

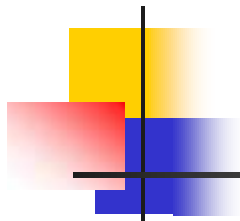


Survey of WiMAX, LTE and UMB

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Outline

- Power control in WiMAX
- Power control in LTE
- Power Control in UMB
- Comparison of the three technologies



WiMAX power control

- Closed loop power control in the standard for OFDMA-phy
- Open Loop power control in the standard for OFDMA-phy

Closed-loop Power Control

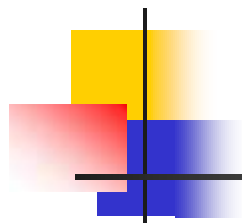
CL Power Control 8.4.10.3.1

- 8.4.10.3.1 Closed loop power control
- For the periodic ranging, once MS sends periodic ranging code and fails to receive RNG-RSP, MS may adjust its Tx power for the subsequent periodic ranging codes transmission up to `PTX_IR_MAX` (6.3.9.5.1).
- For the bandwidth request ranging, once MS sends bandwidth request ranging code and fails to receive CDMA allocation IE or RNG-RSP, MS may adjust its Tx power for the subsequent bandwidth request ranging codes transmission up to `PTX_IR_MAX` (6.3.9.5.1).



PTX_IR_MAX

- See equations 10-11 in page 175 of 802.16 2004 for definition of PTX_IR_MAX.
- $P_{TX_IR_MAX} = EIRXP_{IR,max} + BS_EIRP - RSS$



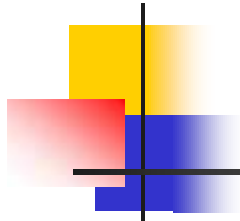
RNG-RSP message contents

- Power adjustment
- Frequency adjustment
- CID
- Ranging code attributes
 - Symbol time reference
 - Sync channel reference
 - Frame number to send the ranging code
 - Ranging code index
- Etc.

Initial ranging, periodic ranging



- BS processes the received ranging codes to estimate CIR, SINR, time of arrival which allows the BS to indicate to MS to adjust timing offset or transmit power level.
- Initial and periodic ranging allow the BS and MS to perform timing and power synchronization.



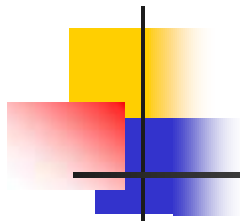
Ranging Codes

- Ranging Codes:
 - PN sequence of length 144 bits chosen from a set of 256 codes.
 - Initial ranging: first N codes
 - Periodic ranging: next M codes
 - BW request: next O codes
 - HO ranging: last S codes
 - Indicated by the UL-MAP message



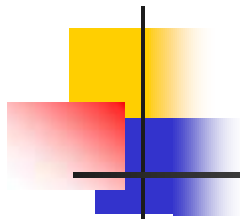
Initial Ranging procedure

- Ranging channel comprises of six sub channels and up to 5 consecutive symbols, the indices of which in the time and frequency domain are indicated by FCH (Frame Control Header). The ranging channel may not be allocated in all uplink sub-frames.
- SS selects one of N codes randomly and transmits over the allocated sub-channels. Collision may occur.
- The ranging code is transmitted over two [or optionally 4 –two ranging codes] OFDMA symbols period.
- PN sequence is BPSK modulated and transmitted over the sub-channels and OFDM symbols allocated for the ranging channel.



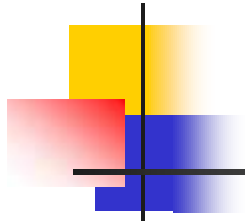
Periodic ranging

- SS is already synchronized to the BS.
- Modulate one ranging code on the ranging sub channel over one OFDMA symbol period
- Modulate three consecutive ranging codes on the ranging sub channel over three OFDMA symbols periods. [one code per symbol period]

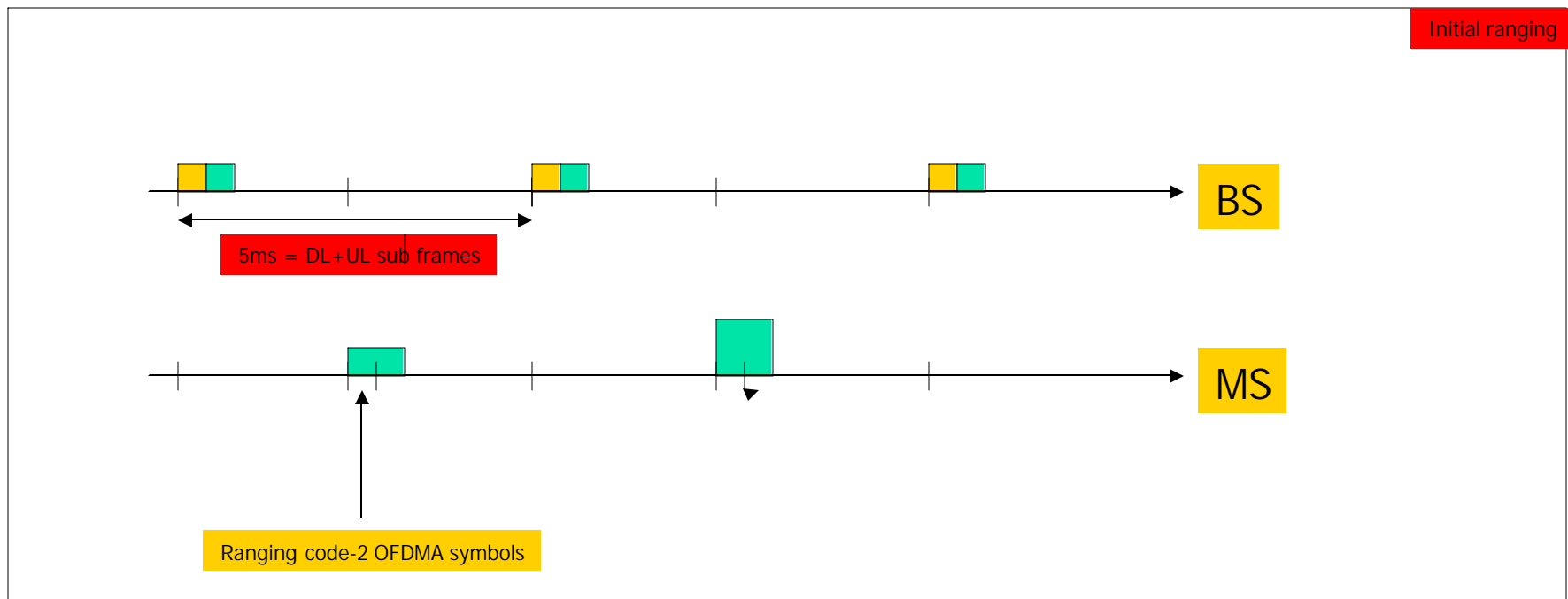


Ranging Channel

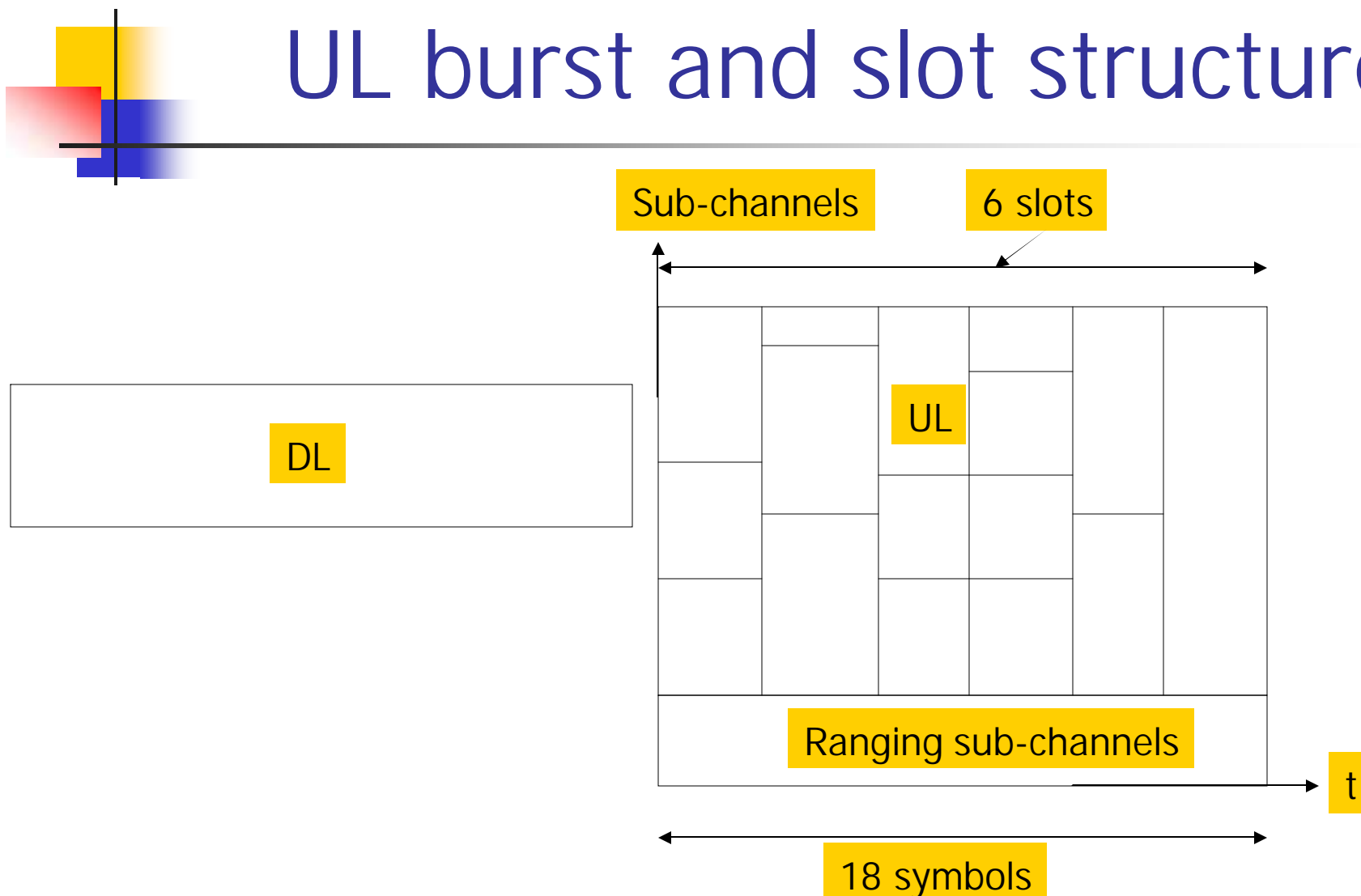
- Ranging channel comprises of one or more groups of six adjacent sub-channels and up to 5 consecutive symbols, the indices of which in the time and frequency domain are indicated by FCH (Frame Control Header). The ranging channel may not be allocated in all uplink sub-frames.
- SS selects one of N codes randomly and transmits over the allocated sub-channels. Collision may occur.
- The ranging code is transmitted over two [or optionally 4 –two ranging codes] OFDMA symbols period.
- PN sequence is BPSK modulated and transmitted over the sub-channels and OFDM symbols allocated for the ranging channel.



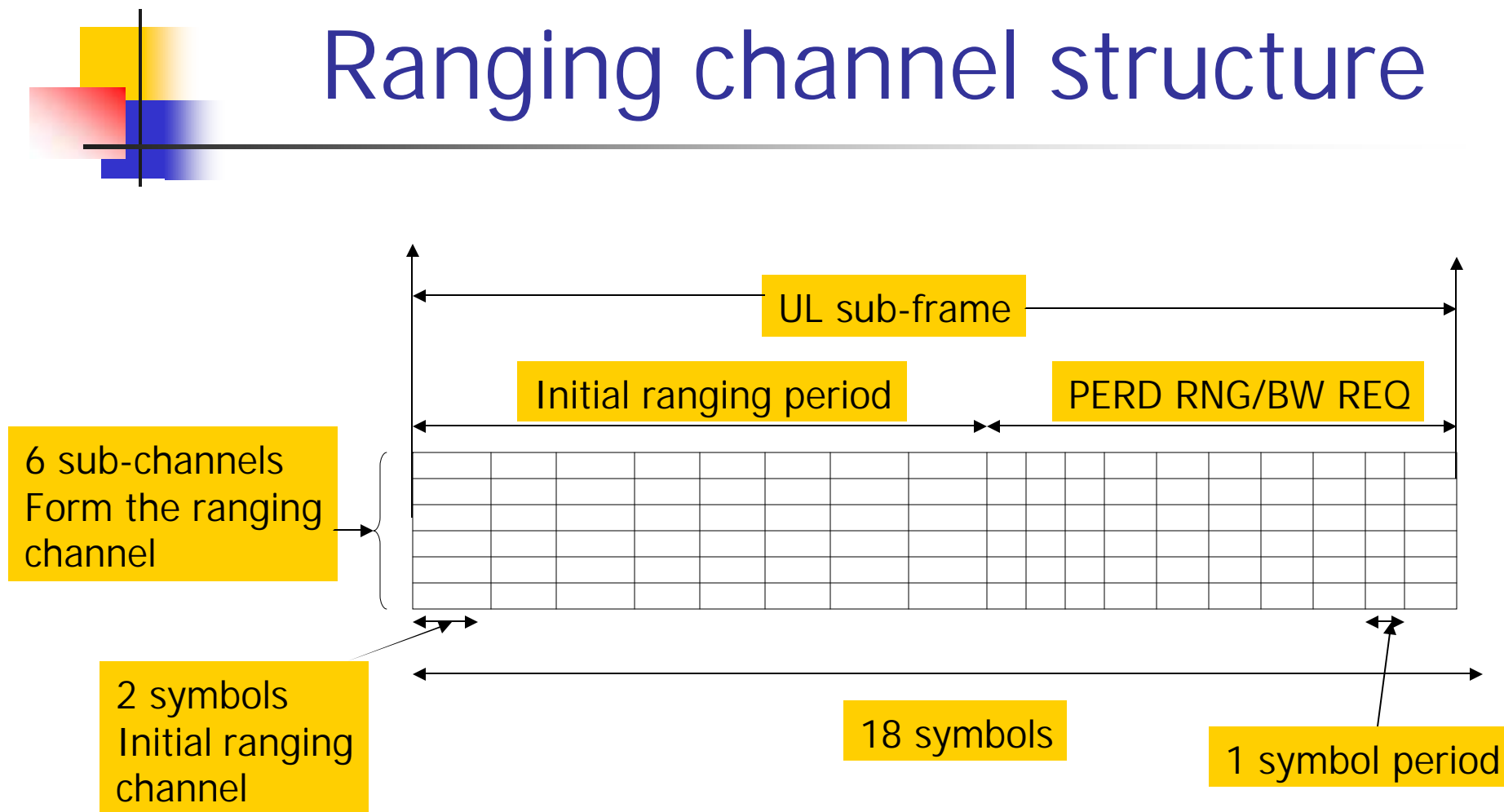
Initial ranging



UL burst and slot structure



Ranging channel structure



Analysis: 1 symbols duration versus 2 symbol duration



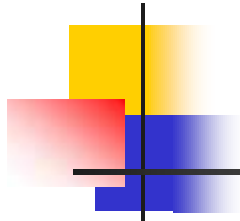
RNG-RSP processing time

- RNG-RSP processing time : Time allowed for an SS following receipt of a RNG-RSP before it is expected to apply the corrections instructed by the BS
 - Minimum value: 2.5 ms from the start of the frame
 - (n+1) where frame n is the frame containing the RNG_RSP. If there is an UL allocation to the SS before the 2.5 ms in frame n+1 then the power change shall be applied before the end of the frame n+1.



Ranging response timeout

- T3 Ranging Response reception timeout following the transmission of a Ranging Request.
 - Default: 50 ms
 - Maximum: 200 ms



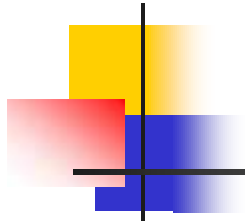
Uplink Interval Usage Code

- Initial maintenance opportunities:
 - $UIUC = 2$
 - Related to initial and periodic ranging
 - Collision occurs in this interval
- Request opportunities:
 - $UIUC = 1$
 - SS requests bandwidth in response to polling from BS
 - Contention mode: Collision may occur in this period
- Data grant period:
 - $UIUC = i-j$
 - SS transmits data bursts in this period
 - Transition gaps between data interval for synchronization purposes.

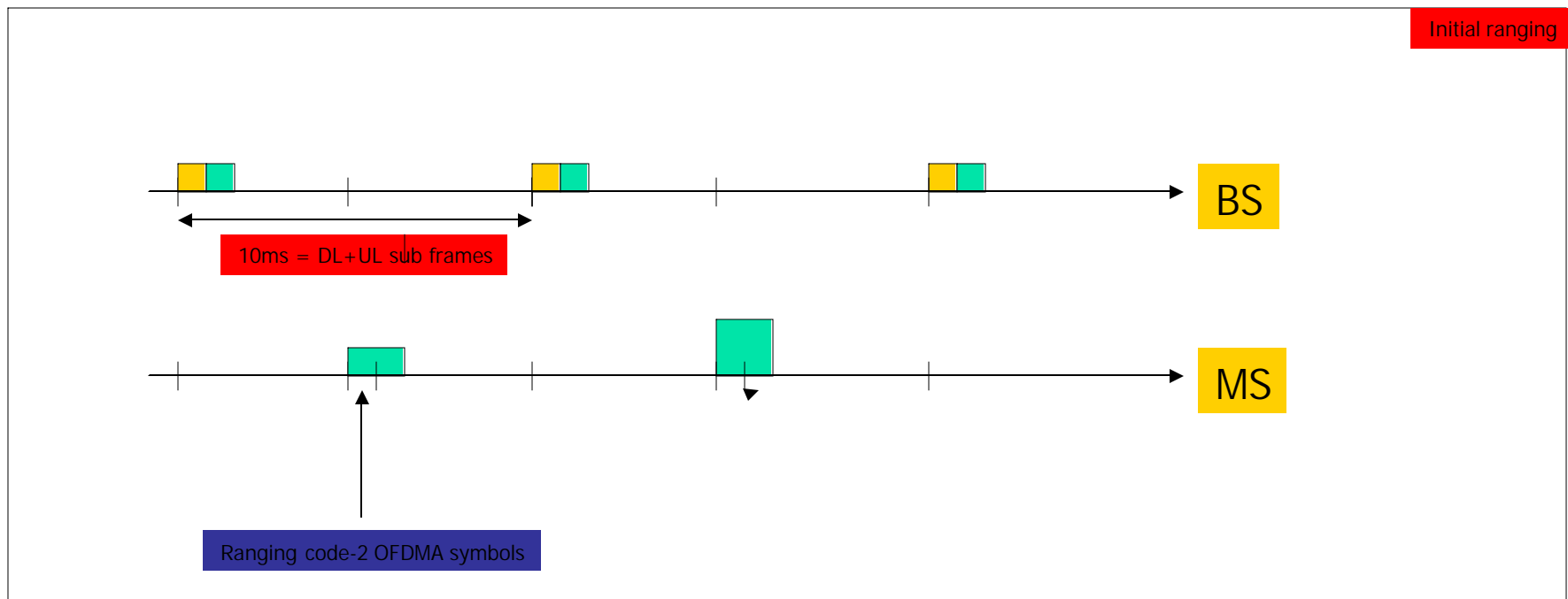


IEs in Uplink Interval

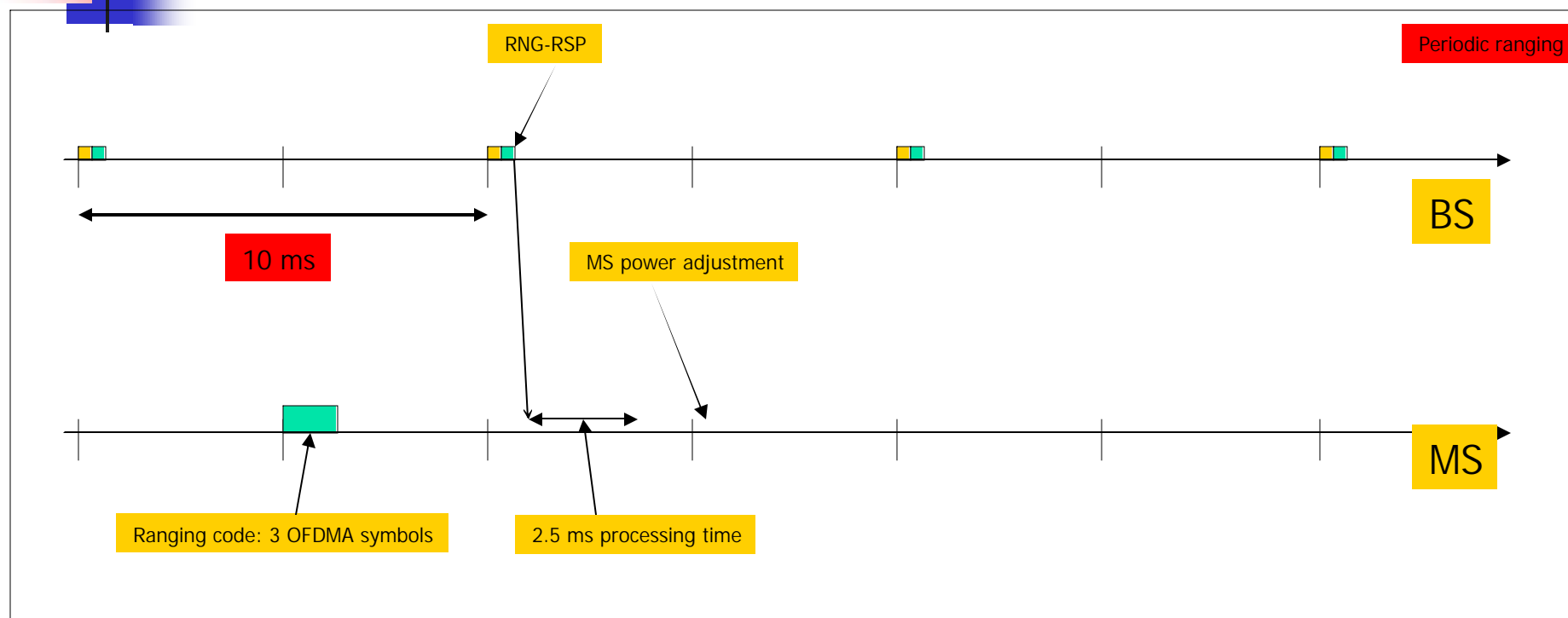
- Initial ranging IE
 - BS specifies an interval in which new stations may join the network.
- Bandwidth request IE
 - BS specifies an uplink interval in which requests may be made for bandwidth.
 - Broadcast: Invitation for all to contend
 - Uni-cast: particular SS is allowed to request for bandwidth.
- Data Grant Burst Type IE
 - The BS provides an opportunity for an SS to transmit one or more uplink PDUs.
- End of map IE
 - End of allocations in the IE list
- Gap IE
 - Indicates pauses in uplink transition

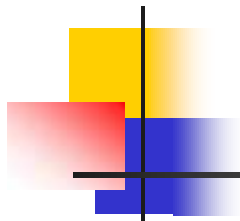


Initial ranging



Closed loop power control based on periodic ranging





Uplink sub channel formation UL-PUSC (Uplink Partial Usage of Subcarriers)

- Subcarriers are first divided in tiles.
- Each tile has four subcarriers over three OFDM symbols.
- Subcarriers are divided into 8 data and 4 pilot subcarriers.
- Tiles are re-numbered randomly and divided into six groups.
- Subchannel is formed by taking 6 tiles from the same group.

Open Loop Power control in WiMAX

- 8.4.10.3.2 Optional open loop power control
- When the open loop power control is supported and the uplink power control mode is changed to open loop power control by PMC_RSP, the power per a subcarrier shall be maintained for the UL transmission as follows.
- This open loop power control shall be applied for the all uplink bursts.
- $P(\text{dBm}) = L + C/N + NI - 10\log_{10}(R) + \text{Offset_SSperSS} + \text{Offset_BSperSS}$ (138a)
 - where
 - P is the TX Power level (dBm) per a subcarrier for the current transmission, including MS Tx antenna gain.
 - L is the estimated average current UL propagation loss. It shall include SS Tx antenna gain and path loss, but exclude the BS Rx antenna gain.
 - C/N is the normalized C/N of the modulation/FEC rate for the current transmission, as appearing in Table 334. Table 334 can be modified by UCD (Normalized C/N override).
 - R is the number of repetitions for the modulation/FEC rate.
 - NI is the estimated average power level (dBm) of the noise and interference per a subcarrier at BS, not including BS Rx antenna gain.
 - Offset_SSperSS is the correction term for SS-specific power offset. It is controlled by SS. Its initial value is zero.
 - Offset_BSperSS is the correction term for SS-specific power offset. It is controlled by BS with power control messages. When Offset_BSperSS is set through the PMC_RSP message, it shall include BS Rx antenna gain.

Open Loop Power control in WiMAX



- The estimated average current UL propagation loss, L , shall be calculated based on the total power received on the active subcarriers of the frame preamble, and with reference to the BS_EIRP parameter sent by the BS.
- The default normalized C/N values per modulation are given by Table 334. The operating parameters BS_EIRP and NI are signaled by a DCD message (see Table 358).
- Additionally, the BS controls the Offset_BSperSS using PMC_RSP message (6.3.2.3.58) to override the Offset_BSperSS value, or using RNG-RSP (6.3.2.3.6), **Fast Power Control (FPC) message (6.3.2.3.34)**, Power Control IE (8.4.5.4.5) and UL-MAP_Fast_Tracking_IE (8.4.5.4.22) to adjust the Offset_BSperSS value.
- The accumulated power control value shall be used for Offset_BSperSS.
- The Offset_BSperSS can be updated using relative or fixed form (as a function of the relevant adjustment commands used). Fixed form is used when the parameter is obtained from a PMC_RSP message. In this case, the SS should replace the old Offset_BSperSS value by the new Offset_BSperSS sent by the BS. With all other messages mentioned in the previous paragraph, relative form is used. In this case, MS should increase and decrease the Offset_BSperSS according to the offset value sent by BS.
- The actual power setting shall be quantized to the nearest implementable value, subject to the specification (8.4.12.1). For each transmission, the SS shall limit the power, as required to satisfy the spectral masks and EVM requirements.



UL-MAP Fast Tracking IE

- The UL Fast tracking IE is an optional field in the UL-MAP. When this IE is sent, it provides an indication about corrections that should be applied by MS's that have transmitted in the previous UL frame.
- Each indication byte shall correspond to one unicast allocation-IE that has indicated an UL burst allocation in the previous UL-MAP.
- The order of the indication bytes shall be the same as the order of the unicast allocation-IE in the UL-MAP.
- The response time for corrections following receipt of this IE shall be equal to "Ranging Response Processing Time" as defined in 10.1.

Table 253b – UL-MAP fast Tracking IE

- Power correction 2 bits Power correction indication:
 - 0b00: no change;
 - 0b01: +2 dB;
 - 0b10: –1 dB;
 - 0b11: –2 dB;
- Frequency correction 4 bits The correction is 0.1% of the carrier spacing multiplied
 - by the 4-bit number interpreted as a signed integer (i.e., 0b1000: –8; ... 0b0000: 0; ... 0b0111: 7)
- Time correction 2 bits The correction is $\text{floor}(2 / F_s)$ multiplied by:
 - 0b00: 0; 0b01: 1; 0b10: –1; 0b11: Not used



UL-MAP fast Tracking response processing time

- Fast-Tracking Response Processing Time:
 - Time allowed for an MS following receipt of a UL-MAP Fast tracking indication response before it is expected to apply the corrections instructed by the BS.
 - Default value: one DL sub-frame duration
 - Maximum value: 25 ms

8.4.5.4.5 Power Control IE format

- Power control 8 bits Signed integer, which expresses the change in power level (in 0.25 dB units) that the SS should apply to correct its current transmission power.
- Power measurement frame 8 bits: The 8 LSB of the frame number in which the BS measured the power corrections referred to in the message.



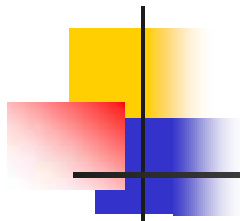
Power control IE processing time

- Power control IE processing time: Time allowed for an SS following receipt of a UL-MAP including a power control IE before it is expected to apply the corrections instructed by the BS.
 - 2.5 ms from the start of the frame (n+1) where frame n is the frame containing the UL map containing the power control IE. If there is an UL allocation to the SS before the 2.5 ms in frame n+1 then the power change shall be applied before the end of the frame n+1.



FPC (6.3.2.3.34) 802.16e

- 6.3.2.3.34 Fast Power Control (FPC) message
- Change first paragraph as indicated:
- Power control shall be effected by the use of periodic ranging. In addition, the BS may adjust the power levels of multiple subscribers simultaneously with the Fast Power Control (FPC) message. Ss shall apply the indicated change within the "SS downlink management message FPC processing time".
- If the SS cannot apply the commanded power correction (SS is already at maximum or minimum power) the SS shall send a RNG-REQ message with "Ranging Anomalies" parameter.
- FPC shall be sent on the broadcast CID.
- **Implementation of FPC message at BS is optional.**



FPC

- Broadcast message
- Number of Stations: Multiple SS
- CID field: basic connection identifier associated with an SS.
- Power adjust field: [multiples of .25 dB]
- FPC processing time in SS : Max. time between reception of Fast Power Control management message and compliance to its instructions by SS.
 - 2.5 ms from the start of the frame (n+1) were frame n is the frame containing the FPC. If there is an UL allocation to the SS before the 2.5 ms in frame n+1 then the power change shall be applied before the end of the frame n+1.

Passive Uplink open loop power control (8.4.10.3.2)



- Passive Uplink open loop power control:
 - In passive Uplink open loop power control the SS will set `Offset_SSperSS` to zero and modify the TX power value using Equation (138a).

Active Uplink open loop power control (8.4.10.3.2)

- An alternative way is that the SS may adjust Offset_SSperSS value within a range.
- $\text{Offset_Boundlower} \leq \text{Offset_SSperSS} \leq \text{Offset_Boundupper}$ (138b) where
 - Offset_Boundupper is the upper bound of Offset_SSperSS
 - Offset_Boundlower is the lower bound of Offset_SSperSS
- Or in case ARQ is enabled at some UL connections, the Offset_SSperSS may be updated automatically based on the Ack/Nack within the range as specified by Equation (138c). The specific algorithm is described as follows (in dB):
 - if NAK is received $\text{Offset_SSperSS} = \text{Offset_SSperSS} + \text{UP_STEP}$
 - else if ACK is received $\text{Offset_SSperSS} = \text{Offset_SSperSS} - \text{DOWN_STEP}$ (138c)
 - else where $\text{Offset_SSperSS} = \text{Offset_SSperSS}$
 - where
 - UP_STEP is the up adjustment step as specified by "SS-specific up power offset adjustment step" TLV
 - DOWN_STEP is the down adjustment step as specified by "SS-specific down power offset adjustment step" TLV.
 - The operating parameters UP_STEP , DOWN_STEP , Offset_Boundupper , Offset_Boundlower are signaled by a dedicated UCD message TLV.

8.4.10.3.2.1 UL Tx power and Headroom transmission condition

- SS may report its transmission power status using Bandwidth request and UL Tx Power Report header (6.3.2.1.2.1.2), PHY channel report header (6.3.2.1.2.1.5) or UL Tx Power Report extended subheader (6.3.2.2.7.5).
- Further, when the following conditions are met, SS may send its transmission power status using Bandwidth request and UL Tx Power Report header (6.3.2.1.2.1.2), PHY channel report header (6.3.2.1.2.1.5) or UL Tx Power Report extended subheader (6.3.2.2.7.5).
- $M_{avg}(n_{last}) - M_{avg}(n) \geq Tx_Power_Report_Threshold$ (dB) or
- $n - n_{last} \geq Tx_Power_Report_Interval$ (138d)
- where
- $M(n) = L + NI + Offset_SSperSS + Offset_BSperSS$ (dB)
- $M_{avg}(n) = 10 \log(p_avg \cdot 10^{M(n)/10} + (1 - p_avg) 10^{(M_{avg}(n-1))/10})$
- n_{last} is the time index when the last SS Tx Power Report is sent. The unit is frame.
- $Tx_Power_Report_Threshold$, $Tx_Power_Report_Interval$, and p_avg are indicated in UCD. In UCD, there are sets of those parameters sets: Depending on the allocation CQICH to SS, the corresponding parameter set shall be used.



6.3.2.1.2.1.2 Bandwidth request and UL Tx Power Report header

- The Bandwidth Request and UL Tx Power Report PDU shall consist of bandwidth request and UL Tx Power Report header alone and shall not contain a payload. The bandwidth request and UL Tx Power Report header is illustrated in Figure 20a.
- The Bandwidth request and UL Tx Power Report header shall have the following properties:
 - a) This is a MAC signaling header type I.
 - b) The CID shall indicate the connection for which uplink bandwidth is requested.
- BR 11bits Bandwidth Request: The number of bytes of uplink bandwidth requested by the MS. The bandwidth request is for the CID. The request shall not include any PHY overhead. It is incremental BW request. In case of the Extended rtPS, if the MSB is 1, the BS changes its polling size into the size specified in the LSBs of the this field.
- UL Tx power 8 bits UL: Tx power level in dBm for the burst that carries this header (as described in 11.1.1).
- The value shall be estimated and reported for the burst.
- CID 16 bits The CID shall indicate the connection for which uplink bandwidth is requested.
- HCS 8 bits Header Check Sequence (same usage as HCS entry in Table 5).

6.3.2.1.2.1.5 PHY channel report header



- The fields of the PHY channel report header are defined in Table 7d.
- Table 7d—PHY channel report header fields
- **UL-TX-POWER 8 bits:** UL Tx power level in dBm for the burst that carries this header (11.1.1). The value shall be estimated and reported for the burst.
- **UL-HEADROOM 6 bits :** Headroom to UL maximum power level in dB, for the burst that carries this Header, from 0 to 63 in 1 dB steps. Should the headroom exceed 63 dB, the value 63 shall be used. The minimum value is shall be reported for the burst.

Open Loop Power Control

1. SS changes the value of Offset_SSperSS based on the ACK/NAK reception.

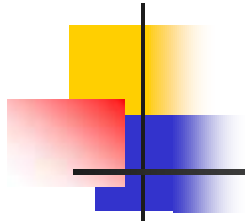
1. Additionally, the BS controls the Offset_BSperSS using PMC_RSP message to override the Offset_BSperSS value, or using:

- RNG-RSP,
- Fast Power Control (FPC) message,
- Power Control IE and
- UL-MAP_Fast_Tracking_IE

to adjust the Offset_BSperSS value.

1. Calculate the transmit power using equation 138A
2. Report the transmit power and power headroom Using BW Request and Phy channel report header.

MS

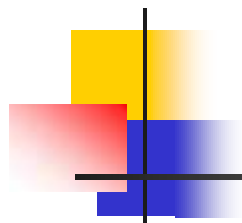


Outline

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- Comparison

Power Control in LTE

36.213



- Power control determines the energy per resource element (EPRE). The term resource element energy denotes the energy prior to CP insertion. The term resource element energy also denotes the average energy taken over all constellation points for the modulation scheme.



LTE Uplink power control

- Uplink power control consists of open and closed loop components and controls energy per resource element applied for a UE transmission. For intra-cell uplink power control the closed loop component adjusts a set point determined by the open loop power control component.
- Upon reception of an a-periodic transmit power command in an uplink scheduling grant the UE shall adjust its transmit EPRE accordingly. EPRE is set in the UE. A cell wide overload indicator (OI) is exchanged over X2 for inter-cell power control.

UE behaviour

physical shared channel:

Physical uplink shared channel

- The setting of the UE Transmit power for the physical uplink shared channel (PUSCH) transmissions is defined by

$$P_{pusch} = \min(P_{max}, 10\log_{10}(M) + P_o + \alpha \cdot PL + \Delta_{mcs} + f(\Delta_i))$$

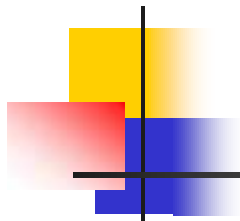
- Where,
- P_{max} is the maximum allowed power that depends on the UE power class
- M is the number of assigned resource blocks as indicated in the UL scheduling grant
- P_o is a UE specific parameter with 1 dB resolution
- α is cell specific path loss compensation factor (can be set to one to allow full path loss compensation) that has 8 values from 0.4 to 1 in steps of 0.1 with one of the possible values being zero.
- PL is the downlink pathloss calculated in the UE from a RSRP measurement and signalled RS transmit power
- Δ_{mcs} is signaled by RRC (Δ_{mcs} table entries can be set to zero). MCS is signaled in each UL scheduling grant
- Δ_i is a UE specific correction value and is defined differently dependent on scheduling as given by:
 - Scheduled
 - Δ_i is included in each UL scheduling grant
 - Function $f(*)$ signaled via higher layers
 - $F(*)$ represents either accumulation or current absolute value
 - Not scheduled
 - Δ_i is included in each DL scheduling assignment or jointly coded with other UE specific correction values on a TPC PDCCH
 - The UE attempts to detect a TPC PDCCH and a DL scheduling frame on every subframe except when in DRX.
 - The Δ_i from a DL scheduling assignment overrides any command from a TPC PDCCH when both are received in a given subframe
 - .Function $f(*)$ represents accumulation only

Physical uplink control channel UE behaviour

- The setting of the UE Transmit power for the physical uplink control channel (PUCCH) transmissions is defined by

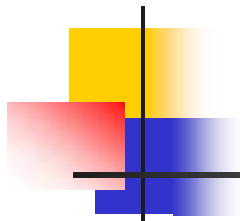
$$P_{pucch} = \min(P_{\max}, 10\log_{10}(M_{pucch}) + P_{o-pucch} + PL + \Delta_{mcs-pucch} + g(\Delta_j))$$

- where M_{pucch} is the number of assigned resource blocks for the PUCCH
- $\Delta_{mcs-pucch}$ is signaled by RRC ($\Delta_{mcs-pucch}$ table entries can be set to zero)
 - MCS is signaled using higher layer signaling
- $P_{o-pucch}$ is a UE specific parameter with 1 dB resolution
- j is a UE specific correction value, also referred to as a TPC command, included in a DL scheduling assignment or sent jointly coded with other UE specific correction values on a TPC PDCCH.
 - The UE attempts to detect a **TPC PDCCH** and a DL scheduling frame on every subframe except when in DRX.
 - The TPC command from a DL scheduling assignment overrides any command from a TPC PDCCH when both are received in a given subframe.
 - Function $g(^*)$ represents accumulation



Parameter definitions

- P0 controls the mean received SINR
 - separate for data and control
- Alpha controls the received SINR variance ('fairness')
 - separate for data and control
- Delta (i) is the slow or fast closed loop power control element which compensates the following:
 - Power amplifier error
 - Path loss estimation error
 - Interference level change from other cells: inter-cell interference level change
- Fast fading is not compensated by delta_i.

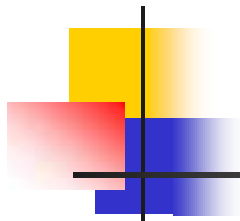


Why delta mcs?

- Helps with changing the coding and modulation level of scheduled uplink transmissions.
 - Table entries could be set to zero in which case delta mcs is signaled via RRC signaling. [UL grants]
 - Or the non-zero table entries could be broadcast via eNB.

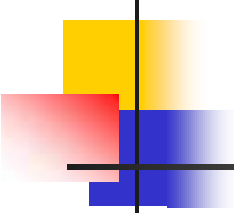
Overload indication

Ericsson: R1-073038



- “Cell wide overload indicator (OI) exchanged over X2 on a slow basis
 - according to RAN3 LS [R1-071804 (R3-070702)], expected average delay is in the order of 20ms
 - FFS: Number of bits in the OI
- Neighboring eNB can control individual UEs served by that eNB through it’s scheduler based on OI and available knowledge (e.g. pathloss obtained from normal handover measurements)”

LTE DL sub frame-slot structure



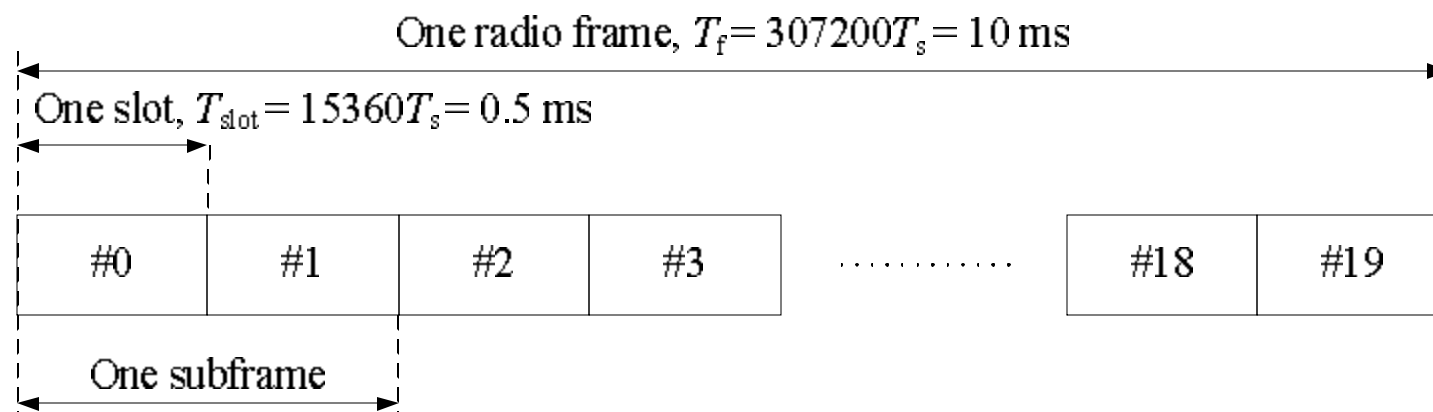
- 12 x 15 kHz sub carriers = 180 KHz
- 7 OFDMA symbols constitute one slot = .5 ms
- Two time slots form a sub-frame [1 ms]
- 10 sub-frames form a Frame.
- 1 resource block = 7 symbols x 12 sub carriers = 84 resource elements



4.1 Frame structure type 1

- Frame structure type 1 is applicable to both full duplex and half duplex FDD and to TDD. Each radio frame is long and consists of 20 slots of length , numbered from 0 to 19. A sub frame is defined as two consecutive slots where sub frame i consists of slots i and $i+1$.
- For TDD, a subframe is either allocated to downlink or uplink transmission. Subframe 0 and subframe 5 are always allocated for downlink transmission.

Figure 4.1-1: Frame structure type 1.

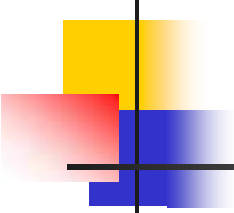


Physical channels and physical signals

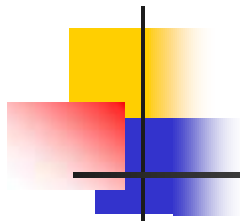


- Physical channels
 - An uplink physical channel corresponds to a set of resource elements carrying information originating from higher layers and is the interface defined between 36.212 and 36.211. The following uplink physical channels are defined:
 - - Physical Uplink Shared Channel, PUSCH
 - - Physical Uplink Control Channel, PUCCH
 - - Physical Random Access Channel, PRACH
- Physical signals (Skip)
 - An uplink physical signal is used by the physical layer but does not carry information originating from higher layers. The following uplink physical signals are defined:

Slot structure and physical resources: Resource grid

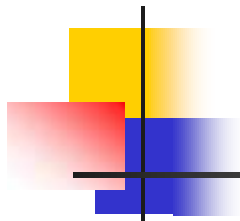


- The transmitted signal in each slot is described by a resource grid of $N_{RB}^{UL} N_{sc}^{RB}$ subcarriers and SC-FDMA symbols. The resource grid is illustrated in the next slide. The quantity N_{RB}^{UL} depends on the uplink transmission bandwidth configured in the cell and shall fulfil $6 \leq N_{RB}^{UL} \leq 110$
- The set of allowed values for N_{RB}^{UL} is given by [6].
- The number of SC-FDMA symbols in a slot depends on the cyclic prefix length configured by higher layers and is given in Table 5.2.3-1.



Resource elements

- Each element in the resource grid is called a resource element and is uniquely defined by the index pair (k, l) in a slot where $k = 0, \dots, N_{\text{RB}}^{\text{UL}} N_{\text{sc}}^{\text{RB}} - 1$ and $l = 0, \dots, N_{\text{ymb}}^{\text{UL}} - 1$ are the indices in the frequency and time domain, respectively. Resource element (k, l) corresponds to the complex value $a_{k, l}$.
- Quantities $a_{k, l}$ corresponding to resource elements not used for transmission of a physical channel or a physical signal in a slot shall be set to zero.



Resource blocks

- A resource block is defined as $N_{\text{symp}}^{\text{UL}}$ consecutive SC-FDMA symbols in the time domain and $N_{\text{sc}}^{\text{RB}}$ consecutive subcarriers in the frequency domain, where $N_{\text{symp}}^{\text{UL}}$ and $N_{\text{sc}}^{\text{RB}}$ are given by Table 5.2.3-1. A resource block in the uplink thus consists of $N_{\text{symp}}^{\text{UL}} \times N_{\text{sc}}^{\text{RB}}$ resource elements, corresponding to one slot in the time domain and 180 kHz in the frequency domain.

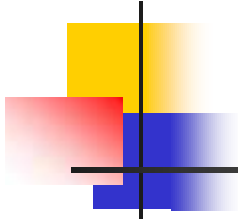


Table 5.2.3-1

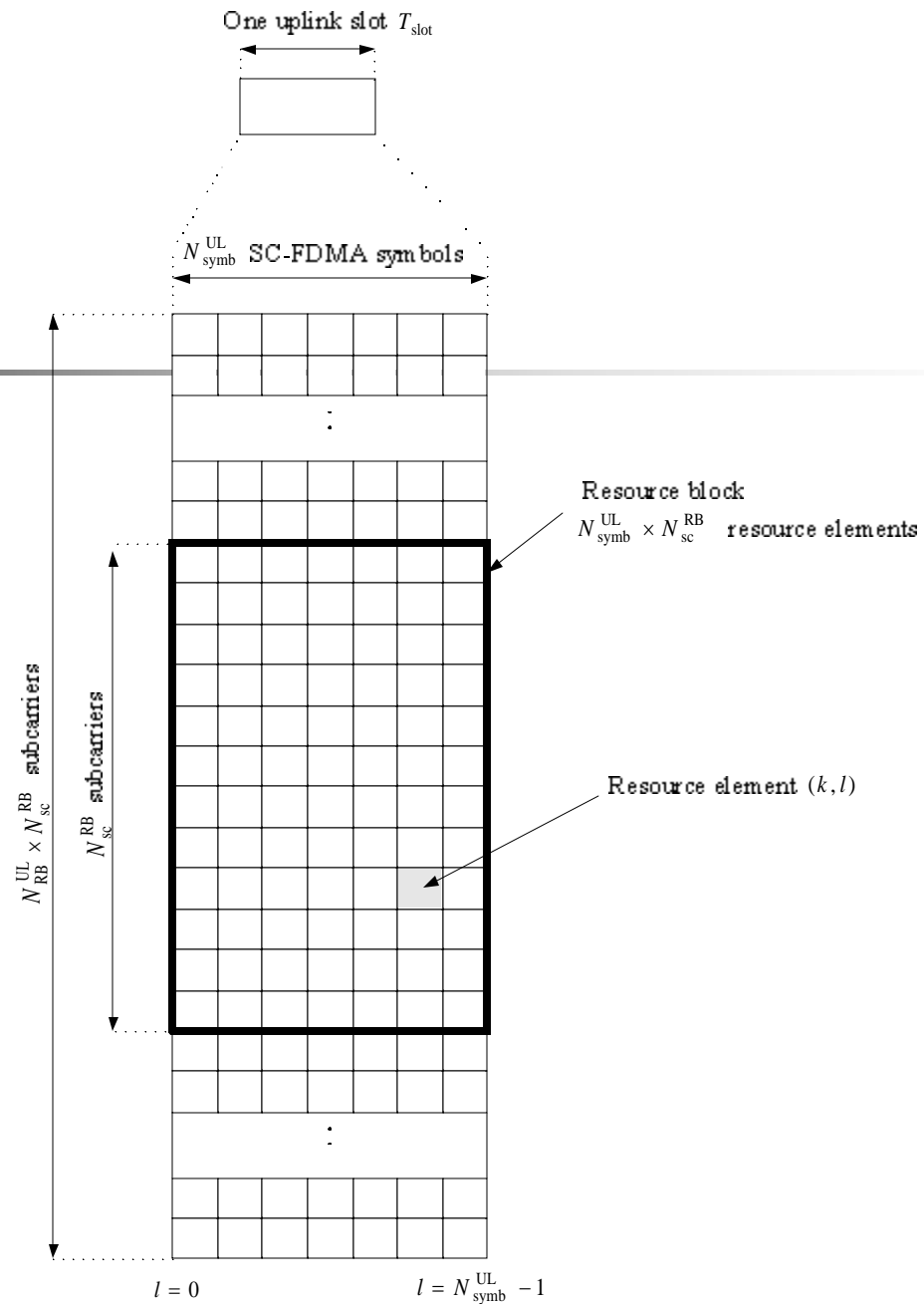
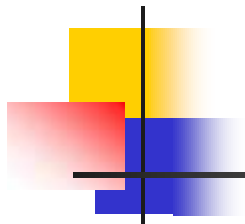
Table 5.2.3-1: Resource block parameters.

Configuration <i>(k, l)</i>	N_{sc}^{RB}	N_{symb}^{UL}	
		Frame structure type 1	Frame structure type 2
Normal cyclic prefix	12	7	9
Extended cyclic prefix	12	6	8

The relation between the resource block number n_{PRB} and resource element (k, l) in a slot is given by

$$n_{PRB} = \left\lfloor \frac{k}{N_{sc}^{RB}} \right\rfloor$$

Uplink Resource Grid

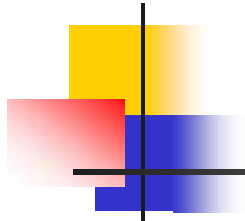




Physical downlink control channel PDCCH formats

- The physical downlink control channel carries scheduling assignments and other control information. A physical control channel is transmitted on an aggregation of one or several control channel elements (CCEs), where a control channel element corresponds to a set of resource elements. Multiple PDCCHs can be transmitted in a subframe.
- The PDCCH supports multiple formats as listed in Table 6.8.1-1.

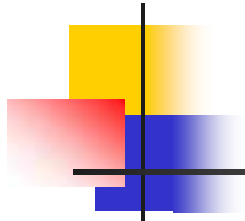
Table 6.8.1-1: Supported PDCCH formats



PDCCH format	Number of CCEs	Number of PDCCH bits
0	1	
1	2	
2	4	
3	8	

Timing issues with closed loop power control of LTE

- PDCCH is sent every sub-frame [1 ms]
- $mcs\text{-}pucch$ is signaled by RRC ($mcs\text{-}pucch$ table entries can be set to zero)
 - MCS is signaled using higher layer signaling [can be done in a single sub-frame]
- The TPC command from a DL scheduling assignment overrides any command from a TPC PDCCH when both are received in a given sub-frame.
- Power control can be performed once every 2-3 ms.
- The whole contiguous frequency block is transmitted in UL LTE, as such the power control may need to track wideband signals [frequency selective fading].



Outline

- Power control in WiMAX
- Power control in LTE
- **Power Control in UMB**
- Comparison

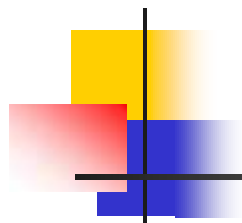


Power control in UMB

- In every PHY Frame in a superframe, the Forward Link control channels, i.e., the Forward Acknowledgment Channel, the Forward Start of Packet Channel, the Forward Reverse Activity Bit Channel, the Forward Shared Control Channel, **the Forward Fast Other Sector Interference Channel, the Forward Interference over Thermal Channel, the Forward Pilot Quality Indicator Channel and the Forward Power Control Channel**, shall be multiplexed together onto a set of NFLCS-BLOCKS hop-port blocks, referred to as the “Forward Link Control Segment”.

3.1.3.3.1 Reverse Pilot Channel

- The Reverse Pilot Channel (R-PICH) is an unmodulated DFT-precoded CDMA signal used to assist the Access Network for Reverse Link power control reference and Reverse Link quality measurement.



Forward Power Control Channel

- F-PCCH Forward Power Control Channel: Carries Reverse Link Power Control Commands

4.1.3.4.8 Forward Power Control Channel

- The Forward Power Control Channel (F-PCCH) carries commands for closed-loop control of the Reverse Link control channel transmit power.
- The FLC MAC Protocol [2] determines the number of the Forward Power Control Channel reports to be transmitted on each Forward Link PHY Frame, which is denoted by TotalFPCReports. Each of these blocks is assigned an index FPCReportIndex which takes values 0 through TotalFPCReports - 1. For each FPCReportIndex, the FLC MAC Protocol [2] determines a one-bit value PCVal to be transmitted, the MACID of the terminal to which this report is targeted and the power density PFPCCH at which it is sent.

4.1.3.4.8.1 Forward Power Control Channel Transmission

- The first symbol of the scrambling sequence generated using the complex scrambling algorithm with input seed $fPHY-HASH(220 \times 51 + SectorSeed)$ is denoted by s . The complex scrambling algorithm is described in 2.5.2 and SectorSeed is defined in 2.3.2.3. BPSK modulation is used to transmit the Forward Power Control Channel.
- If $PCVal = 0$, then define $\alpha = 1$. Otherwise, if $PCVal = 1$, then define $\alpha = -1$. A value of $SQRT(P_{FPCCH}) \times \alpha s$ shall be transmitted on the subcarrier-symbol (FPCReportIndex mod 3) of the Forward Link Control Segment resource index $RFPCCH-BEGIN + FPCReportIndex/3$, provided that subcarrier-symbol is mapped to a Forward Link Control Segment available subcarrier.

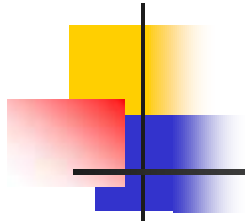


OSICH: Other Sector Interference Channel

- F-OSICH: Forward Other Sector Interference Channel: Carries an Other Sector Interference Indication
 - This channel is transmitted over the super frame preamble.
- F-FOSICH: Forward Fast Other Sector Interference Channel: Carries an Other Sector Interference Indication Transmitted at a Faster Rate But with Less Coverage Than the Forward Other Sector Interference Channel
 - This Channel is transmitted in the Control Segment of PHY Frames

4.1.3.4.6 Forward Fast Other Sector-Interference Channel

- The Forward Fast Other Sector Interference Channel (F-FOSICH) is used to indicate interference levels in a given Reverse Link hop-port subzone to the Access Terminals in other sectors.
- The FLCS MAC Protocol [2] determines the number of the Forward Fast Other Sector Interference Channel reports to be transmitted on each Forward Link PHY Frame, which is denoted by TotalFFOSIReports. Each of these blocks is assigned an index FFOSIReportIndex which takes values 0 through TotalFFOSIReports - 1. For each FFOSIReportIndex, the FLCS MAC Protocol [2] determines a four-bit value FFOSIVal to be transmitted and the power density PFOSICH at which it is sent.
- The Forward Fast Other Sector Interference Channel shall be transmitted on resources RFFOSICH-BEGIN through RFFOSICH-BEGIN + 2NFFOSICH-INDICES - 1, where RFFOSICH-BEGIN = RFPQICH-BEGIN + 2NFPQICH-MESSAGES and NFFOSICH-INDICES equals TotalFFOSIReports. (Skip)



Outline

- Power control in WiMAX
- Power control in LTE
- Power Control in UMB
- Comparison

Comparison Table

	WiMAX Release 1	LTE	UMB
Duplex method	TDD FDD	TDD FDD	FDD Half duplex
Coherence time // Doppler spread @ 2.5 GHz $FD = v f_c / c$	1.2 mph, 4.6 Hz [$T_c = 200$ ms] 27 mph, 104 Hz [$T_c = 10$ ms] 60 mph, 231 Hz [$T_c = 4$ ms]	FFS	FFS
$B_c = 1 / (5 \text{ rms})$ Coherence bandwidth // rms delay spread Assume 1 microseconds	200KHz	200KHz	200KHz
Carrier frequency	2.3, 2.5, 3.3, 3.5 GHz	2.6 GHz specified to operate from 450 MHz to 2.6 GHz	3G bands
Bandwidth	5, 7, 8.75, 10 MHz	1MHz-20 MHz in steps of 180 KHz	5,10,20 MHz
Uplink multiple access DL access	OFDMA OFDM/TDM	SC-FDMA OFDM/TDM	OFDMA/CDMA OFDMA and CDMA are frequency multiplexed in UL. DL: OFDM/TDM
Sub carrier spacing	10.94 KHz	15 KHz	9.6 KHz
Super Frame – Frame – subframe - slot	Frame = 5 ms Ex: UL-subframe = 2.5 ms Ex: DL subframe = 2.5 ms	Frame = 10 ms Subframe = 1 ms [DL-UL] Subframe = 2 slots	Super frame = 25 ms Frame = 1 ms [DL-UL] Frame = 8 OFDMA symbols

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Comparison Table

	WiMAX release1	LTE	UMB
Uplink Resource element	<p>Subcarriers are first divided in tiles. Each tile has four subcarriers over three OFDM symbols. Subcarriers are divided into 8 data and 4 pilot subcarriers. Tiles are re-numbered randomly and divided into six groups. Subchannel is formed by taking 6 tiles from the same group. Slot = 16 subcarriers x 3 OFDMA symbol</p>	<p>180 kHz x 1 ms 12 subcarriers x 8 OFDMA symbols</p>	FFS
Subchannel formation	Contiguous and diverse permutations	Contiguous blocks	FFS
BS scheduling//UL scheduling	CQI in UL through CQICH	Channel dependent scheduling: 1 ms resolution in time 180 KHz resolution in frequency UL: only contiguous blocks of frequency can be assigned in uplink [SC-FDMA] UL channel dependent scheduling is non-trivial	
AMC	<p>yes DL: QPSK, 16 QAM, 64 QAM UL: QPSK, 16 QAM</p>	<p>yes QPSK, 8PSK, 16 QAM, 64 QAM CQI in UL to support this.</p>	yes
UL power control	<p>Mandatory closed loop power control Optional open loop power control</p>	Closed loop and open loop power control	Closed loop power control

Comparison Table: CL Power control

	WiMAX release1	LTE	UMB
UL power control	Mandatory closed loop power control Optional open loop power control	Closed loop and open loop power control	Closed loop power control
Distinguishing features	Ranging channel	OI = Overload indicator signaled to adjacent cells.	OSICH Other Sector Interference Channel
Frequency of power level correction: CLPC	TDD: once every 5 ms	TDD: once every 2-3 ms	FDD: once every 1 ms
Downlink Control channels for power control	RNG-RSP message in response to ranging request	DL-DPCCH channel for issuing TPC or Uplink scheduling grants	Forward power control channel: issues commands to power control the reverse link control channel Forward OSICH channel
Closed loop Power control design approach	Power adjustment field in RNG-RSP L2 message	j = TPC command, included in a DL scheduling assignment or sent jointly coded with other UE specific correction values on a TPC PDCCH. The UE attempts to detect a TPC PDCCH and a DL scheduling frame on every subframe. The TPC command from a DL scheduling assignment overrides any command from a TPC PDCCH when both are received in a given subframe. L1 message	L1 power control commands

Comparison Table: OL Power control

	WiMAX release1	LTE	UMB
Open loop power control	Based on path loss, NI = average interference plus noise level at BS per subcarrier: Signaled by DCD message MAC messages from the BS	Path loss	FFS Path loss
MCS	C/N = Required for the current modulation and coding scheme: Signaled by UCD if the table is changed.	mcs is signaled by RRC (mcs table entries can be set to zero). MCS is signaled in each UL scheduling grant	FFS
Feedback for open loop.	$Offset_SSperSS$ is the correction term for SS-specific power offset. It is controlled by SS. Its initial value is zero. In active open loop power control, this value is based on ACK/NAK in response to UL ARQ. UCD message TLV signals this value.	NA	NA
Feedback for open loop	$Offset_BSperSS$ is the correction term for SS-specific power offset. It is controlled by BS with power control messages. When $Offset_BSperSS$ is set through the PMC_RSP message, it shall include BS Rx antenna gain. The BS controls the $Offset_BSperSS$ using PMC_RSP message to override the $Offset_BSperSS$ value, or using: RNG-RSP, Fast Power Control (FPC) message , Power Control IE and UL-MAP_Fast_Tracking_IE to adjust the $Offset_BSperSS$ value.	NA	NA