

# Quick Access Channel (QACH) Design for IEEE 802.16m BW-REQ

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Re: PHY: SDD Session 56 cleanup, call for Detailed Physical Layer Comments. In response to IEEE 802.16m-08/033 the Call for Contributions and Comments on Project 802.16m System Description Document (SDD) for Session 57

## Base Contribution:

Purpose: Discussion and Approval

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<http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>.

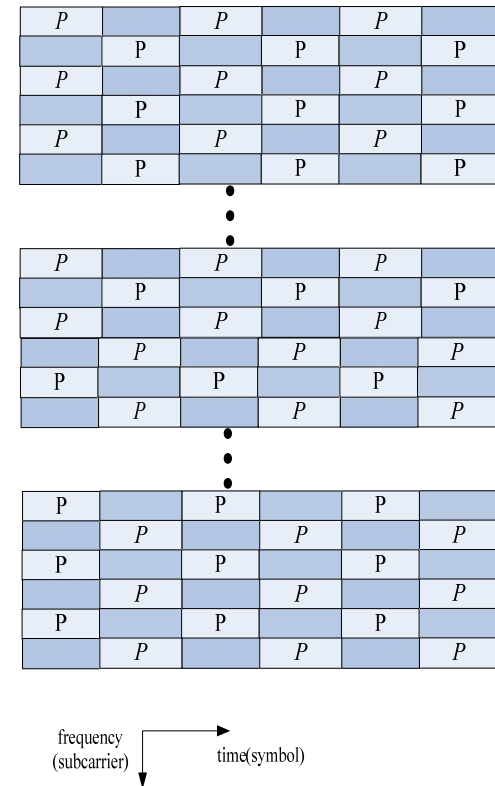
Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat>.

# Outline

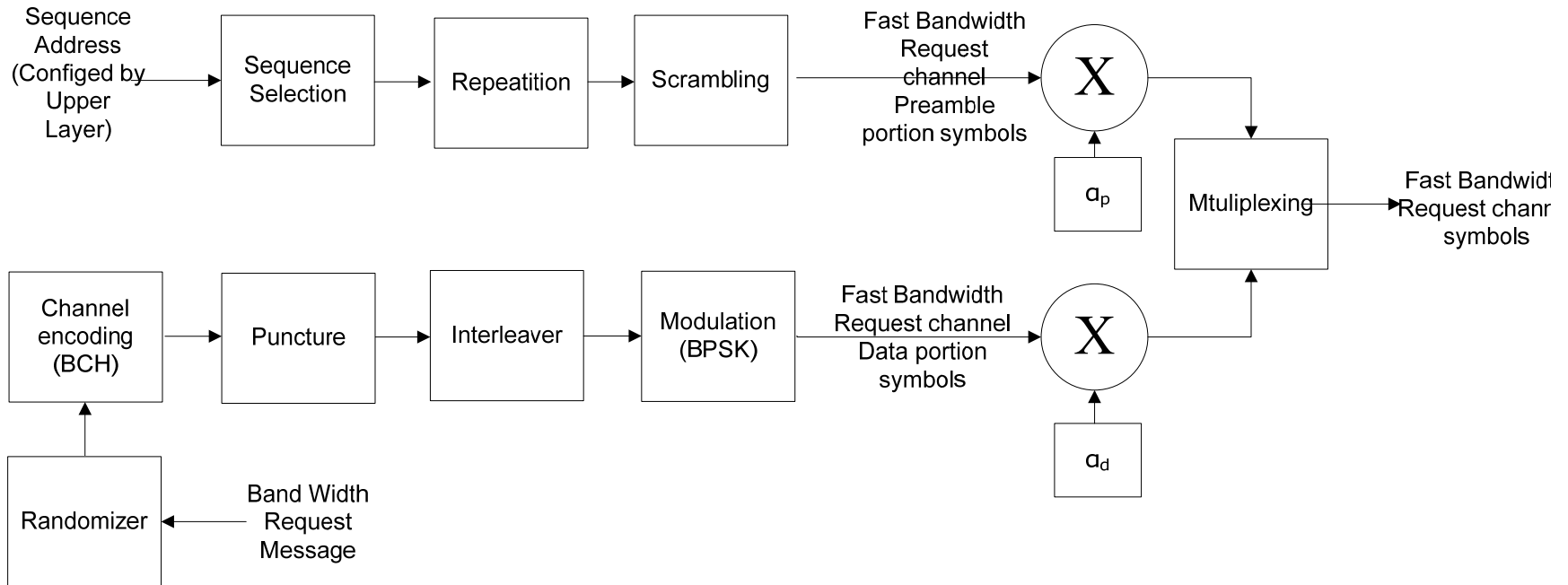
- Fast bandwidth request procedure is adopted in the SDD text Section 11.9.2.5 (IEEE 802.16m-08/003r4) during Session #56 in Denver
- In this contribution we give more details in the PHY and MAC aspects for the quick access channel (QACH) design for the fast BW-REQ procedure

# PHY Channel structure

- Three 6\*6 sub tiles
- Preamble/Data = 1:1
- Preamble:
  - The same orthogonal code transmitted over the preamble ("P") part of three sub tiles
  - The BW-REQ preamble is robustly designed for reliable detection under low SINR and co-channel interference in the BW-REQ channel.
- Data:
  - N (Default 9) info bits, BCH with repetition+BPSK
  - The quick access message may be less robust compared to the BW-REQ preamble.
- Receiver:
  - Preamble: non-coherent detection
  - Data: coherent detection, ML receiver



# PHY Transmitting Chain



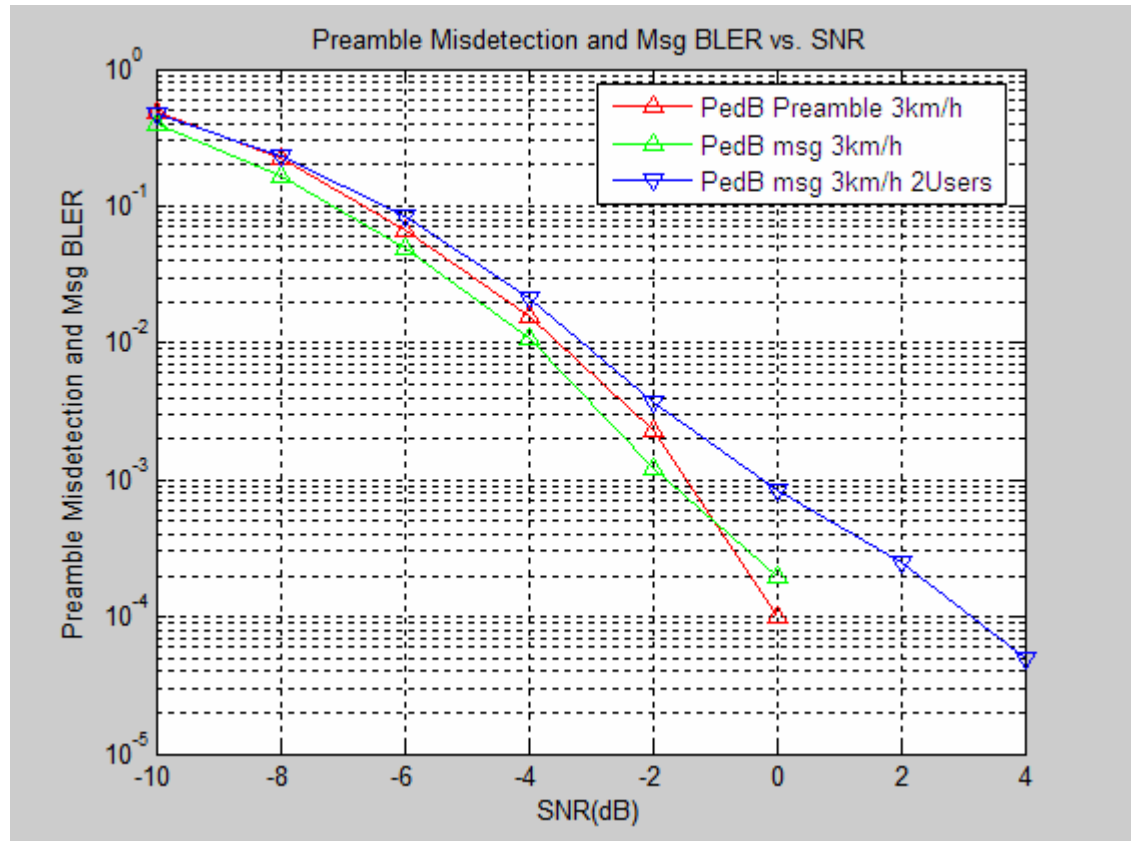
# Simulation Parameters

Parameter Name	Parameter Values
Number of channels	1
Sub carriers per Preamble	18*3
Codes per channel	19
Sub carriers per message	18*3
Message Power Boosting	0dB
Channel coding	BCH(9,32)+repetition
MS speed	3km/h, 30km/h
Channel estimation	2D-MMSE
Message modulation	BPSK
Message size	9 bits
Code type	ZC
Antenna selection	Random
Channel selection	Random
Tx/Rx	1/2 MLD
# users	1, 2
False alarm	0.1%



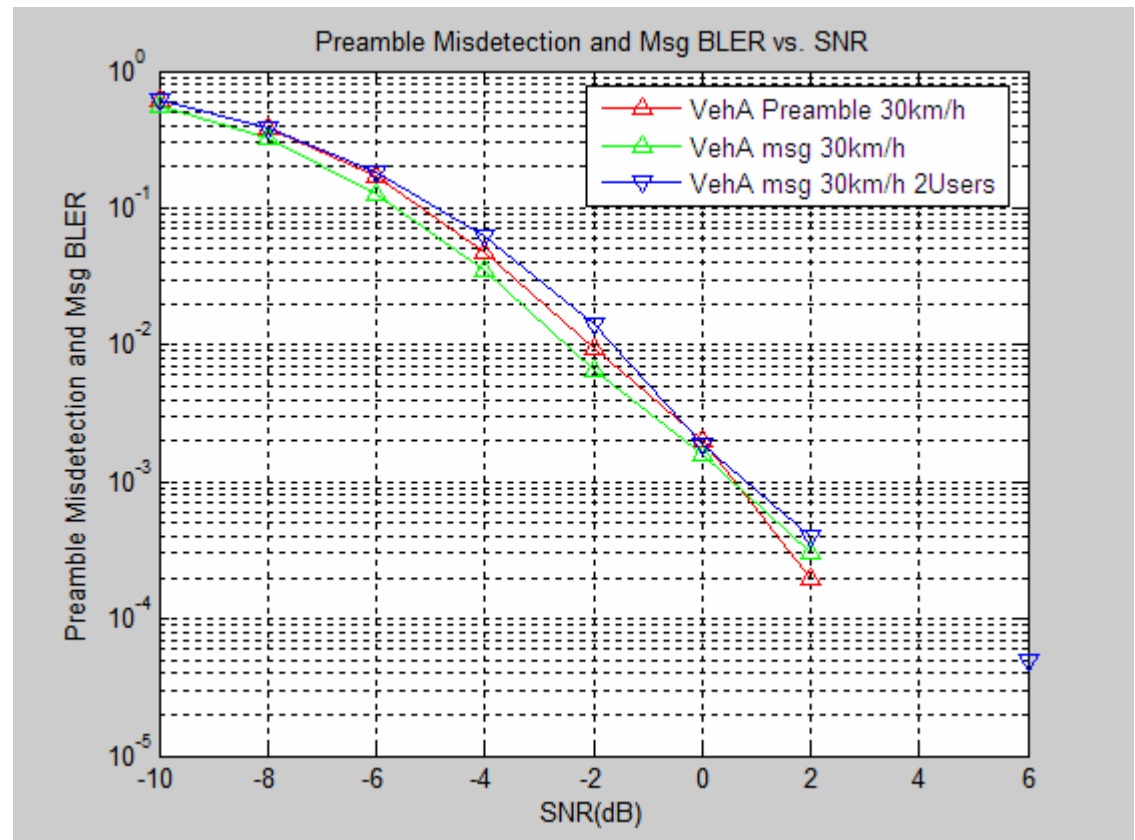
# Performance, PedB 3km/h

- Preamble
  - For 0.1% False alarm, achieve 1% misdetection at roughly -3.6dB
- Data
  - For 1 user, achieve 1% BLER at -4dB
  - For 2 user, achieve 1% BLER at -3dB



# Performance, VehA 30km/h

- Preamble
  - For 0.1% False alarm, achieve 1% misdetection at roughly -2dB
- Data
  - For 1 user, achieve 1% BLER at -2.5dB
  - For 2 user, achieve 1% BLER at -1.5dB





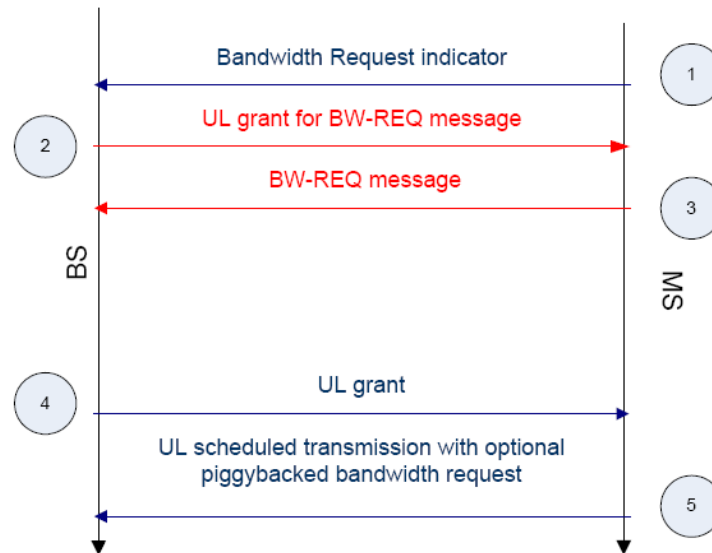
# SDD text Proposal

[insert the following text in section 11.9.2.5.2]

----- Text Changes Start Here -----

The bandwidth request (BW-REQ) channel contains resources for the MS to send in BW-REQ preamble and optional message for quick access at the step-1 of bandwidth request procedure shown in Figure 35. The BW-REQ preamble serves as the BW-REQ indication. The quick access message contains MS identity and buffer report. The minimal size of BW-REQ channel is 18x6 tones, which is allocated into 3 distributed BW-REQ tiles. Each BW-REQ tile is of size 6x6.

----- End of Text Changes -----



The figure 35 from SDD Document (80216m-08\_003r4.pdf)

Figure 35 Bandwidth Request Procedure

# **Backup Slides**

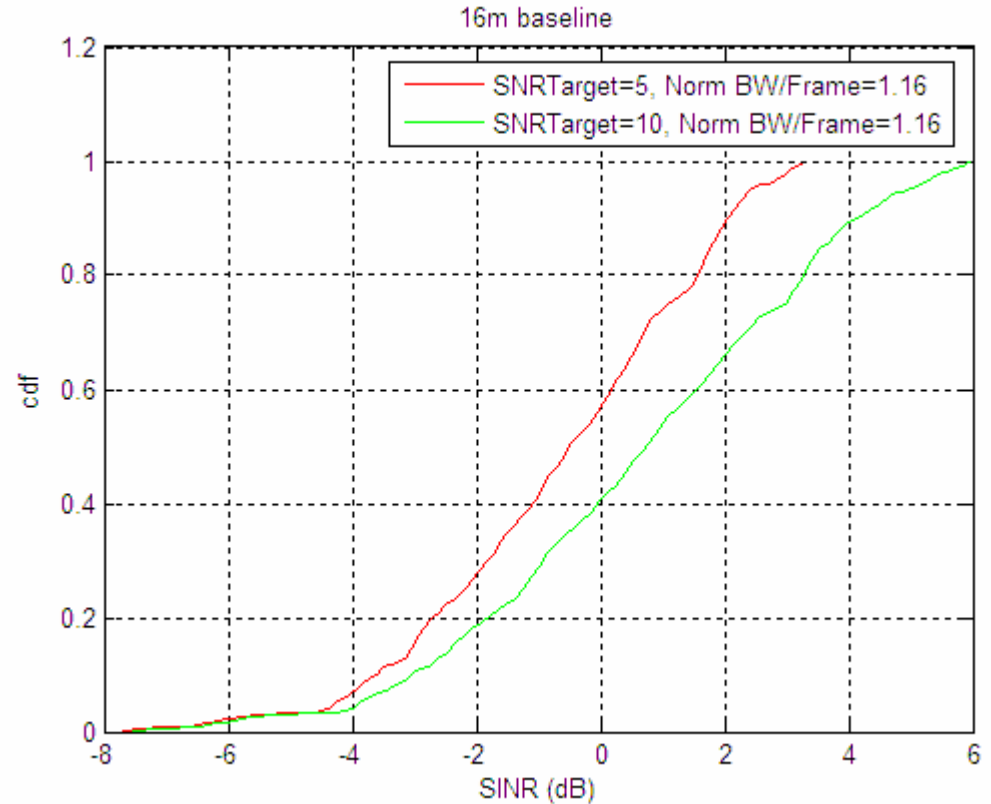
# Power control aspects

- Open loop power control should apply
- There is chance that more than 1 MS is Txing
- Full path loss compensation
- Cell common mapping is assumed where the same Freq-Time position is used for mapping QACH
- Cell-specific mapping should not degrade the performance



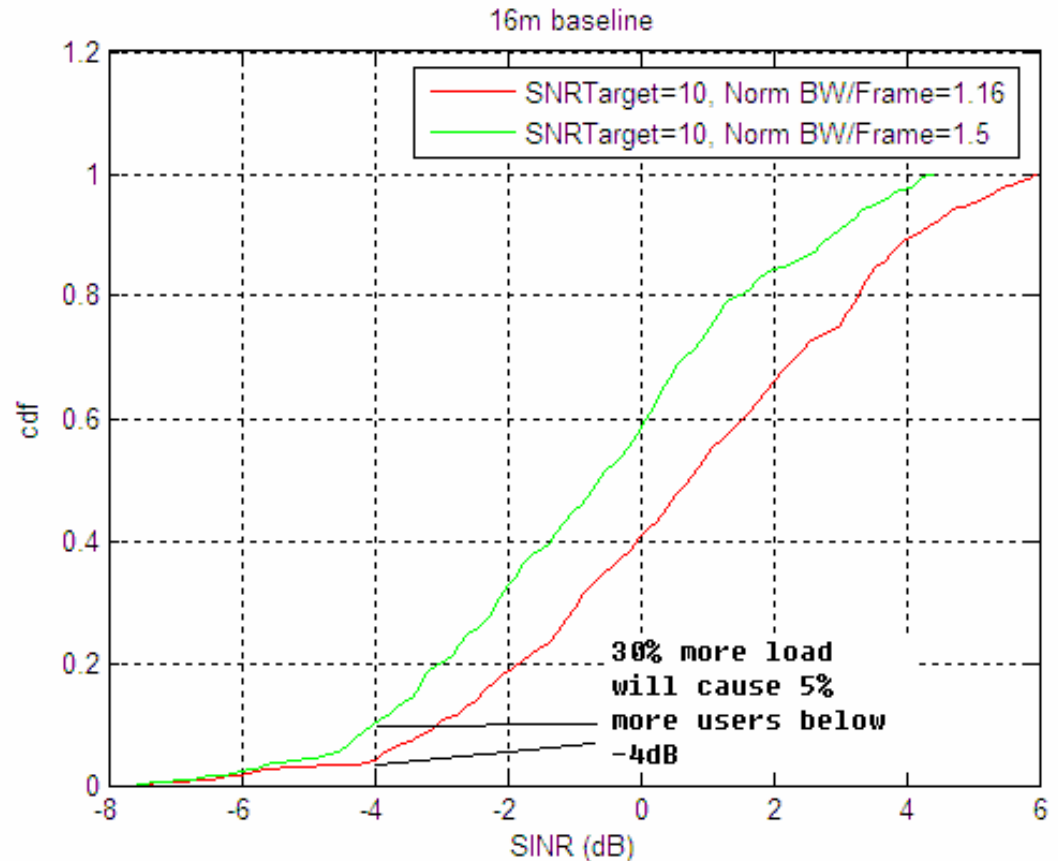
# UL SINR CDF

- 10dB SNR target is needed for 1500 ISD to have 95% coverage for cell common mapping



# SINR degrading for more load

- When load increases, SINR will degrade
- The performance has some reasonable degrading for quite high more load



# MAC aspect of QACH

- Performance comparison (in terms of overhead/latency) between polling (aka scheduled SR), random access (RACH) and quick access (QACH)
  - Polling vs. RACH
  - Polling vs. QACH
- BW-REQ channel MAC bits design

# Compare RACH, QACH and Polling



# System model

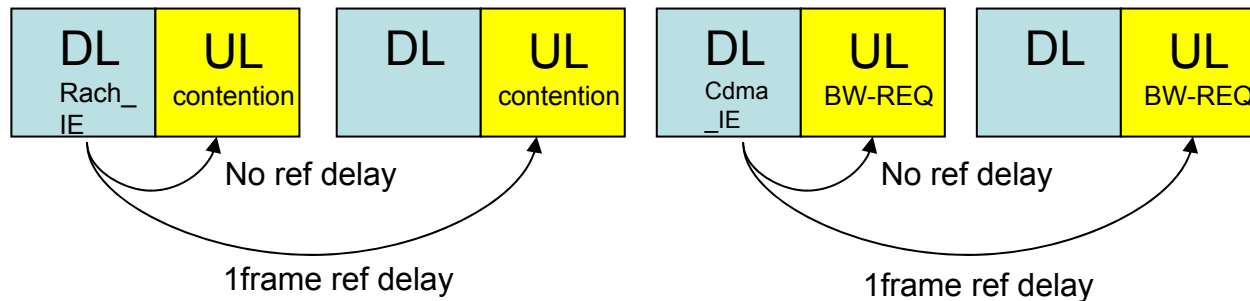
- $N_{UE}$ : number of connected users in system
- $R_{SR}$ : Poisson BW-REQ request rate per MS
- $P_{collision}$ : maximal collision probability (1%)
- $L$ : overhead ratio of one RACH slot over one scheduled SR(10, I here use different notation from the original contribution)
- $T_{SR}$ : interval of scheduled BW-REQ, assuming  $R_{SR} < 1/T_{SR}$
  
- Overhead calculation
  - Scheduled SR: straightforward  $N_{UE}/T_{SR}$
  - RACH: Allocation rate of contention slots  $\times L$
- Calculations in appendix

# Performance metrics

- Polling is a general term for many possible designs based on dedicated BW-REQ resource, for example
  - 16e rtPS (poll BW-REQ message)
  - LTE scheduled SR (poll BW-REQ indication)
  - Embed BW-REQ indication in CQICH (poll either BW-REQ msg or indication, depending on how many bits to include )
- Comparison criteria
  - Under similar QoS requirement, e.g. latency
    - Latency to obtain BW-REQ message (the rest latency for UL access depending on scheduling)
  - Overhead associated with the whole procedure
  - For contention based RACH and QACH
    - Need to consider detection performance (based on LLS)
    - Need to consider collision probability (based on analysis)

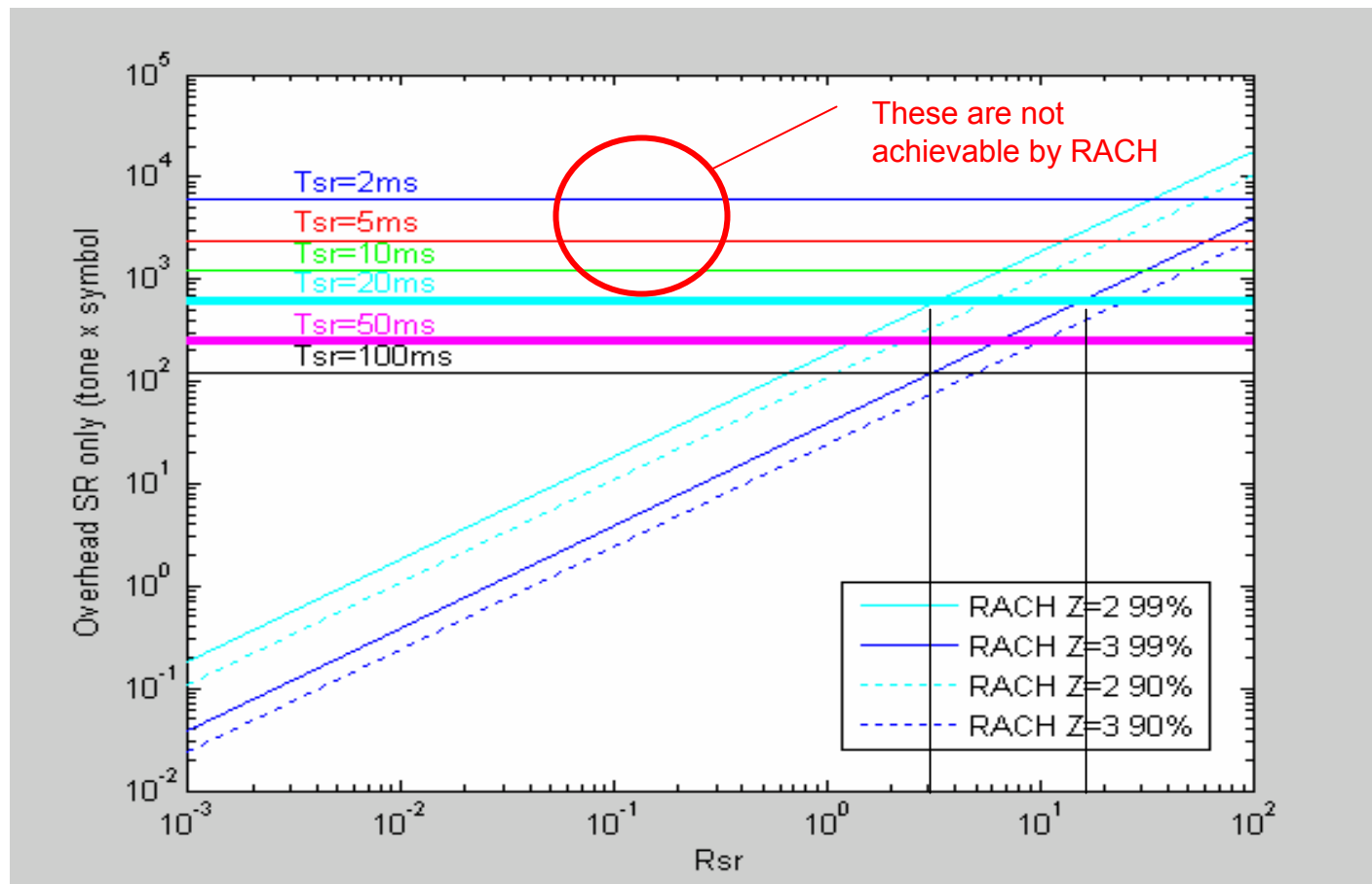
# RACH vs. Polling

- Compare the overhead up to getting the indication, since the rest procedure is the same for RACH and Polling
- RACH configuration
  - $Z=2$  or  $3$ : the max number of resolvable codes per contention RU used in the calculation
  - Target success prob
    - 99% for one contention: one contention is good enough
    - 90% for one contention: two contentions required to get 99% final success prob
- RACH latency
  - Depending on ref delay, it is around 10ms to 20ms latency
  - Comparable to polling with  $T_{sr}=20\text{ms}$  to  $50\text{ms}$  (i.e., mean delay 10 to 25ms)
- Calculation in appendix



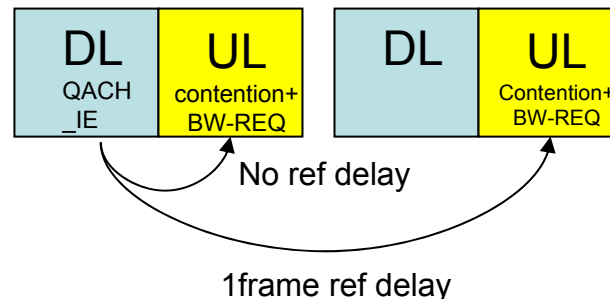
# RACH vs Polling

- Overhead comparison
  - 99% case: compare RACH to polling( $T_{sr}=20\text{ms}$ )
  - 90% case: RACH with 1 retry,
    - compare mean delay with polling( $T_{sr}=20\text{ms}$ )
    - Compare worst delay with polling( $T_{sr}=50\text{ms}$ )
- Roughly, RACH is more efficient if BW-REQ per user is below 1~10/sec



# QACH vs Polling

- Compare the overhead of the overall BW-REQ procedure (indication + BWREQ msg)
- QACH delay
  - Depending on ref delay, it is (slightly larger) 2.5ms to 5ms latency
  - Comparable to polling with  $T_{sr}=5\text{ms}$  to  $10\text{ms}$  (i.e., mean delay 2.5 to 10ms)
- Calculation in appendix





# Conclusion on RACH/QACH vs. polling

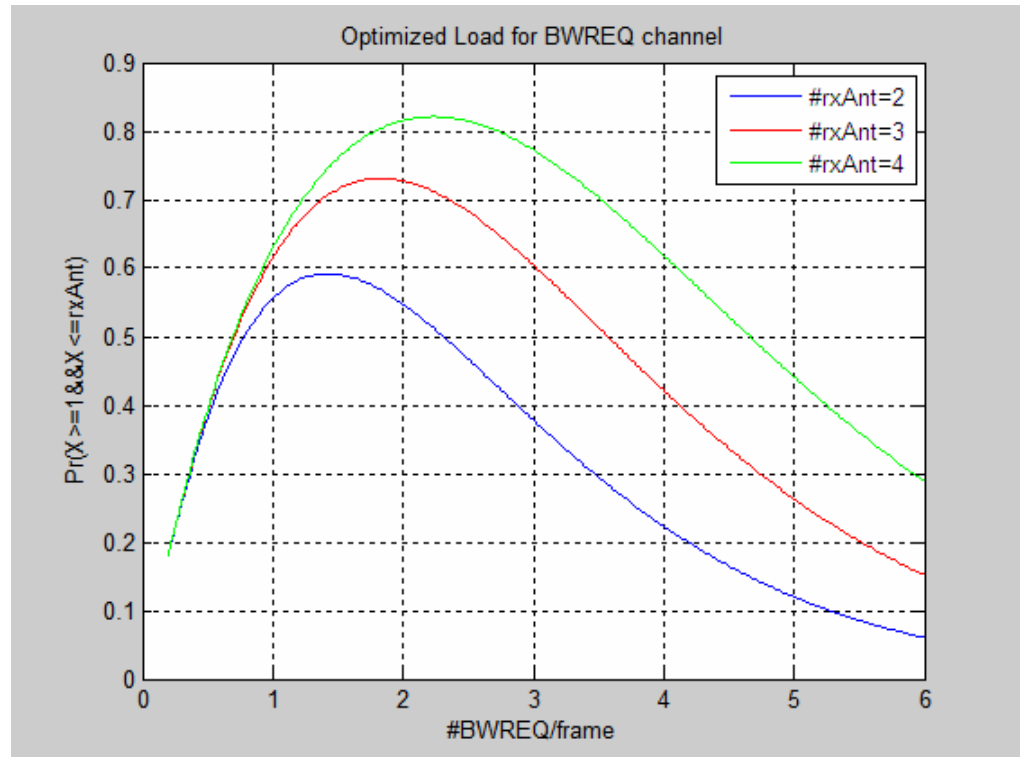
- QACH and RACH offer smaller overhead when BW-REQ is not very high
  - $< 1\sim 10/\text{sec}$  for RACH
  - $< 10\sim 30/\text{sec}$  for QACH
- RACH can not offer small latency due to its protocol design
- QACH improves RACH by offering
  - Similar overall overhead
  - Smaller access latency

# BW-REQ channel MAC bits design



# Traffic Design

- N independent Poisson arrivals with mean interval  $1/\lambda$
- Frame length  $T = 5\text{ms}$
- Optimize offered load to maximize 3-step access prob. of FBWREQ channel
- For max 2 Rx antenna, optimized load is 1.5 BWREQ/frame



$$p(X = i) = \binom{N}{i} (1 - e^{-\lambda T})^i (e^{-\lambda T})^{N-i}$$
$$i = 0, 1, \dots, N$$

# MAC design-Traffic aspects

- Percentage of 3 step access is upper bounded by #Rx antennas
- For 2 Rx antennas, 3 step access is upper bounded by 58%, surely there is some probability that no one is accessing the channel for a given frame
- Optimized load is  $1.5 \text{ BWREQ/Frame} = N \text{ User/Channel} * \lambda$   
 $\text{BWREQ/Second/User} * 0.005 \text{ Second/Frame}$
- For VoIP users having mean talk spurt round length 4 seconds,  $\lambda = 0.25 \text{ BWREQ/second}$ 
  - The optimized N is 1200 User/Channel
  - If considering more robust to instantaneous high load, N should be designed more conservative

# MAC design-PHY aspects

- One channel has M different preambles
- One channel can convey X bits in the message part and Y bits are used for addressing
- Together with codes, total  $N=M*2^Y$  users can be addressed
  - Two users using different preambles can be decoded
  - Two users using same preamble can't be decoded
- The conditional prob for preamble collision was upper bounded by  $1/M$

$$p(\text{CoCode} | \text{TxUser} = 2) = \frac{\binom{M}{1} \binom{2^Y}{2}}{\binom{M 2^Y}{2}}$$
$$= \frac{2^Y - 1}{M 2^Y - 1} < \frac{1}{M}$$

# MAC design

- Jointly considering traffic and PHY limitation
  - One channel is designed to be shared among 608 users, FFS if more than one max user # is needed
    - Short MAC Id = 0,1,...607
  - The channel index is a function of ShortMACId and # of available channels  $f(\text{ShortMACId}, n)$ , where  $n$  is total channels
  - The preamble code index is function of ShortMACId and # of available channels  $g(\text{ShortMACId}, n)$
  - 5 bits are used for addressing in the overall 9 bits
  - The 5 bits inband addressing is  $h(\text{ShortMACId}, n)$
  - 4 bits are used for BWREQ message