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Re:	IEEE 802.16m-08/016r1 - Call for Contributions on Uplink Control Structures
Abstract	This contribution addresses several issues and drawbacks of initial/handover legacy ranging structure. 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 802.16m SDD
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Initial/Handover Ranging for IEEE 802.16m System

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Introduction

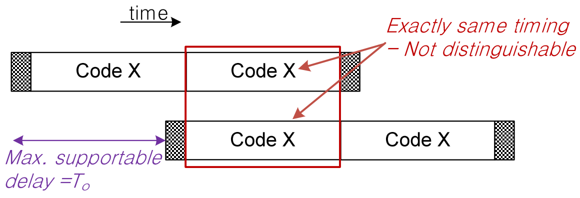
According to the IEEE 802.16m system requirements document [1], IEEE 802.16m shall provide significantly improved coverage with respect to WirelessMAN-OFDMA reference system [2]. Furthermore, the support for larger cell sizes should not compromise the performance for smaller cells. It is also required to support increased number of simultaneous users and enhanced user penetration property. In order to achieve the requirements related to the ranging channel, this contribution addresses the limitations of current IEEE 802.16e ranging structure and propose a new initial/handover ranging structure, which supports up to 50km of cell radius for 802.16m system.

Initial/Handover Legacy Ranging Structure in IEEE 802.16e

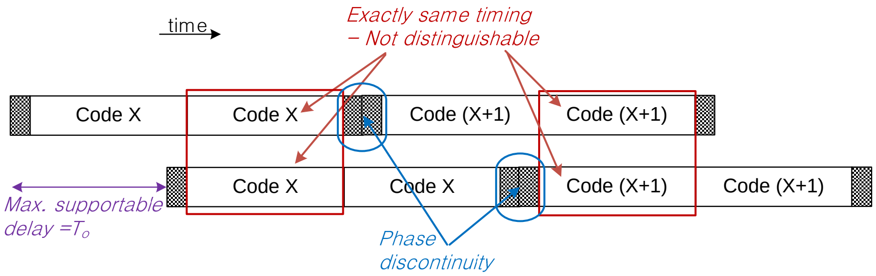
The WirelessMAN-OFDMA reference system has two types of initial/handover ranging structures. As already shown in [4-7], the current ranging channels have several drawbacks as follows:

1. **Limited Coverage for Timing Estimation**

   Figure 1 shows the 2 types of ranging structure for IEEE 802.16e, which consists of 2 or 4 OFDMA symbols, respectively. To cover the propagation delay related to the maximum delay spread and round trip delay (RTD) according to the cell size, the first (and third for Figure 1(b)) OFDMA symbol can be construed as a cyclic prefix to maintain the signal orthogonality at least for one uninterrupted FFT at the second (and forth for figure 1(b)) OFDMA symbol [5]. Then, the maximum supportable cell size is restricted by one useful symbol duration, T_0. If delay is longer than T_0, the detector can not distinguish between longer delay than T_0 and shorter delay than one. With this restricted maximum supportable delay, T_0, the current ranging structure can be covered up to only 12 km cell radius, if transmission power is enough. Even when 4-symbol ranging structure is used, the cell coverage is the same due to the phase discontinuity and there is the only combining gain from two ranging codes.



(a) 2-symbol ranging structure

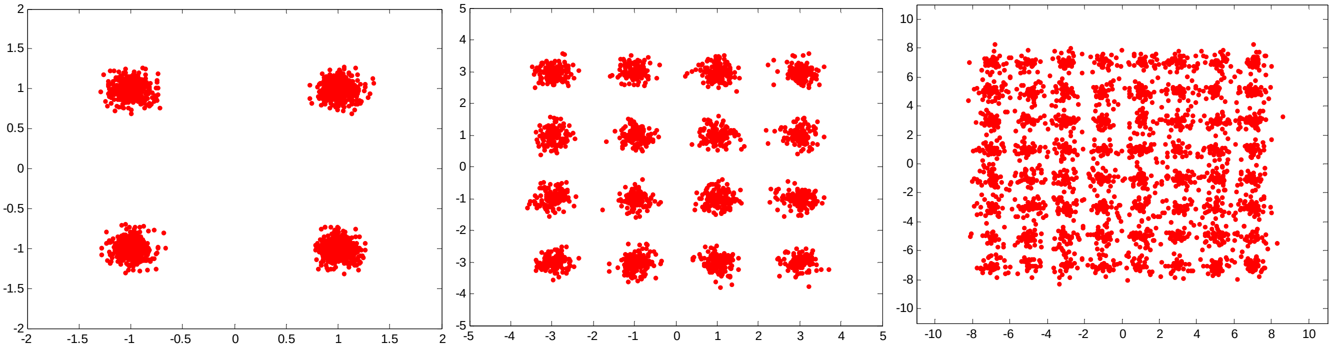


(b) 4-symbol ranging structure

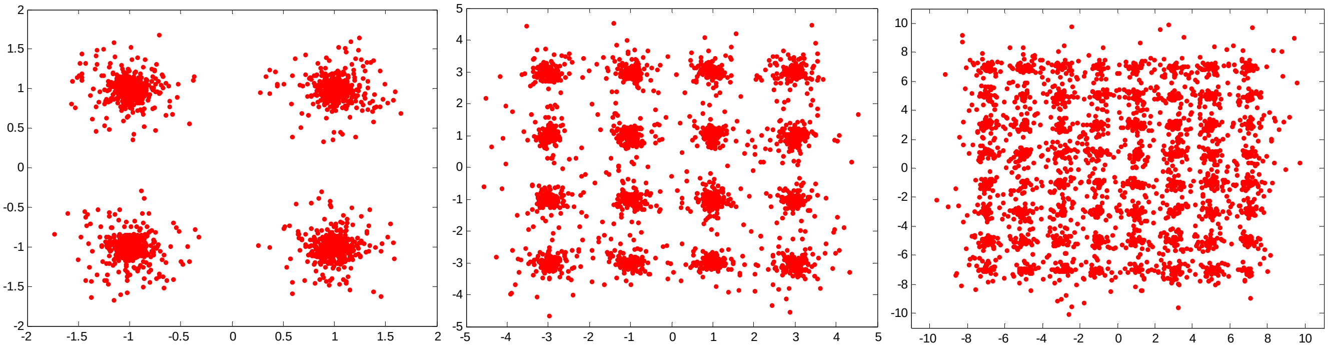
Figure 1. Ranging Structure for WirelessMAN-OFDMA reference system.

2. Interference from Ranging Channel to Data Traffic

One type of interference is in the form of co-channel interference to other ranging signals that coexist on the same ranging subcarriers. Another type of interference is in the form of inter-subcarrier interference (ISI) to data traffic that uses other subcarriers [6]. There are two types of degradation due to ISI. One is data performance degradation due to adjacent ranging delay and the other is ranging performance degradation due to mismatch with adjacent data CP region. Figure 2 illustrates the impact of the ISI on the data constellation due to raging signals delayed over OFDMA CP length.



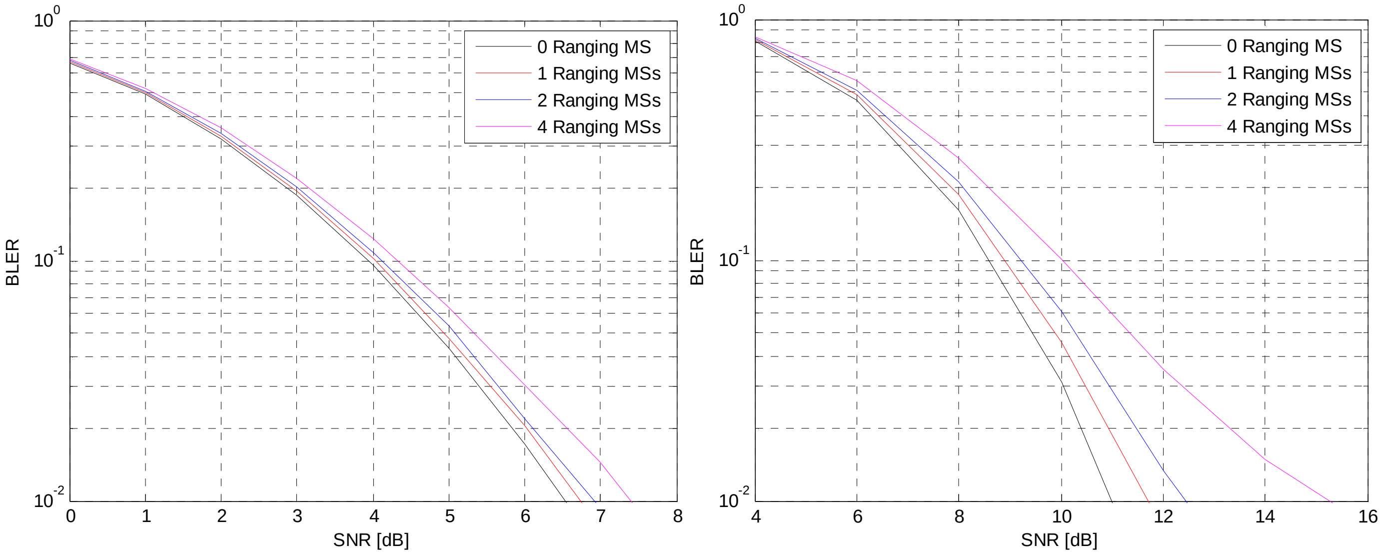
(a) 50 samples longer delay than OFDMA CP



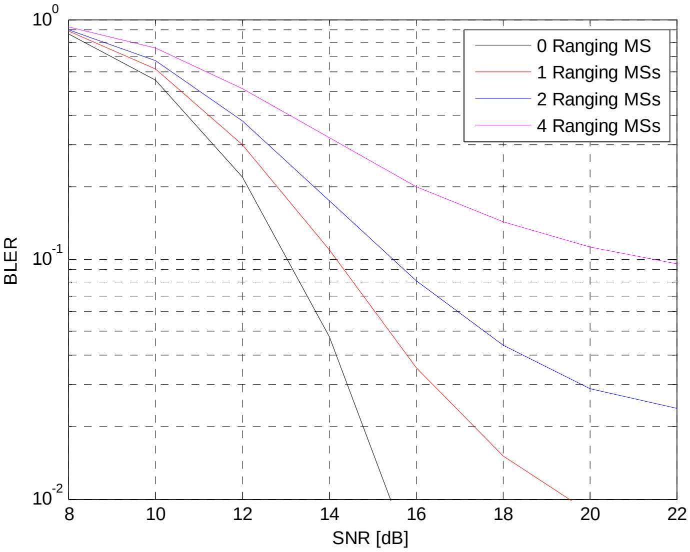
(b) 400 samples longer delay than OFDMA CP

Figure 2. ISI on data constellation due to ranging subcarriers (QPSK, 16-QAM and 64-QAM)

The impact of the ISI from adjacent ranging channel on the block error rate (BLER) is depicted in Figure 3. It is assumed that all uplink MSs transmit with the same signal power and there is one MS transmitting data traffic. Details of the simulation parameters are described in the Appendix. If one, two, or four MSs transmit(s) the ranging code at the same time, the data traffic suffers about 0.2 dB, 0.4 dB, or 0.9 dB of the SNR loss at 1% BLER with QPSK modulation, respectively. For 16-QAM, the loss is increased up to around 0.7 dB, 1.5 dB, or 4.3 dB, respectively. If higher modulation is used, these impacts become more serious.



(a) QPSK (b) 16-QAM



(c) 64-QAM

Figure 3. BLER degradation due to adjacent ranging channel.

3. Insufficient Power Balancing with Data

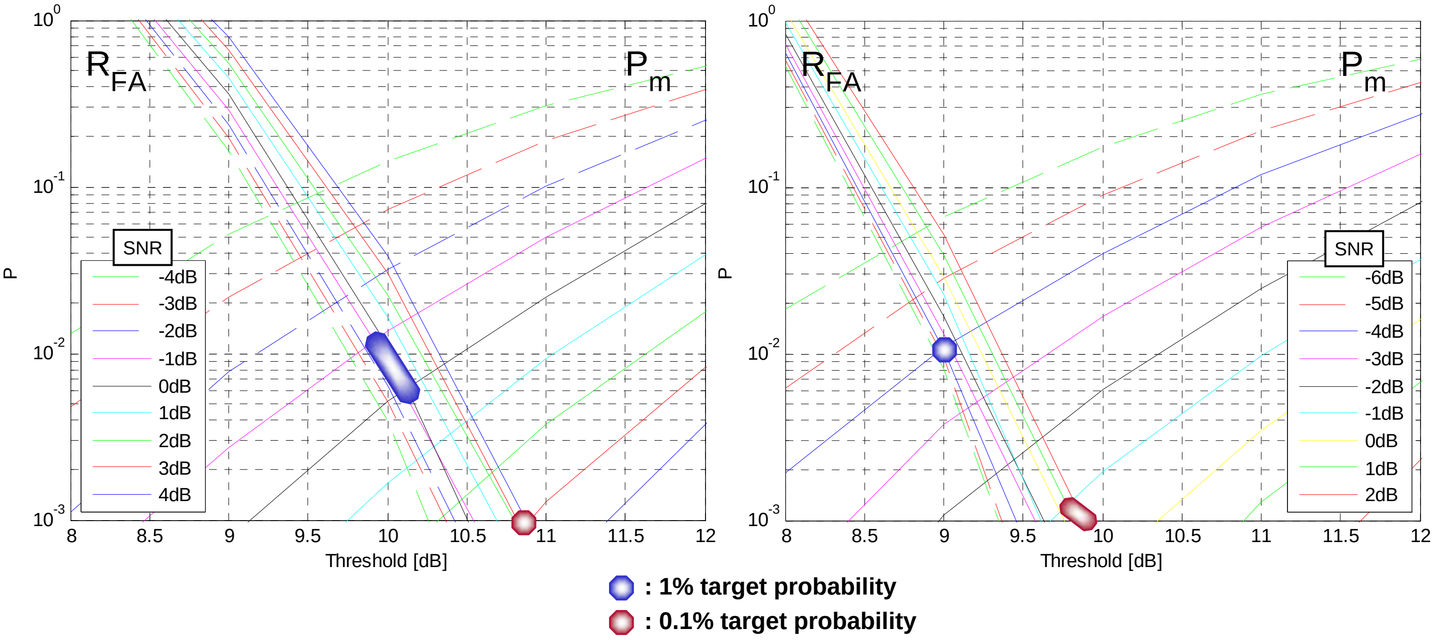
Since, when the minimum uplink data rate from a certain MS can support at the cell edge, the corresponding MS should be able to basically access at the serving BS via the ranging channel. This implies that the required SNRs for UL transmission with minimum data rate and initial/handover ranging coverage are strongly coupled. In order to further investigate this relationship in the legacy ranging channel, two performance metrics are defined as follows:

R_{FA} : The rates of a particular code being detected when the different code was transmitted.

- This rates are obtained by overall false alarm rates from preamble sequences since the BS should perform a correlation for all available preamble sequences per cell.

P_m : The probability of a particular code being does not detected when the particular code was transmitted.

It is assumed that the required SNR of VoIP at 10% BLER is 3 dB and the targets for both false alarm rate and miss-detection probability are 0.1%, which is the same target in the LTE [11], and 1%. Figure 4 shows the performance of legacy ranging channels with various threshold values, which is compared with the difference between peak and mean powers at the correlation stage. It is shown that the required SNR of legacy ranging structure with 2 symbols is about 3 dB or -0.5 dB at 0.1% or 1% target probability, respectively. If 4–symbol ranging structure is used, the required SNR is about -0.5 dB or -4 dB at 0.1% or 1% target probability, respectively. In the following, we consider only 4-symbol legacy ranging structure, which provides wider coverage.



(a) 2-symbol ranging structure

(b) 4–symbol ranging structure

Figure 4. Performance of legacy ranging channels with various thresholds.

In order to compare the coverage between minimum data rate (e.g. VoIP packet) and legacy ranging channel, the estimate of the received SNR in a link budget analysis is obtained as

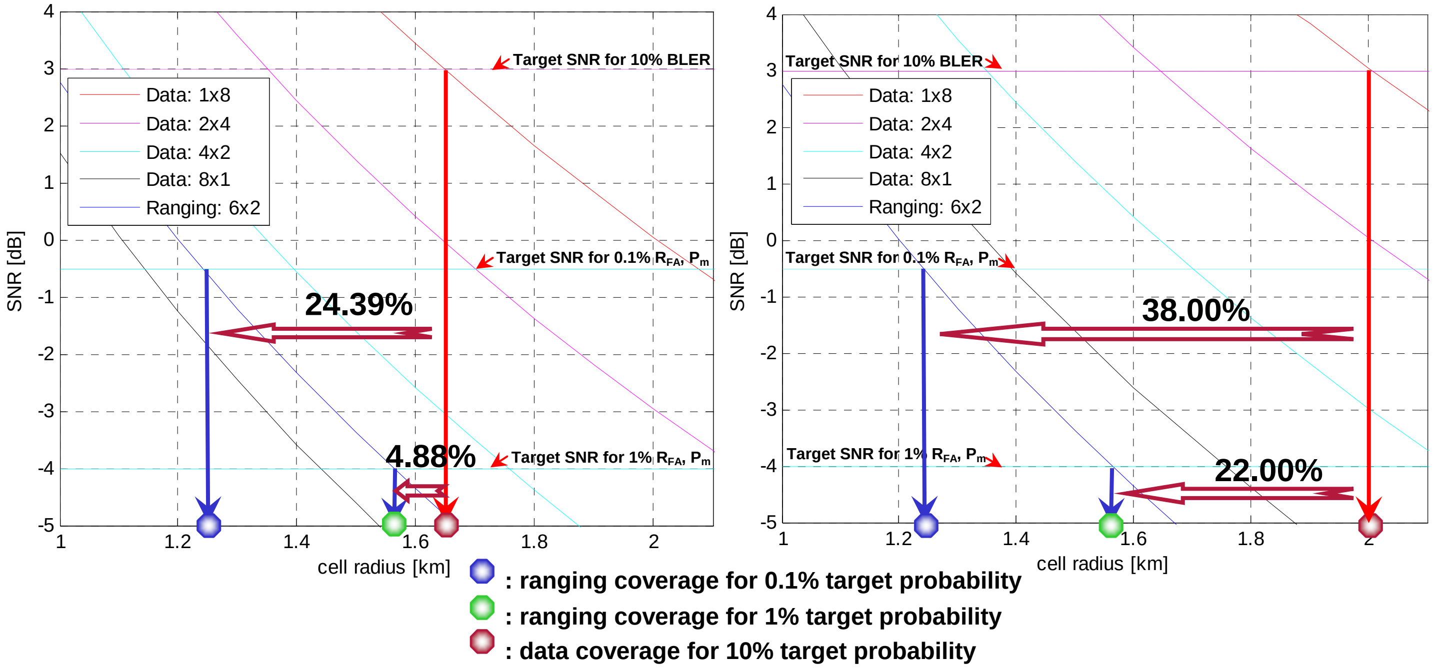
$$SNR = P_{SS} - PL - P_{noise} - NF_{BS} - L_{PL} + G_{BS} + G_{SS} - HF_{BS} - SH \quad \text{[dB]}$$

where P_{SS} is SS maximum transmit power, PL denotes the propagation loss, P_{noise} denotes the thermal noise power, NF_{BS} is the noise figure, L_{PL} is the penetration loss, G_{BS} and G_{SS} denote the BS and SS antenna gain , HF_{BS} denote the BS cable loss and SH denote lognormal shadowing power. The parameter values are based on [3] and, for simple analysis, we use only the antenna gain of boresight, 8 dB lognormal shadowing with f_c=2.5GHz, h_{BS}=32m, h_{MS}=1.5m.

Figure 5 shows the coverage both VoIP (44~46 bytes; 8 subchannels) and ranging under baseline path-loss model in [3]. Since the coverage of data traffic and ranging depends on its time- or frequency-domain span for the resource utilization, we consider several resource allocation sizes, i.e., 8 subchannels = (number of used subchannels in a time-domain) × (number of used subchannels in a frequency-domain), for VoIP transmission. However, the legacy ranging slot consists of 144 subcarriers

(6 subchannels). As shown in Figure 5(a), the VoIP without retransmission via (1×8) resource size can cover up to 1.64 km cell radius, whereas the coverage of the legacy ranging is only up to 1.24 km or 1.56 km cell radius at 0.1% or 1% target probability, respectively. This implies that some MSs, who transmit the VoIP data at the required SNR level, can not access the system via ranging channel. Therefore, the actual cell coverage is reduced to around 24.39 % or 4.88 %, which is the coverage of the legacy ranging channels. In Figure 5(b), the coverage of VoIP with 1 retransmission is extended up to 2.0 km cell radius. However, the actual cell coverage is also reduced to around 38.00 % and 22.00 %, respectively. It should be noted that if the number of access MSs at the same time increases under same target probability, this discrepancy of coverage between data and ranging channels increases.

The traffic channel coverage may enhance when the HARQ retransmission (maximum 8) and repetition (maximum 6) in [3] is supported as well as the physical resource unit is reduced such as 18 (or 9) subcarriers. In the IEEE 802.16m SRD [1], since the link budget improvement is required for the cell coverage enhancement, the legacy ranging structure has a serious limitation to meet the coverage requirements for IEEE 802.16m system.



(a) without retransmission of data (b) with 1 retransmission of data

Figure 4. The coverage comparison between legacy ranging and traffic channels.

4. Insufficient Link-Budget for Maximum Cell Coverage

Figure 5 shows the received SNR versus the cell radius according to the various channel environments. It is shown that the received SNRs are too low to detect ranging codes at large cell with all realistic path-loss channel models. Even if we consider only ideal free-space model and no interference, the legacy ranging structure with 4 OFDMA symbols can cover only 13.5 km and 22.7 km cell radius at 0.1% and 1% target probability, respectively. Therefore, the legacy ranging structure of reference system can NOT support the coverage requirement up to 50 km in [1]. To support this coverage requirement, additional link budget enhancement relative to the required SNR for the legacy ranging structure is over 11.4 dB at 0.1 % target probability (4.5 dB at 1% target probability).

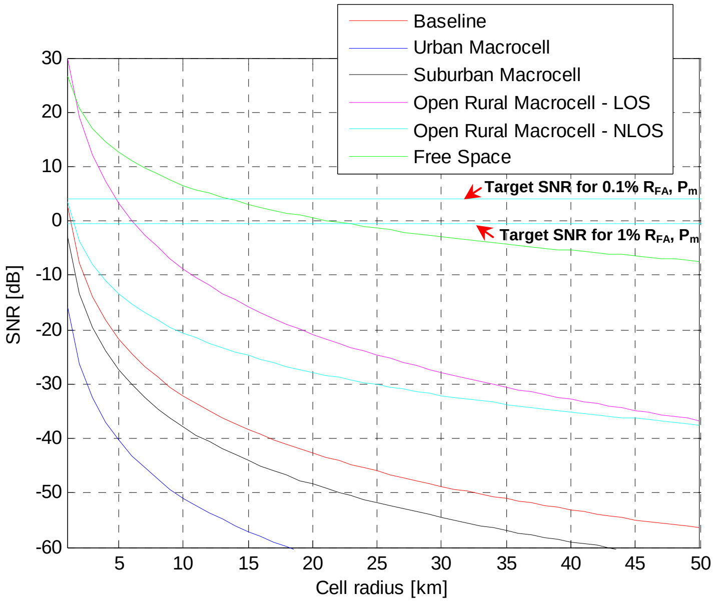
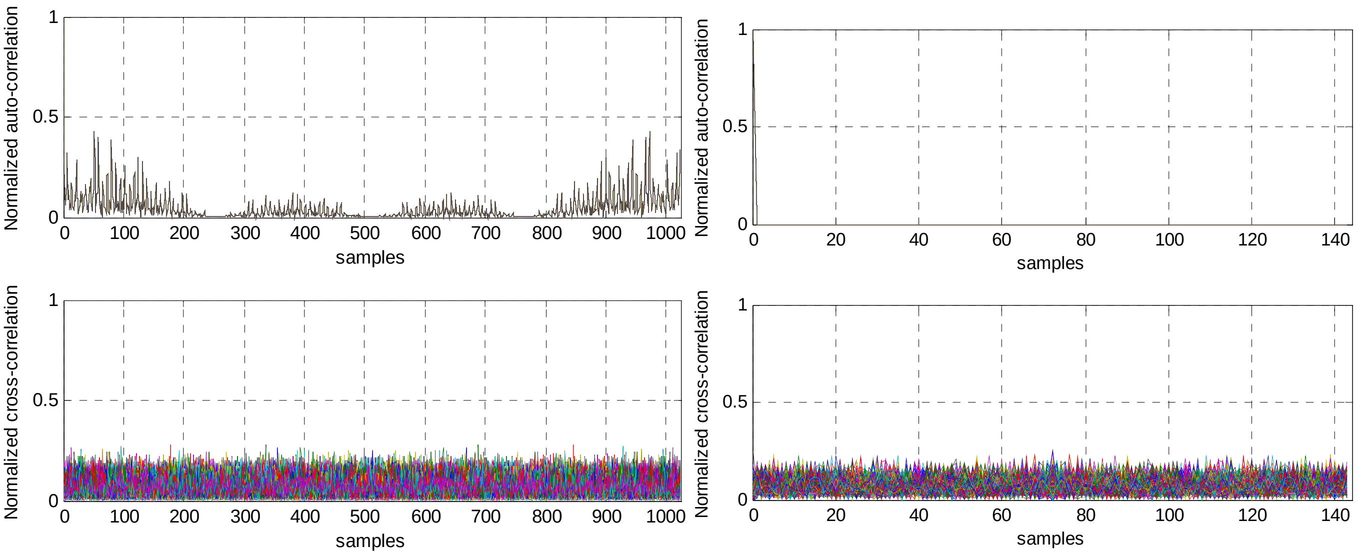


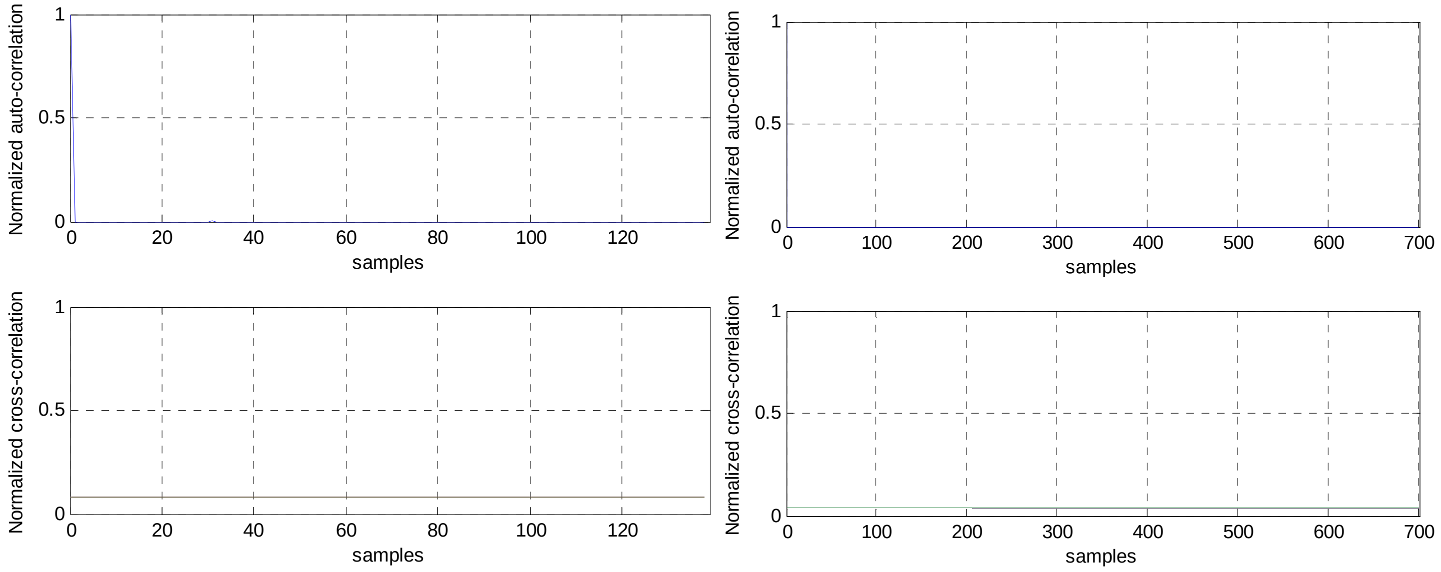
Figure 5. The received SNR vs. cell radius with various channel models.

5. Poor Cross Correlation Property

The legacy ranging codes are subsequences of Pseudo Noise (PN) sequence from PRBS. The cross correlation of the subsequences are quite high and the ranging codes are modulated in frequency domain, which means that in time domain the cross correlation between different codes is not optimized. Figure 6 compares the correlation property between legacy ranging codes and Zadoff-Chu (ZC) codes [8]. We assumed the length of ZC sequence is 139 and 701 as prime numbers. It is shown that the normalized cross-correlation of 16e codes is around 10 dB attenuation compared with the maximum autocorrelation value for AMC or PUSC, whereas the normalized cross-correlation of ZC codes with the lengths of 139 and 701 is about 21.4 dB and 28.5 dB attenuation compared with its maximum autocorrelation value, respectively.



(a) 144 length 16e codes – PUSC (b) 144 length 16e codes - AMC



(c) 139 length ZC codes - AMC

(d) 701 length ZC codes - AMC

Figure 6. An illustration of the correlation property between legacy and ZC codes

Table 1 shows the cross-correlation attenuation with various number of ranging codes. We can see that if there are several codes transmitting simultaneously, the cross-correlation level degrades seriously in the legacy ranging codes. It is also shown that the attenuation of ZC codes outperforms that of legacy codes. For example, if 7 MSs are trying to access in the same ranging slot at the same time, legacy codes can NOT be detected, i.e., the 16e codes can support in practical few users. In addition, we can find that the cross-correlation attenuation of a single legacy code is almost same with that of 4 ZC codes with the length of 701. This implies that the legacy ranging channel needs a large number of slots than new structure with ZC code of 701 length. It should be noted that using the cyclic shift of ZC codes with the same index allows more users under the same attenuation level and low detection complexity. The details of the proposed 16m ranging channel is shown in the following section.

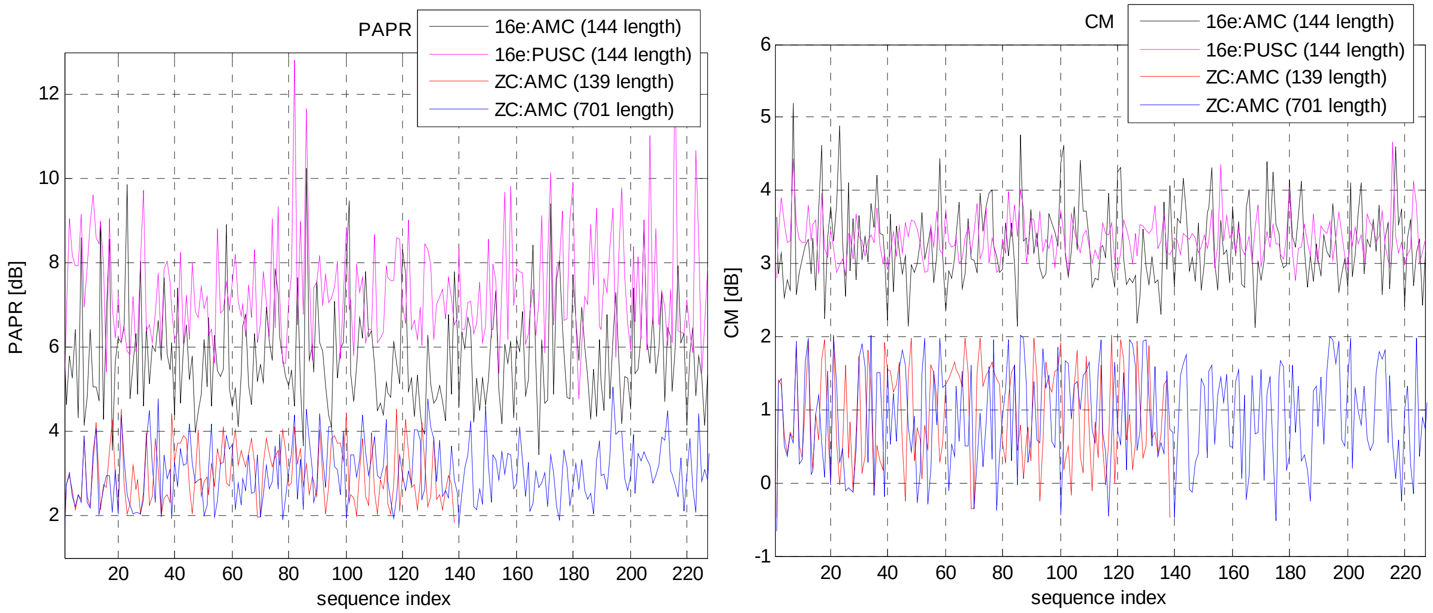
Table 1. The cross-correlation attenuation due to the increase of number of codes [dB]

	1 code	2 codes	3 codes	4 codes	5 codes	6 codes	7 codes
16e codes (144)-AMC	**12.041**	10.461	6.881	4.001	1.709	0.185	-0.023
16e codes (144)-PUSC	**11.046**	9.069	5.963	3.689	1.523	0.174	-0.023
ZC codes (139)	21.430	16.117	**11.224**	6.864	3.531	1.261	0.010
ZC codes (701)	28.457	22.786	17.290	**12.158**	7.686	4.234	1.804

6. Poor PAPR/CM

In order to provide the significant improvement of the coverage and link budget addressed in [1], the low PAPR and CM [9] property should be considered for cell edge and/or poor channel condition.

Figure 7 shows PAPR/CM property of legacy ranging codes and ZC codes. The CM of legacy codes is 2.1~5.1 dB, whereas the CM of ZC codes is 0.4~2.2 dB. The PAPR/ CM of legacy ranging signals is quite large, which reduces the output power from an MS and link budget due to backoff requirement.



(a) PAPR (b) CM

Figure 7. PAPR and CM property

7. Resource Waste

The ranging resource is not fully optimized. Even if 2-symbol ranging structure is used for a cell with large delay over the OFDMA CP, the actual used resource unit is 3 OFDMA symbols because the last symbol can be reserved as a guard time to prevent inter-symbol interference to next OFDMA symbol. As a result, the legacy ranging structure uses the symbol-wise utilization such as one CP symbol, one code symbol, and one GT symbol without resource optimization. In the case where the first and third symbols can be used as the CP for uninterrupted FFT as shown in Figure 8, there are multiple CP symbols and a GT symbol following a ranging slot. In addition, even though the remaining OFDMA symbol(s) after a ranging slot can be used as a periodic ranging or BR transmissions, the efficient utilization of the resources or the flexibility of the control channel allocation may be quite limited to the allocation of such a ranging slot.

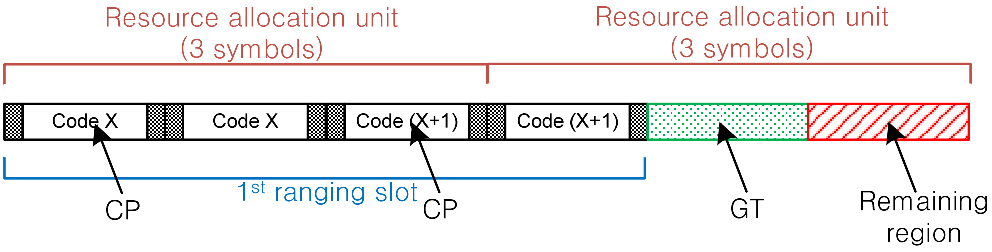


Figure 8. Example of resource usage in a 4-symbol ranging structure

Design Criteria for Ranging Structure for IEEE 802.16m System

In the following, we consider some design criteria for ranging structure in the IEEE 802.16m system. Then, based on the several consideration points, we propose a new 802.16m ranging structure with the time expansion to enhance the supportable cell coverage and to be robust against the adjacent channel impact and large delay in accordance with the 802.16m requirements.

1. **Time-Domain Aspects**
   - 1.1 The CP (cyclic prefix) is needed to prevent the inter-subcarrier interference and to provide frequency domain detector for simple implementation.
   - 1.2 The GT (guard time) is needed to prevent the inter-symbol interference to next OFDMA symbol.
   - 1.3 The preamble has the length over the maximum delay considering RTD and channel delay, e.g., 344.7856 μs (11.43 μs+333.3556 μs), to support up to 50 km cell radius as a baseline structure.
   - 1.4 In a time domain, the ranging signal should have low cross-correlation and low PAPR/CM property for IEEE 802.16m system.

2. **Frequency-Domain Aspects**
   - 2.1 The localized frequency region should be used to prevent the interference to adjacent channels and to increase the number of available ranging codes (including the cyclic shifts), which provides enhanced ranging detection performance [12].
   - 2.2 The edges of the localized ranging frequency region should be reserved as a guard band to prevent inter-subcarrier interference.
   - 2.3 The UL symbol timing accuracy should be smaller than $(T_b/32)/4$, which is the timing synchronization requirements in [8]. As a result, the 16m ranging bandwidth should be larger than 1.4MHz. The number of subcarriers in legacy ranging channel, i.e., 144 subcarriers, is a strong candidate for all system bandwidths in the IEEE 802.16m system.
   - 2.4 Considering the Doppler frequency at 350 km and residual frequency offset (2% of data subcarrier spacing [2]), the minimum ranging subcarrier spacing should be larger than twice 1.0289 kHz (810.1852Hz@2.5GHz + 218.75Hz).

Proposed Ranging Structure for IEEE 802.16m System

Based on the design criteria above, we propose an expanded structure with a length of 6 OFDMA symbols as a baseline ranging structure for IEEE 802.16m system. The proposed ranging structure has 1.575 MHz ranging channel bandwidth, i.e., 144 subcarriers. The ranging resource unit consists of a localized band in the contiguous OFDMA symbols. The remaining resource region can be used for both localized or distributed subchannelization for data traffic or other control signals.

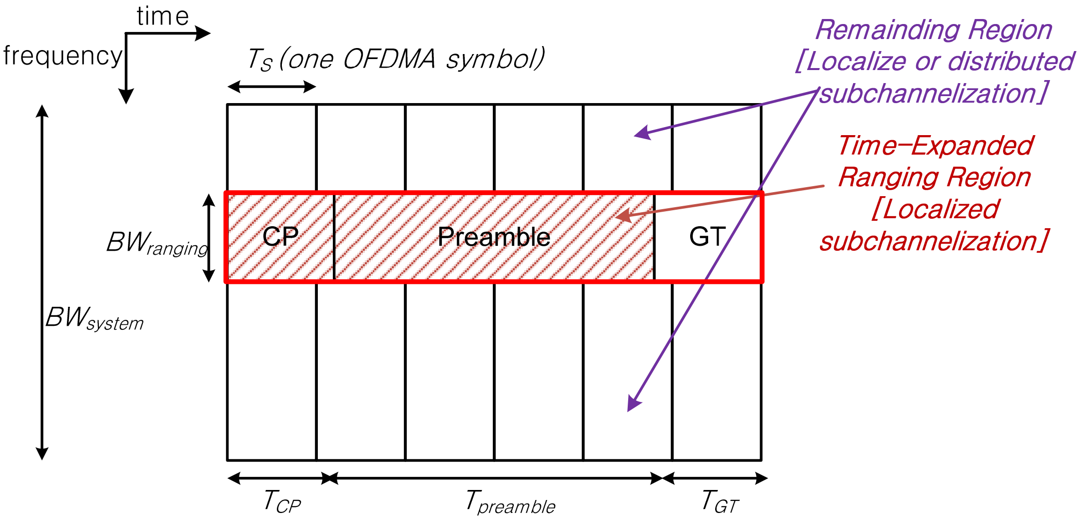
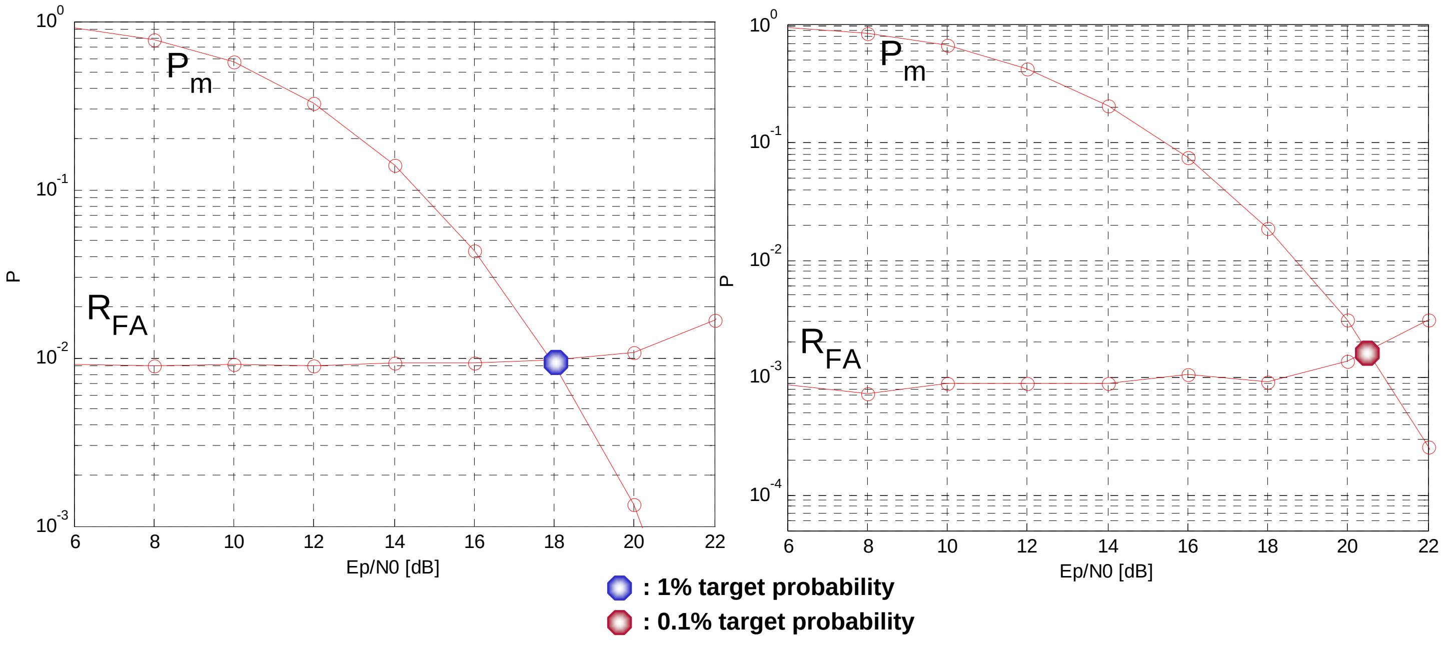


Figure 9. Baseline of time-expanded ranging structure

Figure 10 shows the performance of the proposed ranging channel as an illustration. It is assumed that the lengths of CP, preamble, and GT are 85.71 μs, 457.14 μs, and 74.30 μs, respectively. Then, the ranging structure has 720 subcarriers with the subcarrier spacing of 2.1875 kHz. The ZC sequence with a length of 701 is considered. The remaining subcarriers are used as guard band to prevent inter-subcarrier interference. Assuming that there are 64 opportunity per cell, a cell uses only one root index with 10-sample cyclic shifts. The threshold is determined in terms of the target R_{FA} as the analysis in [11]. We employ the preamble energy per noise spectral density E_p / N_0 because the time duration of one ranging sequence is longer than that of one OFDMA symbol. From Figure 10, we can find that the required E_p / N_0 is 18dB or 20.5 dB at 1% or 0.1% target rates.



(a) Target R_{FA}=1%

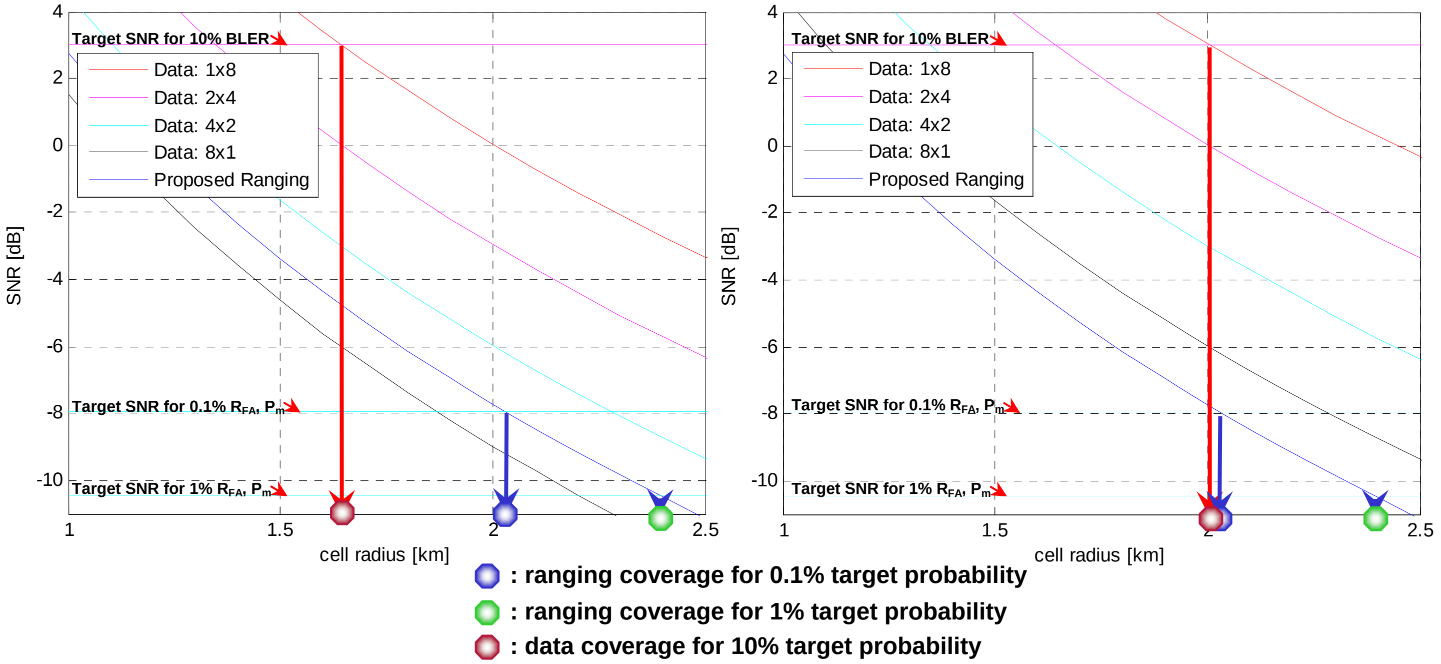
(b) Target R_{FA}=0.1%

Figure 10. The performance of the proposed ranging channel.

For further evaluation on the supportable cell coverage of the proposed ranging channel, using a simple power balancing relation [11]

$$\frac{E_p}{N_0} = \frac{S}{N} \cdot N_p$$

where N_p is the generated sequence length, we obtain that the required SNR of the proposed ranging channel is given by -10.46dB or -7.96 at 1% or 0.1% target rates, respectively. Figure 11 shows the coverage comparison between traffic channel and ranging channel. Compared with the results in Figure 4, it is shown that the proposed time-expanded ranging channel has larger coverage than minimum data rate transmission even when the HARQ retransmission is considered. This implies that all MSs communicating with BS for minimum packet transmission such as VoIP can always access the system by using the proposed ranging channel.



(a) without retransmission of data (b) with 1 retransmission of data

Figure 11. The coverage comparison between proposed ranging and data.

As compared with the maximum cell coverage of the legacy ranging channel in Figure 5, the proposed ranging structure can cover a cell radius of 50 km at the free space environment without interference irrespective of the target rates as shown in Figure 12. It should be also noted that the required preamble energy may be increased to support the realistic path-model and interference-limited environments. Further performance evaluation and the investigation of the specific parameters are required along with the design of the uplink data and control channels for the IEEE 802.16m system.

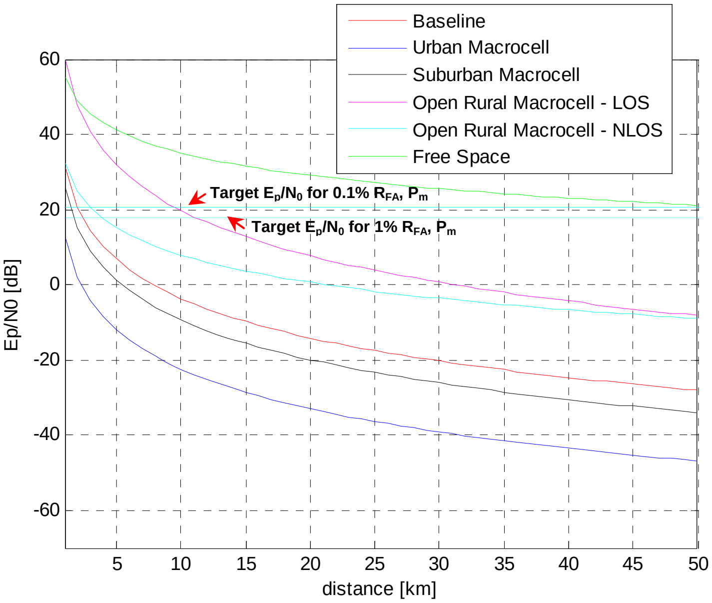


Figure 13. The received E_p / N_0 according to cell radius.

Conclusion

In this contribution, we addressed some drawbacks of initial/handover legacy ranging structure and proposed a new time-expanded initial/handover ranging structure with the following details:

1. Several design criteria in the time- or frequency-domain regarding the CP, preamble, and GT for a new ranging channel should be considered in the IEEE 802.16m system.
2. The proposed ranging structure should be spanned into the multiple OFDMA symbols in the time domain such as 6 OFDMA symbols for a baseline structure.
3. The proposed ranging structure should be allocated in a localized band in the frequency domain for the avoidance of inter-subcarrier interference and enhanced detection performance.
4. The edges of the localized ranging frequency region should be reserved as a guard band to prevent inter-subcarrier interference.

Proposed Text for the System Description Document (SDD)

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[*Editor's Notes: create & add the following section & text into the System Description Document*]

11. Physical Layer

11.x. Uplink Physical Structure

11.x.a. Uplink Physical Resource Allocation

For the uplink resource allocation in the IEEE 802.16m system, the localized resource region should be first reserved for supporting some types of uplink control channels such as a time-expanded initial/handover ranging channel. The remaining resource is used for the localized and/or distributed subchannelization for data traffic or control channels.

11.y. Uplink Control Channels

11. y. a. Initial/Handover ranging channel

The time-expanded ranging channel consists of three parts for cyclic prefix (CP), Preamble, and guard time (GT) as shown in Figure 11.y.a.1. The resource for the time-expanded ranging channel is allocated in the Nr_{sc} consecutive subcarriers by Nr_{sym} consecutive OFDMA symbols. The Nr_{sc} and Nr_{sym} are equal to 144 subcarriers and 6 OFDMA symbols for baseline structure, respectively. The length of CP and GT should be longer than the maximum round trip delay (RTD) according to cell radius. The default length of preamble is longer than the RTD for the maximum cell coverage with a cell radius of 50 km. The Zadoff-Chu sequence and its cyclic shifts are used for the preamble sequence. The details of the length of preamble and preamble configurations are FFS. In order to avoid the inter-subcarrier interference, the frequency edges of the time-expanded ranging resource region may be reserved as a guard band.

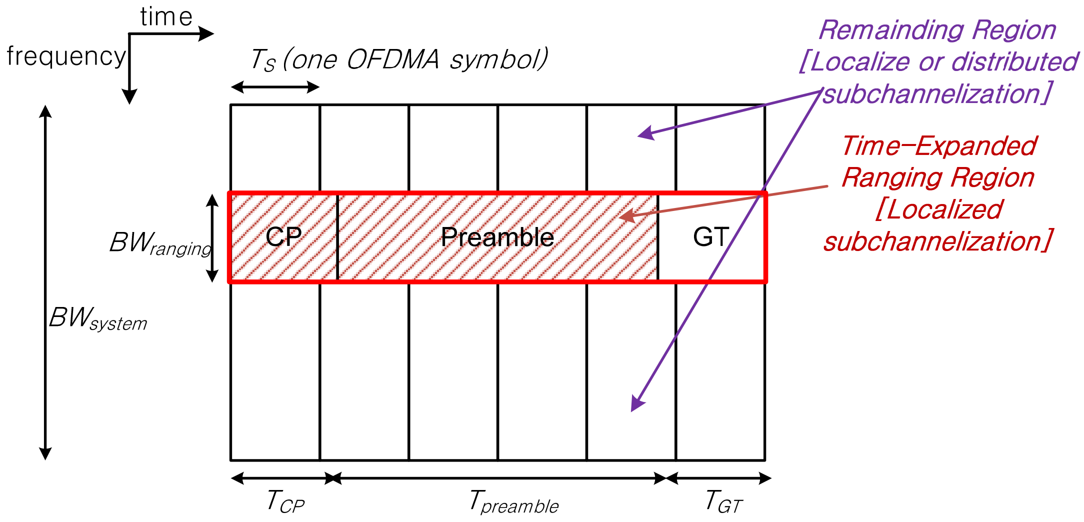

Figure 11.y.a.1. Baseline of Time-Expanded Ranging Structure for IEEE 802.16m System

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Reference

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Appendix : Simulation Parameters

All simulation parameters are based on [3]. 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
	UL Permutation (UL_{Perm})	PUSC with $UL\_Perm\_Base = 0$.
	Residual Frequency Offset	random < 218.75 Hz (< 2% of Δf)
Channel	Multi-antenna Transmission Format	1 Tx
	Receiver Structure	2 Rx
	Fading Channel Model	Modified Pedestrian B
	UE Speed	3 km/h
Data	Data Resource	1 subchannel
	Channel Coding	CTC 1/2 rate
	Channel Estimation	2D MMSE
Ranging	Ranging Resource	144 subcarriers (0~5th subchannel)
	Ranging Detector	Frequency domain energy detector
	Number of Initial Ranging Codes per Slot	64
	Round Trip Delay	random