Dto. de Ingeniería Eléctrica y de Computadoras
Universidad Nacional del Sur

DIEC

WIMAX - OFDMA basics

1. WIMAX – OFDMA characteristics
2. WIMAX frame structure.

WIMAX - OFDMA (I)

WIMAX example: Design requirements and tradeoffs

- Main objective in OFDMA: scalable structure in terms of FFT size and bandwidth, maintaining subcarrier spacing fixed.
- To that purpose it is required to choose admissible values for Doppler shift (coherence time) and coherence bandwidth of the channel.

WIMAX - OFDMA (II)

- To support mobility 125 km/hr is assumed, then maximum Doppler shift with 3.5 GHz (in the 2 – 6 GHz range) is

$$f_D = \frac{\nu}{\lambda} = \frac{35\ \mathrm{m/s}}{0.086\ \mathrm{m}} = 408\ \mathrm{Hz}$$

(worst case: 700 Hz, corresponding to 6 GHz).

- ICI power corresponding to f_D is limited (experimentally) to – 27 dB.

WIMAX - OFDMA (III)

- The coherence time of that channel (a measure of time variation in the channel), is the following

$$T_c = \sqrt{\frac{9}{16\pi f_D^2}} = 1.03\ \mathrm{ms}$$

- That means an update rate of (approx.)1 KHz is required for channel estimation and equalization.

DIEC

WIMAX - OFDMA (IV)

- On the other hand, subcarrier spacing design requires a flat fading characteristic for worst case delay spread values (20 μs), then the coherence bandwidth is

$$B_c = \frac{1}{5\sigma_\tau} = \frac{1}{5\times 20\ \mu s} = 10.0\ \mathrm{KHz}$$

- This means that for delay spread values of up to 20 μs, multipath fading can be considered as flat fading over a 10 KHz subcarrier width.

WIMAX - OFDMA (V)

Without scalability, performance is reduced or cost is increased for low and mid-size channel bandwidths.

Table 1: OFDMA scalability parameters

Parameters	Values				
System bandwidth (MHz)	1.25	2.5	5	10	20
Sampling frequency (F_s,MHz)	1.429	2.857	5.714	11.429	22.857
Sample time ($1/F_s$,$nsec$)	700	350	175	88	44
FFT size (N_{FFT})	128	256	512	1024	2048
Subcarrier frequency spacing	11.16071429 kHz				
Useful symbol time ($T_b=1/\ f$)	89.6 µs				
Guard time ($T_g=T_b/8$)	11.2 µs				
OFDMA symbol time ($T_s=T_b+T_g$)	100.8 µs				

WIMAX - OFDMA frame structure (I)

Like in OFDM, there are three types of OFDMA subcarriers

- Data subcarriers for data transmission,
- Pilot subcarriers for various estimation and synchronization purposes,
- Null subcarriers for no transmission at all, used or guard bands and DC carriers

WIMAX - OFDMA frame structure (II)

- A subset of subcarriers (distributed or adjacent), with permuted index, is grouped to form a *subchannel*.
- Subchannels permutation provide interference averaging benefits and diversity for aggressive frequency reuse systems.
- A transmitter is assigned one or more subchannels in DL direction (16 subchannels are supported in UL).

Pilot allocation depends on the subchannelization mode:

Downlink Fully Used Subchannelization (FUSC): pilot tones are allocated first, and remaining subcarriers are divided between subchannels (one set of common pilots).

- Downlink Partially Used Subchannelization (PUSC): all subcarriers (data and pilots) are partitioned in subchannels, then pilots are allocated (each subchannel has their own subset of pilots).
- Uplink subchannelization: same as DL PUSC.

WIMAX - OFDMA frame structure (III)

DL- FUSC: all the data subcarriers are used to create the various subchannels.

Index of the pilots belonging to the variable sets changes from one OFDM symbol to the next, whereas index of pilots belonging to the constant sets remains unchanged.

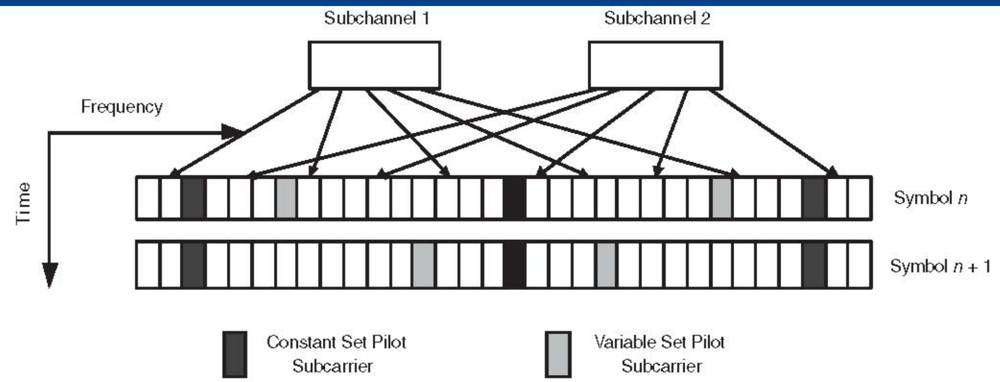


Figure 8.9 FUSC subcarrier permutation scheme

Table 8.5 Parameters of FUSC Subcarrier Permutation

	128	256[a]	512	1,024	2,048
Subcarriers per subchannel	48	N/A	48	48	48
Number of subchannels	2	N/A	8	16	32
Data subcarriers used	96	192	384	768	1,536
Pilot subcarrier in constant set	1	8	6	11	24
Pilot subcarriers in variable set	9	N/A	36	71	142
Left-guard subcarriers	11	28	43	87	173
Right-guard subcarriers	10	27	42	86	172

a. The 256 mode, based on 802.16-2004, does not use FUSC or PUSC but has been listed here for the sake of completeness.

WIMAX - OFDMA frame structure (IV)

DL PUSC: all the subcarriers are first divided into six groups.

Permutation of subcarriers to create subchannels is performed independently within each group.

All the subcarriers (except the null) are first arranged into clusters. In each cluster, the subcarriers are divided into 24 data and 4 pilot subcarriers.

Clusters are then renumbered using a pseudorandom numbering scheme. After that, clusters are divided into six groups. A subchannel is created using two clusters from the same group.

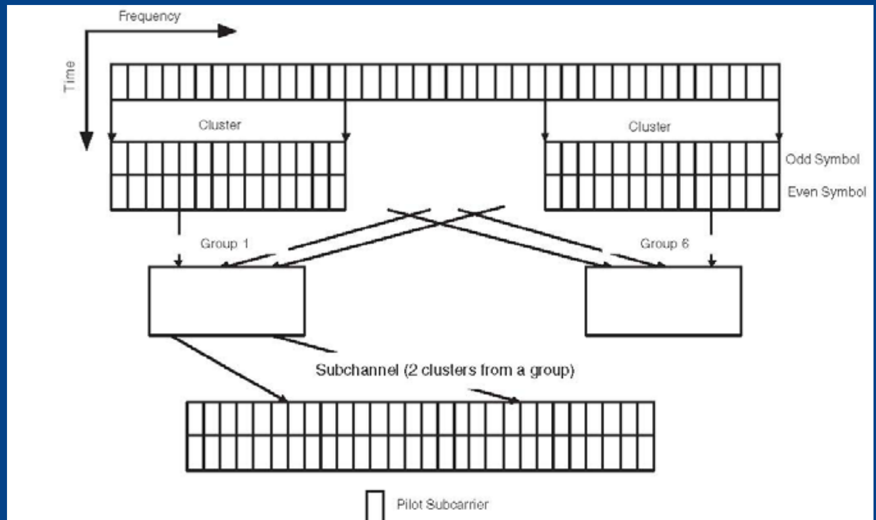


Figure 8.10 DL PUSC subcarrier permutation scheme

Table 8.6 Parameters of DL PUSC Subcarrier Permutation

	128	512	1,024	2,048
Subcarriers per cluster	14	14	14	14
Number of subchannels	3	15	30	60
Data subcarriers used	72	360	720	1,440
Pilot subcarriers	12	60	120	240
Left-guard subcarriers	22	46	92	184
Right-guard subcarriers	21	45	91	183

WIMAX - OFDMA frame structure (V)

UL-PUSC: the subcarriers are first divided into various tiles (tile = 4 subcarriers over 3 OFDM symbols).

The subcarriers within a tile are divided into 8 data subcarriers and 4 pilot subcarriers (tradeoff between higher data rate and more accurate channel tracking).

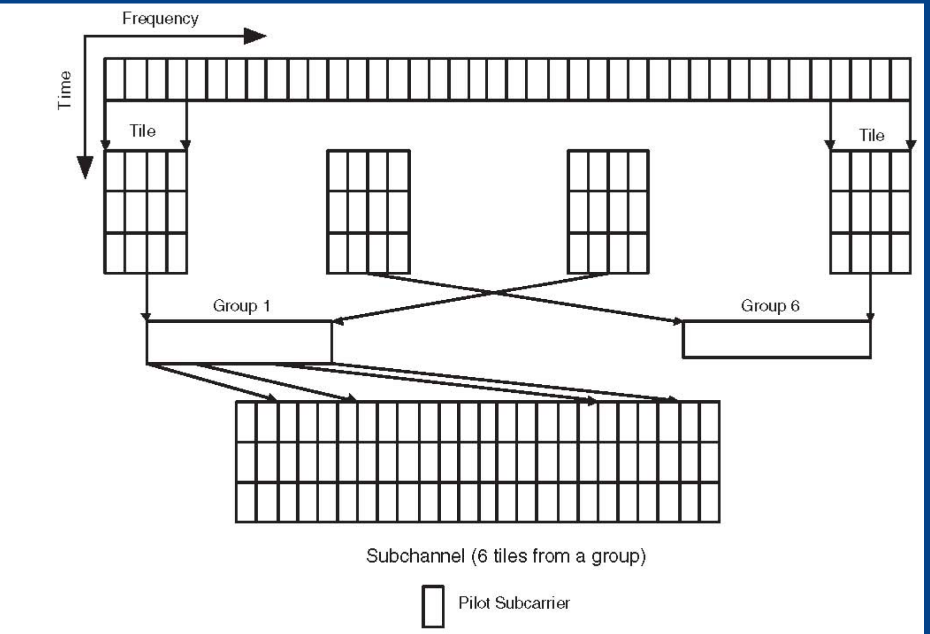


Figure 8.11 UL PUSC subcarrier permutation scheme

WIMAX - OFDMA frame structure (VI)

UL-AMC: 9 adjacent subcarriers (8 data and 1 pilot) are used to form a bin. 4 adjacent bins constitute a band.

An AMC subchannel consists of 6 contiguous bins from within the same band.

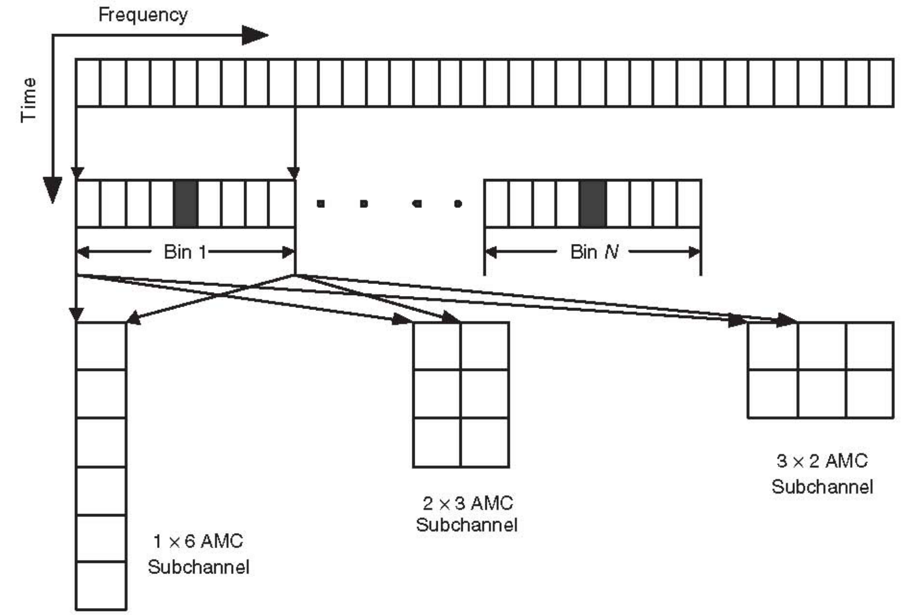


Figure 8.13 Band AMC subcarrier permutation

WIMAX - OFDMA frame structure (VII)

Slots and frame structure: The MAC layer allocates the time/frequency resources to various users in units of *slots*, which is the smallest quanta of PHY layer resource that can be allocated to a single user in the time/frequency domain.

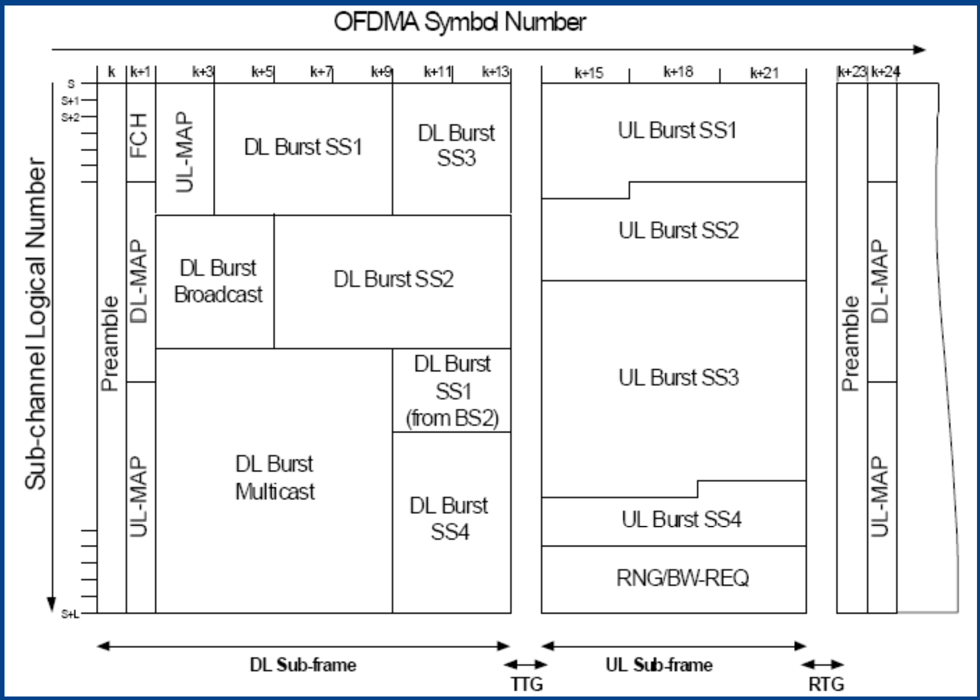
The size of a slot is dependent on the subcarrier permutation mode.

- FUSC: Each slot is 48 subcarriers by one OFDM symbol.
- Downlink PUSC: Each slot is 24 subcarriers by two OFDM symbols.
- Uplink PUSC: Each slot is 16 subcarriers by three OFDM symbols.
- Band AMC: Each slot is 8, 16, or 24 subcarriers by 6, 3, or 2 OFDM symbols.

WIMAX - OFDMA Frame structure (VIII)

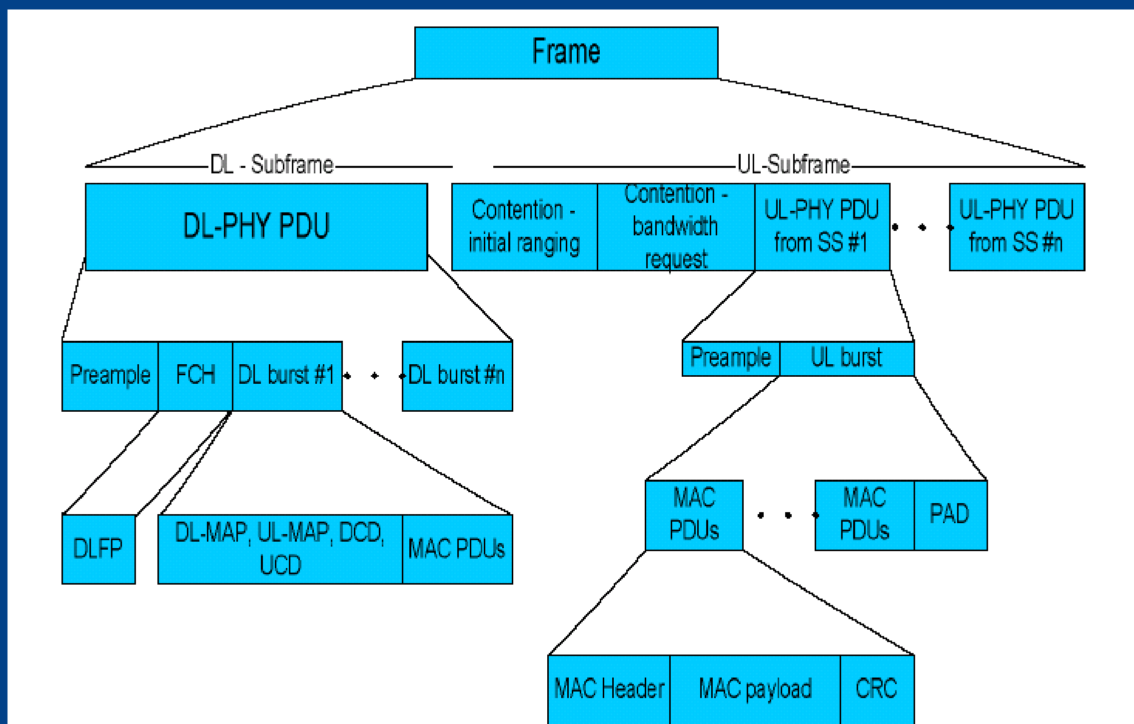
Each frame starts with a preamble followed by the Frame Control Header (FCH), DL-MAP and UL-MAP (these indicate the current frame structure).

BS periodically broadcasts Downlink Channel Descriptor (DCD) and Uplink Channel Descriptor (UCD) messages to indicate burst profiles (modulation and FEC schemes).



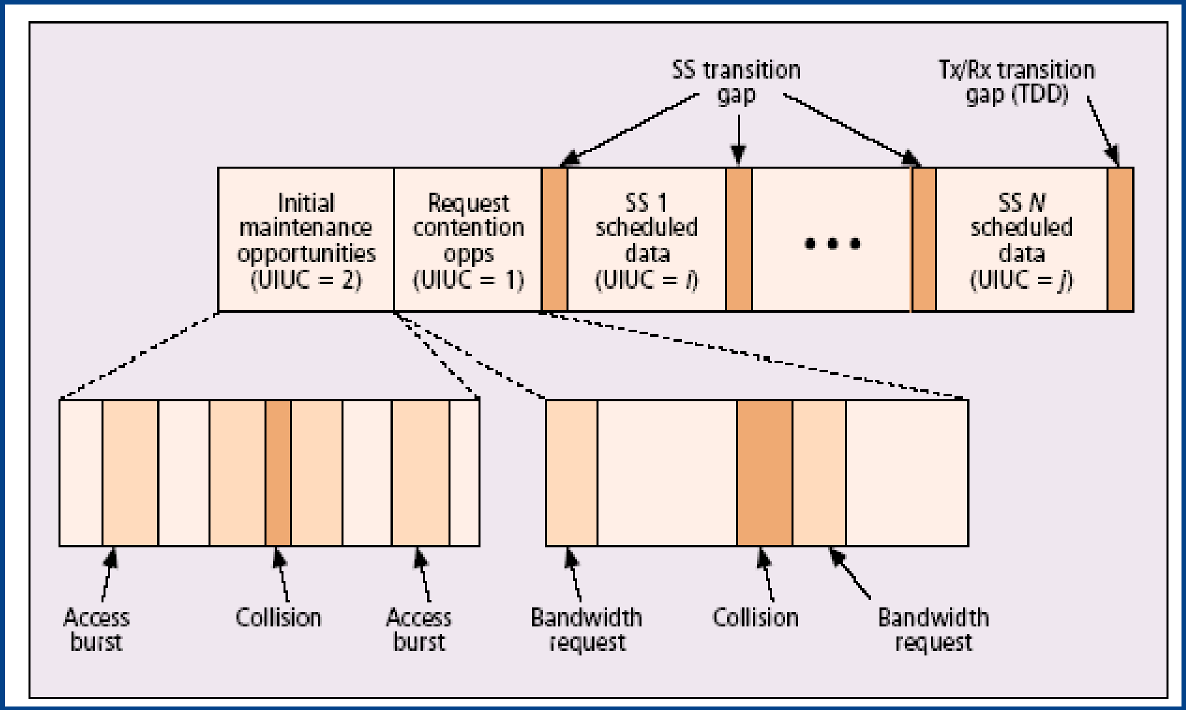
WIMAX - OFDMA Frame structure (IX)

General downlink subframe structure: Downlink Interval Usage Code (DIUC) indicates burst profile



WIMAX - OFDMA Frame structure (X)

General uplink subframe structure: Uplink Interval Usage Code (UIUC) indicates burst profile



WIMAX - OFDMA Frame structure (XI)

Ranging in OFDMA

- Ranging is an uplink procedure that maintains the quality and reliability of the radio-link communication between the BS and the MS.
- When it receives the ranging transmission from a MS, the BS estimate various radio-link parameters (such as CIR, SINR, and timing and frequency offsets) to indicate to the MS any adjustments in the transmit power level or the synchronization parameters.

WIMAX - OFDMA Frame structure (XII)

Ranging in OFDMA

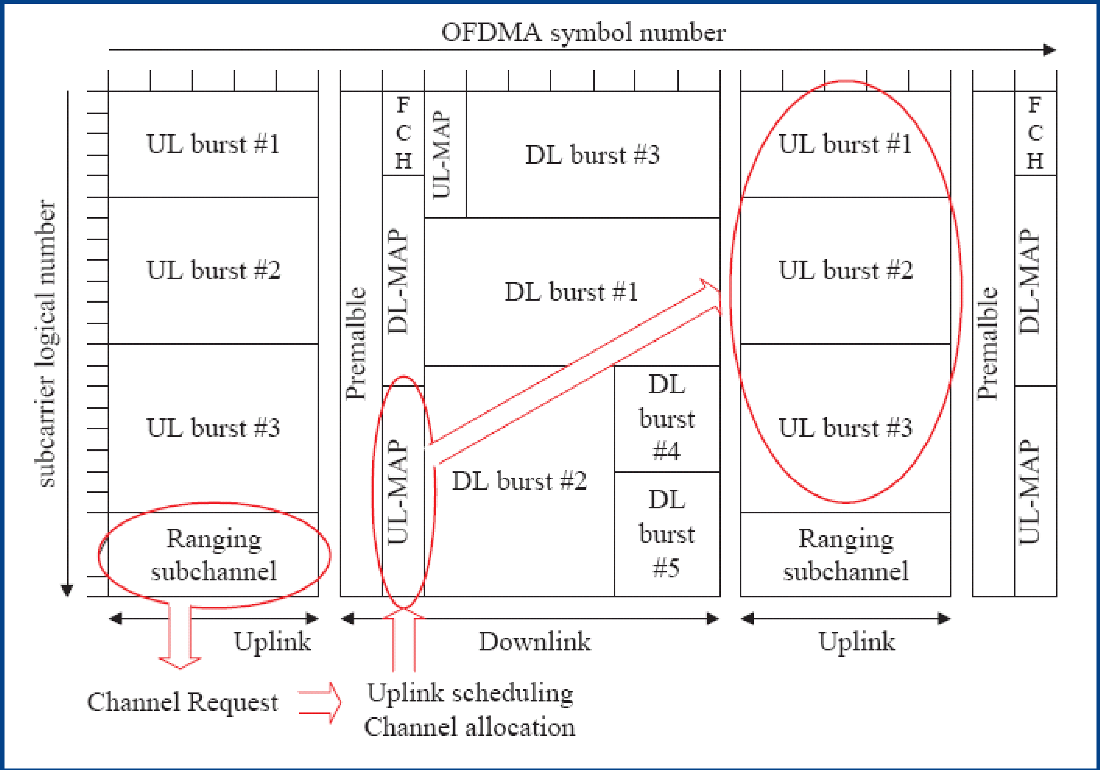
- 4 tasks: initial (synchronization), bandwidth request (allocate resources), handover and periodic ranging.
- CDMA scheme with (BPSK) 144 bit-long ranging codes, that are divided by the BS in 3 sets to identify initial, periodic or bandwidth requests.
- To process an Initial Ranging request, a ranging code is repeated twice and transmitted in 2 consecutive OFDM symbols (optionally 2 codes in 4 consecutive OFDM symbols)
- For Periodic Ranging and Bandwidth Request the options are either 1 or 3 consecutive codes during 1 or 3 OFDM symbols.

Dto. de Ingeniería Eléctrica y de Computadoras
Universidad Nacional del Sur

DIEC

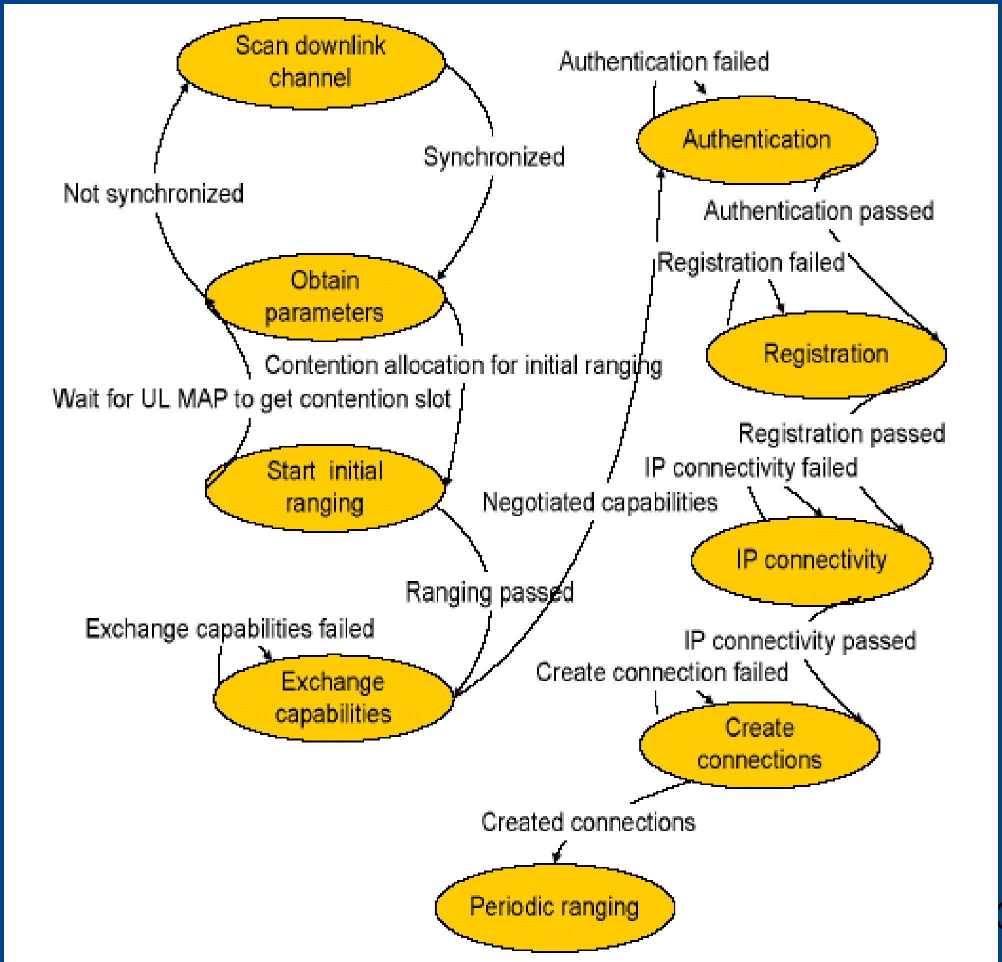
WIMAX - OFDMA Frame structure (XIII)

Basic PHY access process



WIMAX - OFDMA Frame structure (XIV)

Network entry process



Dto. de Ingeniería Eléctrica y de Computadoras
Universidad Nacional del Sur

DIEC

Conclusions

- Scalability is one major design concept in WIMAX – OFDMA
- Subcarrier permutation strategies aim to provide frequency selectivity that is not part of basic OFDM concept.
- WIMAX physical layer is characterized by different degrees of freedom in terms of frame size and functions.
- Among the important functions defined by WIMAX PHY there are initial ranging and bandwidth request.