Ranging Channel Structure for the 802.16m SDD

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Re: IEEE 802.16m-08/725 – Call for Comments on Uplink Control Structures

Base Contribution:

IEEE C802.16m-08/853r2

Purpose:

Propose to be discussed and adopted by TGm for the use in Project 802.16m SDD

Categorization of Ranging Channel

- Non-synchronized ranging channel
  - To acquire UL synchronize for non-synchronized MSs (initial/ handover ranging)
  - Longer delay than OFDMA CP causes
    - Mutual inter-subcarrier interference between data and ranging channel
    - Inter-symbol interference to next OFDMA symbol
- Synchronized ranging channel
  - To maintain UL synchronization for synchronized MSs (periodic ranging)
  - Shorter delay than OFDMA CP

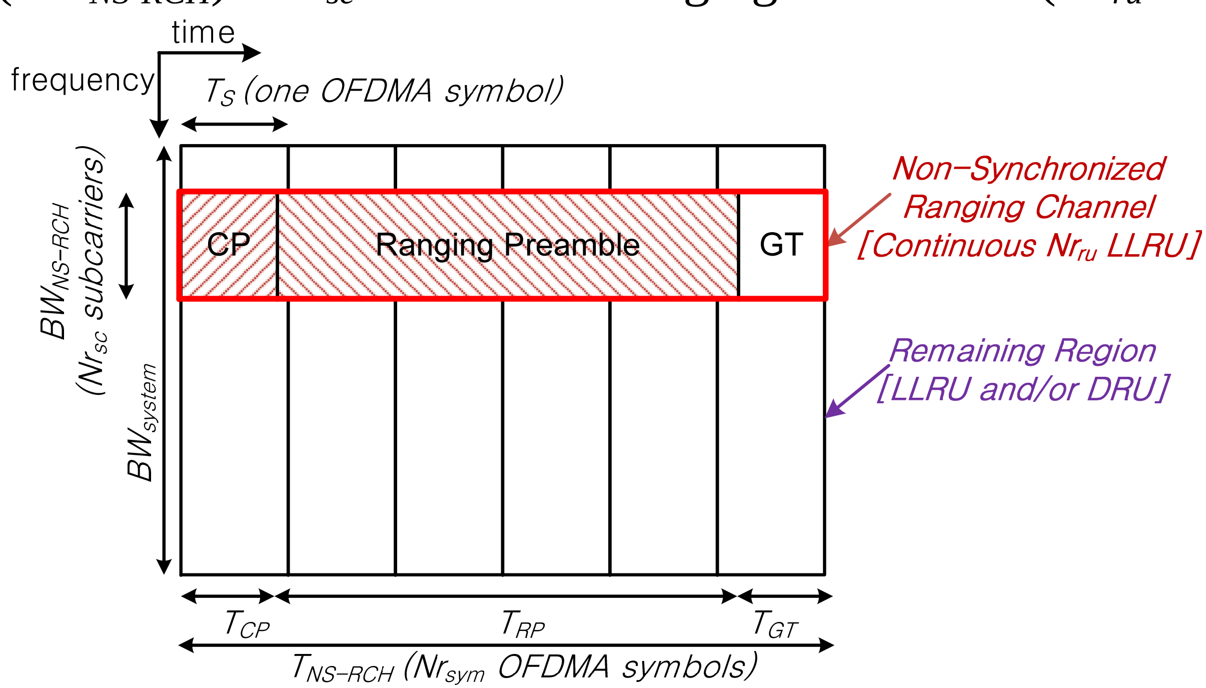
☞ It is necessary to design non-synchronized ranging channel and synchronized ranging channel separately.

Non-Synchronized Ranging Channel Structure

- Long CP (> a OFDMA CP [3-6]) is
  - not shorter than RTD (round trip delay) plus maximum delay spread
  - robust against large time offset
  - To utilize efficient resource usage
  - To use frequency domain detector with low complexity
- GT (guard time) [3-6] is
  - not shorter than RTD
  - To avoid inter-symbol interference between OFDMA symbols
- Preamble Spreading through several OFDMA symbols is
  - not shorter than ranging CP length at least
  - To improved link-budget by at least 3 dB [1]
  - To support the coverage not shorter than other control/data channel
  - To easily extend up to 100 km cell [1]
- Localized Ranging Channel Resource Allocation is
  - To efficiently avoid the mutual inter-subcarrier interference
  - To improve detection performance [7-8]
  - To efficiently support large code set with ZCZ (zero correlation zone)
- Guard Band is
  - To effectively reduce mutual inter-subcarrier interference

Proposed Non-Synchronized Ranging Channel

- Constitution of three parts
  - CP (cyclic prefix)
  - RP (ranging preamble)
  - GT (guard time)
- Resource allocation
  - Time ($T_{NS\text{-}RCH}$) : Nr_{sym} OFDMA symbols
  - Frequency ($BW_{NS\text{-}RCH}$) : Nr_{sc} continuous ranging subcarriers (Nr_{ru} LLRU)



Mutual Inter-Subcarrier Interference

- Ranging performance degradation due to miss-alignment with data CP
  - Once data signal power is larger than ranging power
    - Data signal were received by target power (Target SNR is 10 dB for QPSK data)
- Data performance degradation due to long delay of ranging signal
  - When ranging power is comparable to data power
    - Both data and ranging UE signal were transmitted by equal (maximum) power

⇨ The performance degradation with 2 guard subcarriers for each edge can be halved compared to no guard subcarrier.

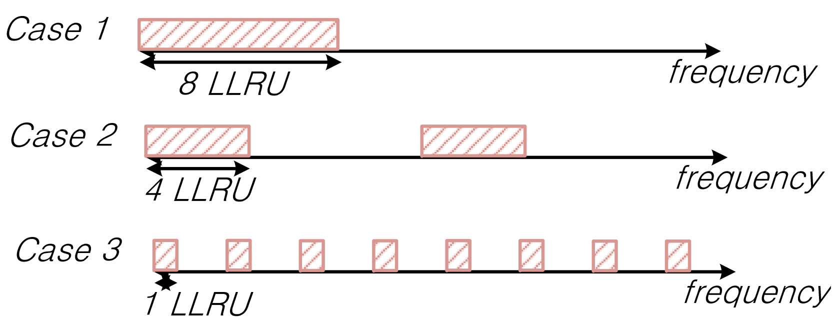
	Length of ranging codes	# of ranging guard subcarriers (guard bandwidth)	Performance Degradation for 1% target [dB]
Ranging Performance Degradation	719 w/o data	.	.
	719 w data	0 / 1 (0 Hz)	0.27
	709 w data	5 / 6 (10.9375 kHz)	0.17
	701 w data	9 / 10 (19.6875 kHz)	0.15
Data Performance Degradation	w/o ranging	.	.
	w 719 (8 MSs)	0 / 1 (0 Hz)	0.88
	w 709 (8 MSs)	5 / 6 (10.9375 kHz)	0.42
	w 701 (8 MSs)	9 / 10 (19.6875 kHz)	0.40

☞ The guard band can be used to reduce the impact of mutual inter-subcarrier interference.

Localized Resource Allocation

- Trade-off between localized allocation and distributed allocation for non-coherent detection
  - Inter-subcarrier Interference
    - Reduced from localized allocation easily
  - Good (sharp) auto-correlation property
    - Obtained from localized allocation
  - Frequency diversity
    - Obtained from distributed allocation
    - Obtained from localized allocation with wider BW than coherent BW
  - Localized allocation have better detection performance than distributed allocation

⇨ Merits of localized allocation
  - Enhanced detection performance [7-8]
  - Efficient reduction for the mutual inter-subcarrier interference
  - Increase number of available codes such as ZCZ (zero correlation zone)



Resource Allocation	Performance Degradation for 1% P_m and P_{FA-64} [dB]
Case 1	.
Case 2	0.75
Case 3	1.65

☞ 16m ranging channel shall be allocated in localized frequency band.

Ranging Bandwidth

- UL timing accuracy shall be shorter than $(T_b/32)/4$ [9]
  - Timing estimation error shall be shorter than 8 samples (8*89.29ns) at 10 MHz
- In general, timing resolution is inversely proportion to the occupied bandwidth
  - Ranging channel shall be allocated the frequency band larger than 1.4 MHz.

⇨ The ranging channel shall be allocated 8 LLRU.

  - 16m Ranging channel shall be provided better than or comparable to the timing accuracy of the legacy ranging channel.

Ranging Bandwidth (code length)	8 LLRUs / 1.575 MHz (719)	7 LLRUs / 1.3781 MHz (619)	6 LLRUs / 1.1813 MHz (523)	5 LLRUs / 0.9844 MHz (449)	4 LLRUs / 0.7875 MHz (359)
95% CDF of timing estimation error [samples]	7.90	8.01	8.40	8.80	8.95

☞ 16m ranging bandwidth shall be the same size of legacy ranging bandwidth. (144 data subcarriers)

Ranging Preamble Length

- Preamble shall be spanned over several OFDMA symbols
  - To improved link-budget by at least 3 dB [1]
  - To support the coverage not shorter than other control/data channel
  - To easily extend up to 100 km cell [1]
- Simple power balancing between data and ranging channel as follow [10]

$$\frac{E_p}{N_0} \cdot \frac{1}{T_p} = \frac{E_b}{N_0} \cdot R$$

where T_p is the preamble duration, R is data rate.

  - For examples, data rate is 64 kbps, Ep/N0=18 dB, Eb/N0=3 dB
    - The required preamble length become larger than 4 OFDMA symbol duration

⇨ The ranging preamble shall be spanned over several OFDMA symbols.

☞ It is preferable that the default ranging structure is occupied one sub-frame (PRU) in the time domain.

Proposed SDD Text 1

--- *Start of the Text* ---

11.x.2.4. UL Ranging Channel

[same contents adding below sentence with 11.x.2.4 in C802.16m-08/725 or the latest version.]

The UL ranging channel can be further classified into ranging channel for non-synchronized MS and synchronized MS.

11.x.2.4.1. Non-Synchronized Ranging Channel

The Non-synchronized ranging channel is used to acquire UL synchronization for non-synchronized MSs such as initial and handover ranging.

11.x.2.4.1.1 Multiplexing with other control channels and data channels

[Same contents in 11.x.2.4.1 with an addition of 'non-synchronized' in C802.16m-08/725 or the latest version]

11.x.2.4.1.2. PHY structure

11.x.2.4.2. Synchronized Ranging Channel

The synchronized ranging channel is used to maintain UL synchronization for synchronized MSs such as periodic ranging.

11.x.2.4.2.1 Multiplexing with other control channels and data channels

[Same contents in 11.x.2.4.1 with an addition of 'synchronized' in C802.16m-08/725 or the latest version]

11.x.2.4.2.2. PHY structure

[Same contents in 11.x.2.4.1 with an addition of 'synchronized' in C802.16m-08/725 or the latest version]

--- *End of the Text* ---

Proposed SDD Text 2

Start of the Text

11.x.2.4.1.2. PHY structure

The physical non-synchronized ranging channel consists of three parts: 1) cyclic prefix (CP), 2) ranging preamble and 3) guard time (GT) as illustrated in Figure 11.x.2.4.1.2. The length of CP shall not be shorter than the sum of the maximum channel delay spread and round trip delay (RTD) of supported cell size. The length of GT shall not be also shorter than the RTD of supported cell size. The length of preamble shall be equal to or longer than CP length of non-synchronized ranging. The details on the length of each part and its configurations are FFS.

The physical resource of non-synchronized ranging channel is consecutive Nr_{ru} LLRUs ($BW_{NS\text{-}RCH}$ Hz) and Nr_{sym} OFDMA symbols ($T_{NS\text{-}RCH}$ sec). As a default configuration, Nr_{ru} and Nr_{sym} are equal to [TBD] LLRUs and 6 OFDMA symbols, respectively. The guard subcarriers shall be reserved at the edge of non-synchronized ranging channel(s) physical resource.

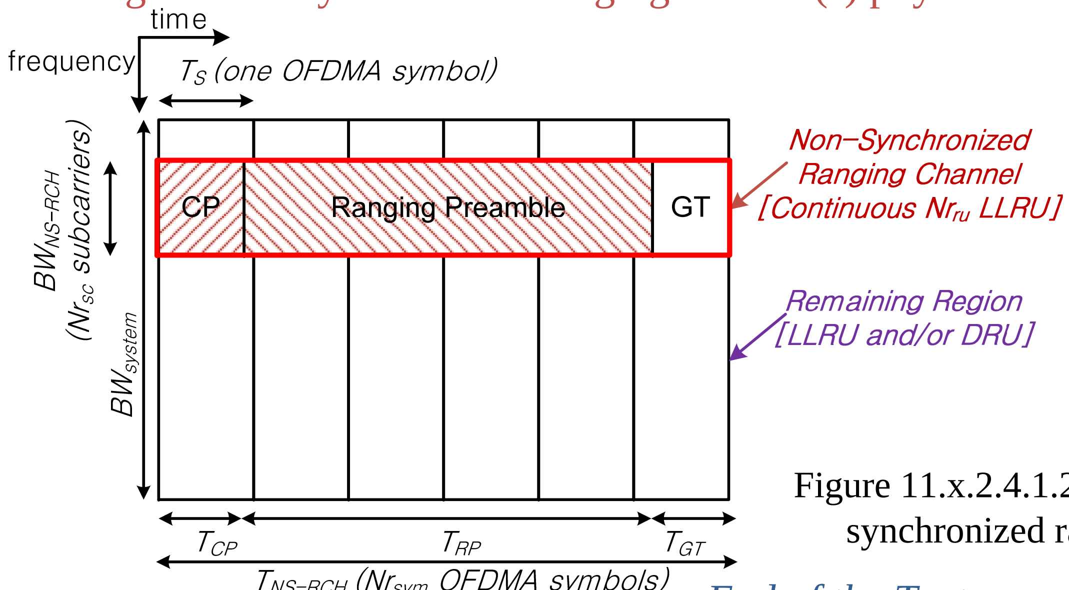


Figure 11.x.2.4.1.2. Examples of non-synchronized ranging structure

End of the Text

Reference

[1] IEEE 802.16m-07/002r4, “IEEE 802.16m System Requirements,” October 2007.

[2] IEEE 802.16m-08/004r1, “Project 802.16m Evaluation Methodology Document (EMD),” March 2008.

[3] IEEE C802.16m-08/448r1, “Initial/Handover Ranging for IEEE 802.16m System,” March 2008.

[4] IEEE C802.16m-08/471, “Uplink Control Structures,” March 2008.

[5] IEEE C802.16m-08/329, “Ranging Code Design for IEEE 802.16m,” March 2008.

[6] IEEE C802.16m-08/375, “Uplink Control Structure for RACH and PRCH,” March 2008.

[7] IEEE C802.16d-04/47r1, “OFDMA PHY Enhancements for Ranging,” March 2004.

[8] 3GPP R1-050777, “RACH Preamble Design,” August 2005.

[9] WiMAX Forum Mobile System Profile Release 1.0 (Revision 1.4.0), May 2007.

[10] 3GPP R1-060998, “E-UTRA Random Access Preamble Design,” March 2006.

Annex A. Simulation Parameters

	Parameters	Assumptions
System	Carrier Frequency (f_c)	2.5 GHz
	Total Bandwidth (BW)	10 MHz
	Number of Points in Full FFT (N_{FFT})	1024
	Sampling Frequency (F_s)	11.2 MHz
	Subcarrier Spacing (Δf)	10.9375 kHz
	OFDMA Symbol Duration without Cyclic Prefix ($T_0 = 1/\Delta f$)	91.43 μs
	Cyclic Prefix Length (faction of T_0)	1/8
	OFDMA Symbol Duration with Cyclic Prefix (T_S)	102.86 μs for CP=1/8
	Residual Frequency Offset	random < 218.75 Hz (< 2% of Δf)
Channel	Multi-antenna Transmission Format	1 Tx
	Receiver Structure	2 Rx
	Fading Channel Model	Pedestrian B
	UE Speed	3 km/h
Data	Data Resource	1 LLRU
	Channel Coding	CTC 1/2 rate
	Channel Estimation	2D MMSE
	Target BLER	1 %
Ranging	Ranging Resource	Continuous 8 LLRU
	Ranging Subcarrier Spacing	2.1875 kHz
	Ranging Detector	Frequency domain energy detector
	Number of Initial Ranging Codes per Channel	64 w/o cyclic shift
	Round Trip Delay	random
	Target Miss-Detection Probability	1 %
	Target Overall False Alarm Rate	1 %

- P_m : Miss-detection probability per code is defined as the probability of the transmitted code not being detected when a single ranging code was transmitted.
- R_{FA} : The overall false alarm rate per ranging channel is defined as

$$R_{FA} = 1 - \left(1 - R_{FA-code}\right)^{Nr_{seq}}$$

where $R_{FA\text{-}code}$ denotes the false alarm rate of a particular ranging code being detected when a different ranging code was transmitted, and Nr_{seq} denotes the number of ranging codes in a ranging channel.