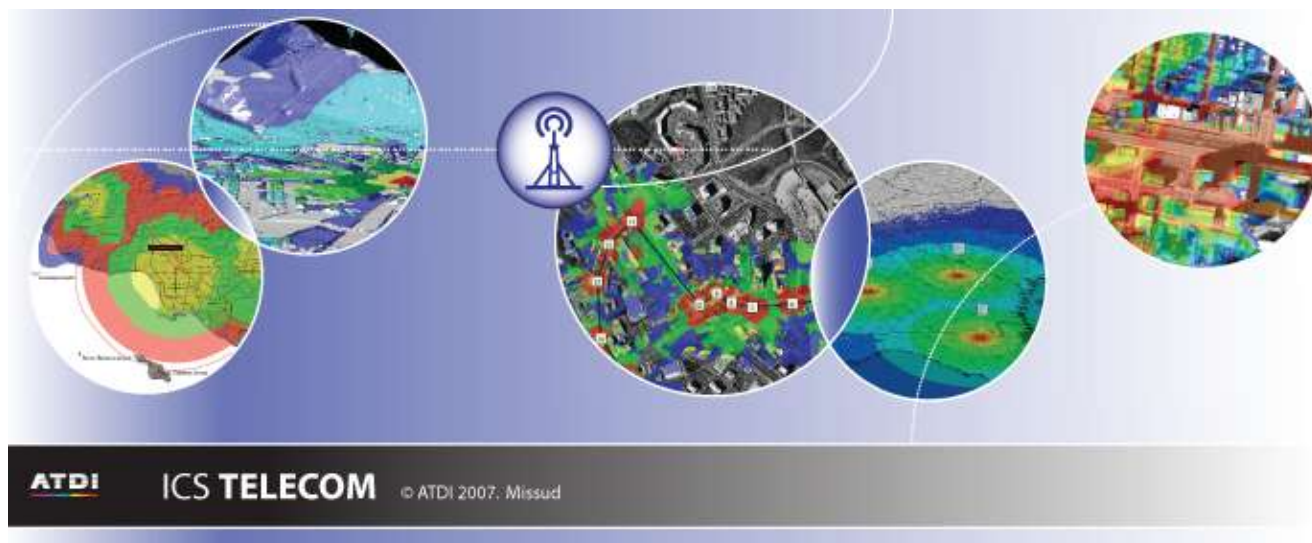


■ White Paper  
May 2008

General consideration in  
Wimax technologies



## ABSTRACT



WiMAX™ is based upon the IEEE 802.16 standard enabling the delivery of wireless broadband services anytime, anywhere. WiMAX products can accommodate fixed and mobile usage models. The IEEE 802.16 standard was developed to deliver non-line-of-sight (LoS) connectivity between a subscriber station and base station with typical cell radius of three to ten kilometers. All base stations and subscriber stations claiming to be WiMAX compliant must go through a rigorous WiMAX Forum Certified™ testing process. WiMAX Forum Certified systems can be expected to deliver capacity of up to 40 Mbps per channel. This is enough bandwidth to simultaneously support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. The WiMAX Forum expects mobile network deployments to provide up to 15 Mbps of capacity within a typical cell radius of up to three kilometers. WiMAX technology already has been incorporated in notebook computers and PDAs to deliver high speed mobile Internet services anytime, anywhere.



## Table of contents

<b>1 – Planning process</b> .....	<b>4</b>
1.1 – General considerations .....	4
1.2 – Propagation models .....	5
1.3 – Coverage calculation .....	5
<b>2 – COFDM aspects</b> .....	<b>6</b>
2.1 Modulation and sensitivity .....	6
2.2 Duplexing Scheme in WiMAX: TDD or FDD .....	6
2.3 Adaptive modulation.....	7
<b>3 – CPE</b> .....	<b>8</b>
4.1 – Technical parameters.....	8
4.1.1 <i>Radiation pattern</i> .....	8
4.1.2 <i>Power control</i> .....	8
4.2 – Service Flow .....	8
4.3 Parenting .....	9
4.4 QoS curve according to the contention ratio.....	9
<b>5 – The Base station</b> .....	<b>10</b>
5.1 - Antenna consideration.....	10
5.2 Throughput at the BS level .....	10
<b>7 – Mobile Wimax specificities</b> .....	<b>11</b>
7.1 – Mobile WiMax PHY Layer.....	11
7.2 – OFDMA basics .....	12
7.2.1 <i>Frequency Division Multiplexing (FDM)</i> .....	12
7.2.2 <i>Orthogonal Frequency Division Multiplexing (OFDM)</i> .....	12
7.2.3 <i>Orthogonal Frequency Division Multiple Access (OFDMA)</i> .....	13
7.2.4 <i>Scalable Orthogonal Frequency Division Multiple Access (SOFDMA)</i> .....	13
7.3 – OFDMA symbol structure .....	14



## 1 – Planning process

### 1.1 – General considerations

Dimensioning a WiMAX network needs to keep in mind the user traffic demand and the applications he/she shall use so that the density of Base Stations and backbone network dimensioning can fulfil the demand.

Each Base Station will be parameterised to offer a maximum bit rate for both downlink and uplink, and where it can be expected that downlink provides higher throughput (like ADSL). Bit rate depends on C/I ratio, and thus on modulation spectral efficiency.

Users will be modelled regarding their demanded bit rate for both downlink and uplink, and parented/attached to base stations.

As the customer base is growing, there must be a measure of the simultaneity of users requesting bit rate from the Base Stations because most users won't demand data at the same time and many of those connected will demand data whose packets can be delivered assuming some latency or jitter (best effort data applications as web browsing).

The type of WiMAX network design depends on several parameters. Among them can be outlined the phase of the WiMAX life cycle that needs to be simulated, the type of cartography available or that can be afforded, and the kind of outputs that are targeted at the end of the planning process. All these topics are linked one to each other, the planner needs to choose its engineering process according to:

- The time that needs to be spent on the project
- The quality of the result to be obtained

A wide range WiMAX network planning (e.g. over an entire province) gives a rough idea of the number of BTSs to deploy in order to achieve a coverage goal. Medium resolution cartography can be used here, mainly for a question of time processing. Close range analysis (detailed LOS/nLOS/NLOS propagation in high resolution urban environment) raises the simulation accuracy up to the analysis per CPE of its coverage, its achievable Grade of Service, and its uplink and downlink traffic.

Different calculation ranges are possible:

- Wide range analysis

In that case, the network design is based upon large scale, medium resolution cartography. The ground occupancy is defined by a clutter layer, which characteristics (height, attenuation, etc) can be defined clutter class per clutter class. Each receiver is placed either above or within the clutter.



- Close range analysis with outdoor receivers

In that case, high resolution cartographic data (meaning including buildings heights) needs to be defined in the ICS telecom nG project. According to the location of the receiving antennas (above rooftops or on the building side), the field strength calculation will be filtered on the rooftops or on the outline of the buildings.

- Close range analysis with indoor receivers

In that case, a mixed propagation model is applied, in order to calculate the field strength received by a CPE located either in outdoor or indoor environment.

## 1.2 – Propagation models

Please, refer to the specific document “Wimax propagation”.

## 1.3 – Coverage calculation

The coverage of the network can for instance be calculated according to:

- The sensitivity of the receiver in downlink.
- The height of the receiver above ground level.
- The maximum connection range in uplink.

Typical fade margins for the urban ground occupancies (in that case, the corresponding clutter height is fixed at 0m) and typical heights for the vegetation (ICS telecom then calculate the signal loss by diffraction).



## 2 – COFDM aspects

### 2.1 Modulation and sensitivity

Typical sensitivities in fixed mode:

Modulation	Code rate	Sensitivity dBm	Raw Bit Rate DL fixed (Mbps) 3.5 MHz BW	Net throughput DL fixed (Mbps) 3.5 MHz BW
BFSK	1/2	-100	1.41	1.128
	3/4	-98	2.12	1.696
QPSK	1/2	-97	2.82	2.256
	3/4	-94	4.23	3.384
16QAM	1/2	-91	5.64	4.512
	3/4	-88	8.87	7.096
64QAM	2/3	-83	11.29	9.032
	3/4	-82	12.71	10.168

Typical sensitivities in mobile mode:

Modulation	Code rate	Sensitivity dBm	Bit rate DL Mobile (Mbps) 5 MHz BW
QPSK	1/8	-101	Below the noise floor
QPSK	1/2	-94	2.88
16QAM	1/2	-88	5.68

### 2.2 Duplexing Scheme in WiMAX: TDD or FDD

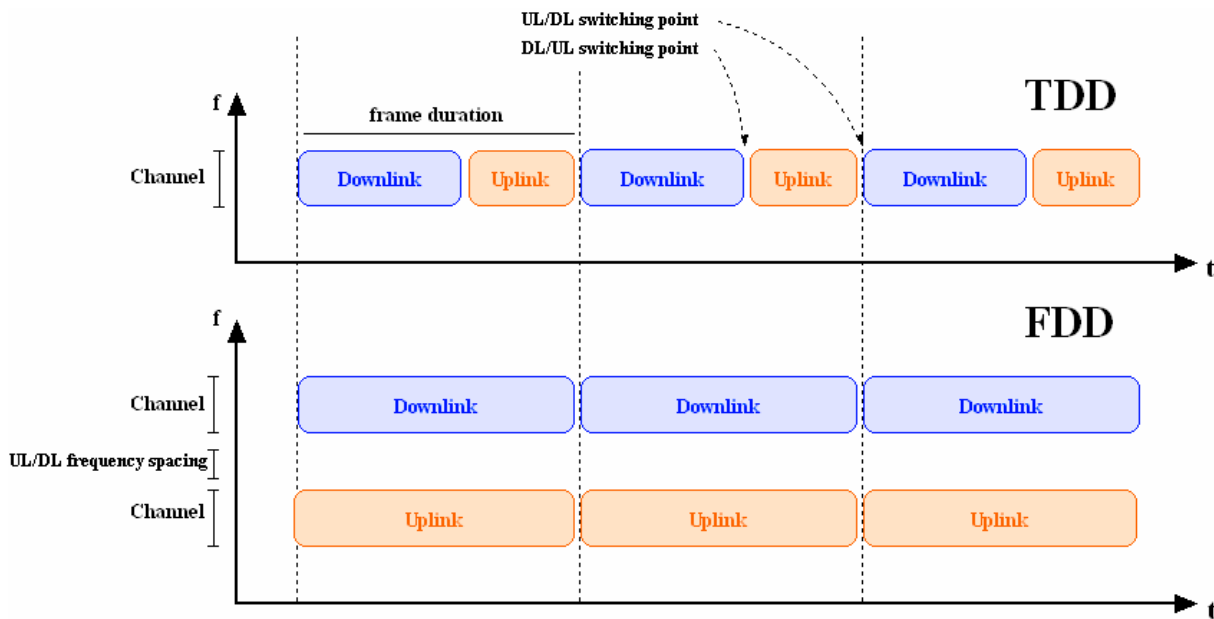
Duplexing refers to the way downlink and uplink data is arranged in a two-way wireless transmission. The downlink carries information from a Base Station to a subscriber. There are two types of duplexing scheme, FDD and TDD.

- Frequency Division Duplex

FDD requires two distinct channels for transmitting downlink sub-frame and uplink sub-frame at the same time slot. FDD is suitable for bi-directional voice service since it occupies a symmetric downlink and uplink channel pair.

- Time Division Duplex

TDD requires only one channel for transmitting downlink and uplink sub-frames at two distinct time slots.



### 2.3 Adaptive modulation

Adaptive modulation allows the WiMAX system to adjust the signal modulation scheme depending on the signal to noise ratio (SNR) condition of the radio link. When the radio link is high in quality, the highest modulation scheme is used, giving the system more capacity. During a signal fade, the WiMAX system can shift to a lower modulation scheme to maintain the connection quality and link stability. This feature allows the system to overcome time-selective fading. The key feature of adaptive modulation is that it increases the range that a higher modulation scheme can be used over, since the system can flex to the actual fading conditions, as opposed to having a fixed scheme that is budgeted for the worst case conditions.

The key parameter for traffic modeling (using adaptive antenna arrays or not) from a planning tool point of view is the bit rate that can be offered for a given received signal level. This characteristic itself depends on the modulation used, hardware algorithms, transmitting and receiving antenna specifications... As in ICS Telecom nG the user can specify its own traffic parameters according to the power received, it is then straightforward to deal with a large set of scenarios. In addition, ICS Telecom nG also includes features dedicated to adaptive modulation, to offer the maximum bit rate according to the best modulation and the signal level received:

- Traffic analysis between two BTS (backbone for instance): a connection between two WiMax stations is created and the bit rate is set according to the margin above minimum received threshold.



- CPE connection at a parent WiMAX sector: The available bit rate at the BTS will be controlled and the CPE (subscriber) connected according the power received (threshold versus modulation scheme). This process can be done in both Uplink and Downlink.

## 3 – CPE

### 4.1 – Technical parameters

In order to refine the capacity analysis in fixed/nomadic WiMax, each CPE can be placed and defined individually.

#### *4.1.1 Radiation pattern*

Each WiMAX CPE is configured using its corresponding radiation pattern. It can be a standard antenna, or being adaptive (better connectivity, with more resistance with regards to the interference).

#### *4.1.2 Power control*

To improve the overall performance of the system, the transmitted power of the CPEs is regulated so that the power received at the base station is at a predetermined level. ICS telecom adjusts the uplink radiated power at the CPE side, thereby limiting cases of interference.

### 4.2 – Service Flow

Each CPE has its own traffic request, in downlink and in uplink. But the way the traffic request is managed by the BS depends on the type of connection that is used. These types are called **Service Flows** by the NWG of the WiMax Forum©.



QoS category	Applications	QoS specifications
<b>UGS</b> Unsolicited Grand Service	VoIP	Maximum Sustained Rate Maximum latency Tolerance Jitter tolerance
<b>rtPS</b> Real-Time Packet Service	Streaming Audio or Video	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Traffic priority
<b>ErtPS</b> Extended Real-Time Packet Service	Voice with Activity Detection (VoIP)	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic priority
<b>nrtps</b> Non Real-Time Packet Service	File Transfer Protocol (FTP)	Minimum reserved rate Maximum sustained rate Traffic priority
<b>BE</b> Best-Effort Service	Data transfer, Web Browsing, etc...	Maximum sustained rate Traffic priority

### 4.3 Parenting

The 802.16 parenting checks:

- The priorities between the service flows
- The fact that the service flows might be contention free (UGS, rtPS...) or contention based (BE)
- The parenting in DL, then in UL
- The maximum tolerable latency between the end user and the source of the signal
- The contention ratio of each CPE
- The adaptive modulation:
- The reliability of each CPE-BS link

### 4.4 QoS curve according to the contention ratio

The QoS of the network also varies according to the time of the journey. Each customer does not use its connection in the same time of the day. The contention ratio of the WiMAX connection can be setup individually, or on a 24 hours basis.



## 5 – The Base station

### 5.1 - Antenna consideration

Each sector of a WiMax BTS can be setup independently in ICS Telecom nG. The directivity of the CPE is also described and taken into account at each stage of the simulation process

- Smart antenna systems:

Various technologies are used for smart antenna systems: Switched Beams, Adaptive Array (AA), Dynamically Phased Array (PA), MIMO, SDMA. The strategies used rely on optimising the gain or the directionality of the radiation patterns, spatial multiplexing, combining multipath signals. These adaptive systems take advantage of their ability to effectively locate and track various types of signals to dynamically minimize interferences and maximize intended signal reception.

The key parameters for field strength predictions are the antenna gain in the transmitting and receiving ways and the sensitivity of the receiver.

- The radio planner can use ICS telecom nG to define manually its own parameters to set the antenna gain and receiving threshold;
- For adaptive antenna arrays, the user defines the composite pattern corresponding to all radiating elements and the number of available elements. The "burst" gain" is calculated and the nominal gain updated, based on the assumption that an antenna array containing M elements can provide a power gain of M over white noise level.
- For switched beams, ICS telecom nG automatically detects the best predefined beam to offer/receive the best signal in a given direction and then applies interference rejection from pattern discrimination and location of the interferers.

In addition to the features available to model adaptive antenna arrays, ICS telecom also includes not only specific functions related to dynamic beam forming according to angle or arrival (off-axis angle) of the signals, but also the capability to modify the coverage according to the directivity of a receiver and the location of its most-probable server.

### 5.2 Throughput at the BS level

The user makes the choice between TDD or FDD type of equipment. The way the BS throughput is managed is different.

For **FDD systems**, the user can specify one throughput value for the downlink, and one for the uplink.



For **TDD systems**, the throughput is shared between the downlink and the uplink. This sharing is defined as an UL/DL duration ratio.

## 7 – Mobile Wimax specificities

Support low packet loss handovers and handover latencies for applications such as near toll-quality VoIP. In that case the receiver can be located wherever on the map, in Outdoor or indoor.

In addition to all types of analysis listed above, ICS telecom nG features dedicated modules for mobile networks: Receiving signals along a mobile path, Handover analysis, in Uplink or downlink, Time of arrival,

To summarize, **802.16d**-type of equipment can be modelled thanks to the Point to Point and Point to Multi-point engines. Static and nomadic terminals can be considered as FWA-type terminals, simulated in ICS telecom nG using directional antennas, individual CPE parameters, adaptive modulation...

**802.16e** can be simulated using the coverage mode. Furthermore, through statistical functionalities, it is possible to take into account the nomadic and mobile behaviour of the users.

### 7.1 – Mobile WiMax PHY Layer

The duplex mode:

The IEEE 802.16e-2005 air-interface supports both Time Division Duplexing (TDD) and Frequency Division Duplexing (FDD) modes. However, the initial release of mobile WiMAX profiles only includes the TDD mode of operation.

The TDD mode is preferred for the following reasons:

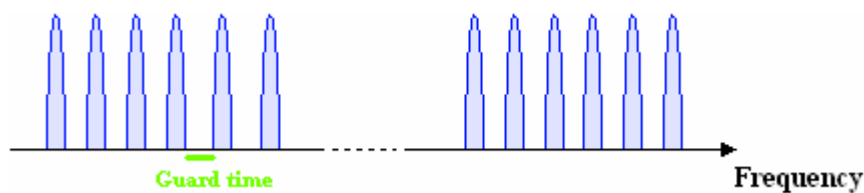
- It enables a dynamic allocation of DL and UL resources to support efficiently asymmetric DL/UL traffic (adaptation of DL:UL ratio to DL/UL traffic).
- It ensures channel reciprocity for better support of link adaptation, advanced antenna techniques such as transmit beam-forming or MIMO.
- Unlike FDD, which requires a pair of channels, TDD only requires a single channel for both downlink and uplink providing greater flexibility for adaptation to varied global spectrum allocations.
- Transceiver designs for TDD implementations are less complex and therefore less expensive.



## 7.2 – OFDMA basics

### 7.2.1 Frequency Division Multiplexing (FDM)

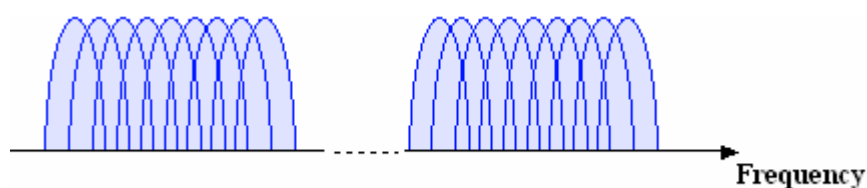
WiMAX air interface is based on OFDM/OFDMA PHY. To understand how OFDM and OFDMA work, it is useful to start with the source namely FDM (Frequency Division Multiplexing).



In FDM system, signals from multiple transmitters are transmitted simultaneously (at the same time slot) over multiple frequencies. Each frequency range (sub-carrier) is modulated separately by different data stream and a spacing (guard band) is placed between sub-carriers to avoid signal overlap.

### 7.2.2 Orthogonal Frequency Division Multiplexing (OFDM)

Like FDM, OFDM also uses multiple sub-carriers but the sub-carriers are closely spaced to each other without causing interference, removing guard bands between adjacent sub-carriers. This is possible because the frequencies (sub-carriers) are orthogonal, meaning the peak of one sub-carrier coincides with the null of an adjacent sub-carrier.



Orthogonal Frequency Division Multiplexing (OFDM)

In an OFDM system, a very high rate data stream is divided into multiple parallel low rate data streams. Each smaller data stream is then mapped to individual data sub-carrier and modulated using some Phase Shift Keying Quadrature Amplitude Modulation (QPSK, 16-QAM, 64-QAM...).

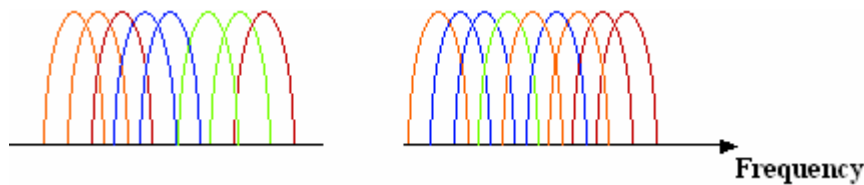
OFDM needs less bandwidth than FDM to carry the same amount of information which translates to higher spectral efficiency. Besides a high spectral efficiency, an OFDM system such as WiMAX is more resilient in NLOS environment. It can efficiently overcome interference and frequency-selective fading caused by multipath because equalizing is done on a subset of sub-carriers instead of a single broader carrier. The effect of ISI (Inter



Symbol Interference) is suppressed by virtue of a longer symbol period of the parallel OFDM subcarriers than a single carrier system and the use of a cyclic prefix (CP).

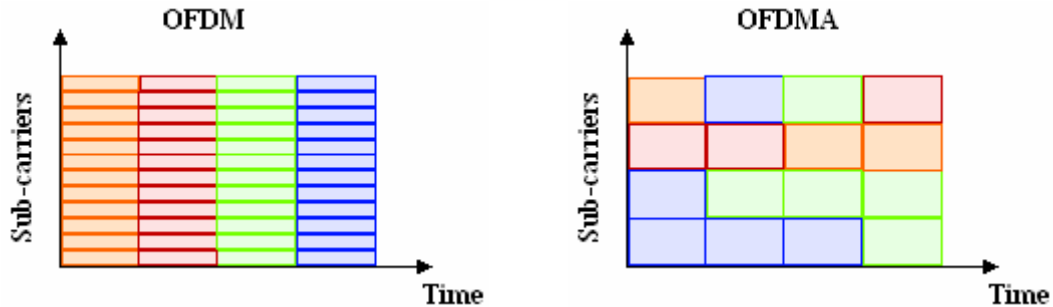
### 7.2.3 Orthogonal Frequency Division Multiple Access (OFDMA)

Like OFDM, OFDMA employs multiple closely spaced sub-carriers, but the sub-carriers are divided into groups of sub-carriers. Each group is named a sub-channel. The sub-carriers that form a sub-channel do not need to be adjacent.



Orthogonal Frequency Division Multiple Access (Sub-carriers with the same color represent a sub-channel)

Sub-channelization defines sub-channels that can be allocated to the mobile units depending on their channel conditions and data requirements. Using sub-channelization, a Mobile WiMAX BS can allocate within the same time slot more transmit power for lower SNR cases and less power for higher SNR cases.



In OFDM, only one MU transmits in one time slot.  
In OFDMA, several MUs can transmit at the same time slot over several sub-channels.

Sub-channelization in the uplink can save a user device transmit power because it can concentrate power only on certain sub-channel(s) allocated to it. This power-saving feature is particularly useful for battery-powered user devices, the likely case in Mobile WiMAX.

### 7.2.4 Scalable Orthogonal Frequency Division Multiple Access (SOFDMA)

Additionally benefit over OFDMA is brought by scalable OFDMA (S-OFDMA). The FFT scales its size to the channel bandwidth in order to keep constant carrier spacing. This brings higher spectral efficiency in wide channels and a cost reduction in narrow channels.



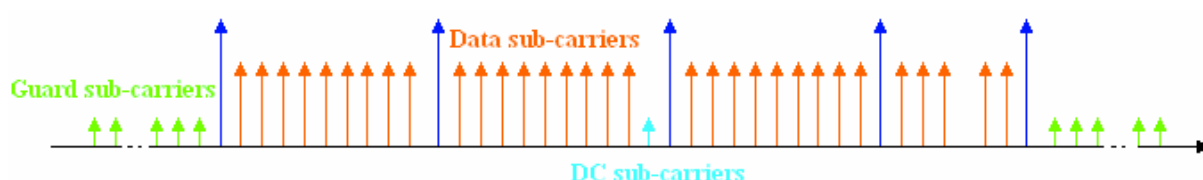
					Parameter in ICS telecom (OFDMA calculator)
Transmission bandwidth	1.25	5	10	20	Configurable
FFT size	128	512	1024	2048	Automatically displayed
Over-sampling rate	28/25				Configurable (default to 28/25)
Sampling frequency	1.4	5.6	11.2	22.4	Automatically calculated
Sub-carrier spacing	10.94				Automatically calculated
Useful Symbol Time (μs)	91.43				Automatically calculated
Symbol guard time interval	1/8				Configurable (default to 1/8)
Guard Time (μs)	11.43				Automatically calculated
OFDMA symbol duration (μs)	102.86				Automatically calculated
Recieve time gap (RTG) (μs)	62.86				Input user
Frame duration (ms)	5				Automatically calculated

### 7.3 – OFDMA symbol structure

There are three types of OFDMA sub-carriers:

- **Data sub-carriers** for data transmission.
- **Pilot sub-carriers** for various estimation and synchronization purposes.
- **Null sub-carriers** for no transmission at all, used for guard bands (left and right) and DC carriers (used at the transmission frequency).

Active sub-carriers are divided into subsets of sub-carriers called sub-channels.



OFDMA sub-carrier structure

The sub-carriers forming one sub-channel may be, but not need to be, contiguous. Different ways of grouping sub-carriers into channels in 802.16 are called **permutations**.

Three main permutations:

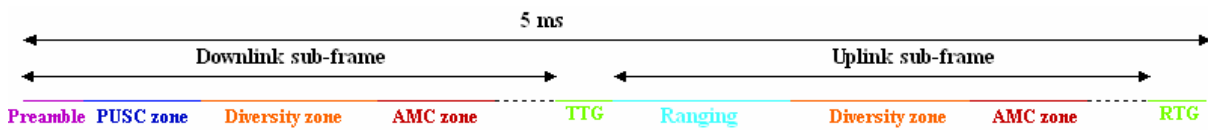
- **FUSC** – Full Usage of Sub-channels (DL only): Achieves best frequency diversity by spreading the subcarriers over the entire band
- **PUSC** – Partial Usage of Sub-channels (UL and DL)
  - o Groups the sub-carriers into tiles to enable fractional frequency reuse scheme (FFRS).
  - o Still has distribution of sub-carriers across band for each sub-channel
- **AMC** (or Band AMC)–Adaptive Modulation and Coding (UL and DL)
  - o a.k.a. Adjacent Sub-carrier Permutation
  - o Uses adjacent sub-carriers for each sub-channel for use with beam forming



Note that alternative permutations, such as **TUSC** (supporting both beam forming and OFDMA permutation) might be used as an option in the DL sub-frame.

There are two main types of sub-carrier permutations: distributed (diversity) and localized (contiguous). In general, distributed sub-carrier permutations perform very well in **mobile applications** while adjacent subcarrier permutations can be properly used for **fixed, portable, or low mobility environments**. These options enable the system designers to trade mobility for throughput.

	Diversity (mobility users)	Contiguous (fixed and nomadic users)
DL	FUSC	AMC
	PUSC	
	TUSC	
UL	PUSC	AMC



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