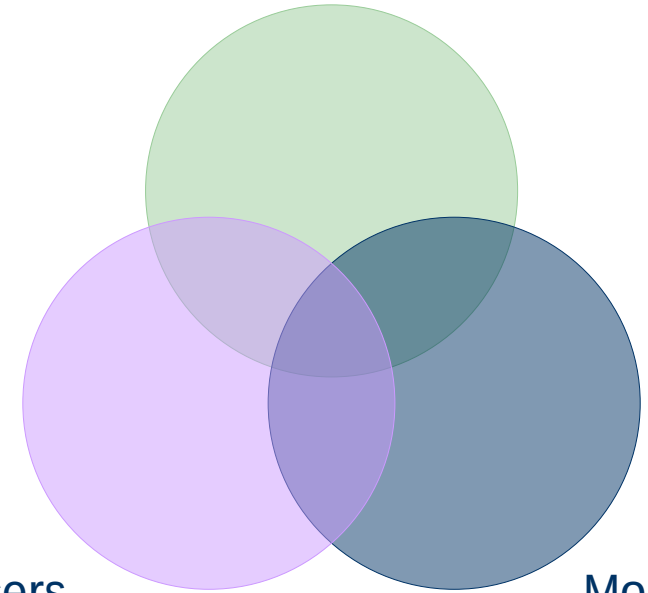
Frame Duration (5ms → 49 OFDM symbols) MS switching time > 50us

* Depending on the decision of TTG/RTG values

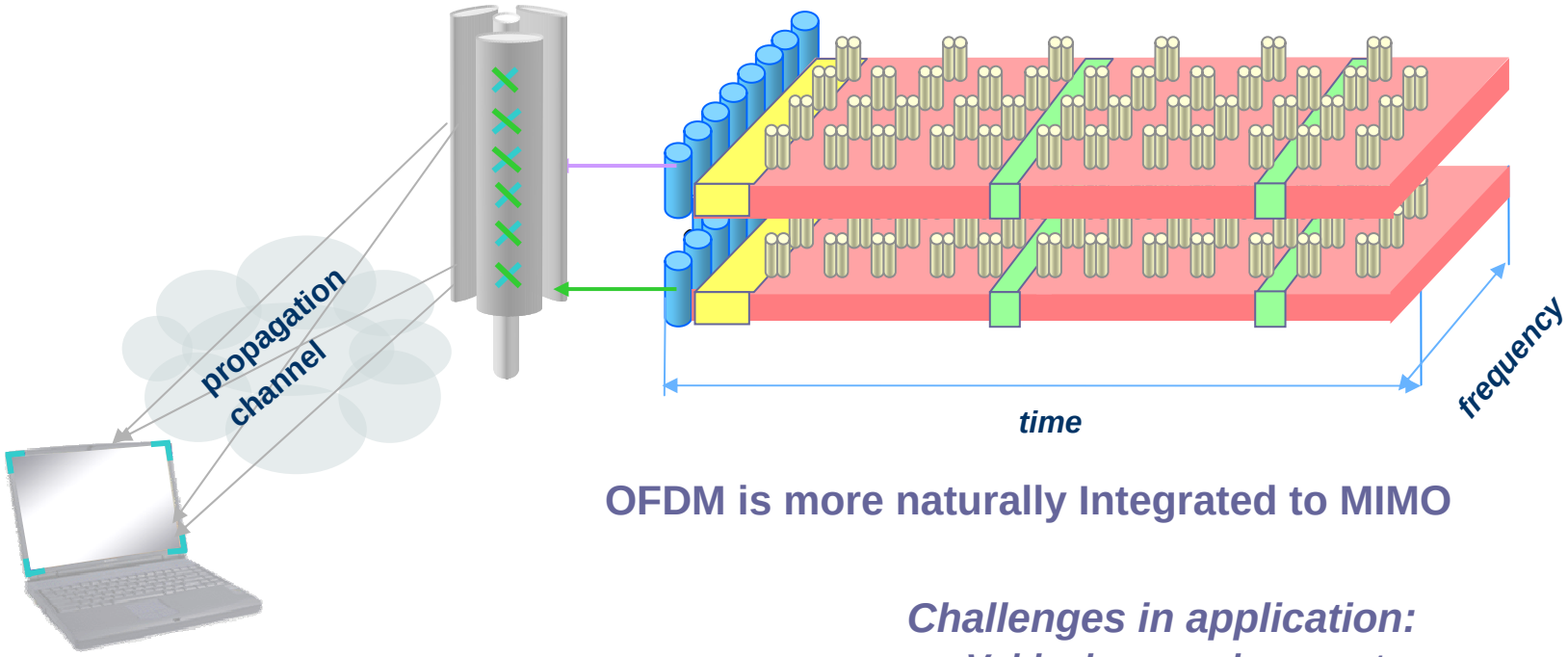
MIMO (Multiple I/P Multiple O/P)

- Two signals sent over 2 independent Radio Links each to users with 2 Rx terminals, using the same resource allocation
  - Spectral efficiency (throughput) improves proportional to N
  - Coverage reliability improves proportional to Sqrt N





Combined OFDM and MIMO



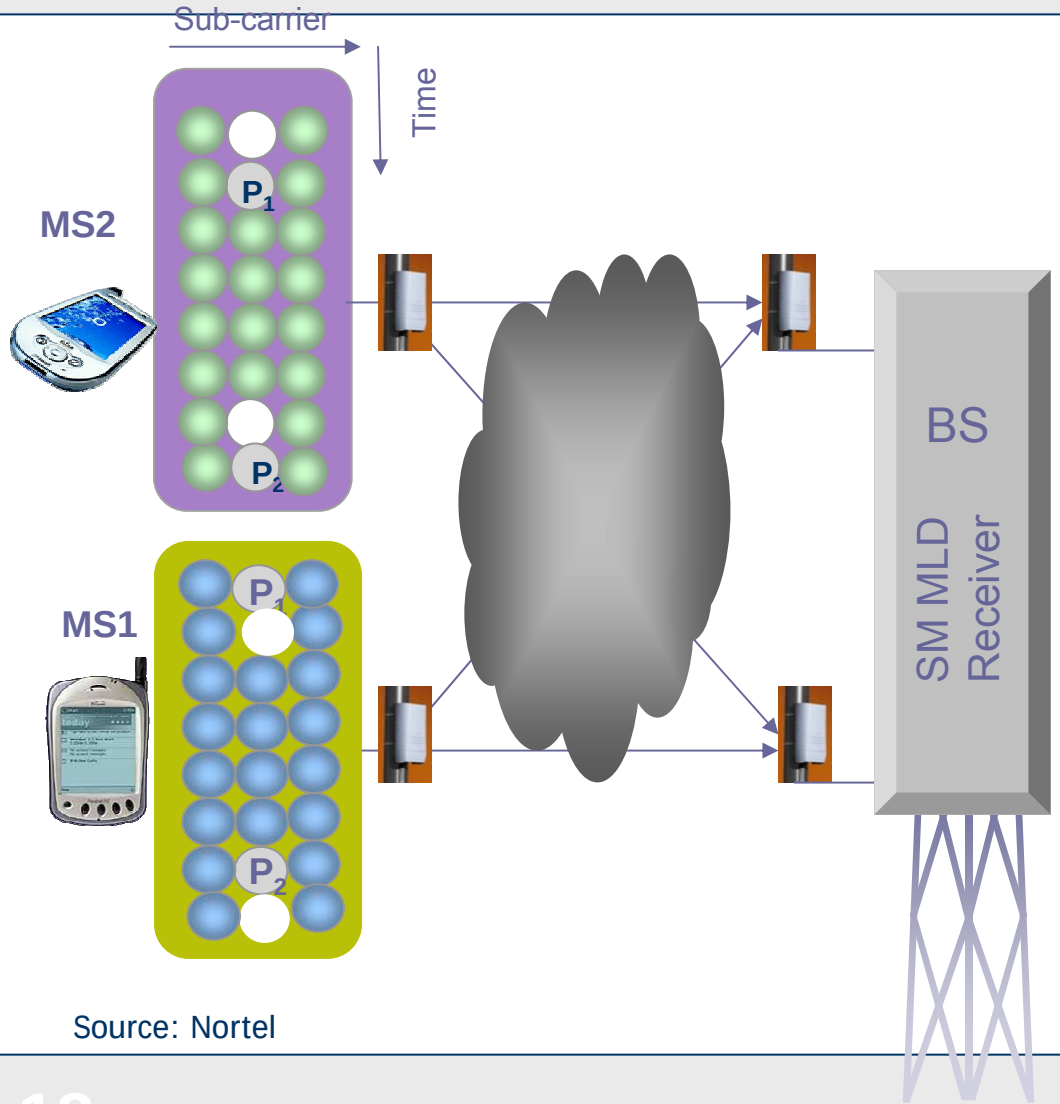
OFDM is more naturally Integrated to MIMO

Challenges in application:

- ***Vehicular speed support***
- ***Cell site limitations***
- ***User peak rate support***

Source: Nortel

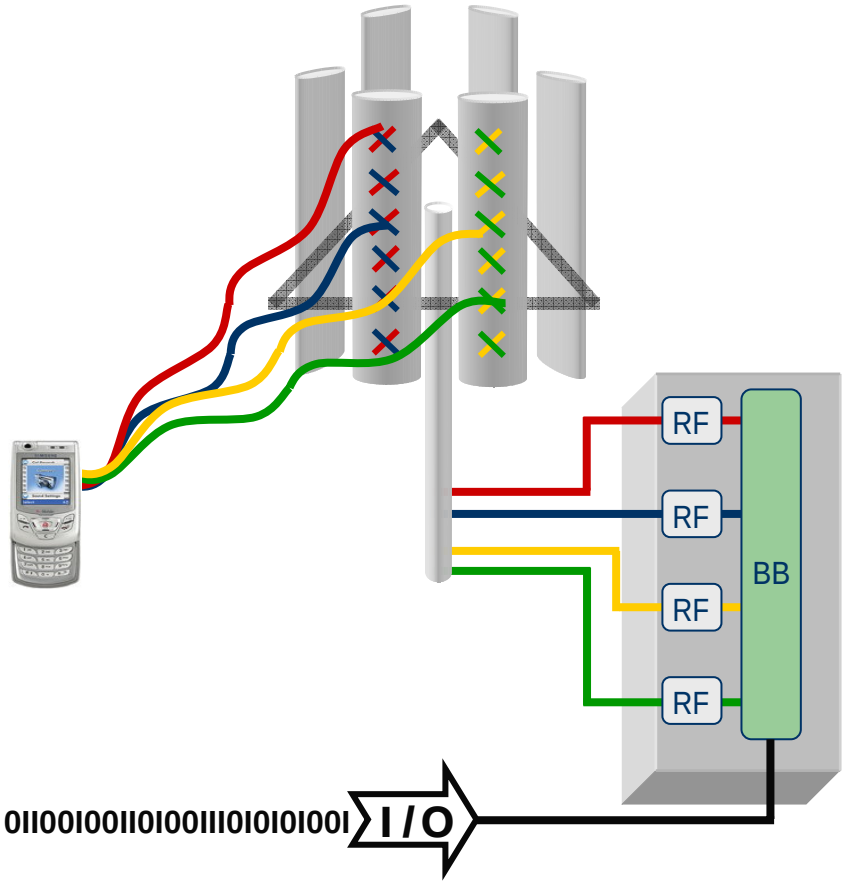
Collaborative Spatial Multiplexing



Source: Nortel

- Same resource granularity
- Same sub-channlization allocation
- Same pilot pattern
- One additional MIMO_UL_Basic_IE processing
- BS can schedule MSs such that the combining channel matrix has two large Eigen Mode

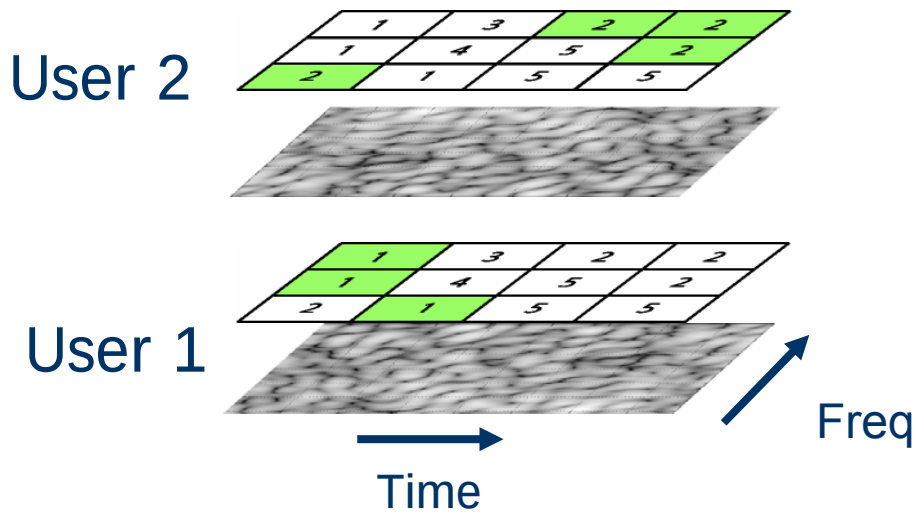
Beam-Forming (Phased Array)



- Signal sent over 4 independent Radio Links with phase adjustments
  - Increases signal strength at receiver, good for low SNR and low mobility

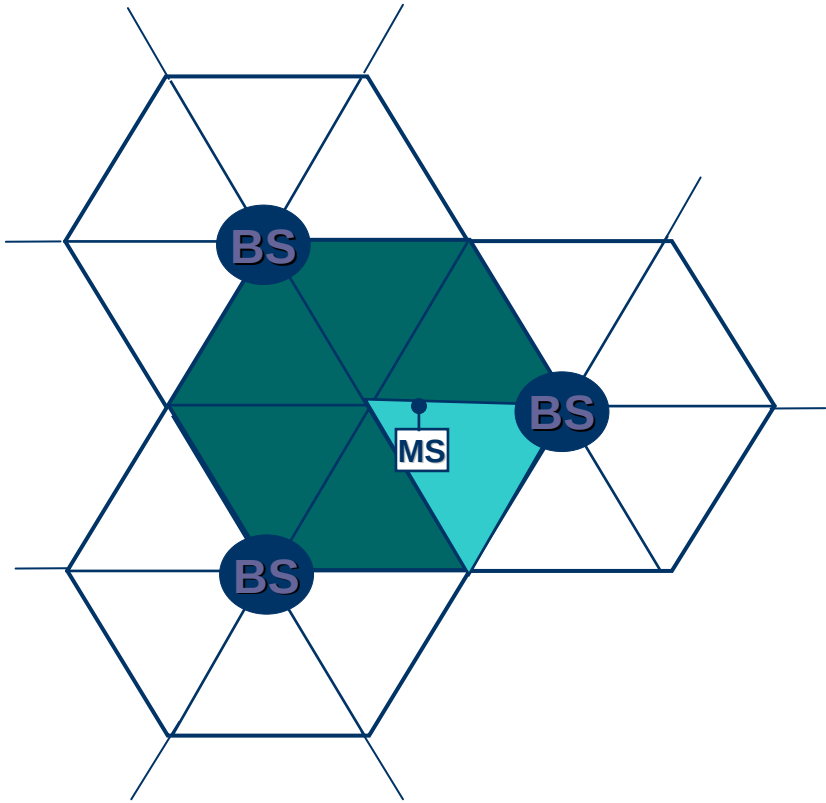
Opportunistic Diversity Scheduling

- Maps users to tiles (Freq.-time) with most favorable channel
- Outperforms similar approaches in CDMA



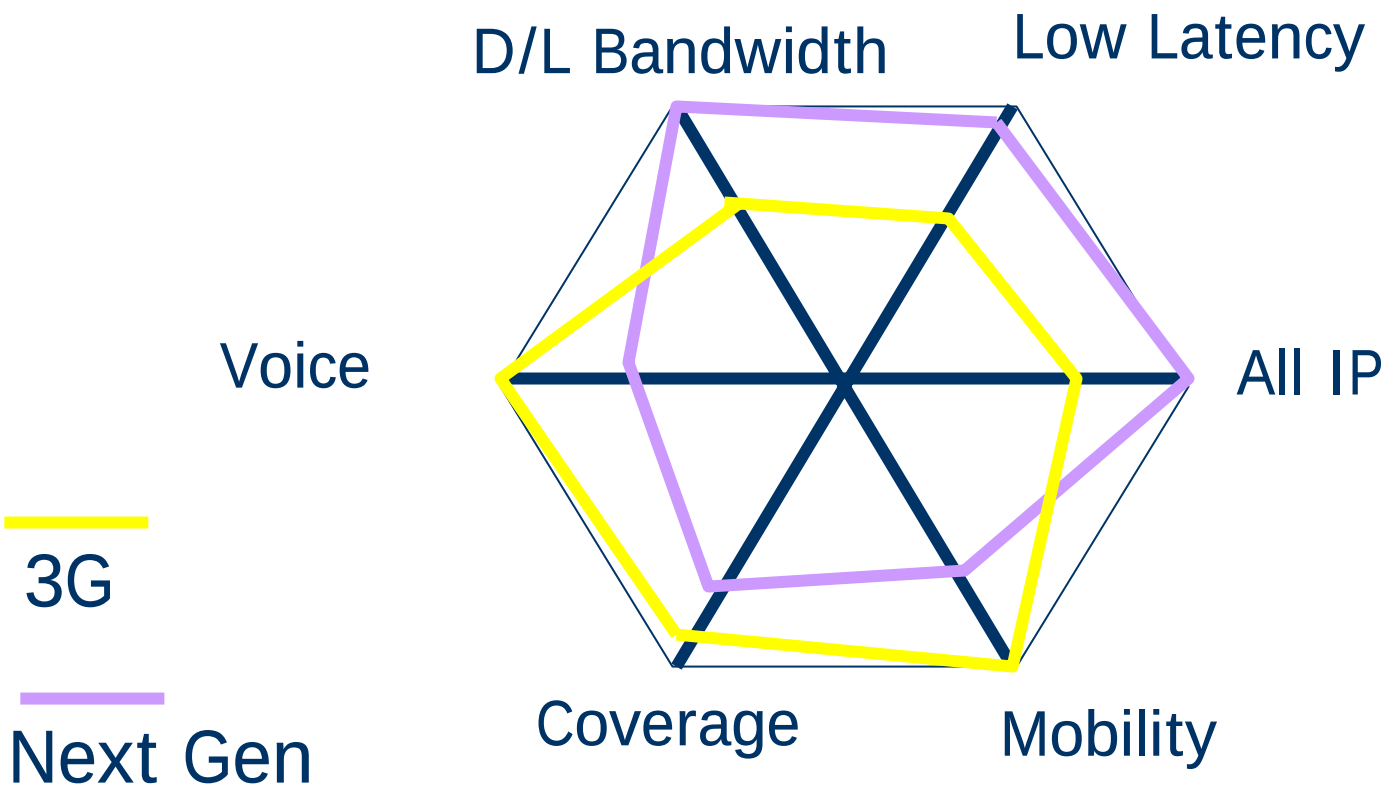
Mobility – Handover

- Handover Schemes
  - Hard Handover (HHO)
  - Optimized Hard Handover (OHHO)
  - Fast Base Station Switching (FBSS)
  - Soft Handover (SHO)
- Handover Control
  - Mobile initiated
  - BS initiated
  - Network initiated
- Handover Scheduling
  - Non-overlapping Subchannels between sectors
  - Robust modulations in cell edge
- Cell Selection
  - Neighbor Advertisements from Serving BS
  - Periodic intervals for scanning neighbor BS's
- Security for Handover
  - 3-way Handshake for Authentication Key validation
  - TEK sharing for FBSS and SHO modes

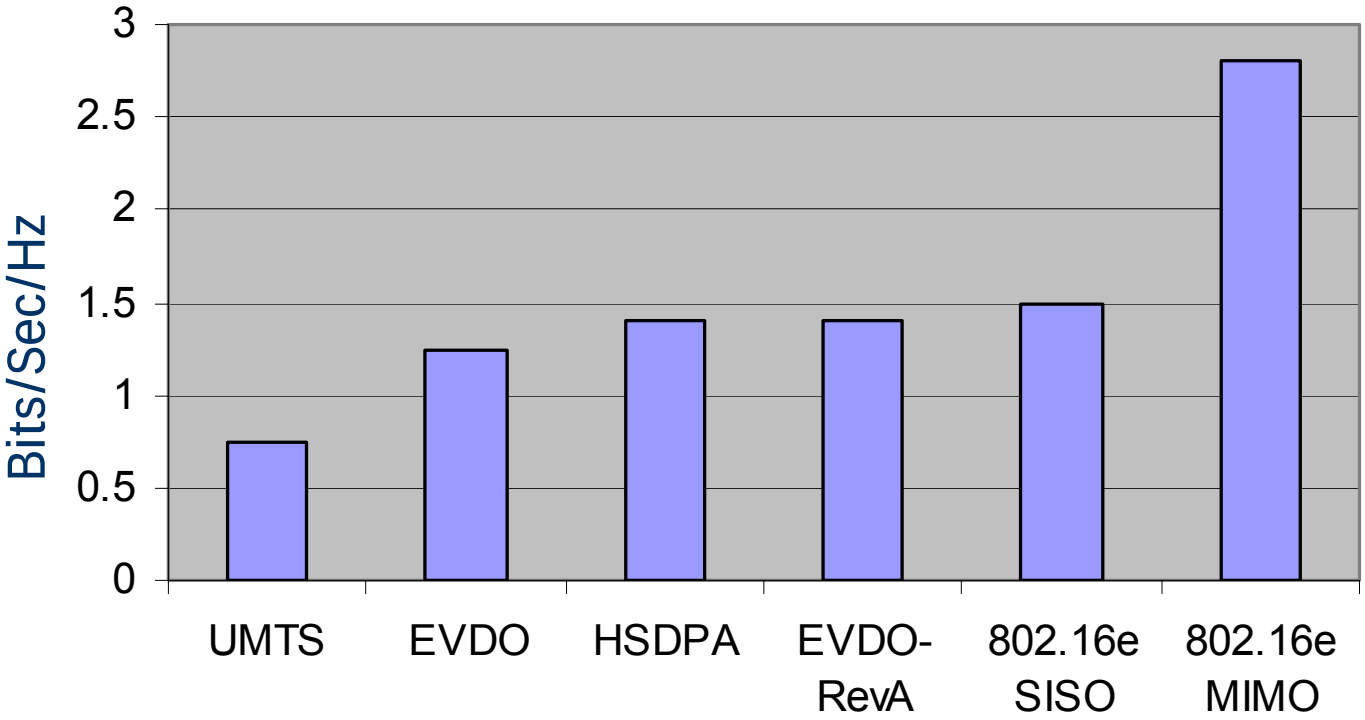


Source: Intel

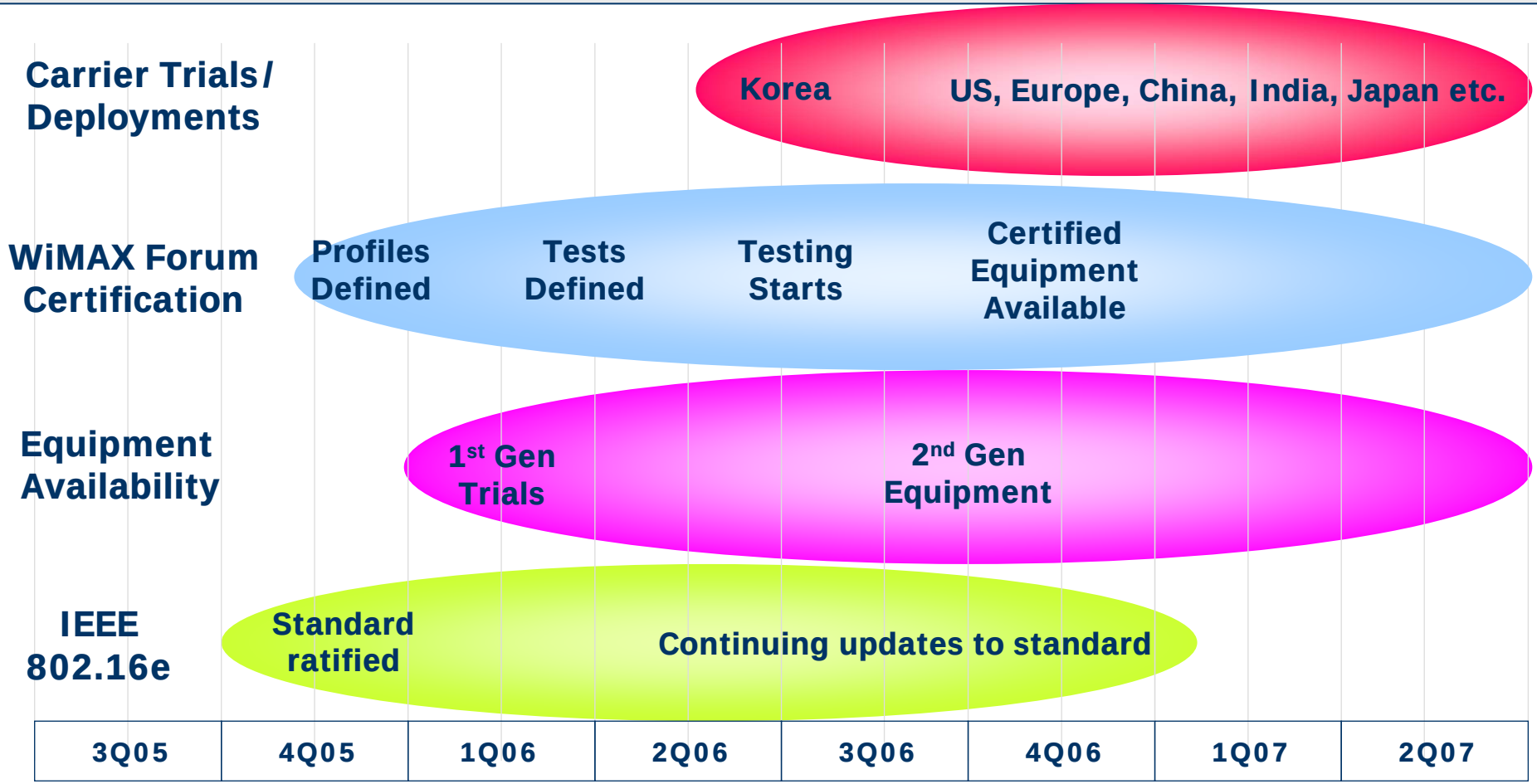
Performance Focus



Spectral Efficiency Comparison



Mobile WiMAX Industry Roadmap



WiBro Terminals Nov'06

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Thank You !