



**Beceem Communications Inc.**

Leading the Wireless Broadband Revolution

# Mobile WiMAX

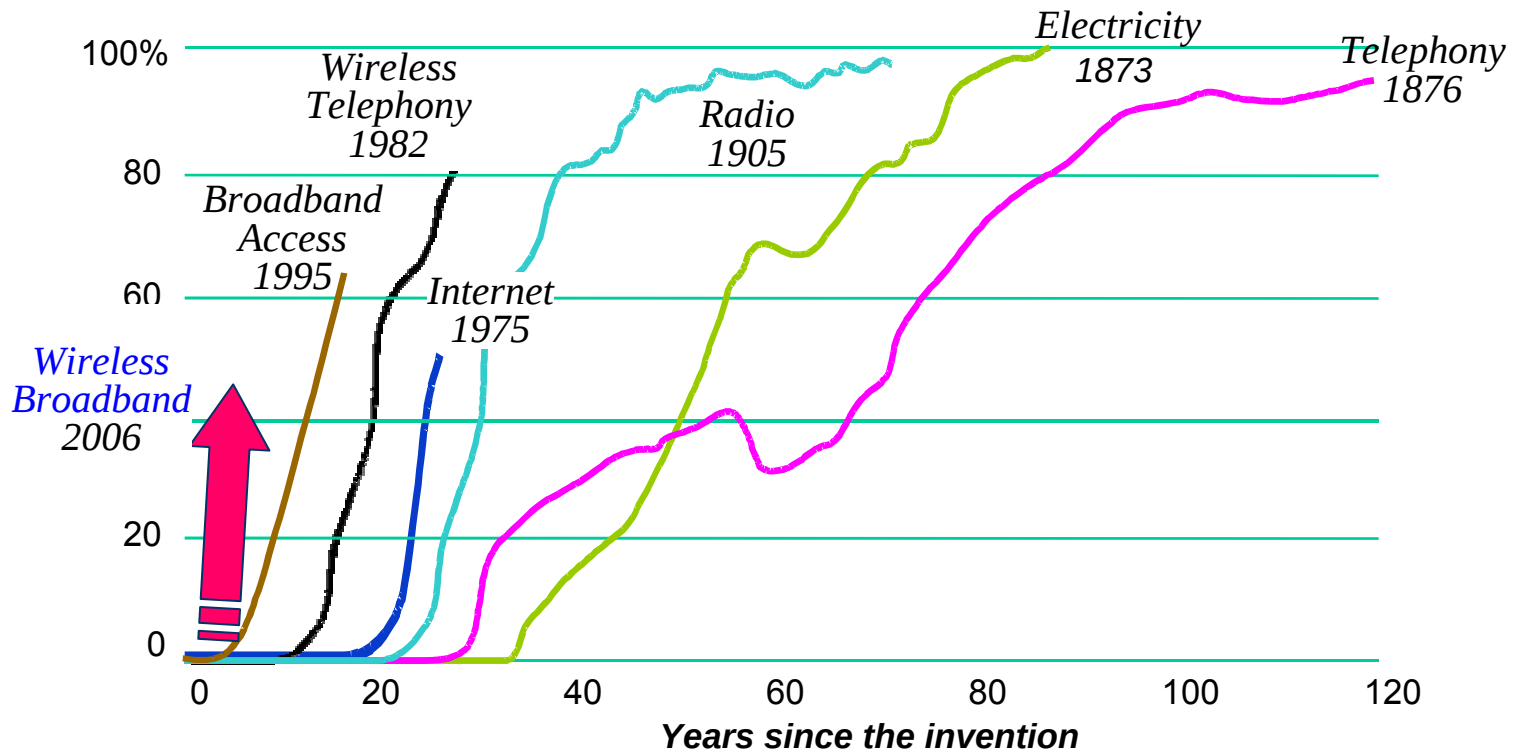
## December 2005

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Chair, Certification Working Group, WiMAX Forum™



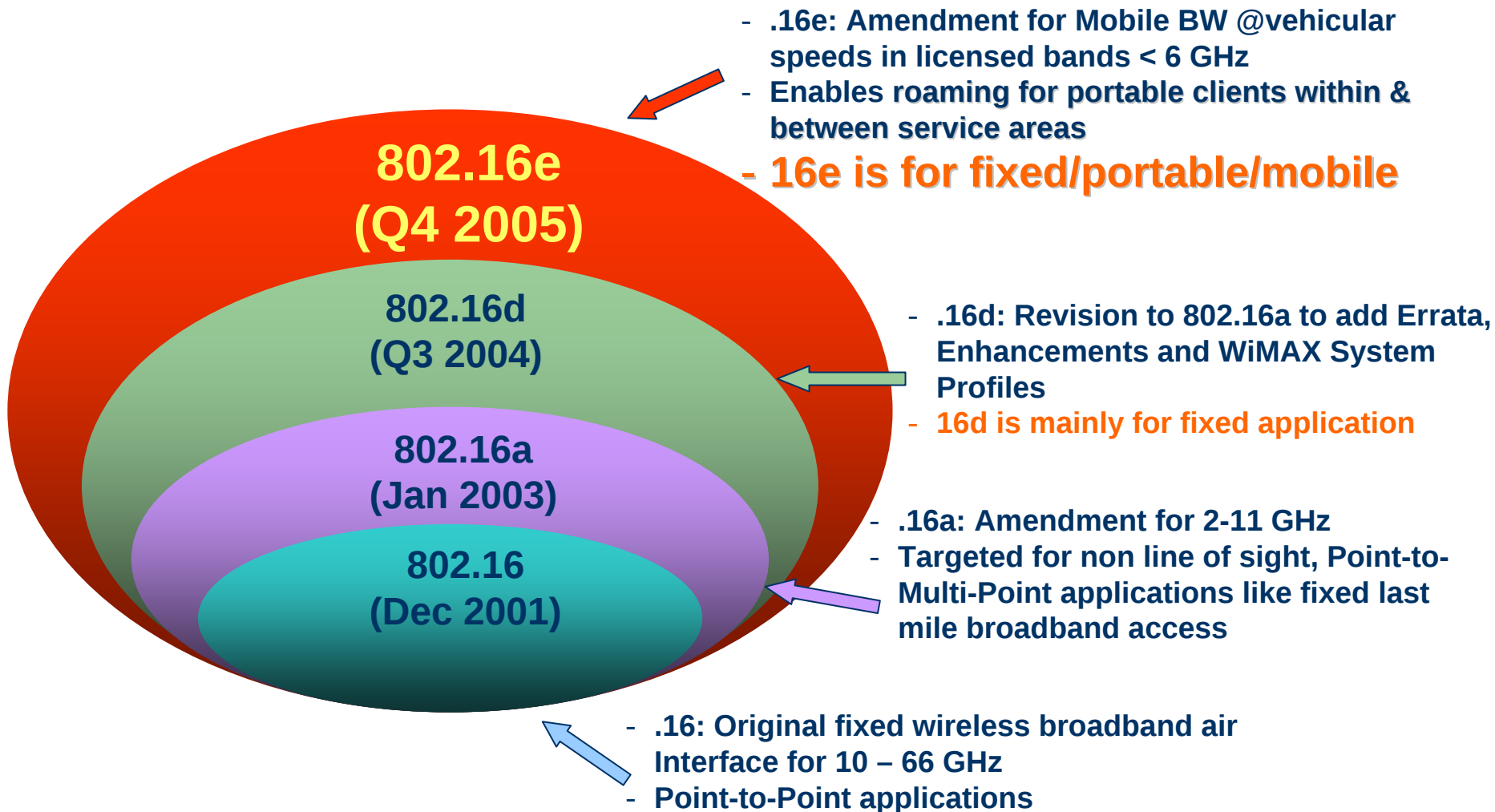
# The Market Opportunity



*Wireless Broadband has tremendous growth potential if ...*



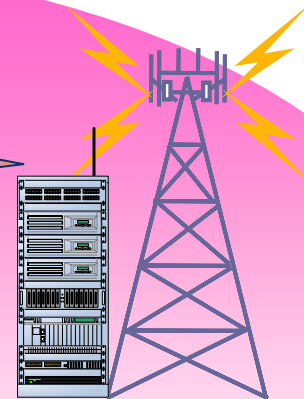
# 802.16 Standards





# 802.16-2004 and 802.16e

**BEST FIT**  
for Converged Fixed / Mobile  
Multi-media Services



**802.16-2004**

**802.16e**



**Fixed Outdoor**

**Indoor unit**

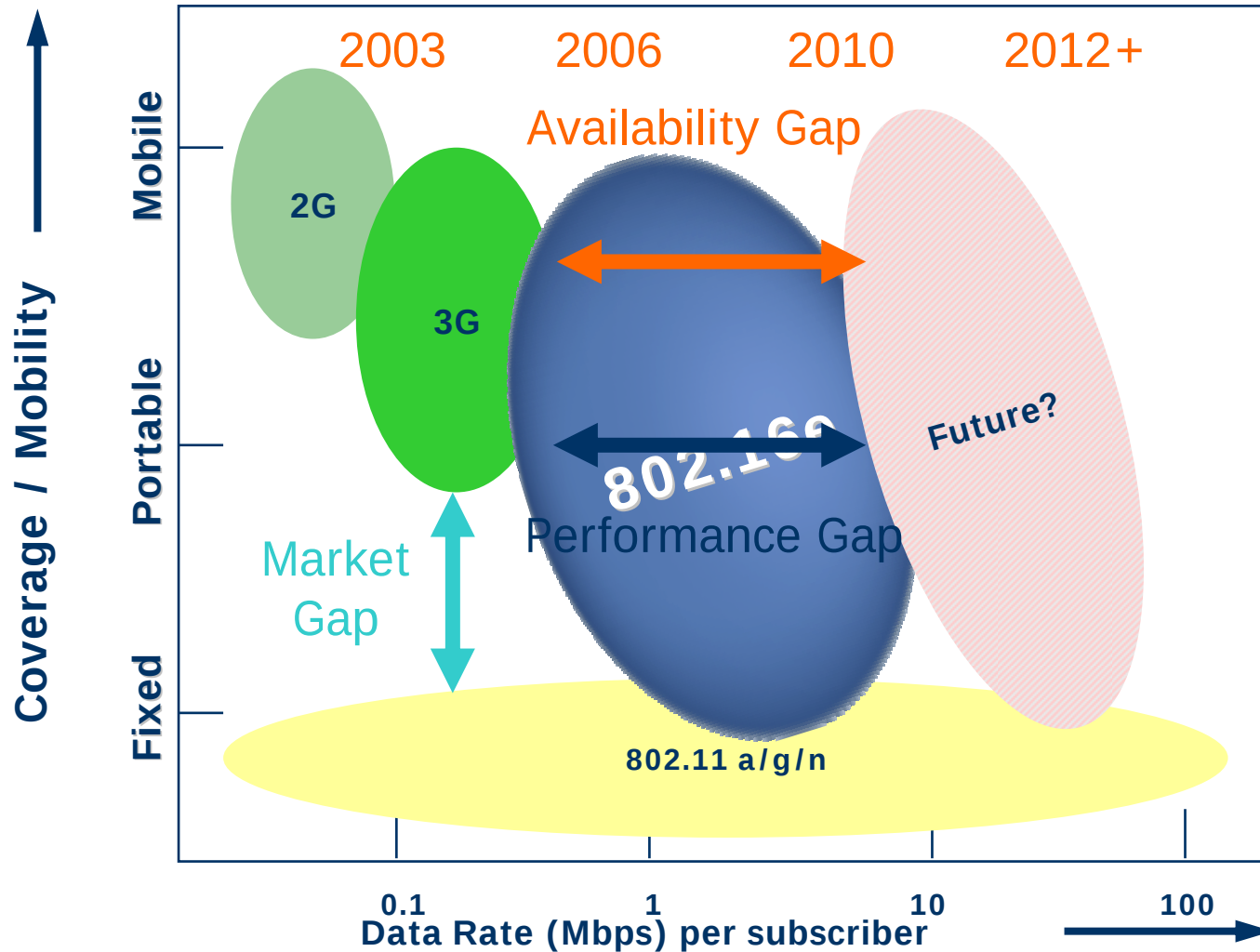
**Portable unit**

**Mobile unit**

**Consumer Devices**

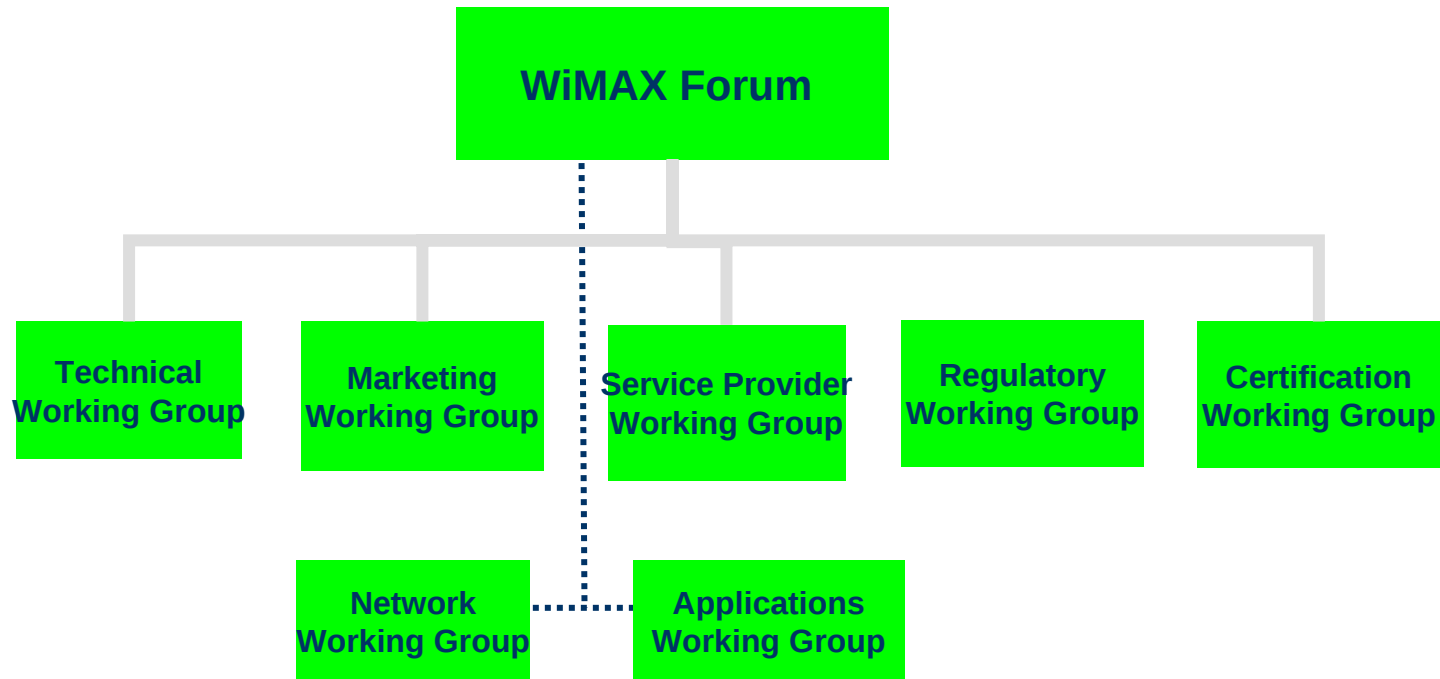


# Broadband Wireless 16e Fills a Market Opportunity





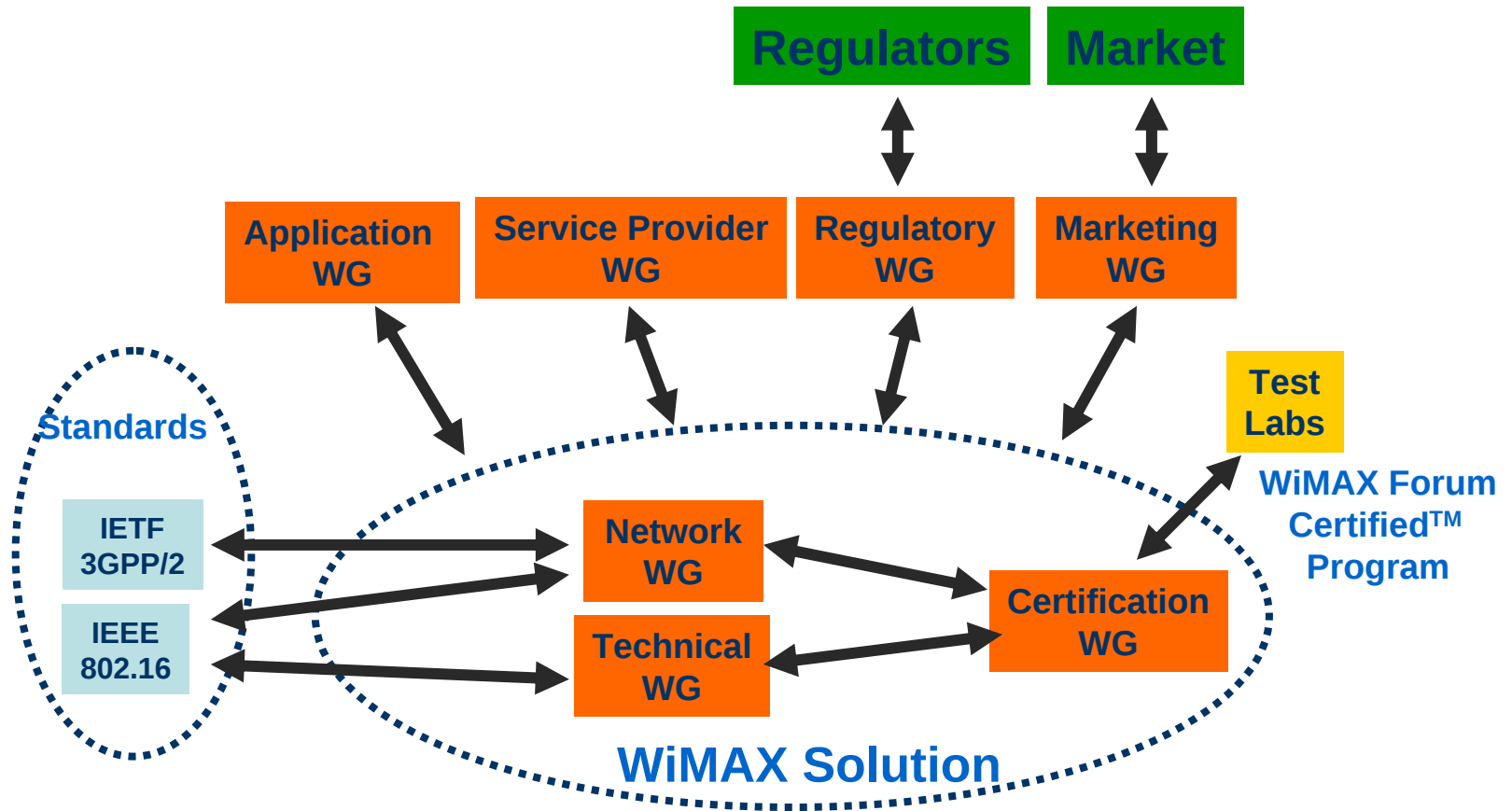
# WiMAX Forum



**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**

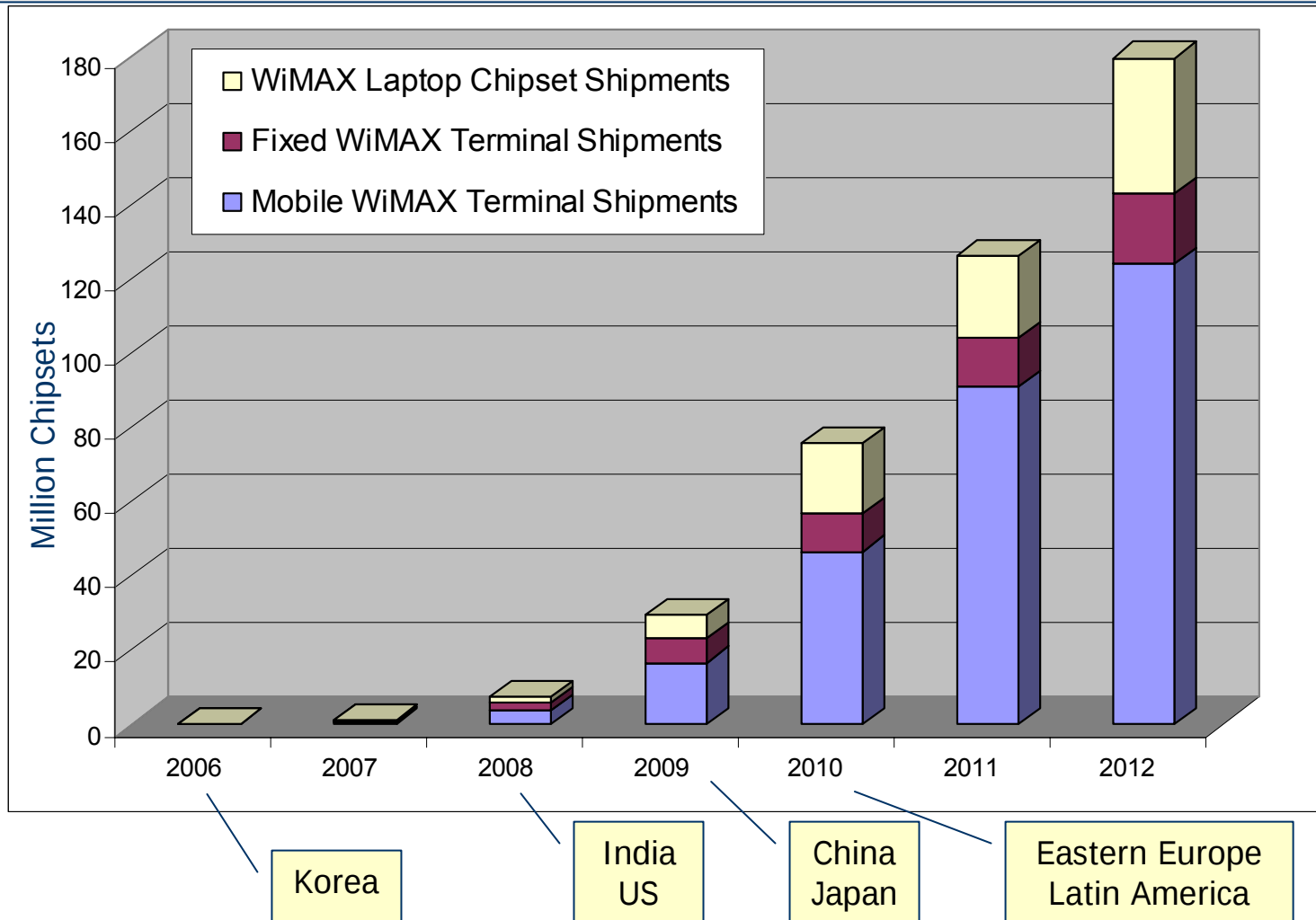


# WiMAX Ecosystem



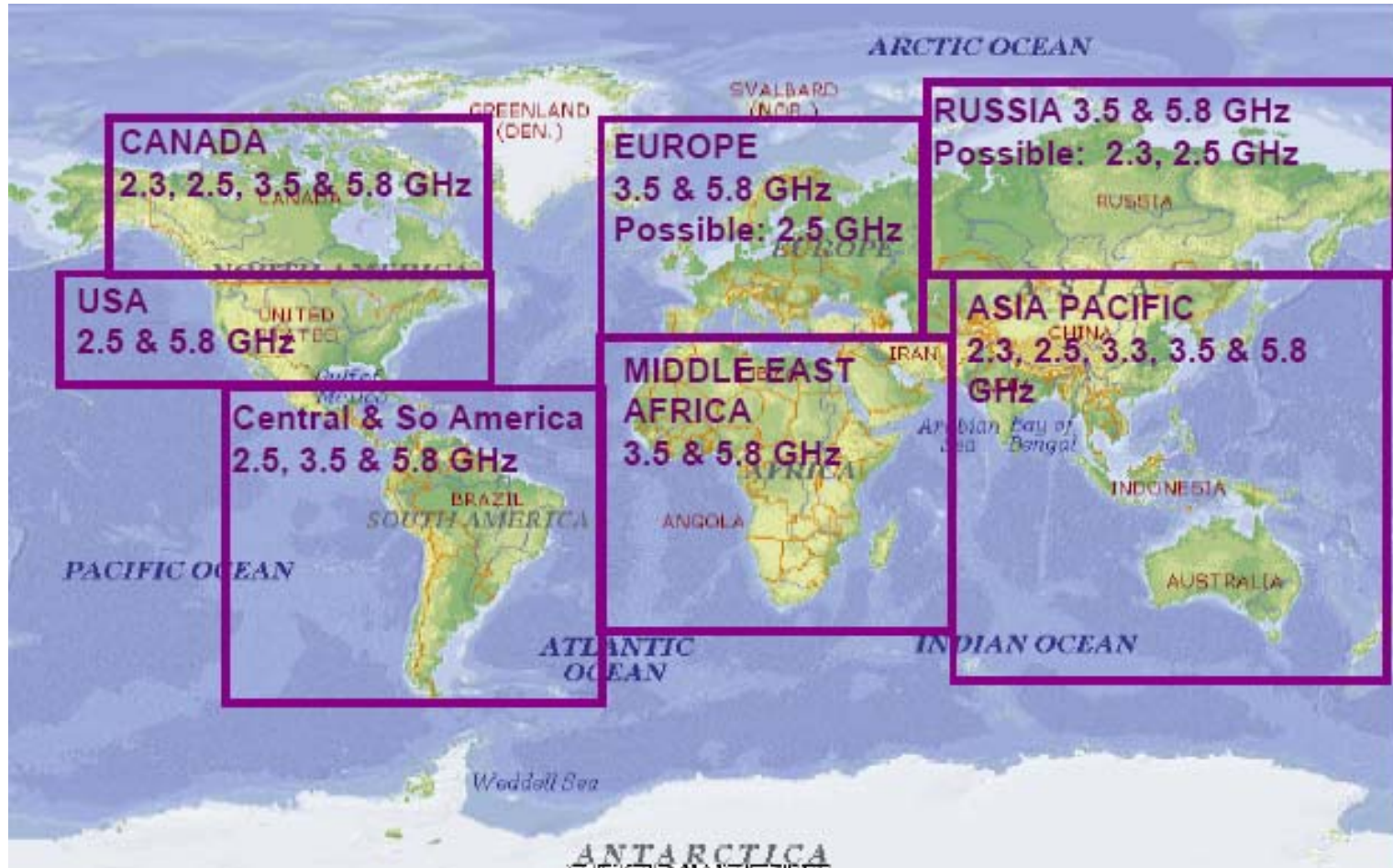


# WiMAX Market Projections





# WiMAX Spectrum Opportunities



Source: Intel – LSG APEC Meeting April '05



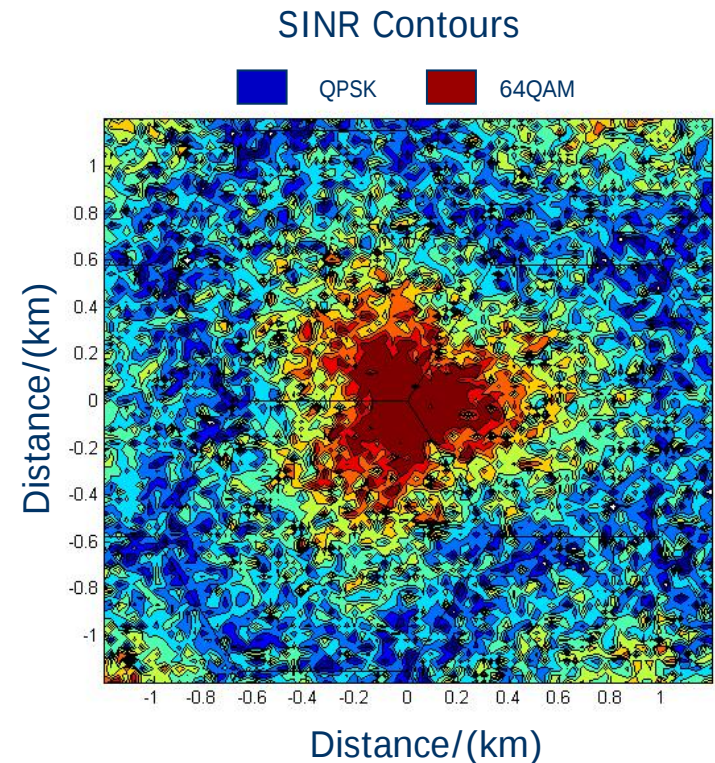
# Early Carrier Interest

| 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

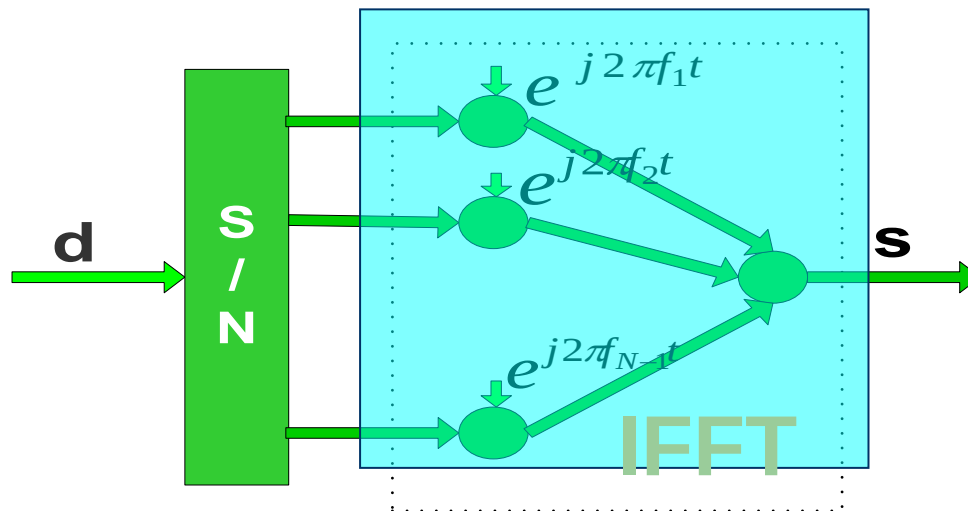
|                          |                                                                                                                                                                   |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Scalability</b> ➡     | <b>Scalable PHY for flexible channel bandwidths (1.25-20 MHz) as global RF band allocations vary.<br/>Flexible frequency re-use schemes for network planning.</b> |
| <b>High Data Rates</b> ➡ | <b>Larger MAC frames with low overhead, Advanced FEC, Adaptive modulation, H-ARQ for reducing packet loss, Beamforming (AAS), Space-Time Diversity, MIMO.</b>     |
| <b>QoS</b> ➡             | <b>Traffic types, QoS with Service Flows, Advanced Scheduling Framework, Adaptive Modulation &amp; Coding, ARQ, H-ARQ</b>                                         |
| <b>Mobility</b> ➡        | <b>Secure Optimized Hard Handover, Fast BS Switching Handover, Soft Handover, Power Management with Sleep and Idle modes</b>                                      |
| <b>Security</b> ➡        | <b>EAP authentication, Encryption with AES-CCM, CMAC Authentication mode, X.509 Certificates, Key Binding, Device and User authentication capability</b>          |

Source: Intel



# Why OFDM?

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

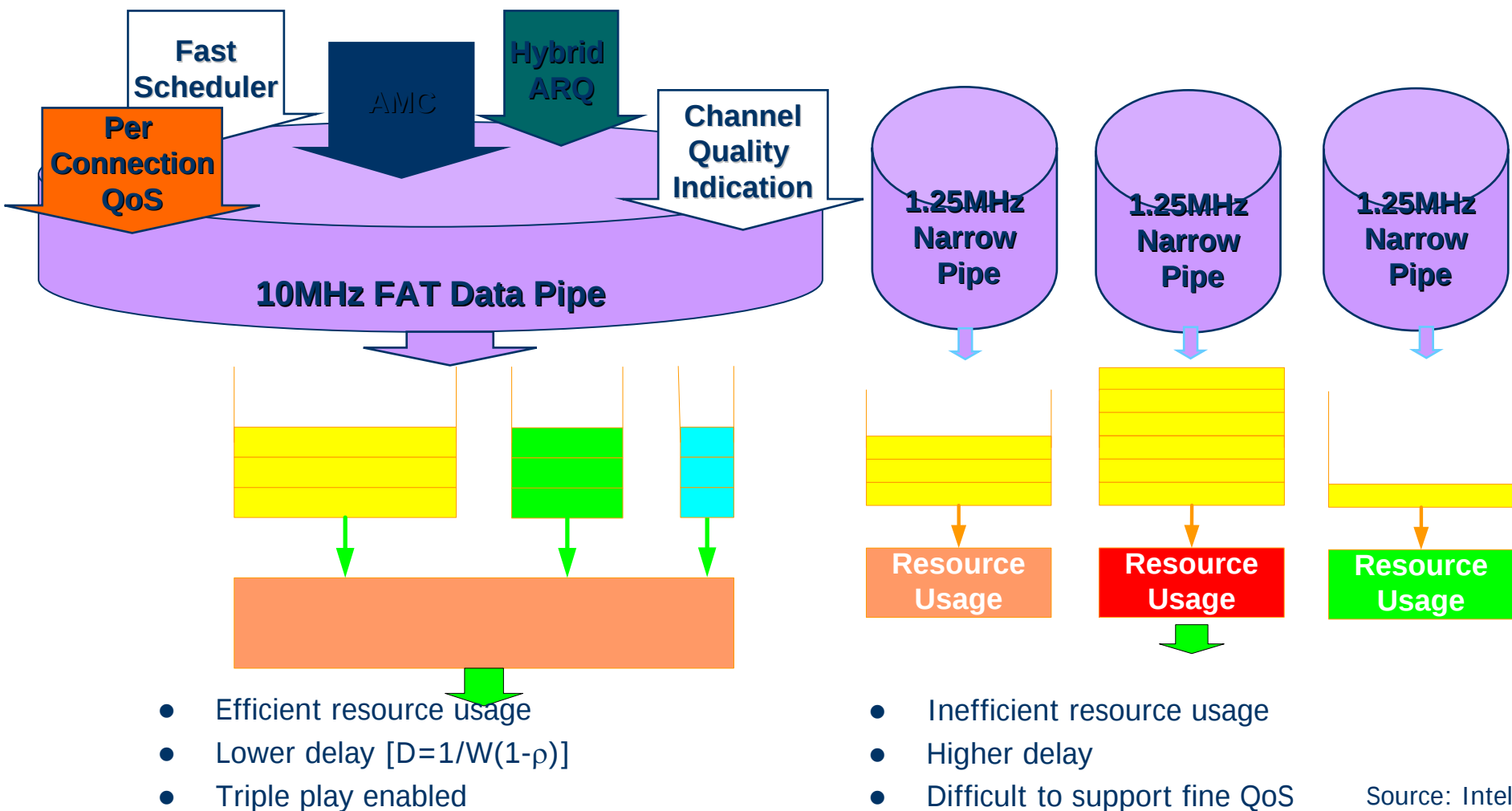


- Orthogonal subcarriers → high spectral efficiency
- FFT fast algorithm → large number of subcarriers, efficient to implement
- Low data rate on each subcarrier → low ISI
- Combining with advanced FEC → reducing burst errors

Source: Intel

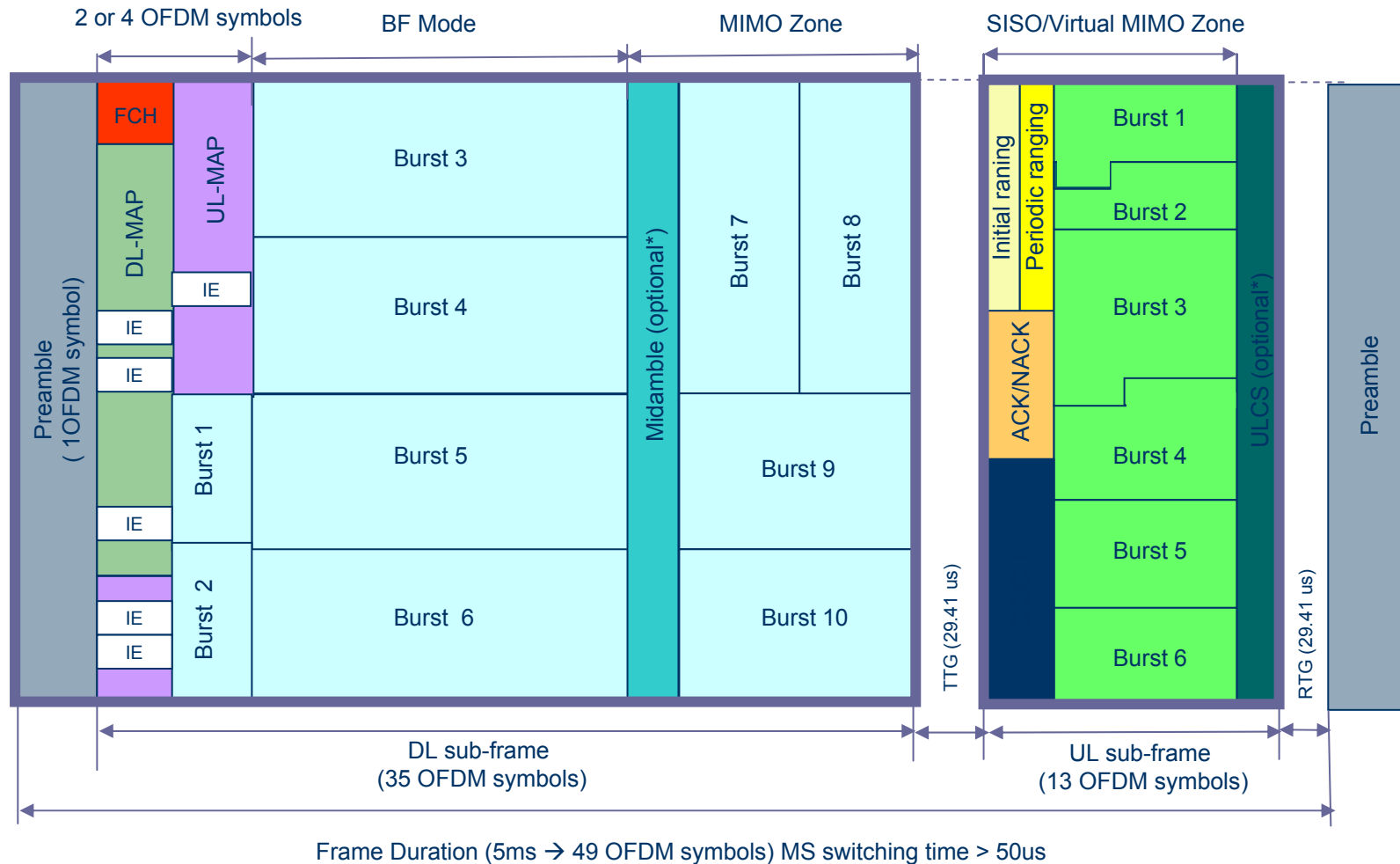


# Quality of Service





# Frame Structure – zoomed in

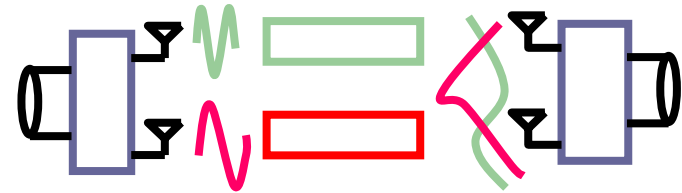


\* Depending on the decision of TTG/RTG values

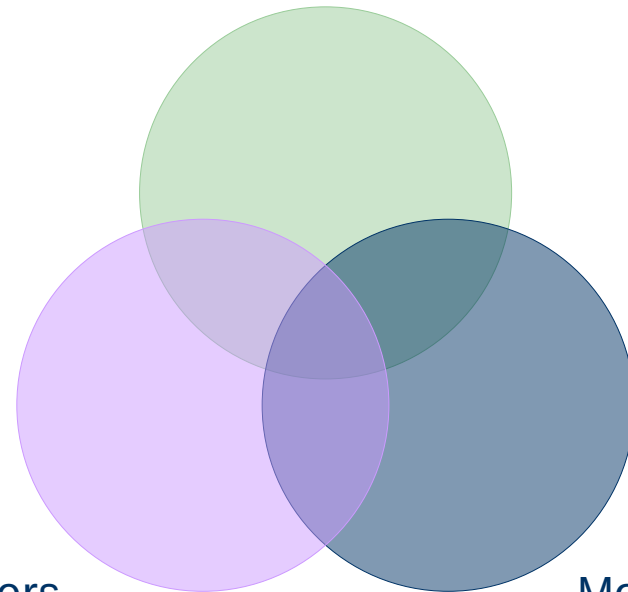


# MIMO (Multiple I/P Multiple O/P)

- 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  $\sqrt{N}$



Outdoor users

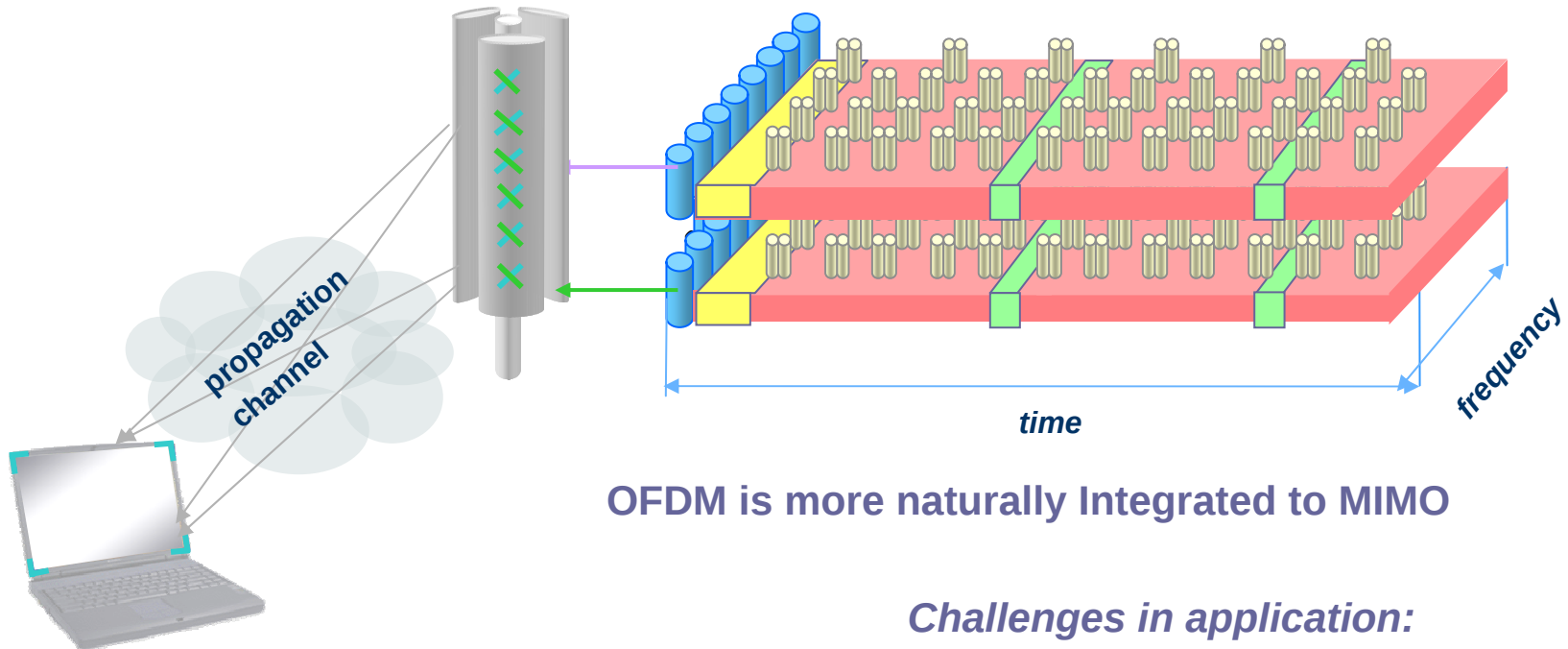


Indoor users

Mobile users



# Combined OFDM and MIMO

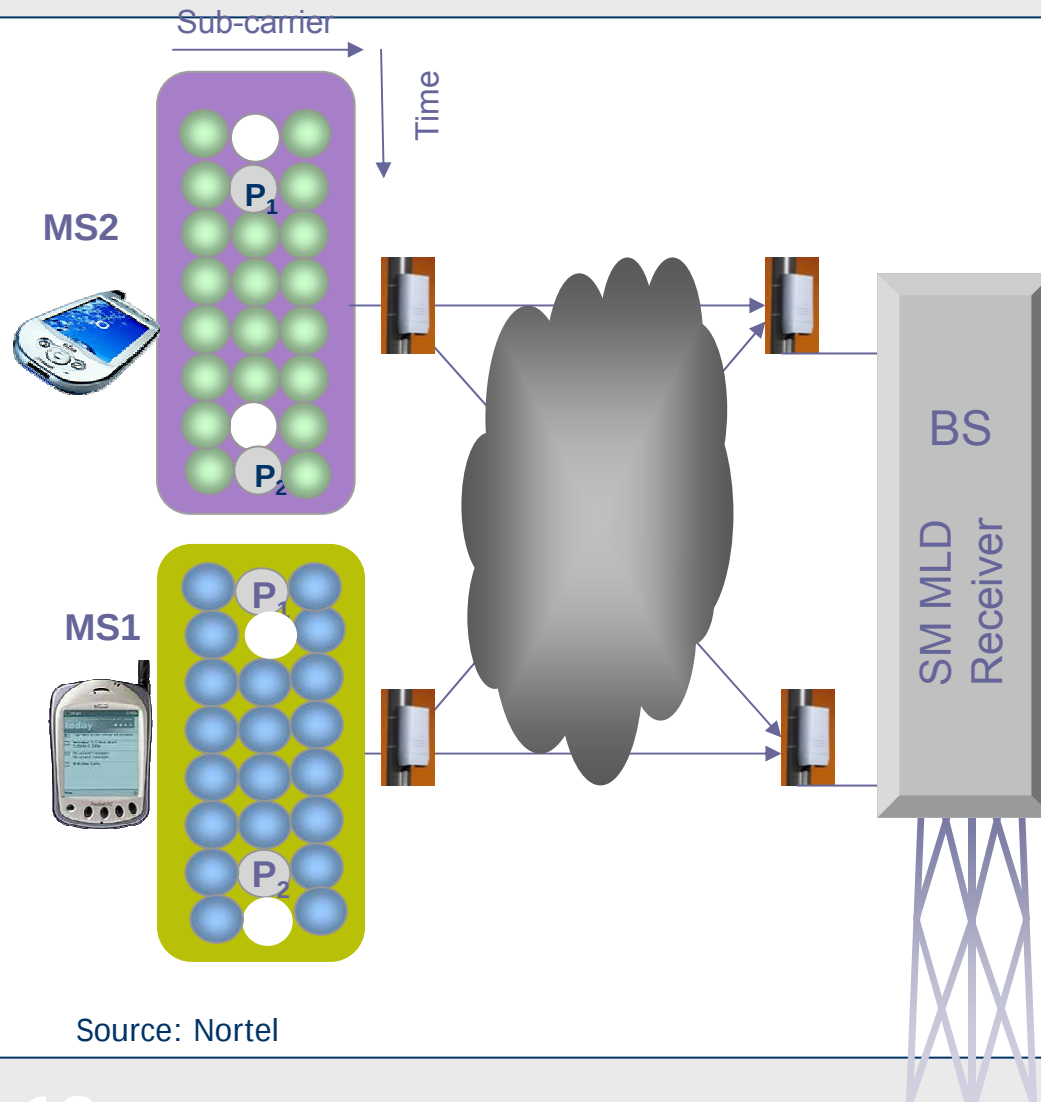


## *Challenges in application:*

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



# Collaborative Spatial Multiplexing

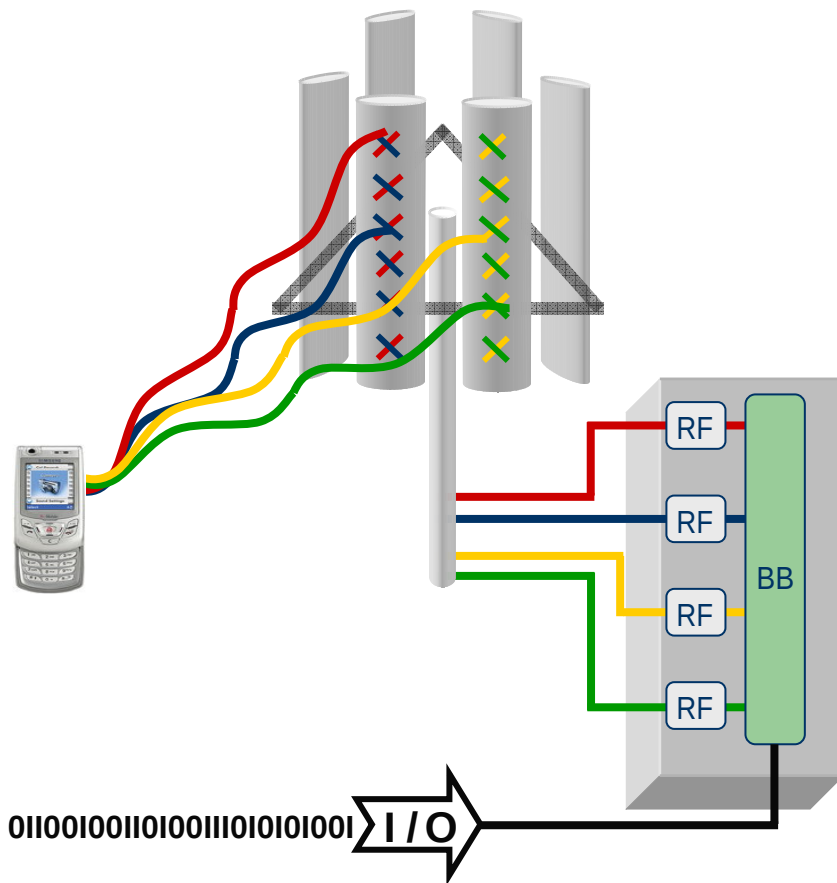


- Same resource granularity
- Same sub-channlization allocation
- Same pilot pattern
- One additional MIMO\_UL\_Basic\_IE processing
- BS can schedule MSs such that the combining channel matrix has two large Eigen Mode

Source: Nortel



# Beam-Forming (Phased Array)

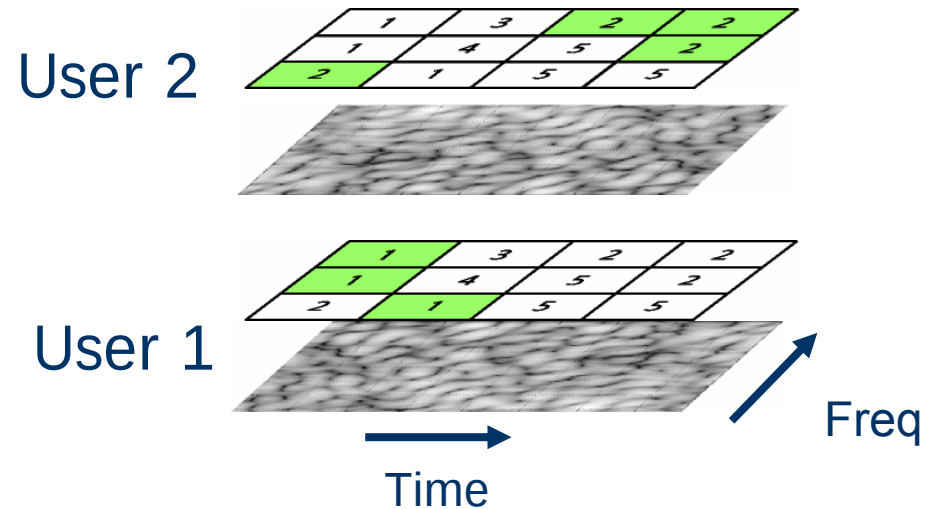


- Signal sent over 4 independent Radio Links with phase adjustments
  - Increases signal strength at receiver, good for low SNR and low mobility



# Opportunistic Diversity Scheduling

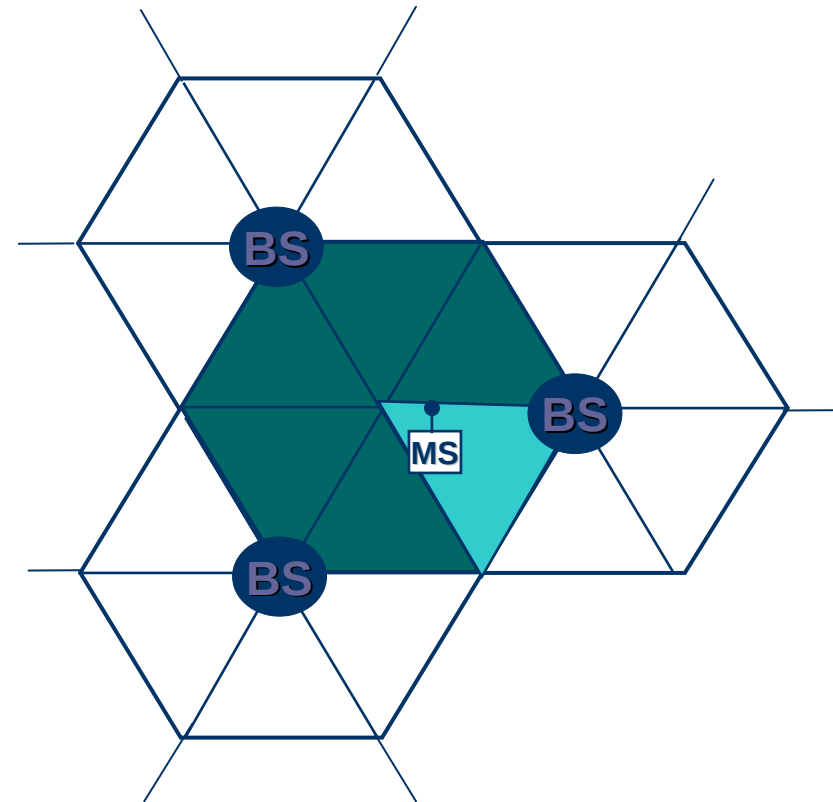
- Maps users to tiles (Freq.-time) with most favorable channel
- Outperforms similar approaches in CDMA





# 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

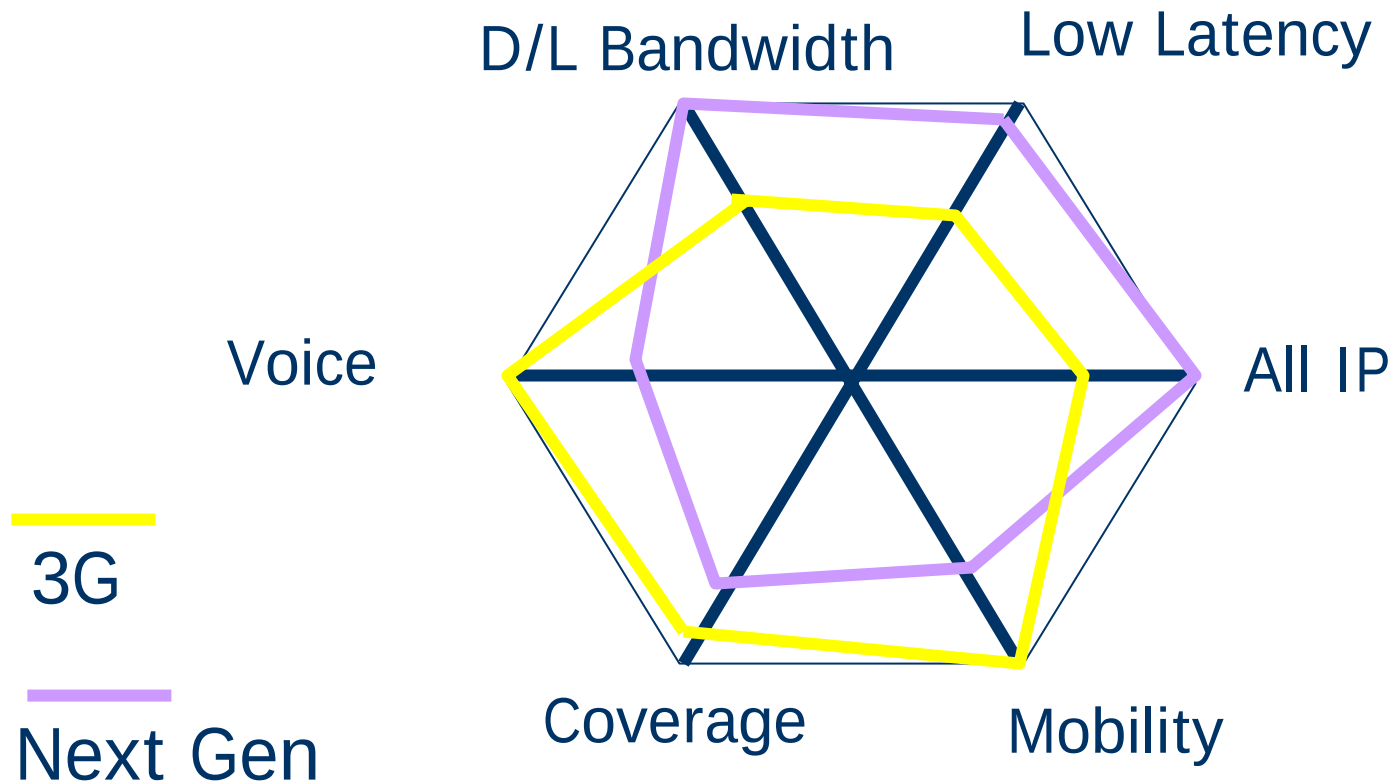


▲ Serving Sector  
▲ Neighbor Sectors Scanned

Source: Intel

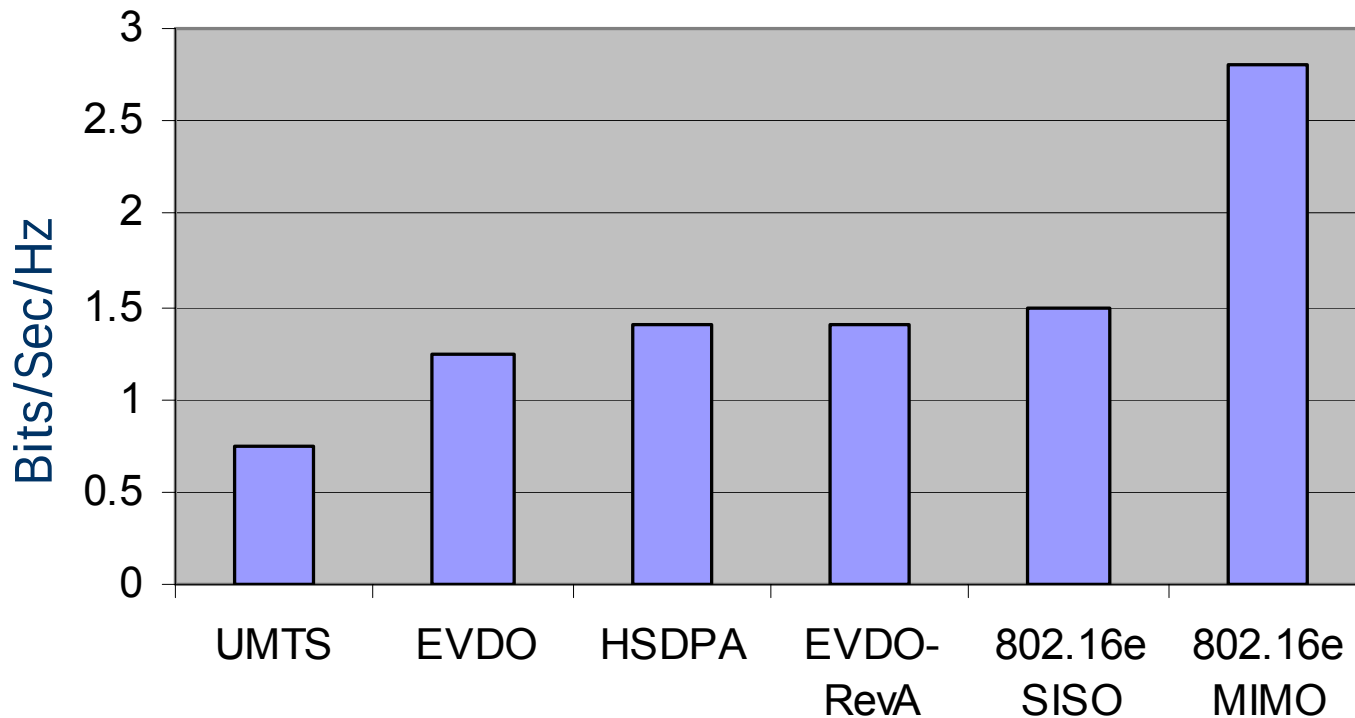


# Performance Focus



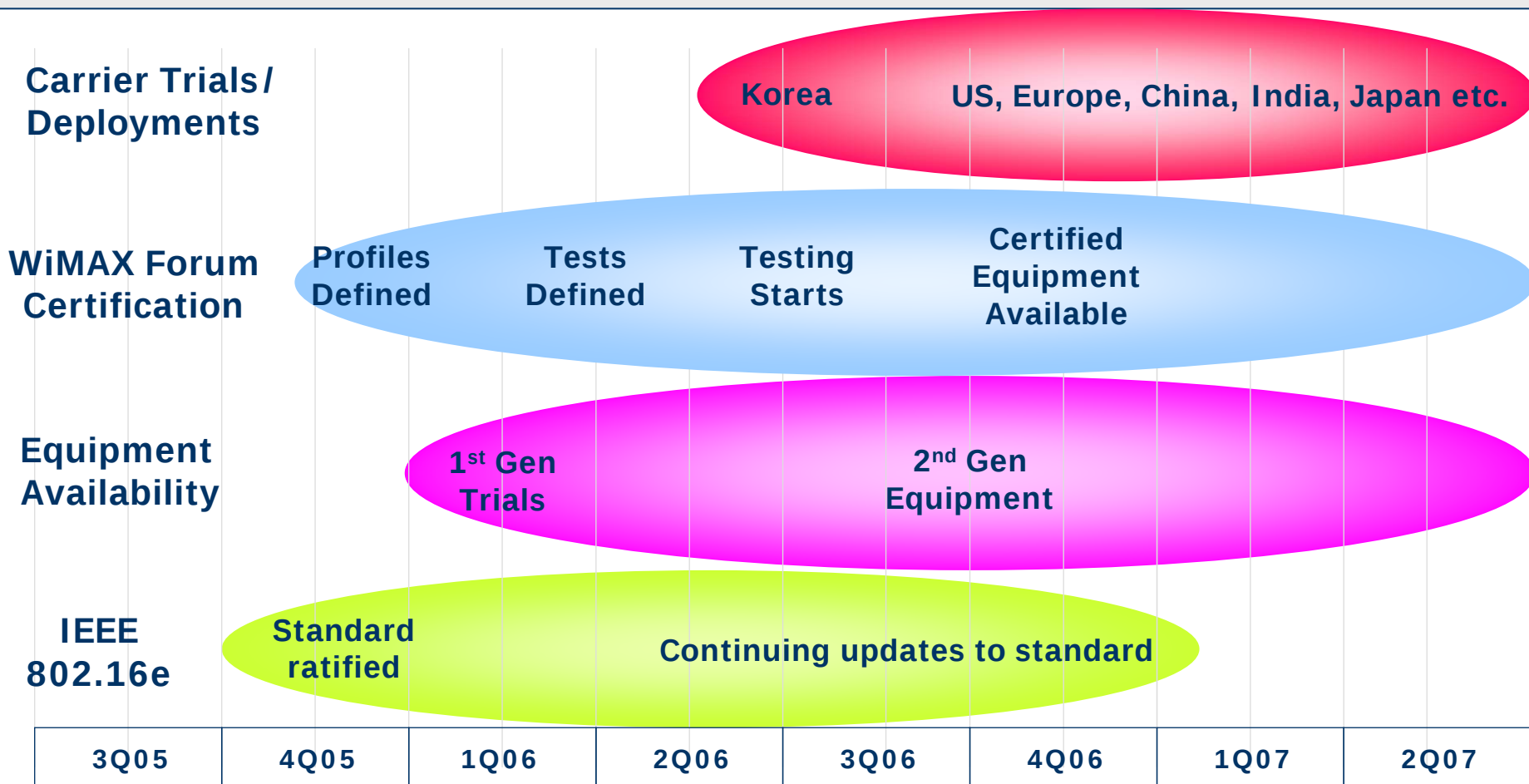


# Spectral Efficiency Comparison





# Mobile WiMAX Industry Roadmap





# WiBro Terminals Nov'06





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**Thank You !**