Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Ranging Channel Structure for Non-Synchronized MSs**
Date Submitted	**2008-09-05**
Source(s)	HyunWoo Lee Young-Hyoun Kwon Jin Sam Kawk Sungho Moon LG Electronics LG R&D Complex, 533 Hogye-1dong, Dongan-gu, Anyang, 431-749, Korea Voice: +82-31-450-1935 E-mail: camille@lge.com WishWill@lge.com samji@lge.com msungho@lge.com
Re:	PHY: Text; in response to the TGm Call for Contributions and Comments 802.16m-08/033 for Session 57
Abstract	This contribution proposes the new ranging structure for non-synchronized MSs. A new ranging structure with the time-expanded concept in a localized band for IEEE 802.16m is proposed to enhance the ranging performance and coverage in accordance with the requirements in IEEE 802.16m SRD.
Purpose	discussion and adoption for Project 802.16m SDD
Notice	
Release	
Patent Policy	

Ranging Channel Structure for Non-Synchronized MSs

HyunWoo Lee, Young-Hyoun Kwon, Jin Sam Kwak, and Sungho Moon
LG Electronics

1. Introduction

According to the IEEE 802.16m system requirements document [1], IEEE 802.16m shall provide significantly improved coverage with respect to WirelessMAN-OFDMA reference system. Furthermore, the support for larger cell sizes should not compromise the performance for smaller cells. It is also required to support increased number of simultaneous users and enhanced user penetration property. In order to meet the requirements related to the ranging channel, the limitations of current IEEE 802.16e ranging structure has been addressed and a new ranging channel structure for non-synchronized MSs has been proposed in [2-4]. In this contribution, we propose the ranging channel structure for non-synchronized MSs with simulation results based on the requirements defined in the July meeting [5].

2. Considerations in Ranging Channel Design for Non-Synchronized MSs

From [2], the following aspects shall be considered in the ranging channel design for non-synchronized MSs:

1. **Long ranging CP (> a OFDMA data CP [2]-[4], [6], [7]])**

   To be robust against the propagation delay related to the maximum delay spread and round trip delay (RTD) according to the cell size, the long ranging CP shall be used to maintain the signal orthogonality. With long ranging CP, it is able to support the frequency domain detection with low complexity as well as efficient resource usage. The ranging CP shall be shorter than RTD according to supportable cell radius plus maximum delay spread.

2. **GT (Guard Time) [2]-[4], [6], [7]**

   The last part of ranging channel for non-synchronized MSs shall be reserved as GT to avoid the inter-symbol interference to next OFDMA symbol due to longer delay of ranging signal. The GT shall be not shorter than RTD.

3. **Ranging preamble spreading through several OFDMA symbols**

   According to the IEEE 802.16m system requirements [1], the link-budget shall be improved 3 dB at least and the coverage can be support up to 100 km cell without compromising of performance. To support these requirements and larger coverage than data and other control channels, the ranging preamble shall be span in time domain. At least, the ranging preamble shall not be shorter than ranging CP length.

4. **Localized Ranging Channel Resource Allocation**

   Localized allocation shall be used to efficiently avoid the mutual inter-subcarrier interference for ranging channel. It enables to improve the detection performance as well [8-9]. In addition, the number of available codes can be increased, e.g., by using of ZCZ (zero correlation zone) sequence for localized allocation.

5. **Guard band**

   Due to different propagation delay and structure between data and ranging channel, there exists the mutual inter-subcarrier interference. To simply and effectively reduce the inter-subcarrier interference, the guard subcarriers shall be reserved at the edge of non-synchronized ranging channel(s) physical resource.

3. Proposed Ranging Channel Structure for Non-Synchronized MSs

Based on the design considerations above, we propose a high-level ranging structure for non-synchronized MSs. The physical ranging channel structure for non-synchronized mobile stations consists of three parts: 1) cyclic prefix (CP), 2) ranging preamble (RP) and 3) guard time (GT) as illustrated in Figure 1. 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 ranging preamble shall be equal to or longer than CP length of ranging channel. The details on the length of each part and its configurations are FFS.

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

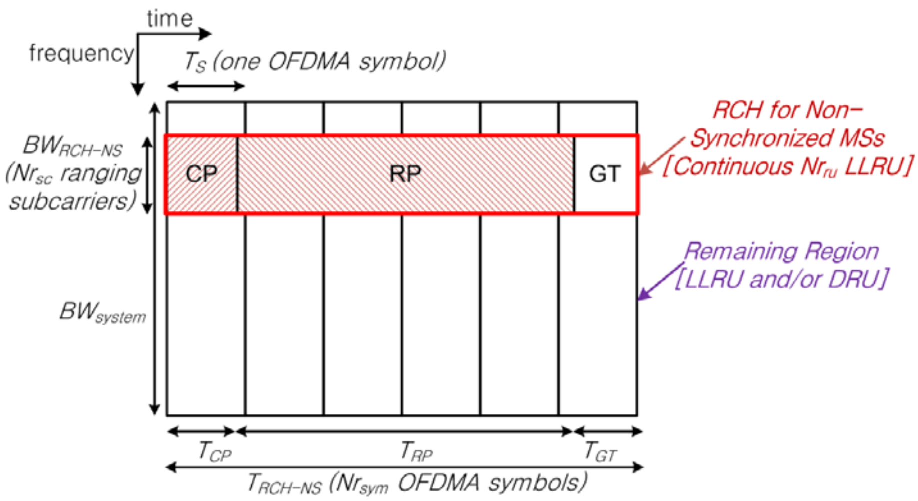


Figure 1. Examples of ranging channel structure for non-synchronized mobile stations

4. Key Performance Aspects for Ranging Structure Design

4.1 Simulation Parameters

All simulation parameters are based on [5, 12]. The details are shown in the Annex. For ranging simulation, it is assumed that the lengths of CP, RP, and GT are 85.71 µs, 457.14 µs, and 74.30 µs, respectively. Using the 144 data subcarriers for ranging bandwidth, the ranging structure has 720 ranging subcarriers with the subcarrier spacing of 2.1875 kHz. The Zadoff-Chu sequence is considered. The remaining subcarriers are used as guard band to prevent inter-subcarrier interference. It is also assumed that there are 64 opportunity per cell. The performance is measured as the preamble energy per noise spectral density E_p/N_0. According to the requirements of UL control RG [5], target overall false alarm rate (R_{FA}) and target miss-detection probability (P_m) is 0.1% and 1%, respectively.

To analyze the impact of mutual inter-subcarrier interference, we assume that data transmission uses one LLRU with real channel estimation. It is also assumed that the target SNRs of 1% BLER for QPSK and 16-QAM are 10 dB and 15 dB, respectively.

In the following, based on the performance evaluation and comparison, we address several key aspects for the ranging structure design such as resource allocation, mutual inter-subcarrier interference, and preamble length with upper simulation parameters.

4.2 Resource Allocation

In the viewpoint of inter-subcarrier interference vs. frequency diversity, there is a trade-off between localized allocation and distributed allocation for non-synchronized coherent detection. The localized allocation is more preferable because the distributed allocation needs more large guard band in order to avoid or effectively reduce the inter-subcarrier interference. Otherwise, the distributed allocation provides a large impact on the ranging and data performance degradation if it is not prevented perfectly. Even though the frequency diversity may be achieved by using the distributed allocation, the ranging bandwidth, which is much larger than the coherence bandwidth, e.g. the legacy ranging bandwidth of 1.575 MHz, is large enough to provide the frequency diversity. Further, the detection performance of ranging code in the distributed allocation can be degraded due to the worse auto-correlation property with a full-length single code. In [7] and [8], it has been already addressed that the localized allocation has better detection performance than distributed allocation for non-coherent detection. In additional, using the localized allocation for ranging channel is more proper to provided the increased number of available codes, e.g., by using ZCZ (zero correlation zone) sequence.

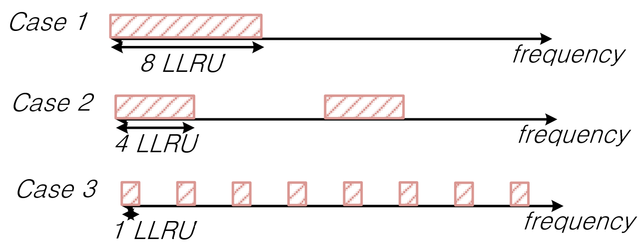


Figure 2. Examples of ranging resource allocation

In order to compare the performance between distributed and localized allocation, we consider three allocation scenarios with total bandwidth of 8 LLRUs as shown in Figure 2. The case 1 is based on the localized allocation with 8 consecutive LLRUs. The cases 2 and 3 are the distributed allocations with 2 and 8 consecutive localized resource blocks each consisting of 4 and 1 LLRUs, respectively. Assume that the length of sequence is 701. The delay of ranging signal is chosen randomly according to the RTD within 5 km cell radius.

Table 1 shows the relative performance degradation of distributed allocation with full-length codes. It is shown that the distributed allocation needs the higher required E_p/N_0 than that of the localized allocation. This implies that the correlation property is more important than full frequency diversity for non-coherent detection.

Table 1. The Performance degradation of distributed allocation when the full length code is used.

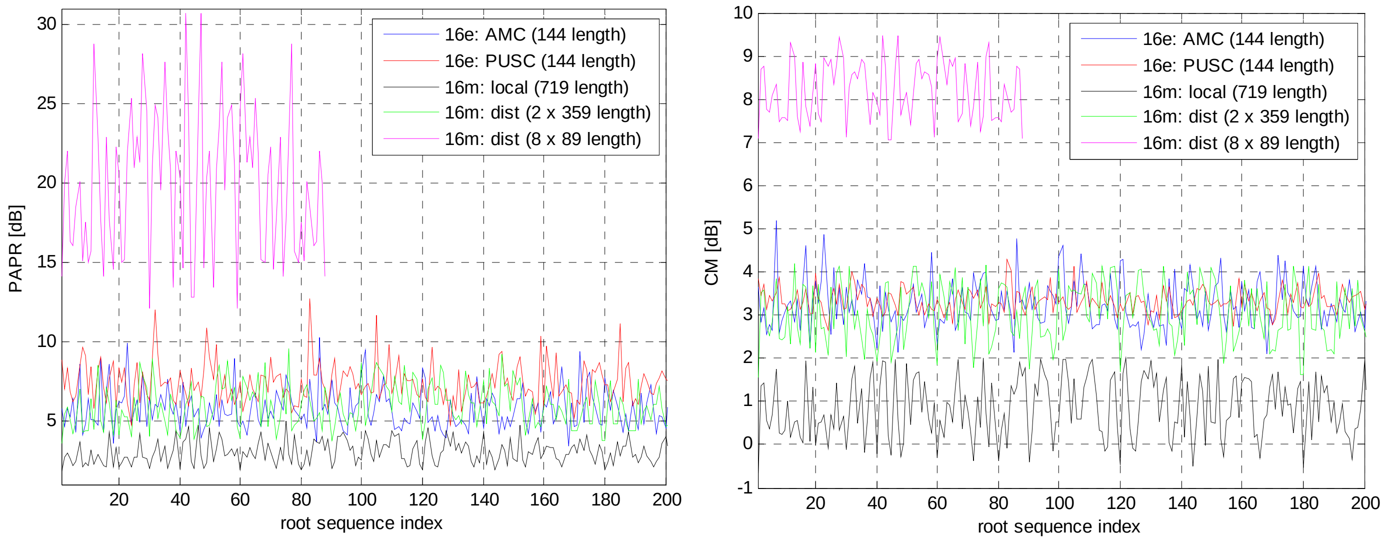
Resource Allocation	Length of code	Performance degradation for 1% P_m and 0.1% R_{FA-64} $[E_p/N_0]$
Case 1	701	-
Case 2	701	0.7 dB
Case 3	701	1.2 dB

In the distributed allocation, the short-length codes can be used to enhance the auto-correlation property and repeated in every consecutive localized resource. In other words, the distributed allocation which has 2 or 8 localized blocks can use the short-length sequence with length of 359 or 89, respectively. In this simulation environment, we consider the parallel correlation stages for each localized block in BS, even if it has high complexity for detection, i.e., the correlation values in each short sequence per localized block are combined. In this case, the inherent auto-correlation properties in the time domain can be maintained. In general, however, due to the short length of sequence, there are several demerits as follows: the increased cross-correlation values, large PAPR/CM properties, the reduced number of available sequence and its limited reuse factor, etc.

Table 2 shows the performance gain of distributed allocation using repeated short sequence. Even if the distributed allocation has a negligible gain than localized allocation, it should be noted that the performance degradation is quite significant if the inter-subcarrier interference is not prevented perfectly (See the next subsection about ISI impacts). As a result, the distributed allocation is not attractive to overwhelm the localized allocation with the frequency diversity when inter-subcarrier interference exists. From the requirement of UL control RG [5], the average PAPR and CM over all ranging codes shall be smaller than those of all legacy ranging codes. The repetition of sequence increases the PAPR and CM value as shown Figure 3 for 20 MHz system bandwidth. Even if it depends on the exact sequence design, it is more preferable that 16m ranging channel is allocated in localized frequency region in various key aspects.

Table 2. The performance gain of distributed allocation when the short length code is used repeatedly.

Resource Allocation	Length of code	Performance gain for 1% P_m and 0.1% R_{FA-64} [E_p/N_0]
Case 1	719	-
Case 2	359 × 2	0.03 dB
Case 3	89 × 8	0.09 dB



(a) PAPR **(b) CM**

Figure 3. PAPR and CM properties

4.3 Mutual Inter-Subcarrier Interference (ISI)

Due to different propagation delay and PHY structures, there exists the mutual ISI between data and ranging channels. In the following, we investigate the performance degradation due to ISI for data and ranging channels. We assume that the propagation delay of ranging signal is chosen randomly from OFDMA CP length to maximum RTD of 5 km cell radius.

1. **Ranging performance degradation due to miss-alignment with data CP**

   Due to the misalignment over data CP length, there exists ISI from adjacent data channel to the ranging channel. This ISI could be more serious when data signal power is larger than ranging power. For this situation, we assume that target received SNR is 10 dB or 15 dB for QPSK or 16-QAM, respectively. Table 4 shows the ranging performance degradation due to ISI form adjacent data channel. From Table 4, the impact of ISI can be significantly reduced if only 2 data subcarriers are used for guard bands.

Table 4. The ranging performance degradation due to ISI from adjacent data channel.

Length of code	# of ranging guard subcarrier (guard bandwidth)	Performance degradation for 1% P_m and 0.1% R_{FA-64} [SNR]	
		w QPSK (10 dB)	w 16-QAM (15 dB)
719 w/o data	-	-	-
719 w data	0 / 1 (0 Hz)	0.24 dB	0.74 dB
709 w data	5 / 6 (10.9375 kHz)	0.19 dB	0.47 dB
701 w data	9 / 10 (19.6875 kHz)	0.15 dB	0.35 dB

2. **Data performance degradation due to long delay of ranging signal**

   Due to the larger delay of ranging signal than OFDMA CP length, there exists ISI from adjacent ranging channel to the uplink data channel. This ISI could be more serious when the ranging signal power is comparable to data power. Thus, we assume that both data and ranging MS signals are transmitted with equal (maximum) power for power limited MS. Also, we assume there are 8 ranging MSs transmitted simultaneously. Even if the ranging load may be small usually, we shall consider a worst case, e.g., inefficient power control, high inter-cell interference, instant high load, etc. Table 5 shows the data performance degradation due to ISI form adjacent ranging channel. It is shown that the impact of ISI can be significantly reduced if only 2 data subcarriers are used for guard bands.

Table 5. The data performance degradation due to ISI from adjacent ranging channel (8 ranging MSs).

Length of code	# of ranging guard subcarrier (guard bandwidth)	Performance degradation for 1% P_m and 0.1% R_{FA-64} [SNR]	
		QPSK	16-QAM
w/o ranging	-	-	-
w 719	0 / 1 (0 Hz)	0.82 dB	3.99 dB
w 709	5 / 6 (10.9375 kHz)	0.48 dB	1.64 dB
w 701	9 / 10 (19.6875 kHz)	0.43 dB	1.36 dB

4.4 Preamble Length

For the system to operate correctly, the ranging channel for non-synchronized MSs shall be able to operate at the same received SNR as data and any associated UL control signaling. In other words, when the minimum uplink data rate from a certain MS can support under worst situation, e.g., cell edge, the corresponding MS shall be able to basically access at the serving BS through the ranging channel for non-synchronized MSs. This implies that the required SNR for UL transmission with minimum data rate and initial/handover ranging coverage are strongly coupled. Simple power balancing between data and ranging channel is given by [11]

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

where T_P is the preamble duration, R is data rate. As the SNR for data channel is a function of the transmission data rate, we therefore need to establish a reasonable minimum data rate for data channel. For simple examples, we can assume that target E_p/N_0 and E_b/N_0 are 18 dB and 3 dB, respectively. Then, even if we consider the 64 kbps as minimum data rate, the required preamble length becomes longer than the duration of 4 OFDMA symbols. Therefore, it is preferable that ranging preamble shall be span in time domain and the length of ranging channel is same to the duration of a PRU (6 OFDMA symbols) as a baseline structure.

5. Conclusion

In this contribution, we proposed an enhanced ranging channel structure for non-synchronized MSs with the following details:

1. Several key structure aspects in the time- or frequency-domain for the 16m ranging channel consisting of the CP, RP, and GT structure should be considered in the IEEE 802.16m system.
2. The enhanced ranging structure should be spanned into the Nr_{sym} OFDMA symbols, i.e., 6 OFDMA symbols, in the time domain.
3. The enhanced ranging structure should be allocated in a localized band in the frequency domain for the avoidance of inter-subcarrier interference, enhanced detection performance and large number of reuse factor.
4. The some ranging frequency region should be reserved as a guard band to prevent inter-subcarrier interference.

Proposed Text for the System Description Document (SDD)

-- *Start of the Text* --

11.9.2.4 Ranging Channel for Non-Synchronized Mobile Stations

[Same contents in 11.9.2.4 in SDD [14] or later version]

11.9.2.4.1 Multiplexing with other control channels and data channels

[Same contents in 11.9.2.4.1 in SDD [14] or later version]

11.9.2.4.2. PHY structure

~~The ranging sequence design and mapping to subcarriers are TBD.~~

The physical ranging channel for non-synchronized mobile stations consists of three parts: 1) cyclic prefix (CP), 2) ranging preamble (RP) and 3) guard time (GT) as illustrated in Figure *x*. 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 ranging preamble shall be equal to or longer than CP length of ranging channel. The details on the length of each part and its configurations are FFS.

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

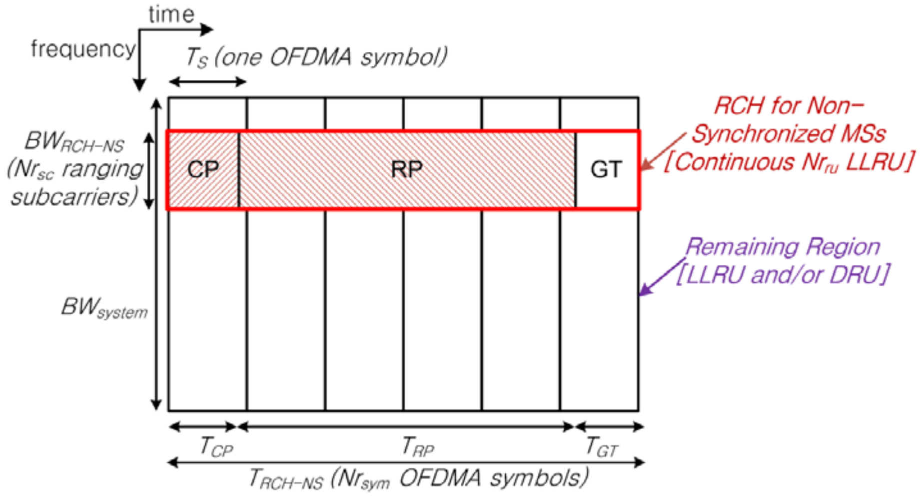


Figure *x*. Examples of ranging channel structure for non-synchronized mobile stations

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

Reference

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

[2] IEEE C802.16m-08/448r1, "Initial/Handover Ranging for IEEE 802.16m System," LG Electronics, March 2008.

[3] IEEE C802.16m-08/471, "Uplink Control Structures," Huawei, March 2008.

[4] IEEE C802.16m-08/853r2, "Ranging Channel Structure for the 802.16m SDD,", LG Electronics, July 2008.

[5] IEEE C802.16m-08/726r2, "Project 802.16m UL Control Structure Rapporteur Group Chairs' Report," July 2008.

[6] IEEE C802.16m-08/329, "Ranging Code Design for IEEE 802.16m," NCTU and MediaTek, March 2008.

[7] IEEE C802.16m-08/375, "Uplink Control Structure for RACH and PRCH," ETRI, March 2008.

[8] IEEE C802.16d-04/47r1, "OFDMA PHY Enhancements for Ranging," Intel, Samsung, Alvarion, et.al., March 2004.

[9] 3GPP R1-050777, "RACH Preamble Design," Texas Instruments, August 2005.

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

[11] 3GPP R1-060998, "E-UTRA Random Access Preamble Design," Ericsson, March 2006.

[12] IEEE 802.16m-08/004r2, "IEEE 802.16m Evaluation Methodology Document (EMD)," July 2008.

[14] IEEE 802.16m-08/003r4, "The Draft IEEE 802.16m System Description Document," July 2008.

Appendix : Simulation Parameters

All simulation parameters are based on [5, 12]. Table A.1 shows short summary.

Table A.1 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	8 LLRU
	Ranging Subcarrier Spacing	2.1875 kHz
	Ranging Detector	Frequency domain energy detector
	Number of Ranging Codes per Channel	64
	Number of Ranging Channel per Sector	1
	Codes Set per Sector	Random within all codes
	Code Selection per MS	Random within code set of sector
	Round Trip Delay	Random
	Target Miss-Detection Probability	1 %
	Target Overall False Alarm Rate	0.1 %