M-Power

The Complexities of Mobile WiMAX

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Agenda

- ***Introduction to the growing need for 4G networks***
- Some basics on modulation and coding
- Air interfaces converge on OFDMA
- Mobile WiMAX 802.16e through introspection

Why Faster Wireless? (4G)

- The race to develop 4G network technologies is well underway
  - Although many operators are still struggling to make money from current networks
- Current Wireless (3G) networks will continue to be operated and enhanced for many years to come.
- Specification, development, rollout and mass production of 4G devices all take time
  - Most 4G systems are at least two years or more away from the mass market.
  - Don't throw away your 3G iPhone just yet…

- There are 2 main goals of a 4G Network…
  - Provide more Bandwidth to UE
  - Get rid of the circuit-switch subsystem and move to all-IP
    - Whilst still maintaining stringent delay requirements for voice

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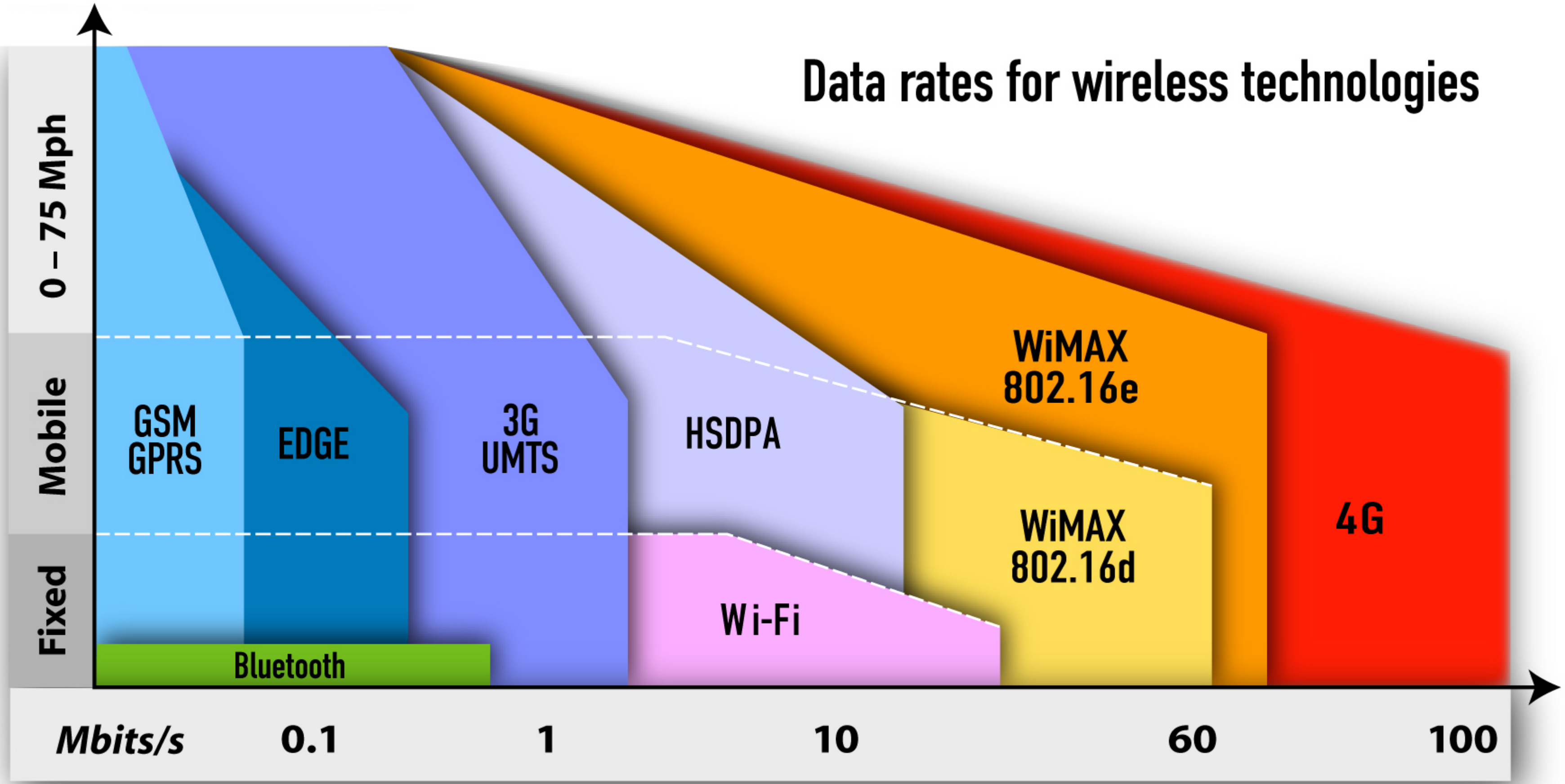
But … Why don't we just use Wi-Fi?

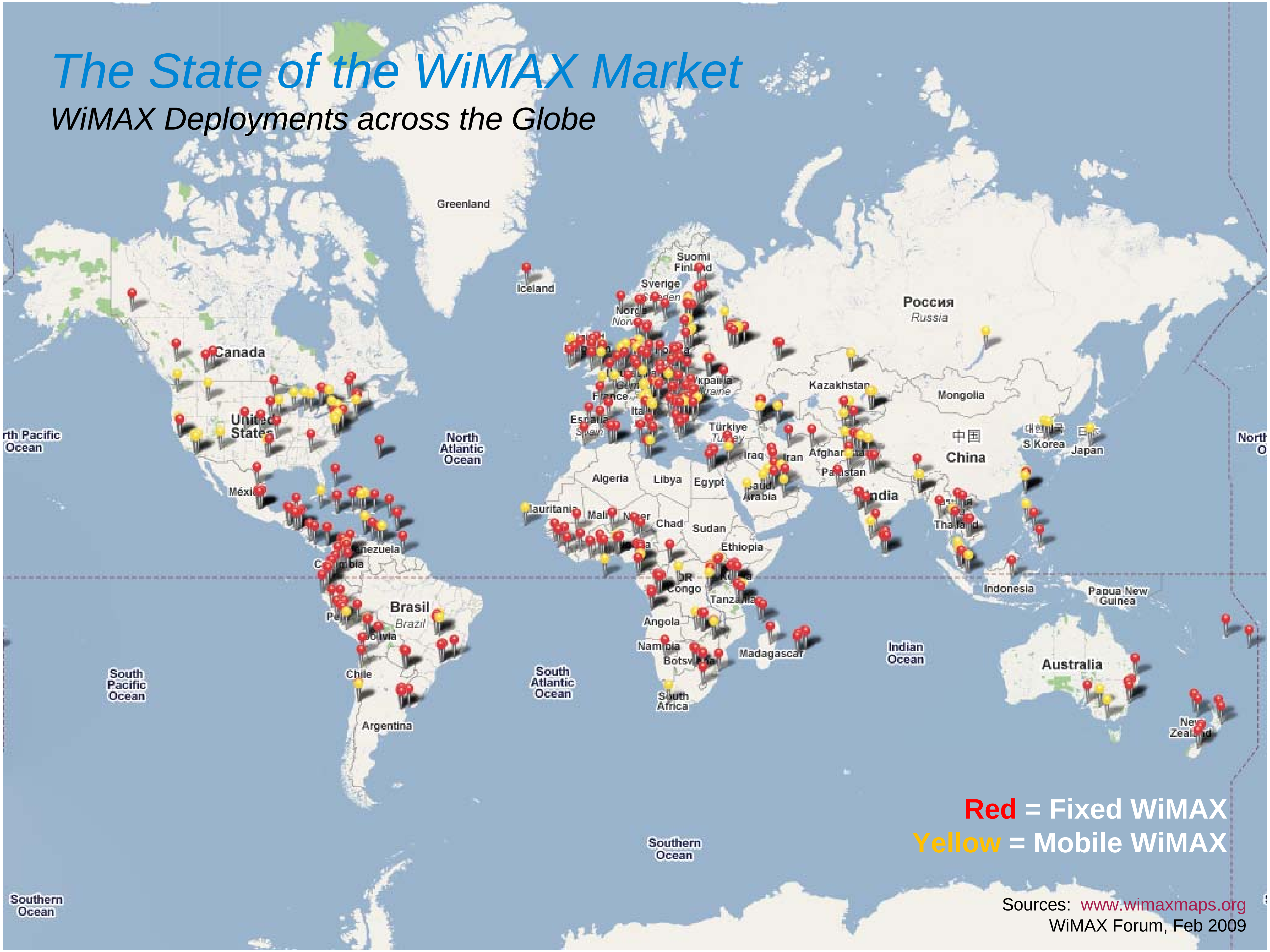


Sources: WiSOA, Siemens, ABI, Intel, Maravedis, Samsung, UMTS Forum, Nokia

We want Bandwidth AND Mobility!

The State of the WiMAX Market

WiMAX Deployments across the Globe



Red = Fixed WiMAX

Yellow = Mobile WiMAX

Sources: www.wimaxmaps.org
WiMAX Forum, Feb 2009

The State of the WiMAX Market

WiMAX Deployments across the Globe

The Good News…

- Over 500 companies in the WiMAX Forum, including
  - 165 service providers
  - 85 silicon component manufacturers
  - 120 system equipment vendors
- About 460 trials and deployments of WiMAX systems (fixed and mobile) in 135 countries
- Significant numbers of companies developing WiMAX products
  - More than 35 companies developing WiMAX Base Stations
  - 30 developing Mobile Devices
  - 25 developing chipsets & reference designs
- Some countries deploying WiMAX in 2009:
  - U.S., Japan, India, Russia, Taiwan

And The Bad News…

- Global economic recession will slow capital investment and deployments
- LTE gaining interest and momentum
  - Over 100 operators committed to LTE
  - Initial trials beginning in 2009, driven by NTT DoCoMo, Verizon, and China Telecom
  - Field trials expected in late 2009 with commercial service probably starting in 2010
- Some companies are reducing or ending investment in WiMAX
  - Nortel, Alcatel-Lucent, Nokia

Sources: www.wimaxmaps.org
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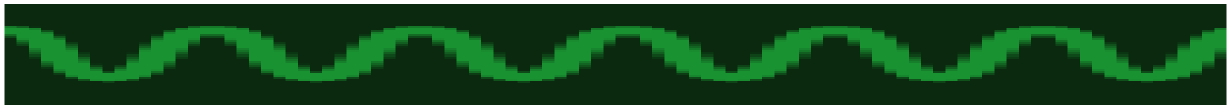
Creating a "carrier" signal

Transmitter



Receiver

Passing a continuously varying electrical current through an antenna produces a smooth and continuous RF wave similar to a sine wave

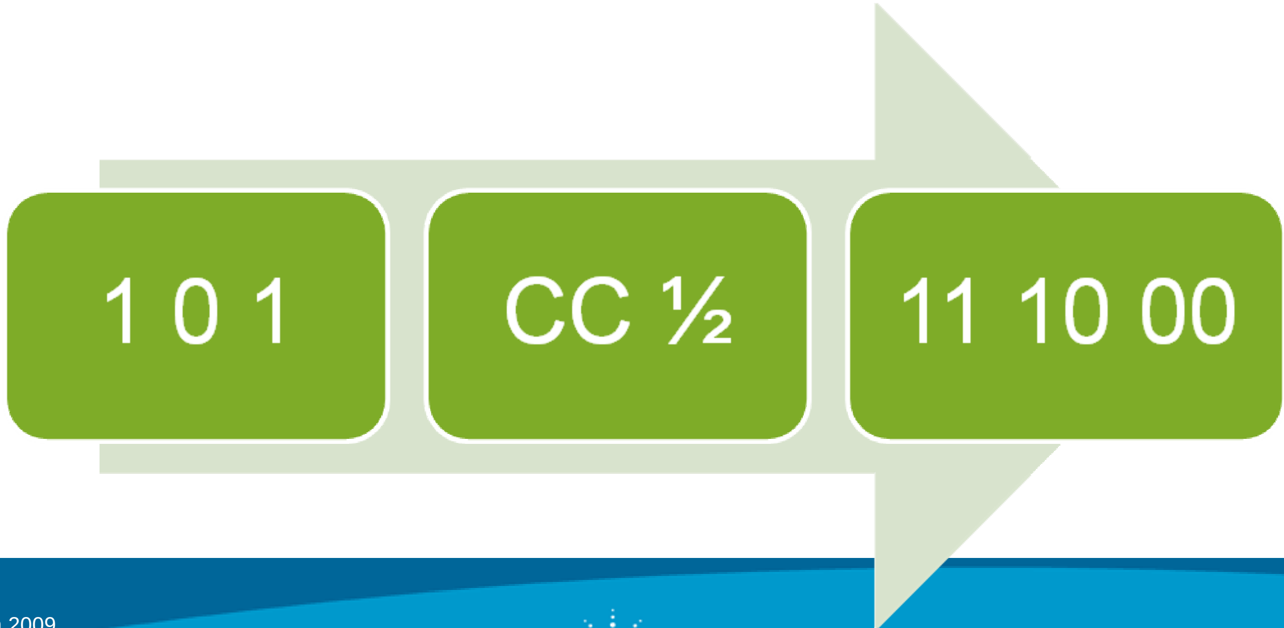
A receiver can pick this up, however at this stage the sine wave contains no information

The sine wave needs to be ***Modulated*** in some way to place information on it

Additionally, this information may be ***Encoded*** in some way to increase robustness to errors

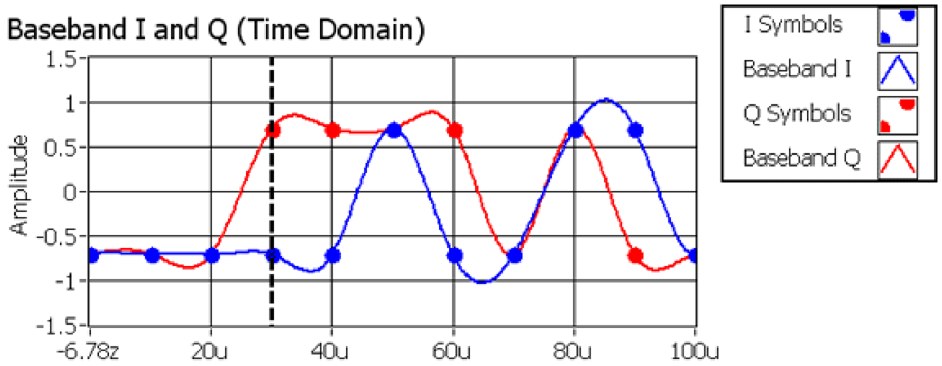
Encoding

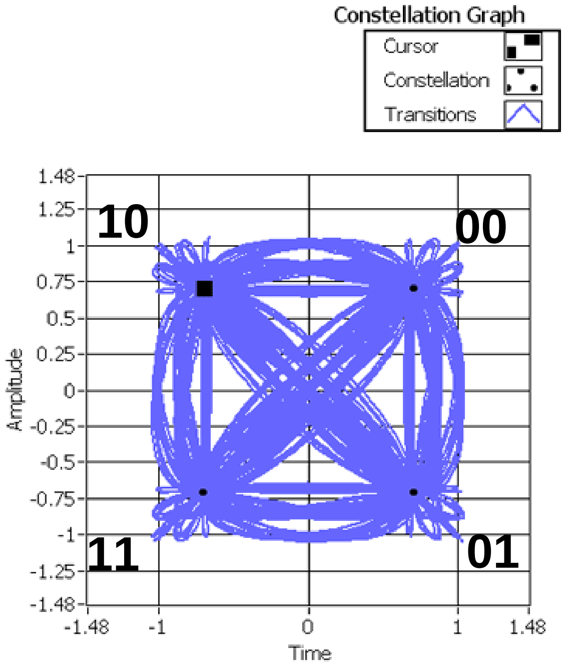
- Coding is the process of changing a message into symbols
- Forward Error Correction (FEC) is a system of coding where the sender adds redundant symbols to messages
- These symbols allow for the detection, and possibly correction, of errors induced by the radio transmission
- The code rate of a FEC code states what portion of information bits are useful (non redundant), e.g. ½ , 2/3, ¾, 5/6



Modulation

- Modulation is the process of varying a waveform to convey a message
- In Quadrature Amplitude Modulation (QAM) , we adjust the phase and amplitude of a sinusoid to convey information
- Each unique combination of *phase* and *amplitude* is called a *symbol*.
- For example, QPSK (4-QAM), consists of four unique combinations of phase and amplitude

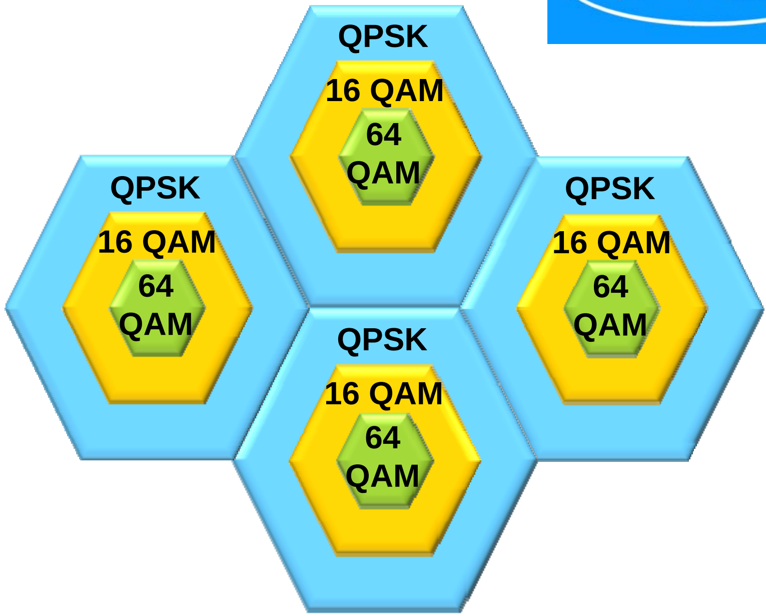


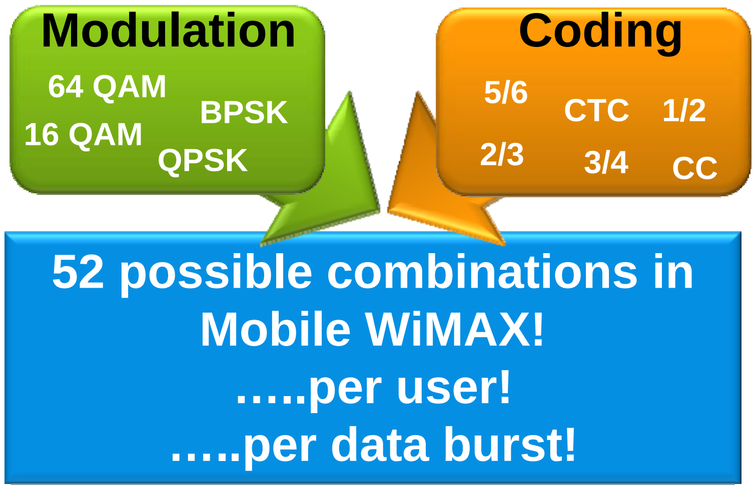


Source: http://zone.ni.com/devzone/cda/tut/p/id/3896

Adaptive Modulation & Coding

- Adaptive Modulation & Coding (AMC) - choose a combination of Modulation and Encoding Techniques *specific to each user*
- Allows high throughput in low-noise environments near the cell centre, and robust transmission near the cell edge.





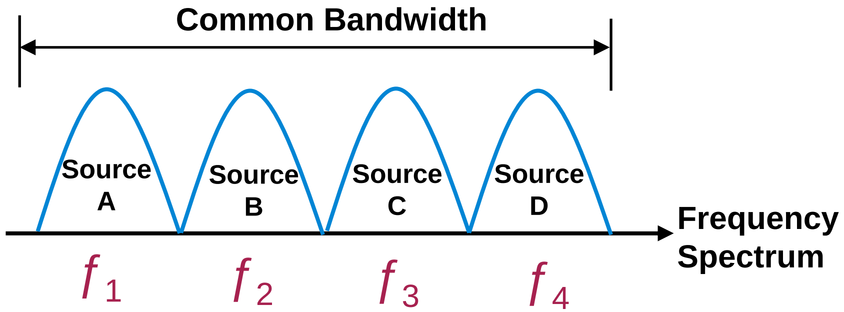
- WiMAX is highly scalable, spectrally efficient, flexible in QoS support, and highly adaptive in data rates…
- …but this results in a very complex radio system with extreme interdependencies between layers

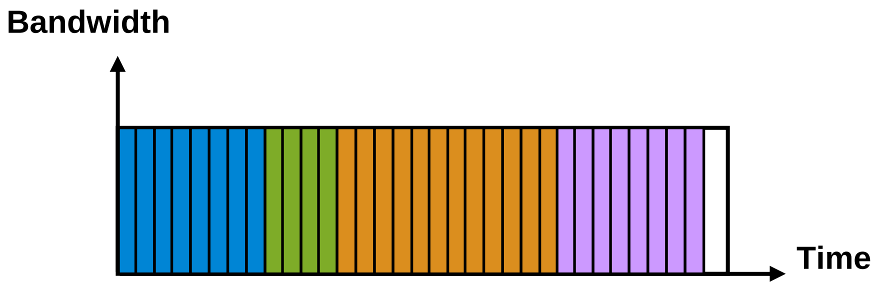
Multiplexing

- Allocation of a single sub carrier to a single data stream or subscriber is inefficient
- Multiplexing allows multiple data streams or subscribers to share a single sub carrier

- Multiplexing can be achieved in a number of ways
- Two popular techniques are:
  - Frequency Division Multiplexing (FDM)
  - Time Division Multiplexing (TDM)

FDM vs. TDM





- FDM:
  - A single frequency carrier is divided into a set of sub frequencies
  - Each sub frequency is allocated to a data source
- TDM:
  - A single high data rate carrier is divided into time slots
  - Time slots are allocated to different lower rate data sources

The Grand Challenge of Spectral Efficiency

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- ***Air interfaces converge on OFDMA***
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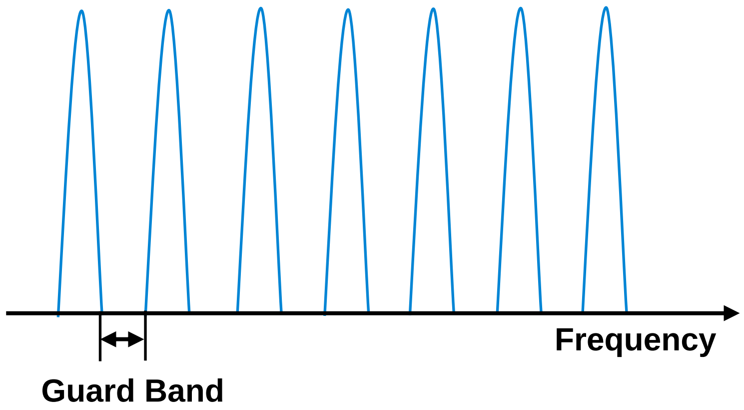
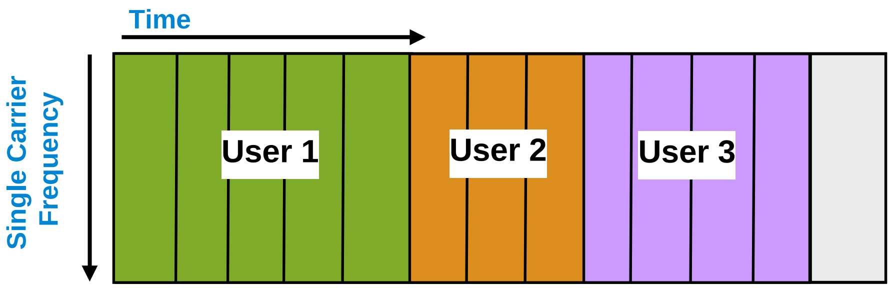
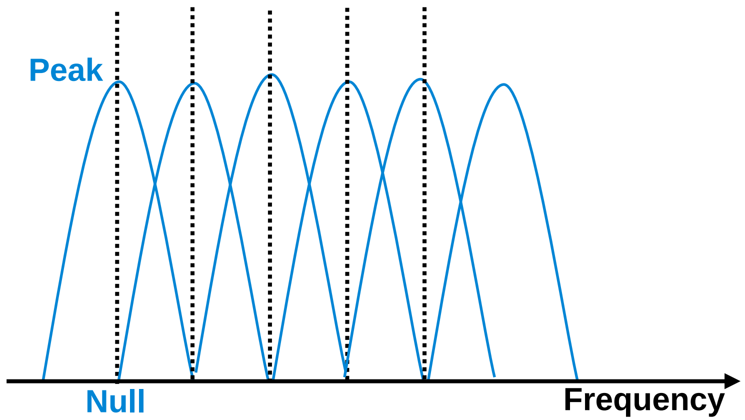
Frequency Division Multiple Access (FDMA)

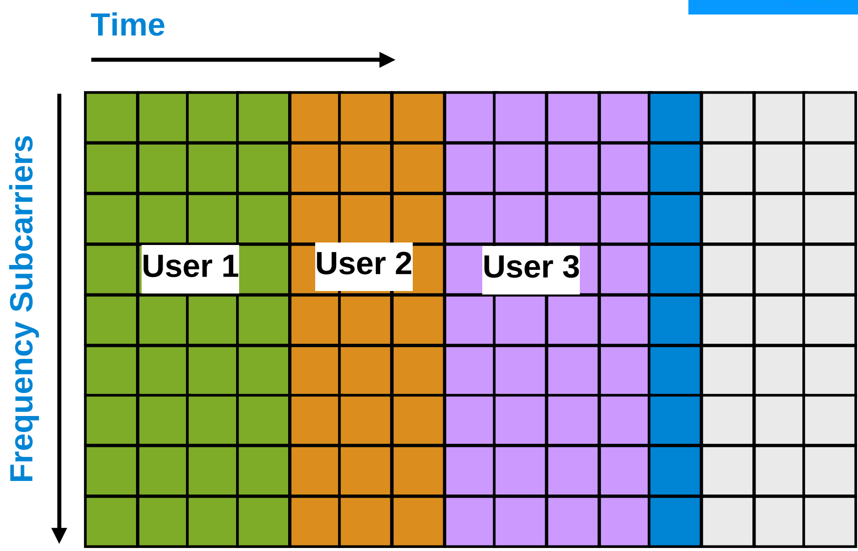




- FDMA shares spectrum but is wasteful due to the requirement of the guard band
- Each sub-carrier is modulated separately
- Each user has access to one sub-carrier for a period of time
- Sub-carriers share the same time slots

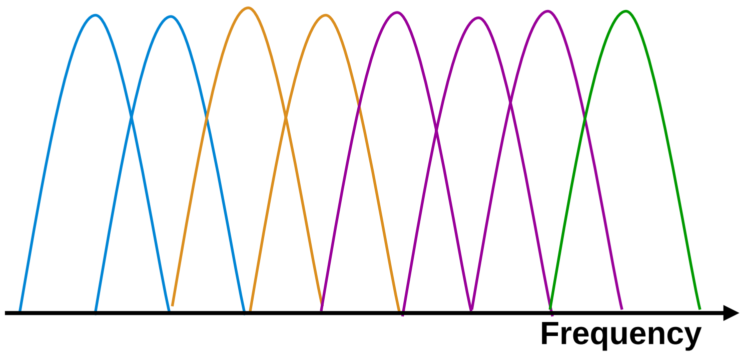
Orthogonal Frequency Division Multiplexing (OFDM)

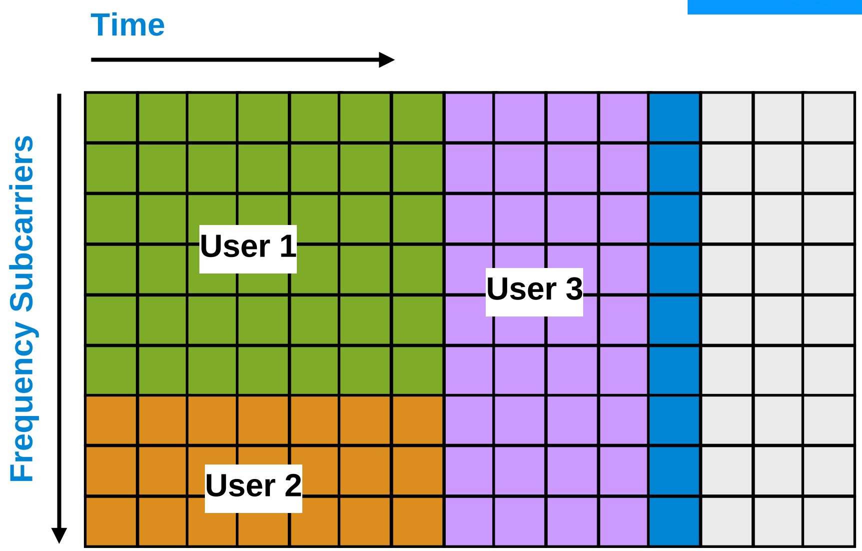




- Removed guard band by making frequencies "*Orthogonal*" thus minimising inter carrier interference
- Peak of one sub-carrier coincides with the null of an adjacent sub-carrier
- Each sub-carrier is modulated separately
- Only one users data is modulated at one time across all sub-carriers
- Multiple access is achieved by time slotting the sub-frame, users share this sub-frame sequentially in time

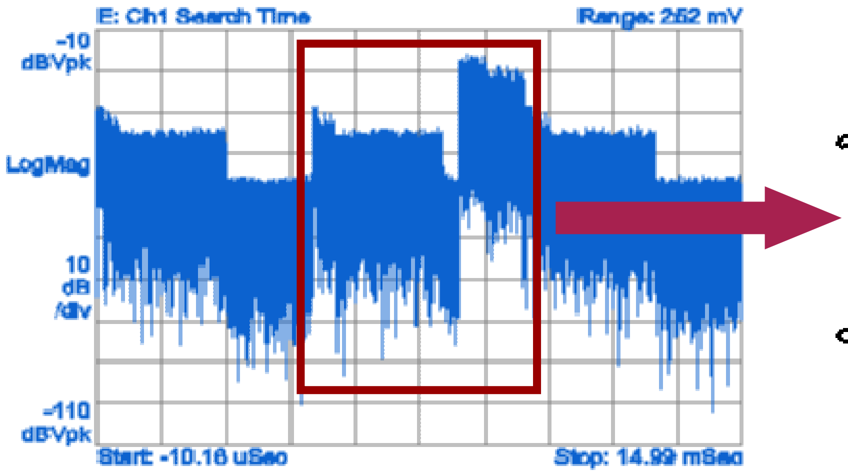
Orthogonal Frequency Division Multiple Access (OFDMA)

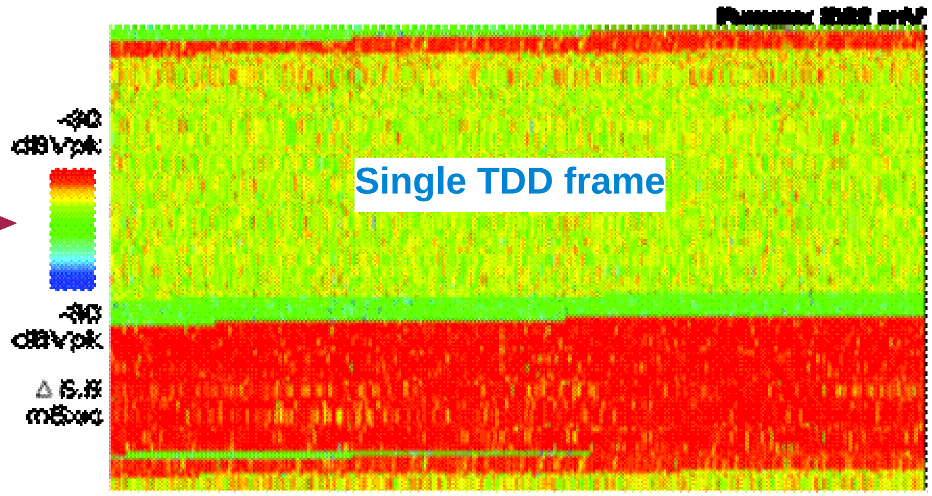


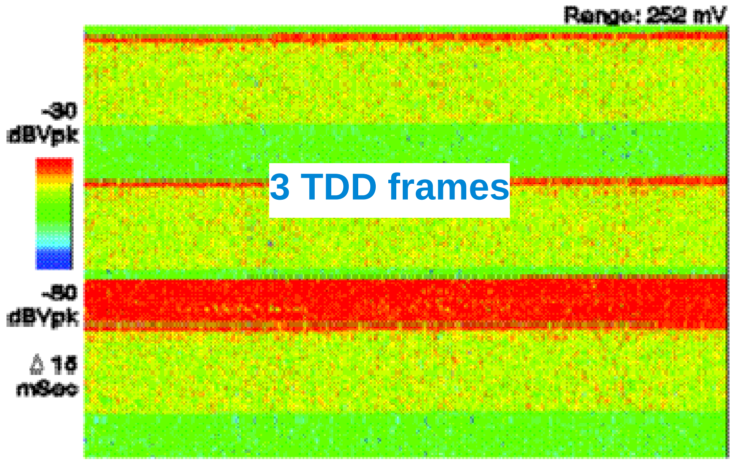


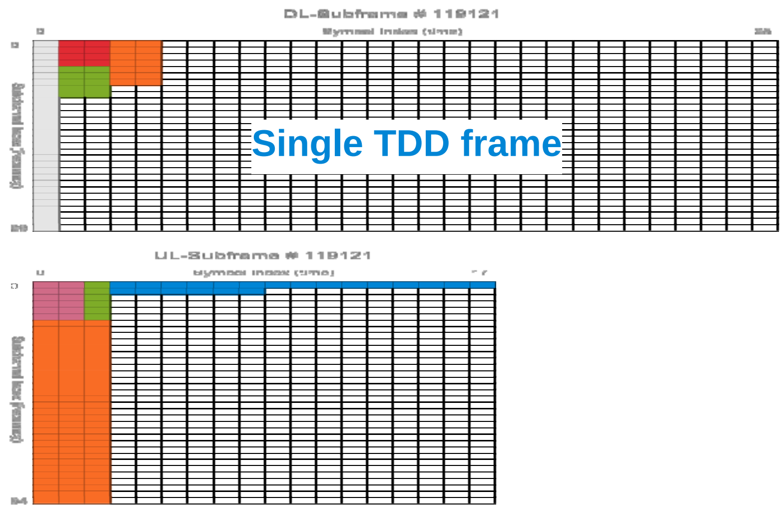
- Sub-carriers are grouped into sub-channels, sub-carriers do not need to be adjacent to each other
- These sub-channels can be allocated to mobile users, allowing them to transmit simultaneously
- Best spectral efficiency, considerable complexity of air interface and base station scheduling

Spectrogram of complex signal









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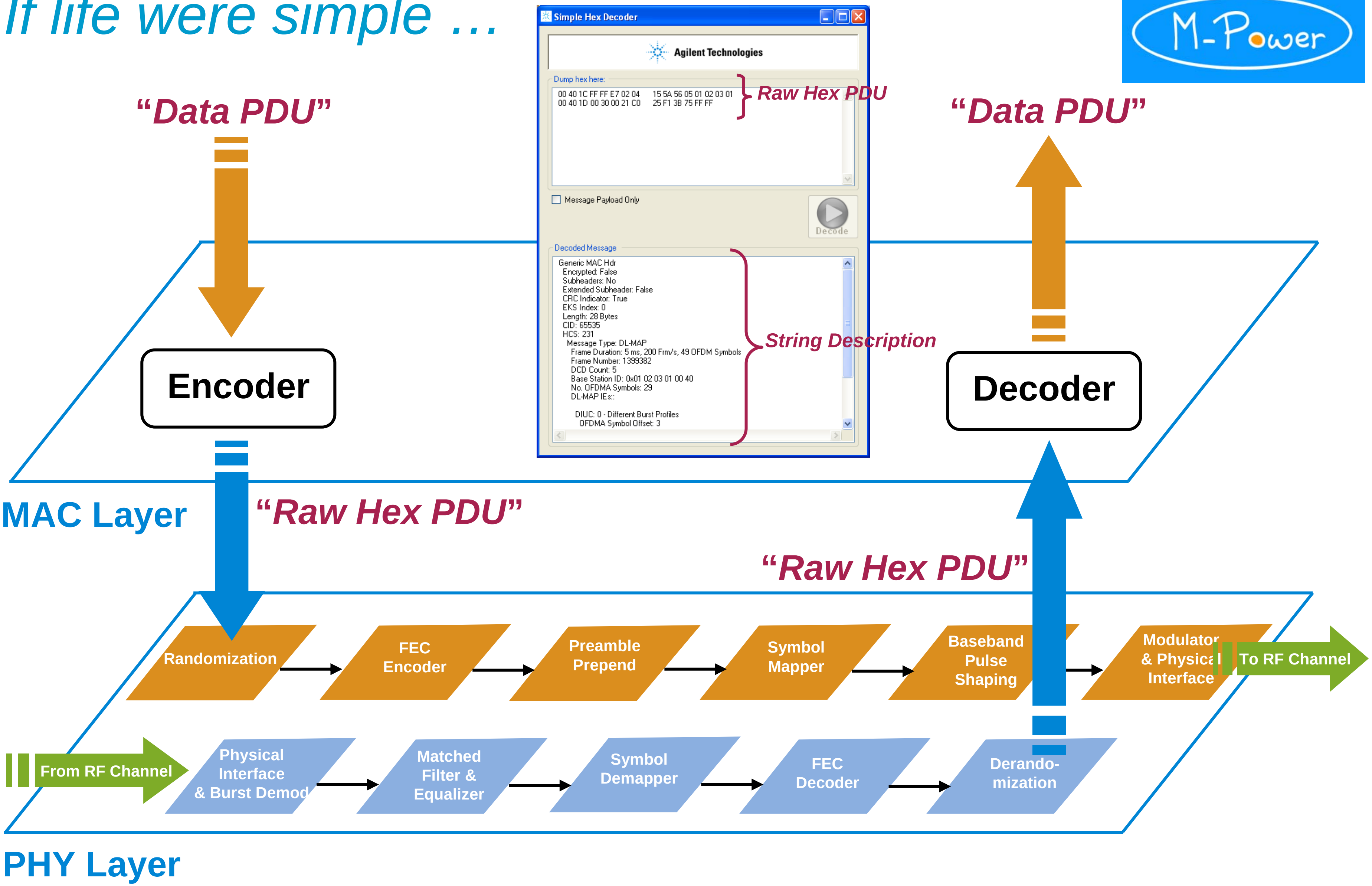
Mobile WiMAX through introspection

"A look at Mobile WiMAX from within"

"based on the analysis of real life captured data and data captured through functional test-sequences"

If life were simple …

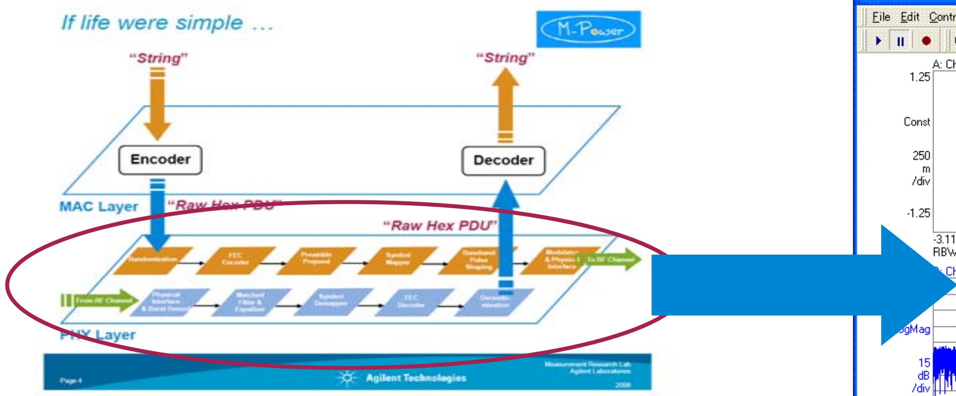


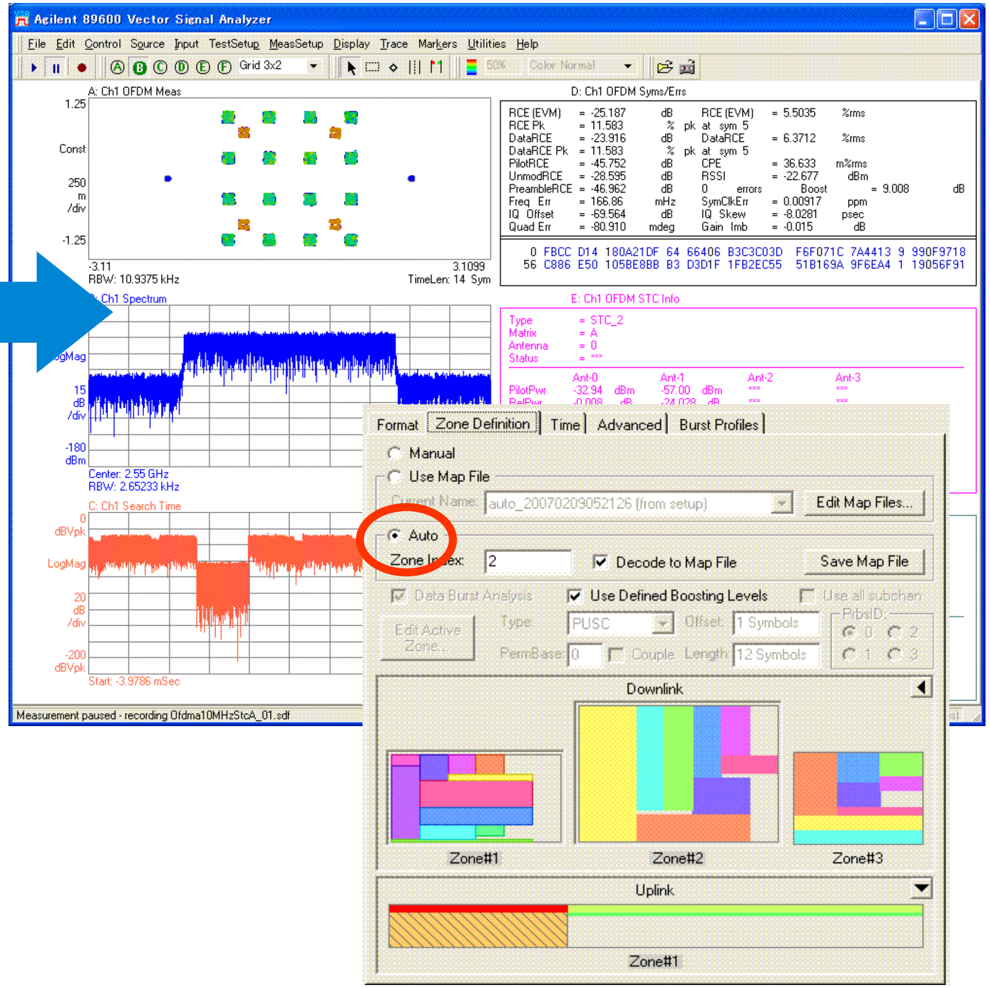
These two layers can no longer be handled in isolation …

- OFDMA is uniquely complex and a strong coupling exists between the PHY and MAC layer
  - We need to correlate measurements from PHY layer with events observed at MAC layer
  - Events at MAC layer may "trigger" changes at PHY layer
  - Correlate what is observed at PHY layer with actual decoded data at MAC layer
    - e.g. we know HARQ data was defined in the burst at PHY layer, but what did it actually convey?
  - Many processes require periods of measurement, and multiple data transactions
    - e.g. Network entry, power control, handover etc.
    - Where did things go wrong and why?
- Basically solving some these complex problems requires understanding of both the PHY and MAC layer

"Problem is compounded when we move further up the protocol stack, by multiple modality devices, multiple antennas, wireless overlays, security (no unifying architecture) and the "array" of mobility management protocols and architectures"

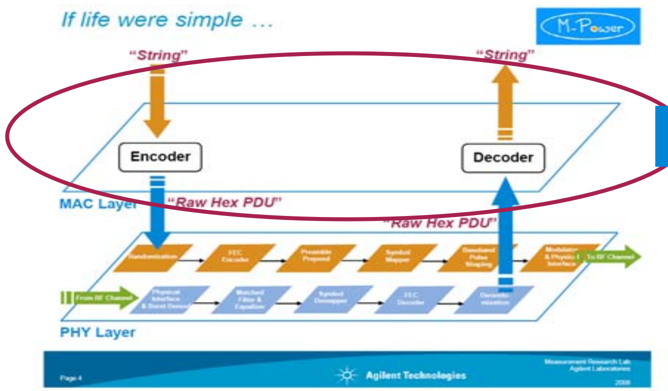
Capturing PHY Layer measurements

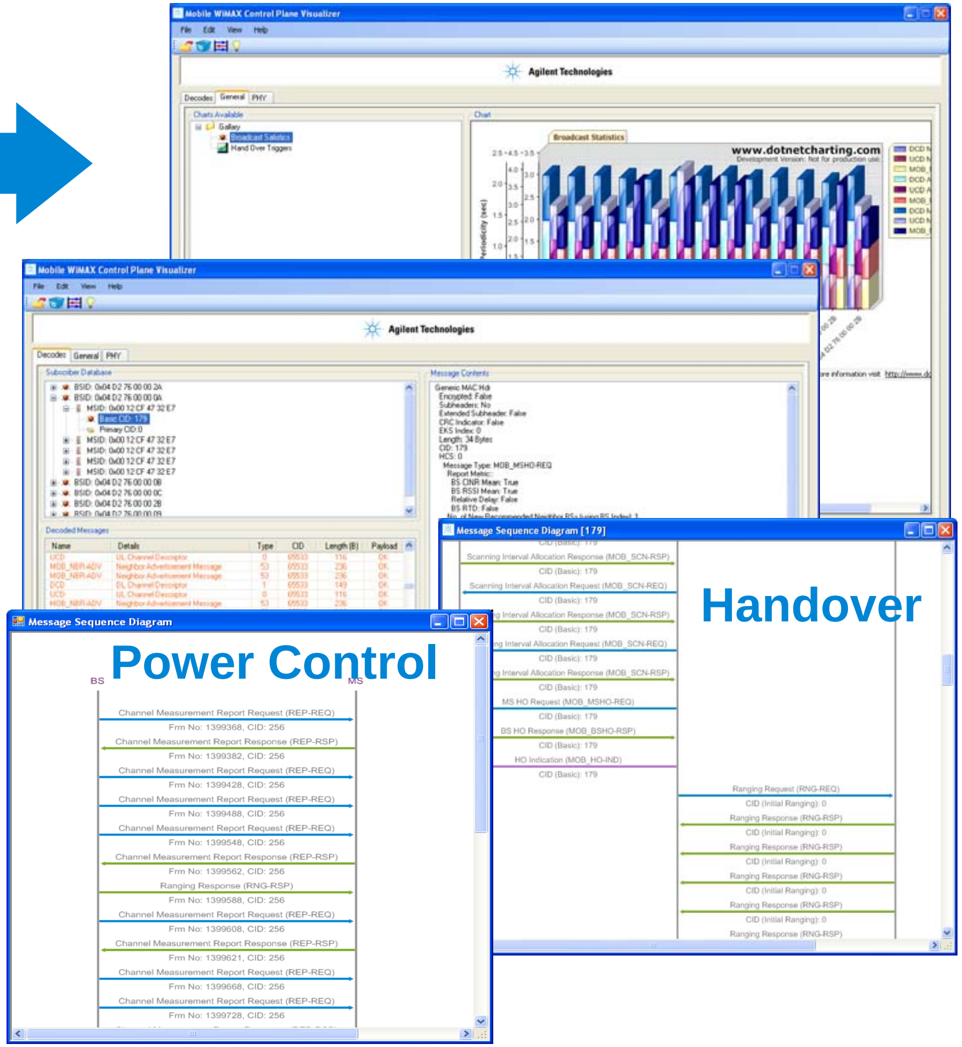




- A complex array of measurements that include:
  - All zones,
  - bandwidths,
  - modulation types,
  - FFT lengths,
  - preambles (EVM, bit error),
  - MIMO,
  - etc.

Capturing MAC Layer measurements





- A further complex array of measurements
  - Infer knowledge on transaction, dialogs and sessions
  - Mine data to take different cuts and target trouble shooting
    - Network entry
    - Power control
    - Ranging
    - Handover, etc.

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PDUs don’t stream, they come in bursts …

MAC | PHY

1st Decode FCH

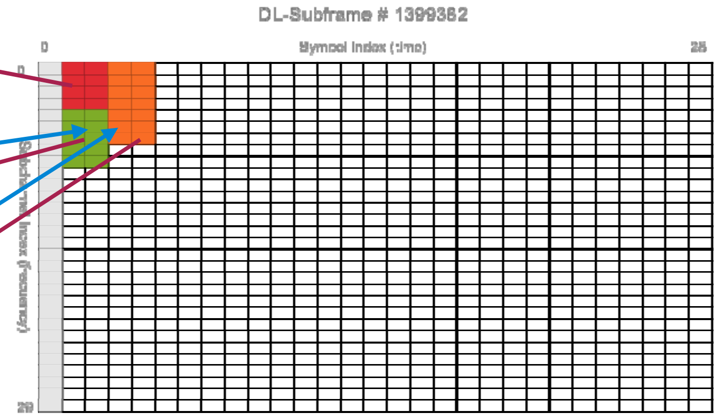
DL Frame Prefix::
- Used Subchannel BitMap:
  - Subchannel group 0: False
  - Subchannel group 1: False
  - Subchannel group 2: True
  - Subchannel group 3: True
  - Subchannel group 4: True
  - Subchannel group 5: True
- Repetition Coding Indication: No repetition coding on DL-MAP
- Coding Indication: CTC encoding used on DL-MAP
- DL Map Length: 5 slots

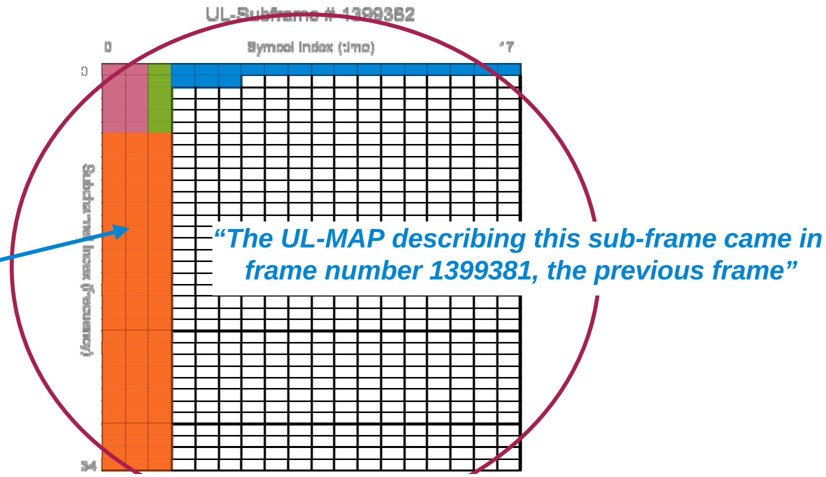
2nd Decode DL-MAP

DIUC: 0 - Different Burst Profiles
- OFDMA Symbol Offset: 3
- Subchannel Offset: 0
- Boosting: Normal (not boosted)
- No. OFDMA Symbols: 2
- No. Subchannels: 7
- Repetition Coding Indicator: No repetition coding

3rd Decode UL-MAP

CID: 65535
- UIUC: 12 - CDMA BR, CDMA Ranging
- OFDMA symbol offset: 2
- Subchannel offset: 0
- No. OFDMA Symbols: 1
- No. subchannels: 6
- Ranging Method: BR/ Periodic ranging over 1 symbol
- Dedicated Ranging Indicator: 0

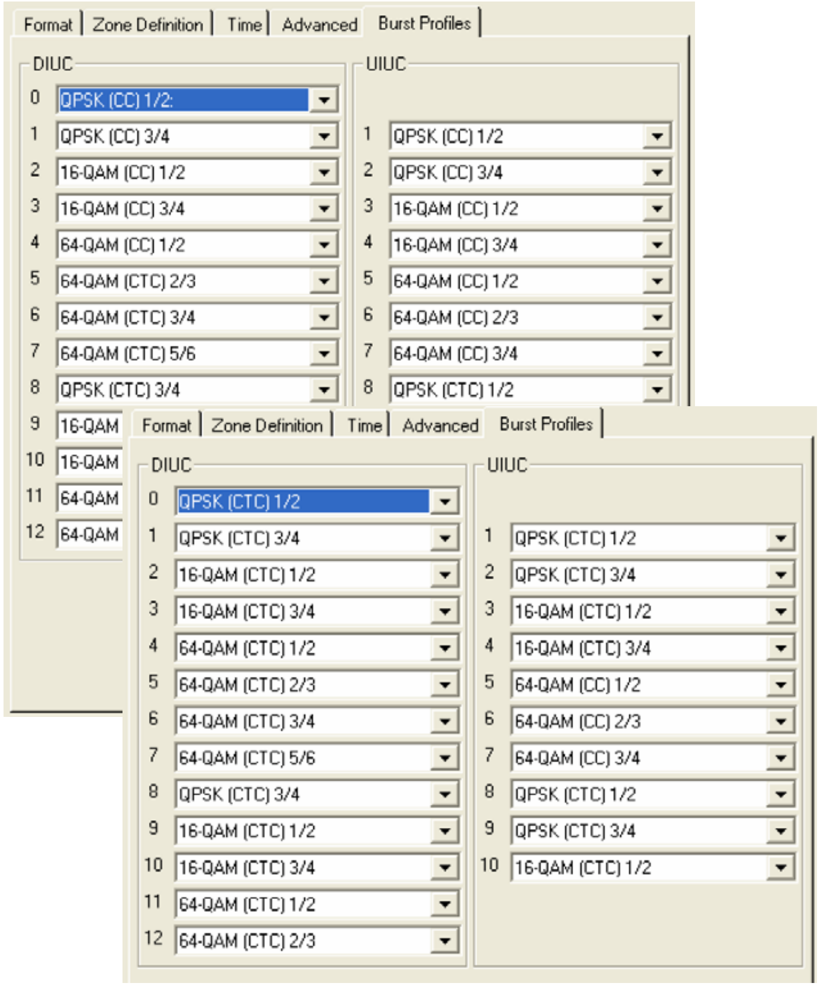




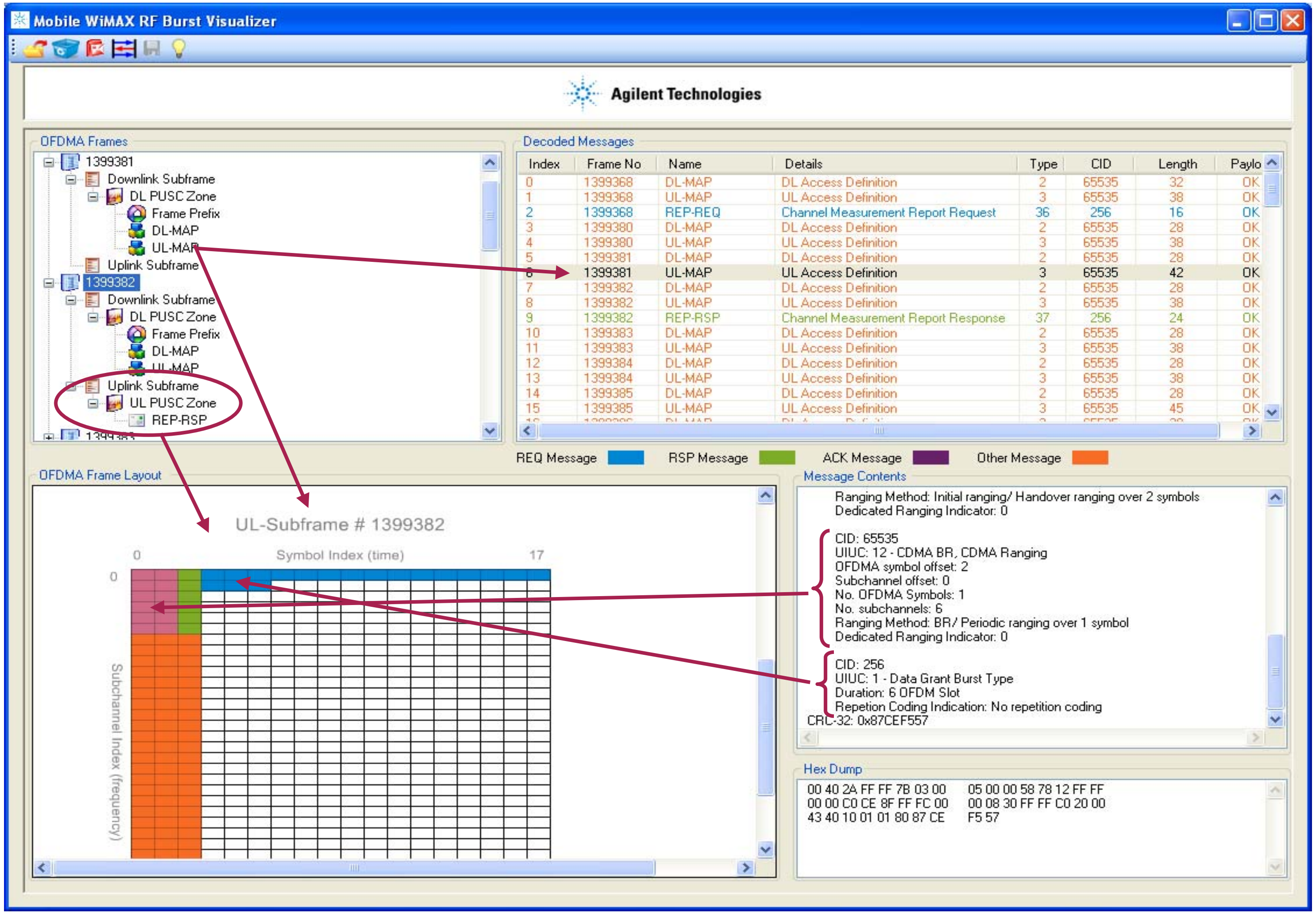
“One can easily observe from this simple case that decoding a 5 msec. frame is an iterative process, going back and forward between the MAC and PHY layer”

Reliance on previous events …

- We have already observed that an uplink sub-frame can only be decoded if we have previously decoded the UL-MAP in the previous frame
- Equally, some parameters required for decoding bursts may need to be learnt from observation of data within other MAC PDUs, in particular
  - Downlink Channel Descriptor (DCD) and Uplink Channel Descriptor (UCD) PDUs
  - They define the downlink and uplink interval usage codes (DIUC and UIUC) describing the PHY characteristics of the independent bursts within a sub-frame
- In some test environments these may be known a-priori and can be configured into the system by the “RF engineer”



Simple Example



Summing up

- Air interfaces are becoming more sophisticated
  - Newer algorithms evolving that optimize performance, efficiency and range
- OFDM used today in an array of technologies
  - Digital Video Broadcast (DVB), Asymmetric Digital Subscriber Line (ADSL), WiFi (IEEE 802.11a and IEEE 802.11g), Wireless HD, etc.
- Two main characteristics of OFDM
  - Reduces inter-symbol interference (ISI) – due to low symbol rate and longer symbol periods
  - Reduces inter-carrier interference (ICI) – due to orthogonal sub-carriers
- OFDMA has become the standard for next-generation wireless
  - Mobile WiMAX, Long Term Evolution (LTE) downlink
- Newer techniques that seek to improve on this are still evolving
  - Example, LTE uplink and the use of SC-FDMA
- Very exciting time with respect to innovation in next-generation wireless networks
  - Will we have wired networks in the future?