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

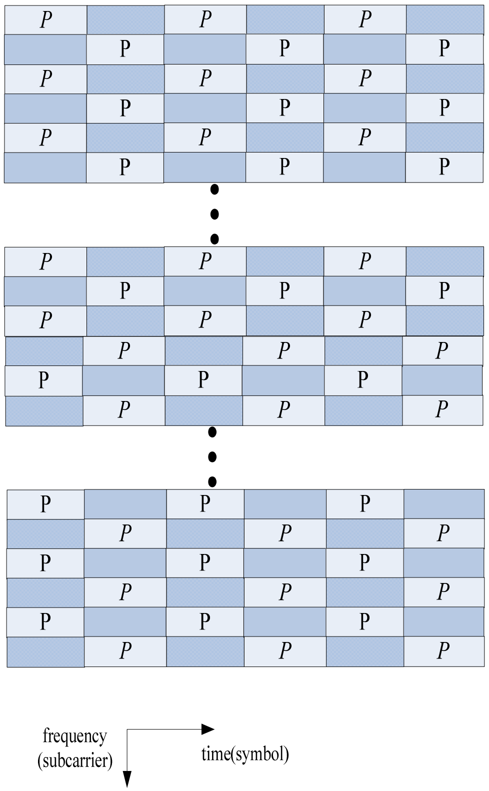
Outline

- 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

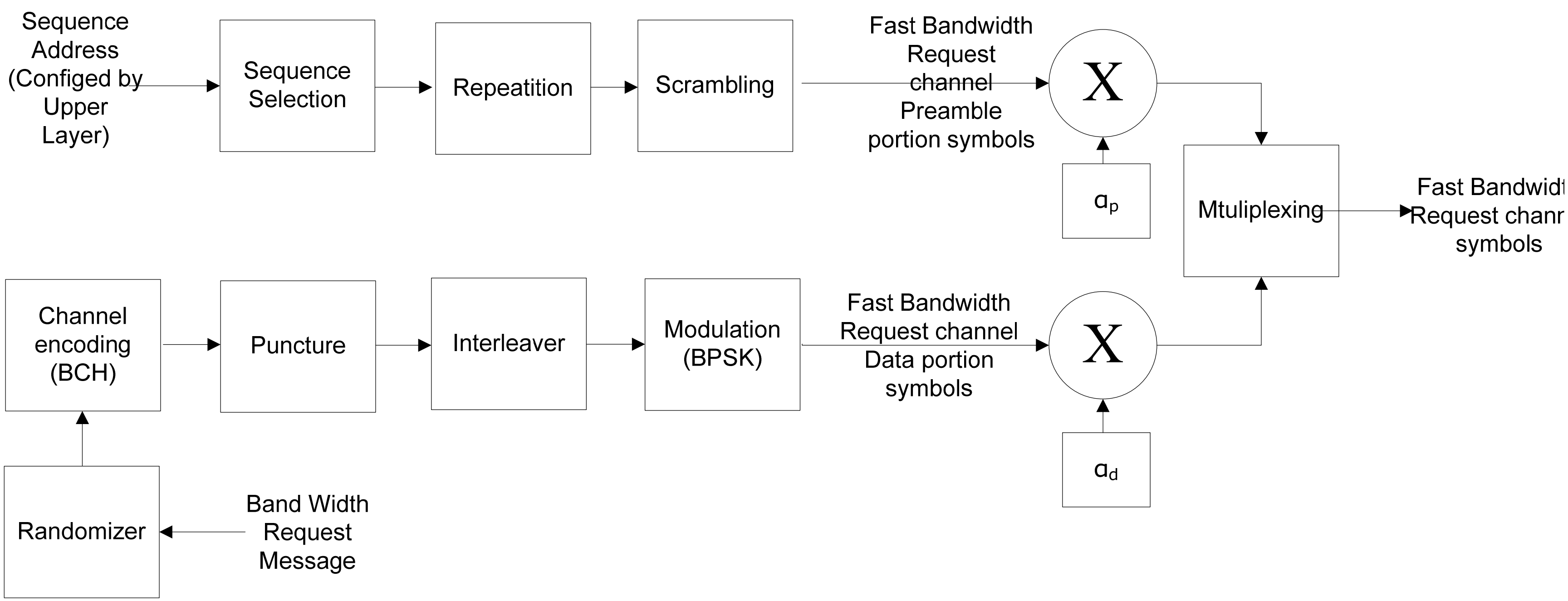
PHY Channel structure

- 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

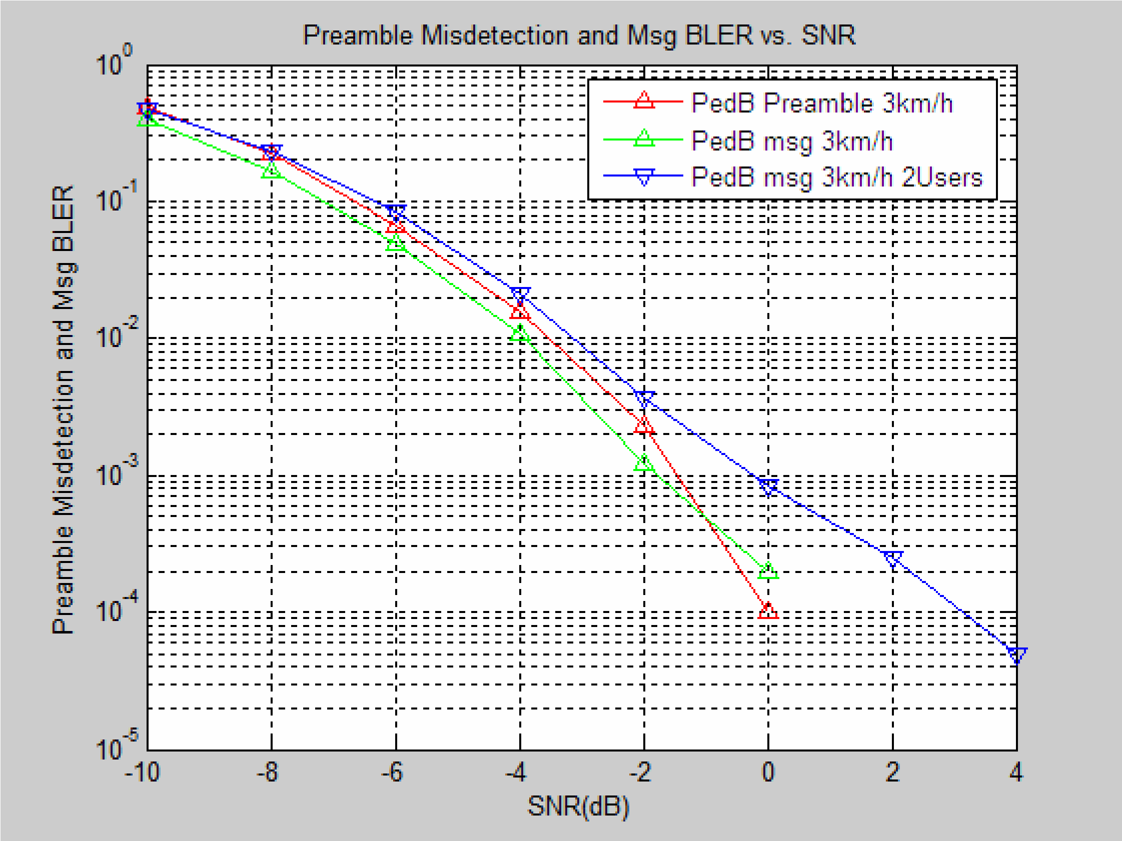
Parameter Name	Parameter Values
Number of channels	1
Sub carriers per Preamble	18*3
Codes per channel	19
Sub carriers per message	18*3
Message Power Boosting	0dB
Channel coding	BCH(9,32)+repeatition
MS speed	3km/h, 30km/h
Channel estimation	2D-MMSE
Message modulation	BPSK
Message size	9 bits
Code type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

Simulation Parameters (Cont.)

Parameter Name	Parameter Values
Code selection	Random
UL Frequency offset	0
UL timing error	0
Interleaver	Off
Interference scenario	noise limited

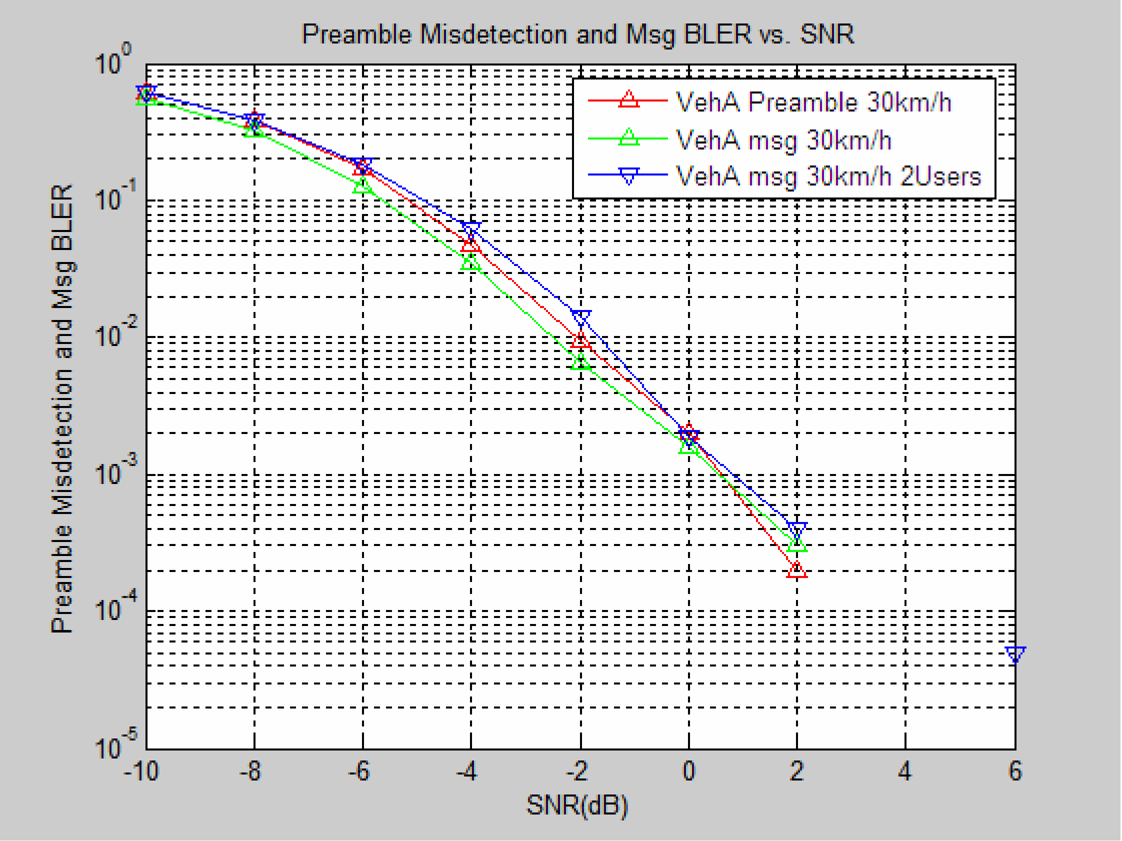
Performance, PedB 3km/h

- 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 access sequence and optional message for quick access at the step-1 of bandwidth request procedure shown in Figure 35. The BW-REQ access sequence serves as the BW-REQ indication. 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)

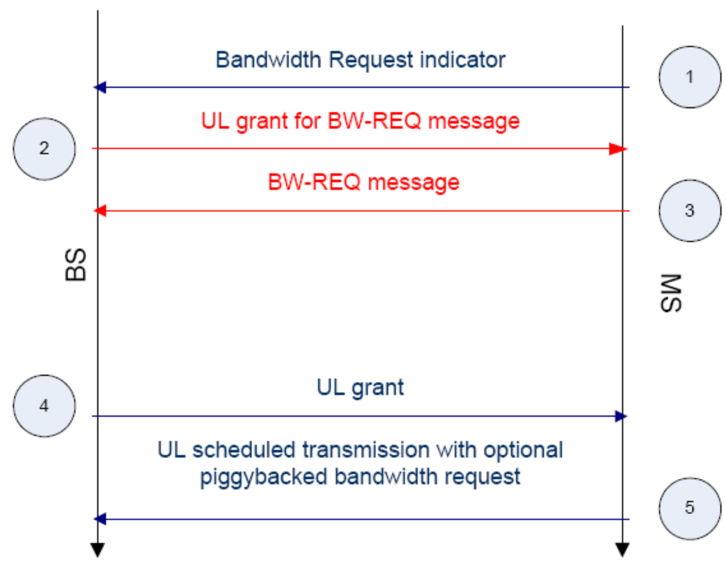


Figure 35 Bandwidth Request Procedure

Backup Slides

Power control aspects

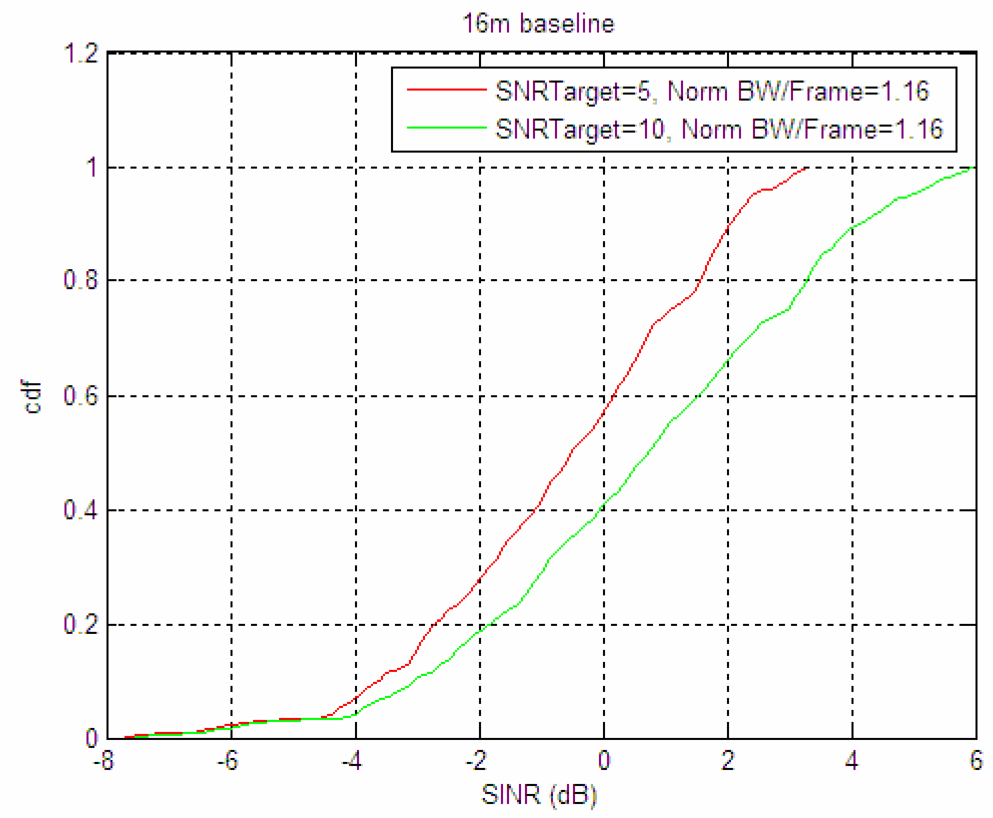
- Open loop power control should apply
- There is chance that more than 1 MS is Txing
- Full path loss compensation
- Cell common mapping is assumed where the same Freq-Time position is used for mapping QACH
- Cell-specific mapping should not degrade the performance

Simulations Parameters

Parameter Name	Parameter Values
Scenario	57 sector Wrap A reuse 1
#UE/sector	10
Total # of BWREQ/Frame	1.16 BWREQ/Frame
BWREQ arrival process	Poisson Arrival
Ant/Receiver	1Tx/2Rx
Network Scenario	EVM Baseline
Power control Algorithm	Full Path loss Compensation
Max MS Tx Power	23dBm
BS Noise Figure	5dB
Noise Floor	-174dBM/Hz

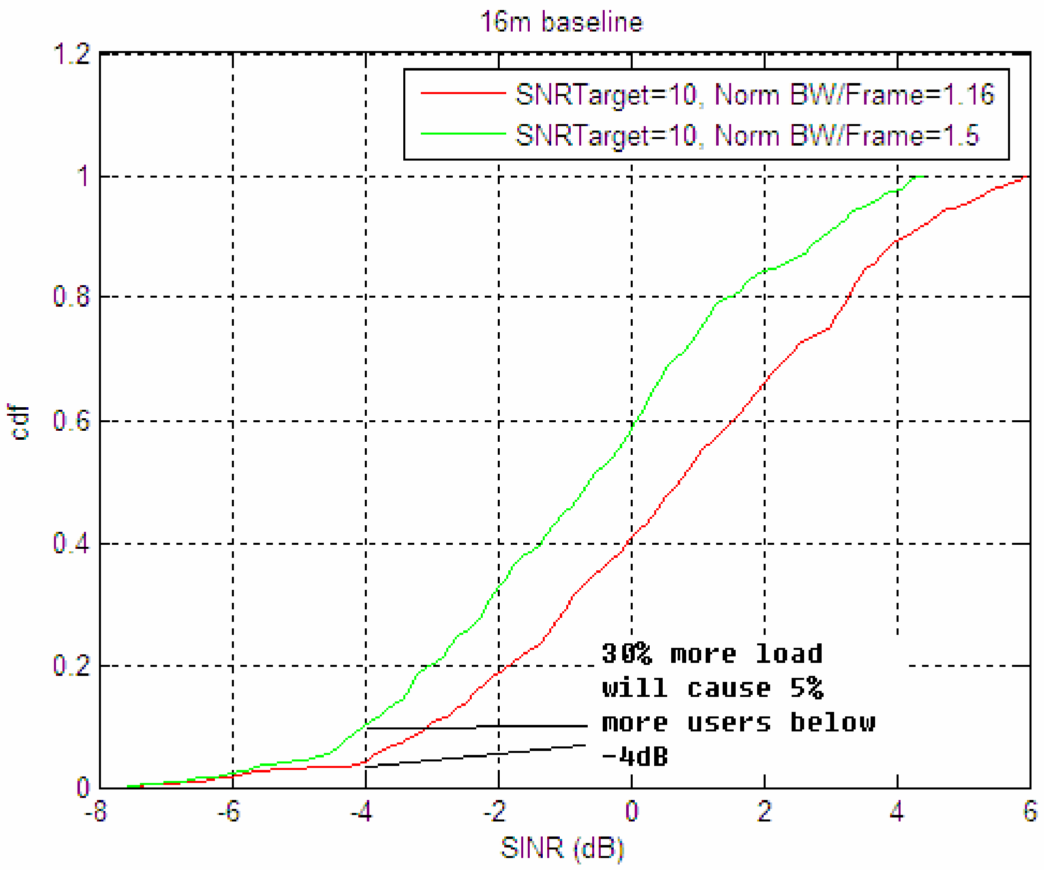
UL SINR CDF

- 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 $R_{SR}<1/T_{SR}$

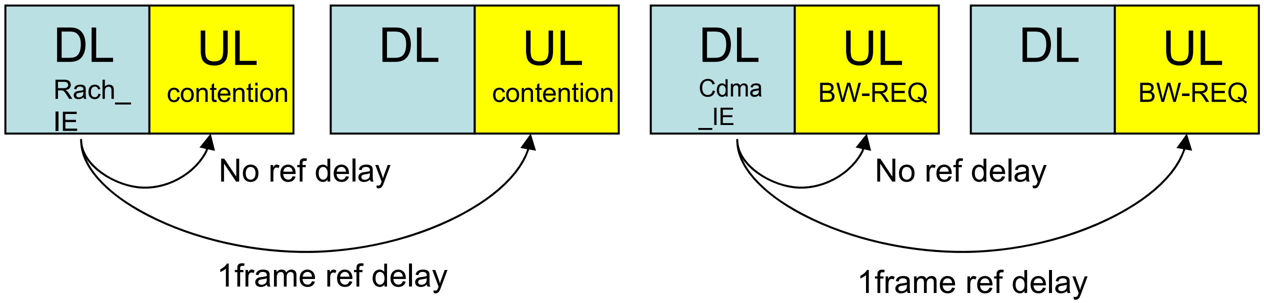
- Overhead calculation
  - Scheduled SR: straightforward N_{UE}/T_{SR}
  - RACH: Allocation rate of contention slots $\times$ L
- Calculations in appendix

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)

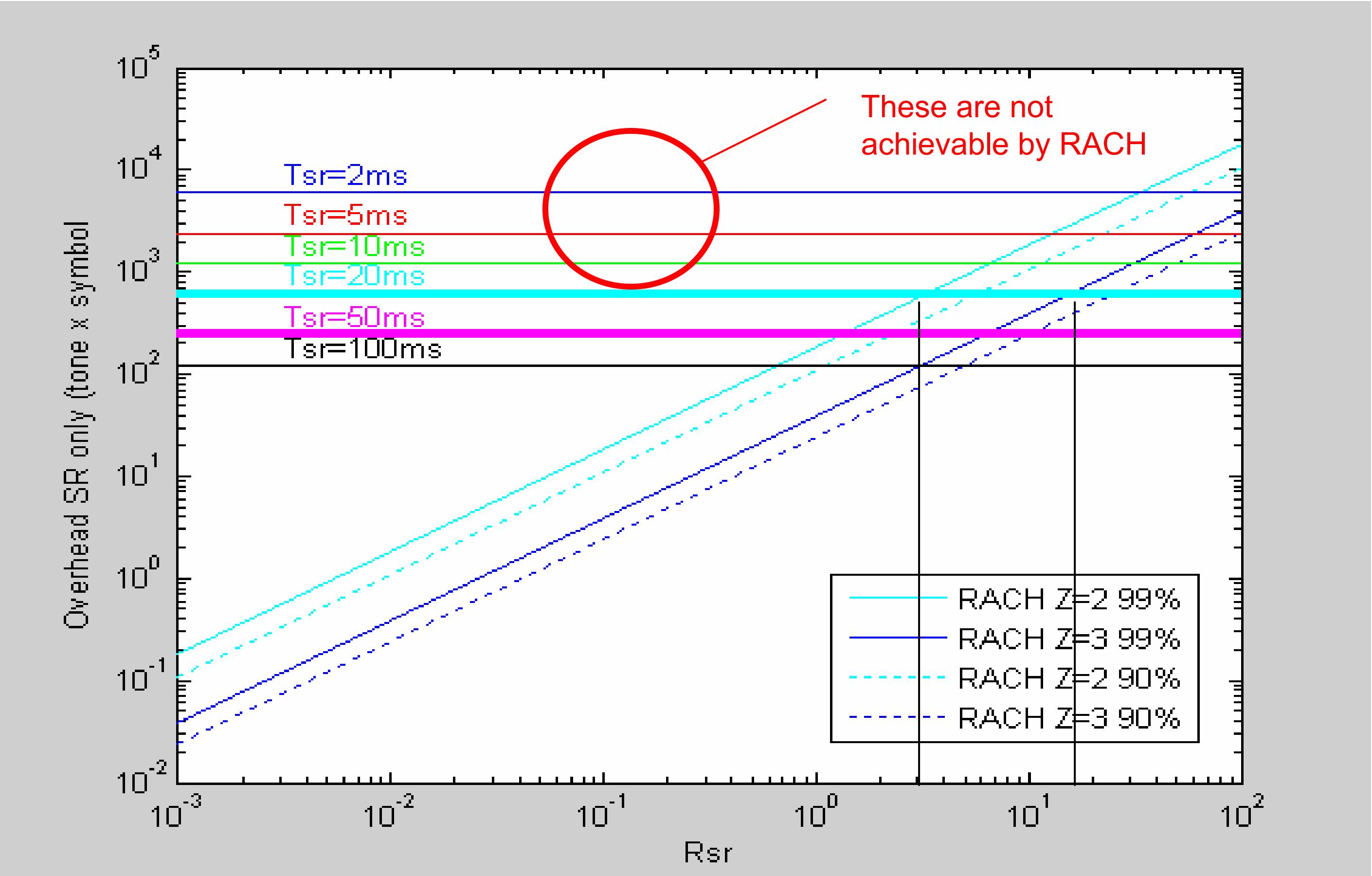
RACH vs. Polling

- 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 Tsr=20ms to 50ms (i.e., mean delay 10 to 25ms)
- Calculation in appendix



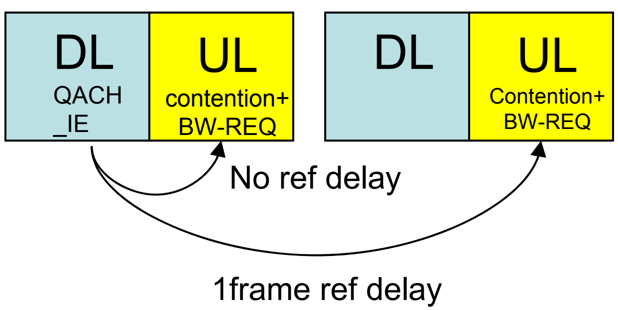
RACH vs Polling

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



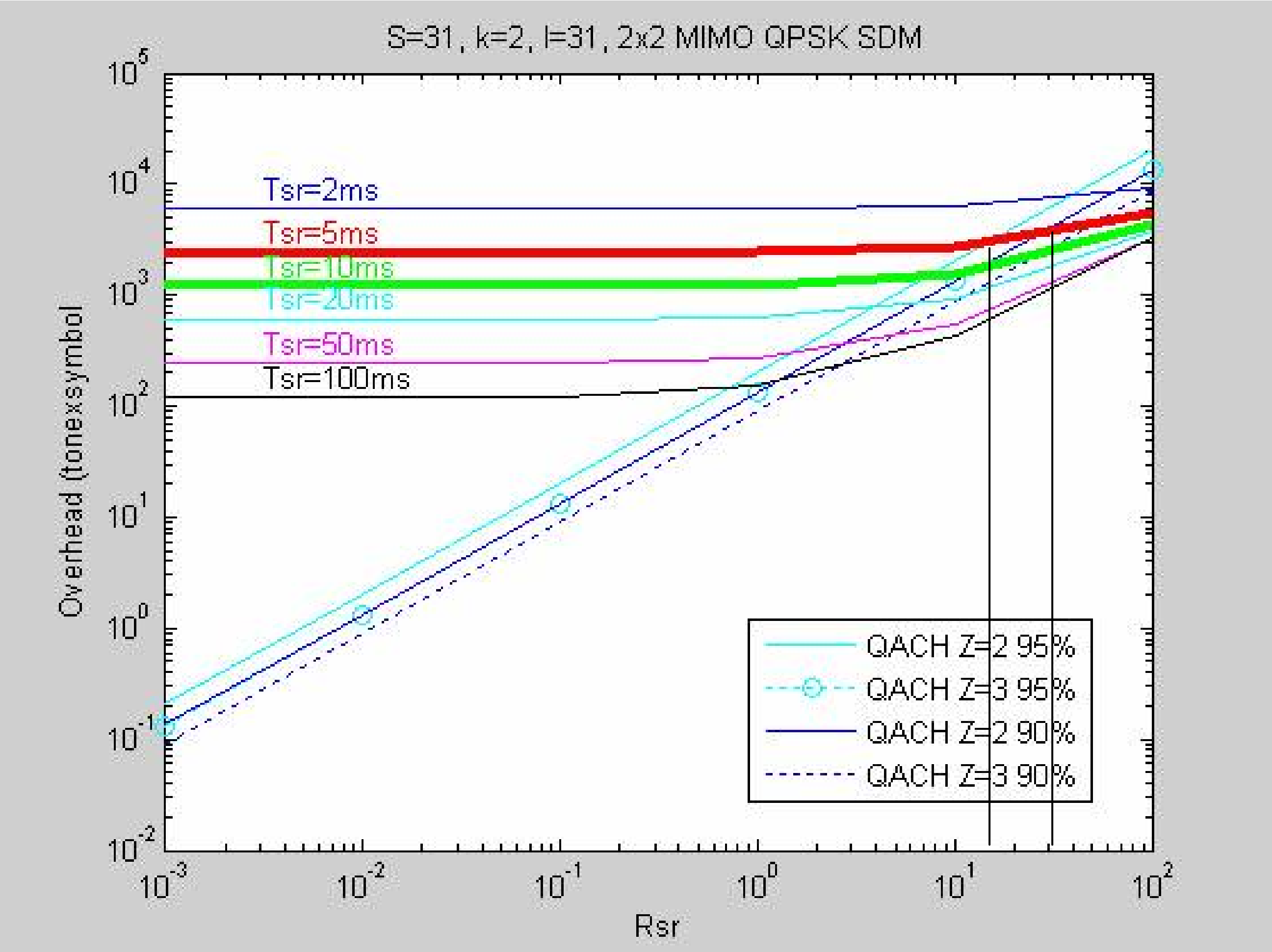
QACH vs Polling

- 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 Tsr=5ms to 10ms (i.e., mean delay 2.5 to 10ms)
- Calculation in appendix



QACH vs. Polling

- Polling overhead is not longer perfect horizontal lines since this is overall MAC procedure overhead (including BW-REQ indication and msg)
- We compare QACH with polling (with Tsr=5ms~10ms)
- QACH is more efficient when BW-REQ per user is below 10~30/sec



Conclusion on RACH/QACH vs. polling

- QACH and RACH offer smaller overhead when BW-REQ is not very high
  - < 1~10/sec for RACH
  - < 10~30/sec for QACH

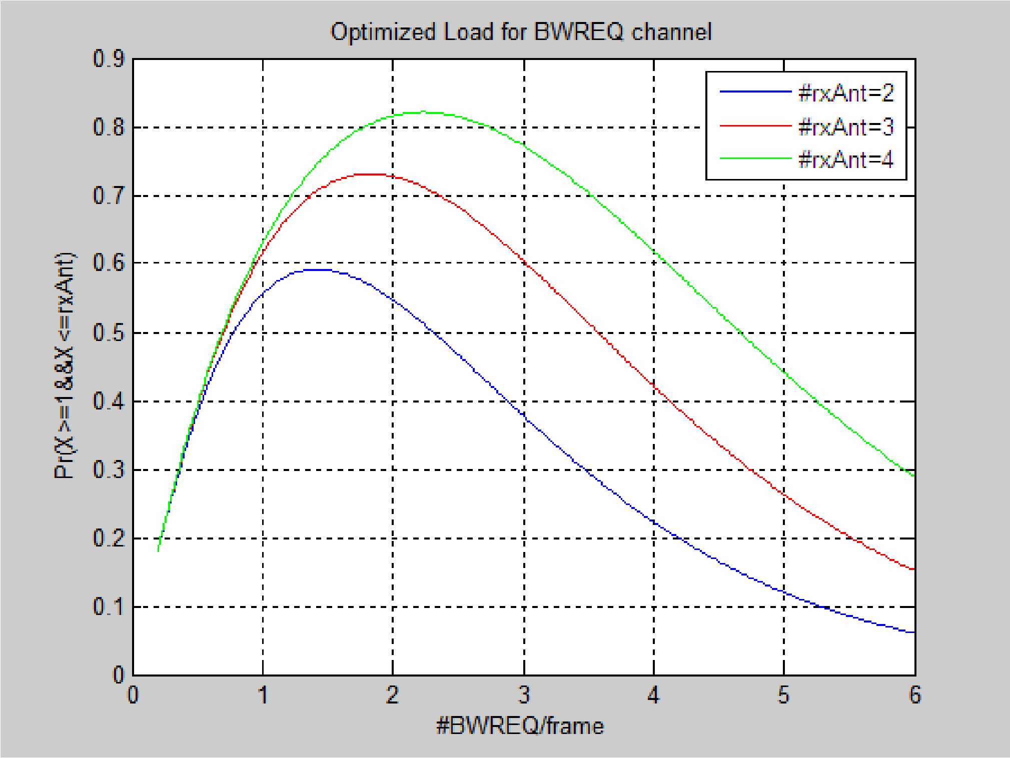
- RACH can not offer small latency due to its protocol design

- 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/λ
- Frame length T = 5ms
- Optimize offered load to maximize 3-step access prob. of FBWREQ channel
- For max 2 Rx antenna, optimized load is 1.5 BWREQ/frame



$$p(X=i)=\binom{N}{i}\left(1-e^{-\lambda T}\right)^{i}\left(e^{-\lambda T}\right)^{N-i}$$

$$i=0,1,\ldots N$$

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 BWREQ/Frame=N User/Channel * λ BWREQ/Second/User * 0.005 Second/Frame
- For VoIP users having mean talk spurt round length 4 seconds, λ = 0.25 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

$$p(CoCode \mid TxUser = 2) = \frac{\binom{M}{1}\binom{2^Y}{2}}{\binom{M\,2^Y}{2}}$$

$$= \frac{2^Y - 1}{M\,2^Y - 1} < \frac{1}{M}$$

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(ShortMACId, n), where n is total channels
  - The preamble code index is function of ShortMACId and # of available channels g(ShortMACId, n)
  - 5 bits are used for addressing in the overall 9 bits
  - The 5 bits inband addressing is h(ShortMACId,n)
  - 4 bits are used for BWREQ message