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Title	**Proposed AWD Text on the Ranging Codes for Non-synchronized AMSs**	
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Re:	IEEE 80216m-09/0020, “Call for Contributions on Project 802.16m Amendment Working Document (AWD) Content” “Comments on AWD 15.3.9 UL-CTRL”	
Abstract	This contribution proposes the text of ranging channel section to be included in the IEEE 802.16m AWD.	
Purpose	To be discussed and adopted by TGm for the IEEE 802.16m AWD	
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Proposed AWD Text on the Ranging Codes for Non-synchronized AMSs

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1. Introduction

This contribution discusses the cell load and ranging load estimation for non-synchronized AMSs and provides a text proposal about the number of opportunities and type of ranging preamble code.

2. Cell Load Estimation

Table 1 describes the representative (busy hour) traffic model for ranging transmissions for non-synchronized AMSs [1].

Table 1. An example traffic model that the ranging channels for non-synchronized AMSs are transmitted in busy hour from [1].

Transmission cause		**Number of attempts**
Initial access	Tracking area update	6 times / hour
	Number of realtime (RT) service calls	1 call / hour
	Number of non-realtime (NRT) service calls	2 calls / hour
Handover complete Cell change interval is assumed to be 20 s.	RT service The holding time is assumed to be 90 s.	4.5 times / call (= 90 / 20)
	NRT service The sojourn time is assumed to be 300 s.	15 times / call (= 300 / 20)
UL bandwidth request	RT service Persistent resource allocation is assumed, hence causing no UL bandwidth request.	0 time / call
	NRT service	4 times / call

From the parameters of Table 1, we don’t consider the ‘tracking area update’ and ‘UL bandwidth request’ because it is not essential for initial/handover ranging channel.

In Table 2, we have calculated the “relative cell load” caused by different number of AMSs present in a cell for 10 MHz system bandwidth. “RT calls in parallel” means the number of calls going on in parallel with a holding time. “Total amount of DL WWW” means the total amount of downloaded traffic in Mbits for non-real-time traffic. It is based on the Web Browsing (HTTP) traffic model of EMD [2] but it is considered only mean value without distribution for simple analysis. It also is assume every AMSs downloads 5 WWW pages per call like [3]. “Relative cell load” is calculated based on the VoIP capacity or absolute sector throughput of SDD [4]. A 10 MHz cell can handle 300 VoIP calls or 16.25 Mbps throughput of NRT user data for TDD mode (5:3 ratios). For

FDD mode, a 10 MHz cell can handle 600 VoIP calls or 26 Mbps throughput of NRT user data.

As can seen from Table 2, a 10 MHz cell should be able to handle around 6000 AMSs and 11000 AMSs for TDD and FDD mode, respectively.

Table 2. Cell load of 10 MHz cell for different numbers of AMS's in the cell

Number of AMSs [k]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	50	100
RT calls in parallel [calls/holding time]	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	500	1250	2500
Total amount of DL WWW [Mbits]	1.21	2.42	3.63	4.84	6.05	7.26	8.47	9.68	10.89	12.10	13.31	14.52	15.73	16.94	18.16	24.21	60.52	121.03
Total relative cell load for TDD [%]	15.78	31.56	47.34	63.13	78.91	94.69	110.47	126.25	142.03	157.82	173.6	189.38	205.16	220.94	236.72	315.63	789.08	1578.16
Total relative cell load for FDD [%]	8.82	17.64	26.47	35.29	44.11	52.93	61.75	70.57	79.4	88.22	97.04	105.86	114.68	123.51	132.33	176.44	441.09	882.18

3. Ranging Load Estimation for Non-Synchronized AMSs

Table 3. Ranging load of 10 MHz cell for different numbers of AMS's in the cell

Number of AMSs [k]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	50	100
RT load	0.28	0.56	0.83	1.11	1.39	1.67	1.94	2.22	2.50	2.78	3.06	3.33	3.61	3.89	4.17	5.56	13.89	27.78
NRT load	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RT HO load	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	15.00	16.25	17.50	18.75	25.00	62.50	125.00
NRT HO load	15.97	31.94	47.92	63.89	79.86	95.83	111.81	127.78	143.75	159.72	175.69	191.67	207.64	223.61	239.58	319.44	798.61	1597.22
Total load	17.50	35.00	52.50	70.00	87.50	105.00	122.50	140.00	157.50	175.00	192.50	210.00	227.50	245.00	262.50	350.00	875.00	1750.00

A brief description of the different rows as follow:

- RT load : This is the load caused by RT call establishments (1 ranging per call). No ranging access is assumed during the VoIP call.
- NRT load : This is the load caused by NRT traffic. The number to be used depends on the operator policy. E.g., how long to keep a AMS in UL synchronization during inactivity, and when to move a AMS to IDLE. Table 3 is assuming that a ranging access attempt per WWW page download.
- RT HO load : This is the handover related ranging load caused by RT calls.
- NRT HO load : This is the handover related ranging load caused by NRT traffic. In this case, the number to be used depends on the operator policy. E.g., how long to keep a AMS in UL synchronization during inactivity, and when to move a AMS to idle. Table 3 is assuming that the AMS access to ranging to re-synchronization every 60s.

It should be noted that the calculations above do have their limitations. E.g., it assumes only 2 types of traffic (RT/NRT) load, etc.

As a result we assume that roughly,

1) Ranging loads of up to 105 access/second and 192 access/second should be considered as normal situation for TDD and FDD mode, respectively.
2) Due to uncertainties in the modeling and for high-load-area cells, also leads of 300 should be supported without to much difficulty.
3) Load of several hundred or even up to 1000 access/second can be considered quite rare.

Note that also it will be able to increase highly for multicarrier mode.

4. Probability of Collision

In the section, we analysis the required number of signatures with analyzed ranging load of section 3 for target collision probability. If more than one AMS transmit the same signature sequence into the same time-frequency ranging channel, the collision of signature sequence occurs. Although ABS can detect which signature sequence is transmitted based on its power profile, ABS generally can not detect whether the collision occurs or not. Therefore, ABS send only one ranging response to corresponding one signature. The ranging response includes one timing advance information, UL bandwidth, AMS ID and so on. The response also includes signature specific ID on the downlink.

In the next step, all AMSs that have the collision in the ranging preamble send 1st UL message which contains MAC message with transmission timing according to the timing advance indicated by the ranging response. This timing advance would be correct value for one of collided AMSs. However, this timing advance is usually not correct value for the other AMSs. Therefore, the 1st UL message transmitted from the UEs with wrong TA value would exceed cyclic prefix length. This 1st UL message would interfere with the next sub-frame. Therefore, the target collision probability of the random access preamble should be small enough (e.g. 1% or less) in order not to decrease the performance of the next sub-frame to the 1st UL message.

For the collision probability calculation methodology, the simple statistical method is used, i.e. based on Poisson distribution [6]. The probability of k ranging access attempts occurred at on transmission opportunity $P_{oppt}(k)$ is defined as

$$P_{oppt}(k)=\frac{1}{k!}\left(\gamma / N_{res}N_{sig}\right)^{k} e^{-\gamma/N_{res}N_{sig}}$$

where γ is the number of ranging access attempts per second, N_{res} is the number of ranging channel per second and N_{sig} is the number of ranging signatures per ranging channel. Therefore, $N_{res}N_{sig}$ is the ranging transmission opportunity per second. The collision probability per one signature index, $P_{coll\ per\ sig.}$, is defined as

$$P_{coll\ per\ sig.} = 1 - \left(P_{oppt}(0) + P_{oppt}(1)\right) = 1 - \left(1 + \gamma / N_{res}N_{sig}\right)e^{-\gamma / N_{res}N_{sig}}$$

The collision probability per one ranging channel, $P_{coll\ per\ ch.}$, is defined as

$$P_{coll\ per\ ch.} = \sum_{i=i}^{N_{sig}} P_{coll\ per\ sig.}$$

Figure 1 shows the examples of calculated collision probabilities per ranging channel. In figure 1, N_{res} is 200 per second which it is corresponded one ranging channel per frame. N_{sig} is 8, 16, 32, 64, and 128, respectively.

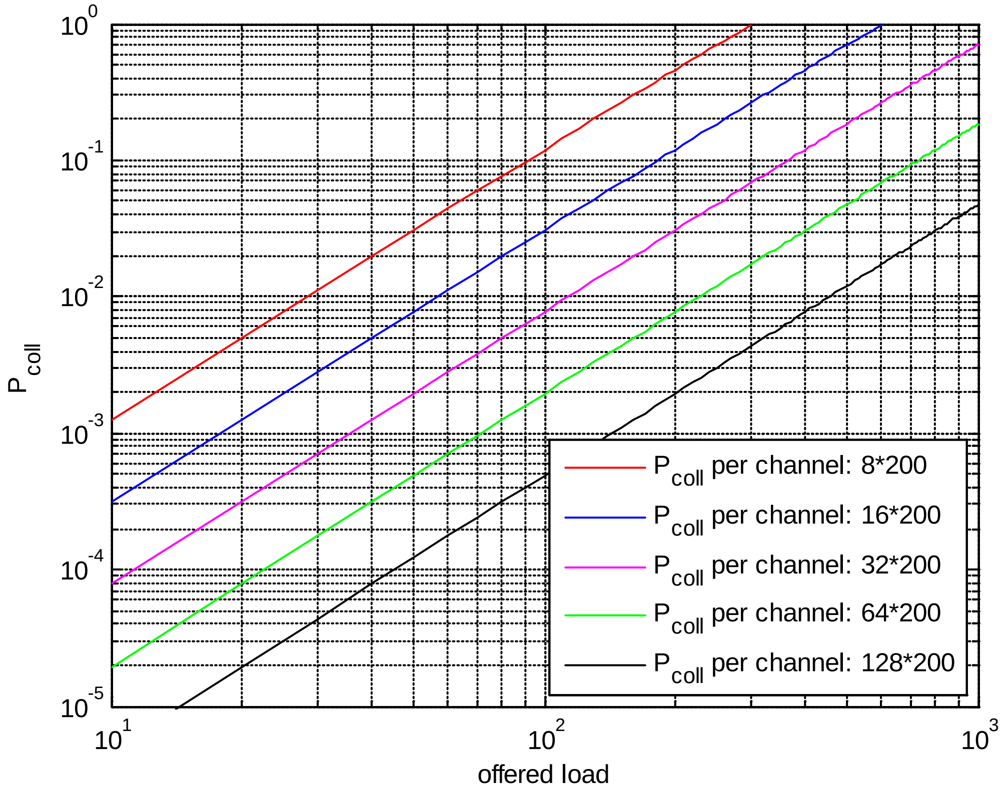


Figure 1. Probability of collision according to different signature

From the figure 1, if we consider a load up to 105 and 192 access/seconds for TDD and FDD mode respectively, and a collision probability per ranging channel of 1%, we need to have

1. 32 signature per ranging channel for TDD mode
2. 64 signature per ranging channel for FDD mode

If we want to supports ranging loads of up to 300 access/second, the amount of required resources would have to double.

5. The number of signature per ranging channel

From the upper analysis, 32 and 64 signature per ranging channel is needed for TDD and FDD mode, respectively. But, it is just normal load when one ranging channel is present per frame. The ranging load as well as ranging channel allocation can be varying in real environments. Also, some situation, e.g., small cell, hot spot, relay, etc, many number of signature is not needed and the increased reuse factor among sectors is more important. Therefore, lower or higher number of signature than 32 and 64 can make flexible system. We are proposed the 2 bits signaling for the number of signature per ranging channel, N_{set}, as Table 4.

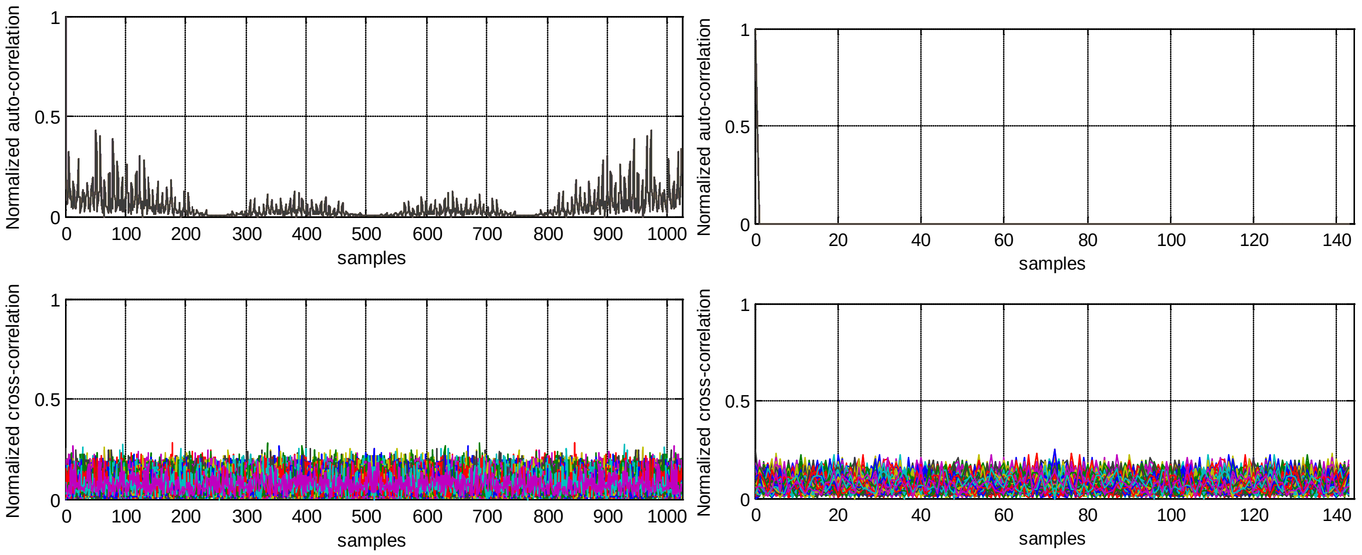
Table 4. The number of signature per ranging channel, N_{set}, according to duplex mode.

N_{set} configurations	**FDD duplex mode**	**TDD duplex mode**
00	128	64
01	64	32
10	32	16
11	16	8

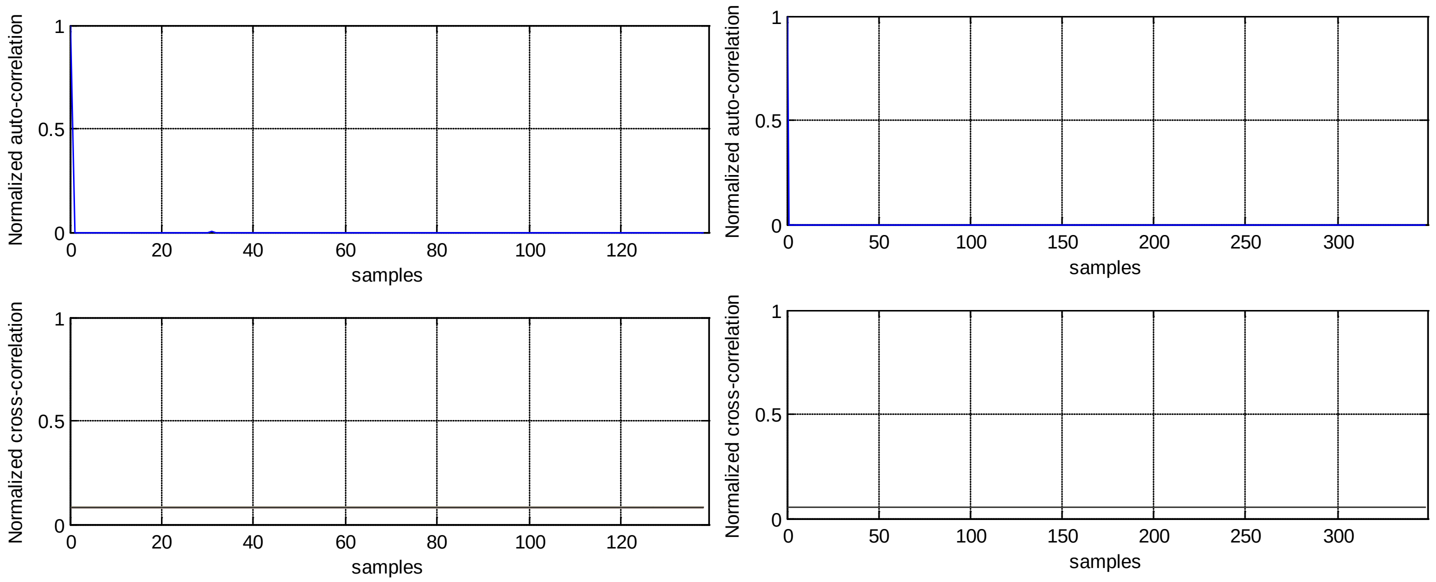
6. Type of ranging preamble code

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 2 compares the correlation property between legacy ranging codes and Zadoff-Chu (ZC) codes. We assumed the length of ZC sequence is 139 and 349 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 349 is about 21.4 dB and 25.4 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) 349 length ZC codes - AMC

Figure 2. An illustration of the correlation property between legacy and ZC codes

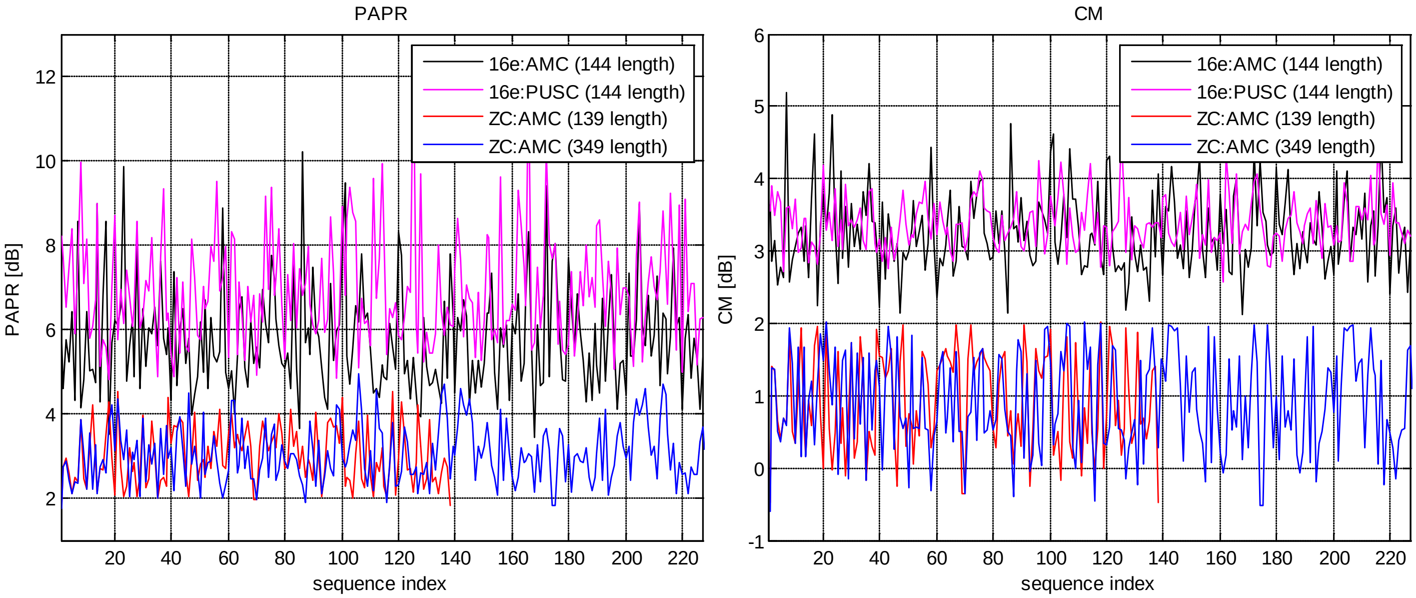
Table 5 shows the cross-correlation attenuation with various number of ranging codes. We can see that if there are several codes transmitting simultaneously, the cross-correlation level degrades seriously in the legacy ranging codes. It is also shown that the attenuation of ZC codes outperforms that 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 MSs. In addition, we can find that the cross-correlation attenuation of a single legacy code is similar with that of 4 ZC codes with the length of 349. This implies that the legacy ranging channel needs a large number of slots than new structure with ZC code of 349 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.

Table 5. 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 (349)	25.428	19.861	14.603	9.786	5.770	2.898	0.971

Poor PAPR/CM

In order to provide the significant improvement of the coverage and link budget, the low PAPR and CM property should be considered for cell edge and/or poor channel condition. Figure 3 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 AMS and link budget due to backoff requirement.



(a) PAPR (b) CM

Figure 3. PAPR and CM property

7. Conclusion

The ranging channel for non-synchronized AMSs should be designed considering situation as follow:

1. Regarding ranging load,
   A. Ranging loads of up to 105 access/second and 192 access/second should be considered as normal situation for TDD and FDD mode, respectively.
   B. Due to uncertainties in the modeling and for high-load-area cells, also leads of 300 should be supported without too much difficulty.
   C. Load of several hundred or even up to 1000 access/second can be considered quite rare.
2. Regarding the number of signature per ranging channel for normal load,
   A. 32 signature per ranging channel for TDD mode
   B. 64 signature per ranging channel for FDD mode
3. The proposed number of signature per ranging channel shown in Table 4.
4. The Zadoff-Chu codes with cyclic shift should be considered as ranging preamble code.

Reference

[1] 3GPP R2-062160, “RACH Contention and Retry Cases,” NTT DoCoMo, September 2006.

[2] IEEE 802.16m-004r5, "IEEE 802.16m Evaluation Methodology Document (EMD)", January 2009.

[3] 3GPP R2-070205, "LTE cell load / RACH load estimations," Samsung, January 2007.

[4] IEEE 802.16m-08/002r8, "IEEE 802.16m System Requirements", January 2009.

[5] 3GPP R1-062176, "Collision Probability Analysis of RACH with Control Information," Panasonic, NTT DoCoMo, September 2006.

[6] IEEE 802.16m-08/0010r1a, "IEEE 802.16m Amendment Working Document," March 2009.

Text proposal for inclusion in the 802.16m amendment

Black text: current text in the subclause *15.3.9.2.4.1 Ranging channel for non-synchronized AMSs* of [6]
~~Red Strike through Text~~: Deleted
Blue text: new text
[Bracketed Italic text]: Informative

[------------------------------------ Text Proposal #1 ---------------------------------]

-- *Text Start* --

15.3.9.2.4.1. Ranging channel for non-synchronized AMSs

~~Ranging preamble codes~~

15.3.9.2.4.1.1. Ranging Preamble Codes

The ranging preamble codes are classified into initial ranging and handover ranging preamble codes. The initial ranging preamble codes shall be used for initial network entry and association. Handover ranging preamble codes shall be used for ranging against a target ABS during handover. For a ranging code opportunity, each AMS randomly chooses one of the ranging preamble codes from the available ranging preamble codes set in a ~~cell~~sector.

The number of available ranging preamble codes in a sector, N_{set}, is broadcasted as part of the system information in the SFH as defiened in Table xx.

Table xx. N_{set} for ranging preamble

N_{set} configuration	N_{set} value	
	FDD duplex mode	TDD duplex mode
0	128	64
1	64	32
2	32	16
3	16	8

-- *Text End* --

[------------------------------------ Text Proposal #2 ----------------------------------]

--- *Text Start* ---

[Insert the following text in the bottom of 'Ranging preamble codes' of the section 15.3.9.2.4.1 Ranging channel for non-synchronized AMSs.]

The Zadoff-Chu sequences with cyclic shifts are used for the ranging preamble codes. The p^{th} ranging preamble code $x_p(k)$ is defined by

$$x_p(k) = \exp\left(-j \cdot \pi \frac{r\,k(k+1) + 2 \cdot k \cdot s \cdot N_{CS}}{N_{RP}}\right), \quad k = 0, 1, \ldots, N_{RP} - 1 \qquad (x+1)$$

where

p is the index for p^{th} ranging preamble code which is made as the s^{th} cyclic shifted sequence from the root index r of Zadoff-Chu sequence.

N_{CS} is the unit of cyclic shift according to the cell size and is defined in Table yy.

N_{RP} is the length of ranging preamble codes.

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