

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

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Re: 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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Outline

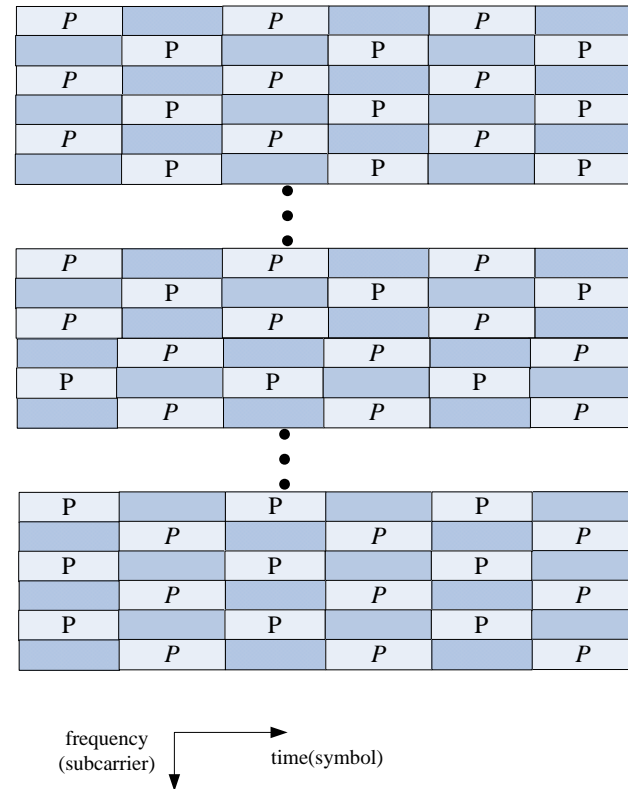
- Fast bandwidth request procedure is adopted in the SDD text Section 11.9.2.5 (IEEE 802.16m-08/003r4) during Session #56 in Denver
- In this contribution we give more details in the PHY and MAC aspects for the quick access channel (QACH) design for the fast BW-REQ procedure

PHY aspect of QACH

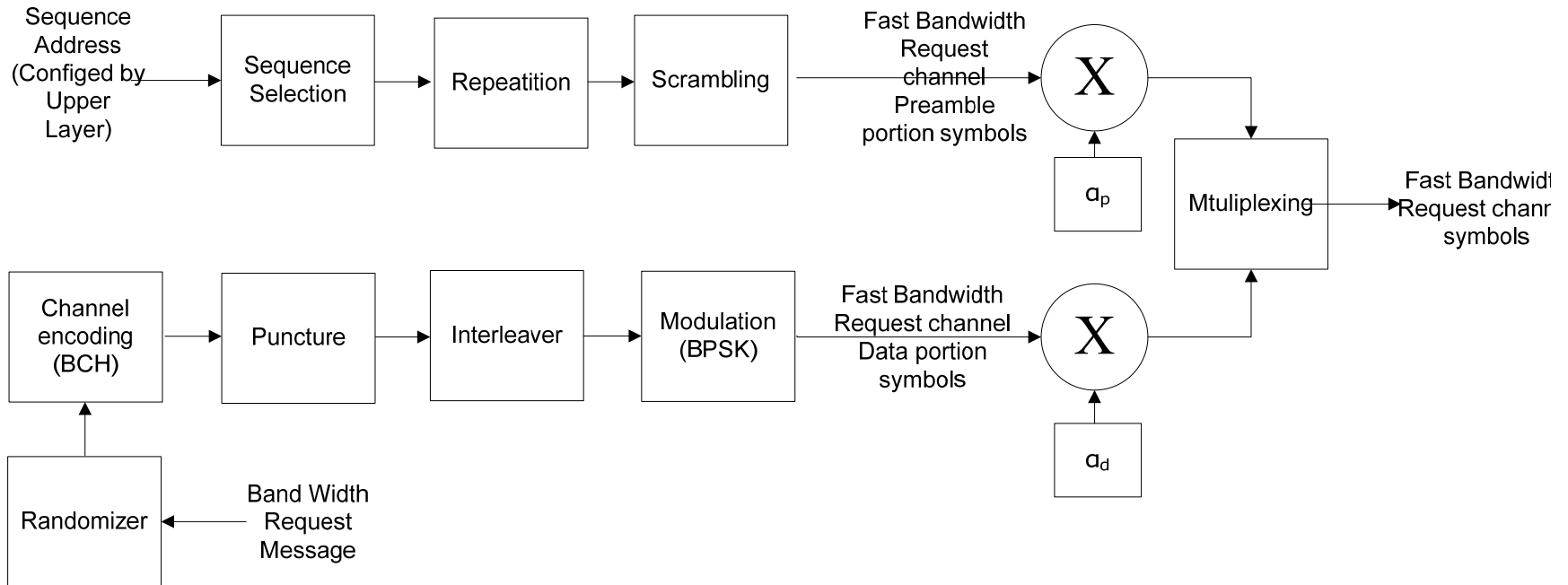
- PHY structure and performance
- Power control aspects

PHY Channel structure

- Three 6*6 sub tiles
- Preamble/Data = 1:1
- Preamble:
 - The same orthogonal code transmitted over the preamble part of three sub tiles
- Data:
 - N (Default 9) info bits, BCH with repetition+BPSK
- Receiver:
 - Preamble: non-coherent detection
 - Data: coherent detection, ML receiver



PHY Transmitting Chain

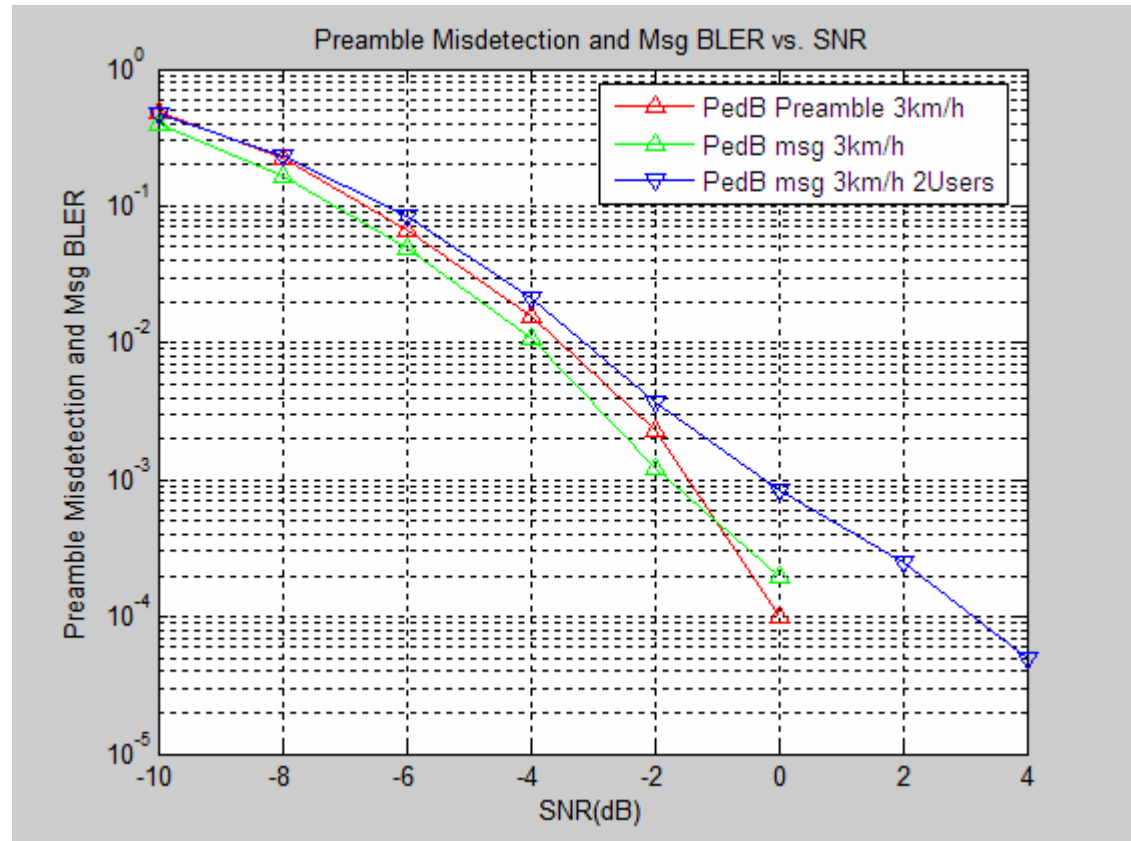


Simulation Parameters

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%

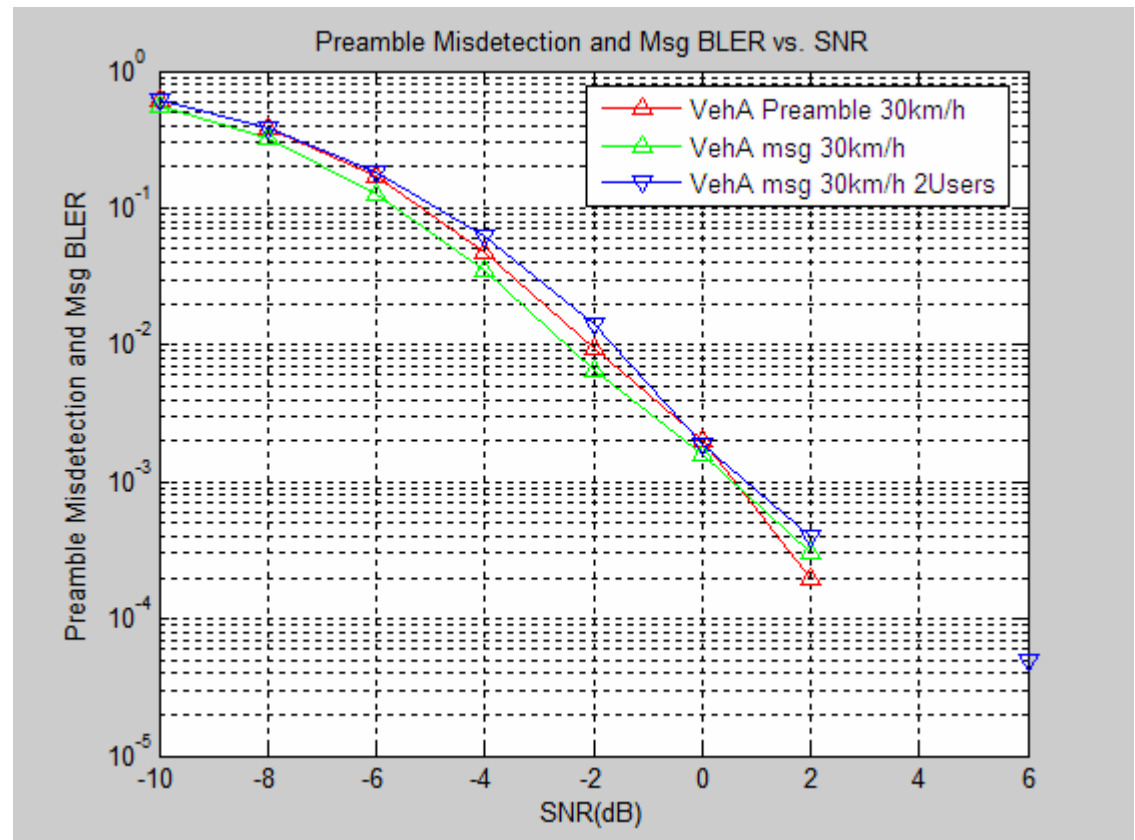
Performance, PedB 3km/h

- 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

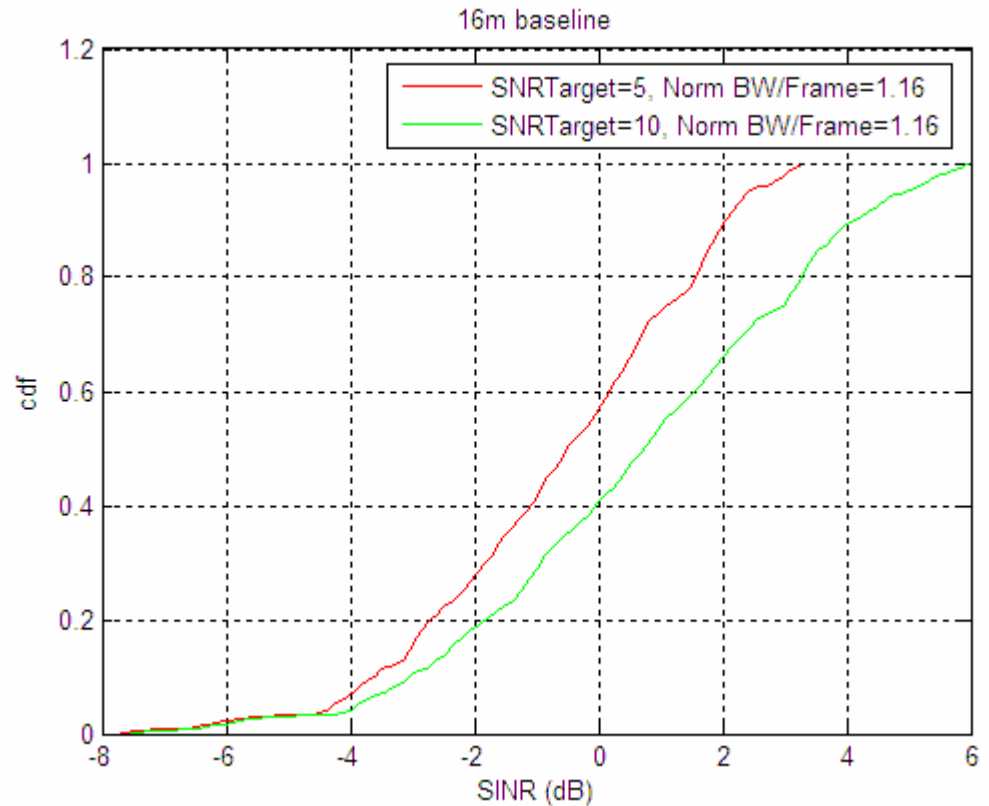


Power control aspects

- 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

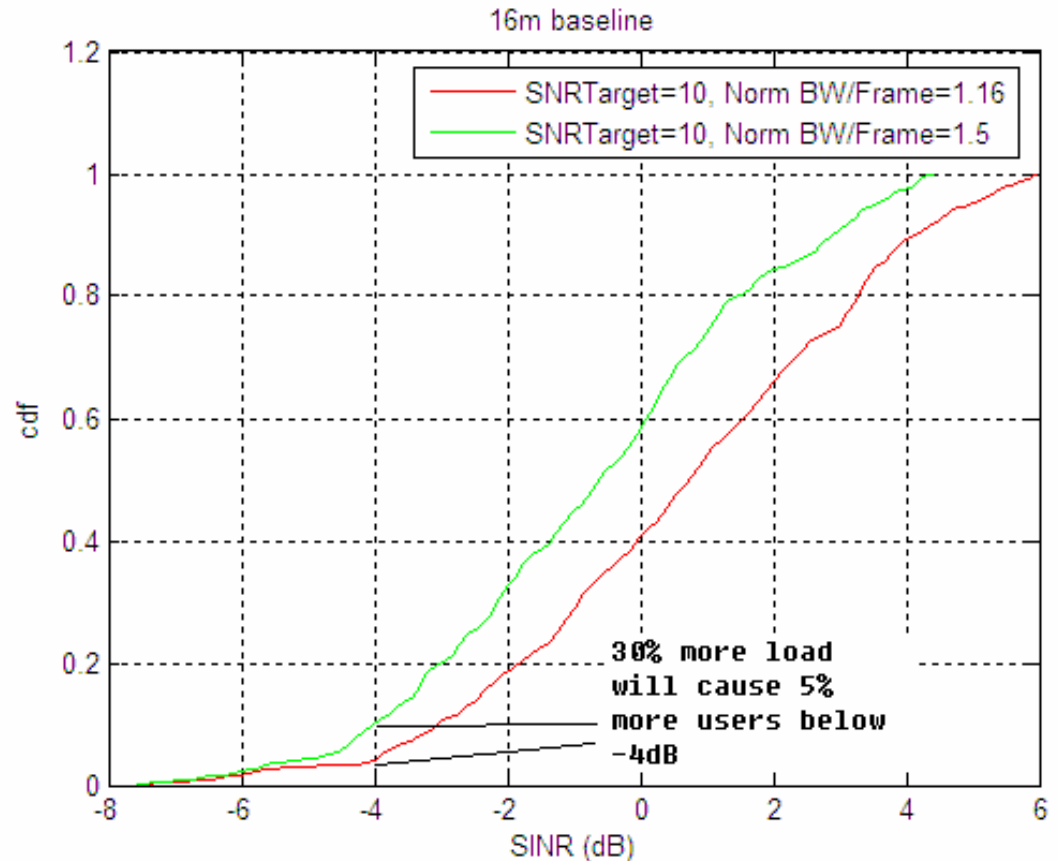
UL SINR CDF

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

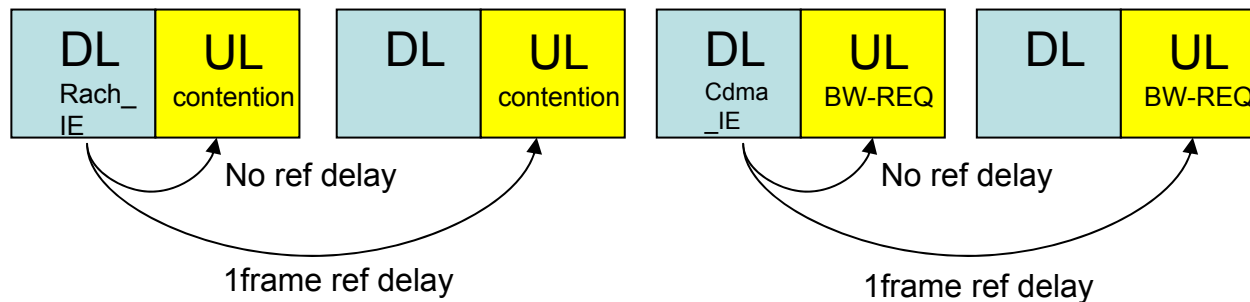
- Overhead calculation
 - Scheduled SR: straightforward N_{UE}/T_{SR}
 - RACH: Allocation rate of contention slots $\times L$
- Calculations in appendix

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)

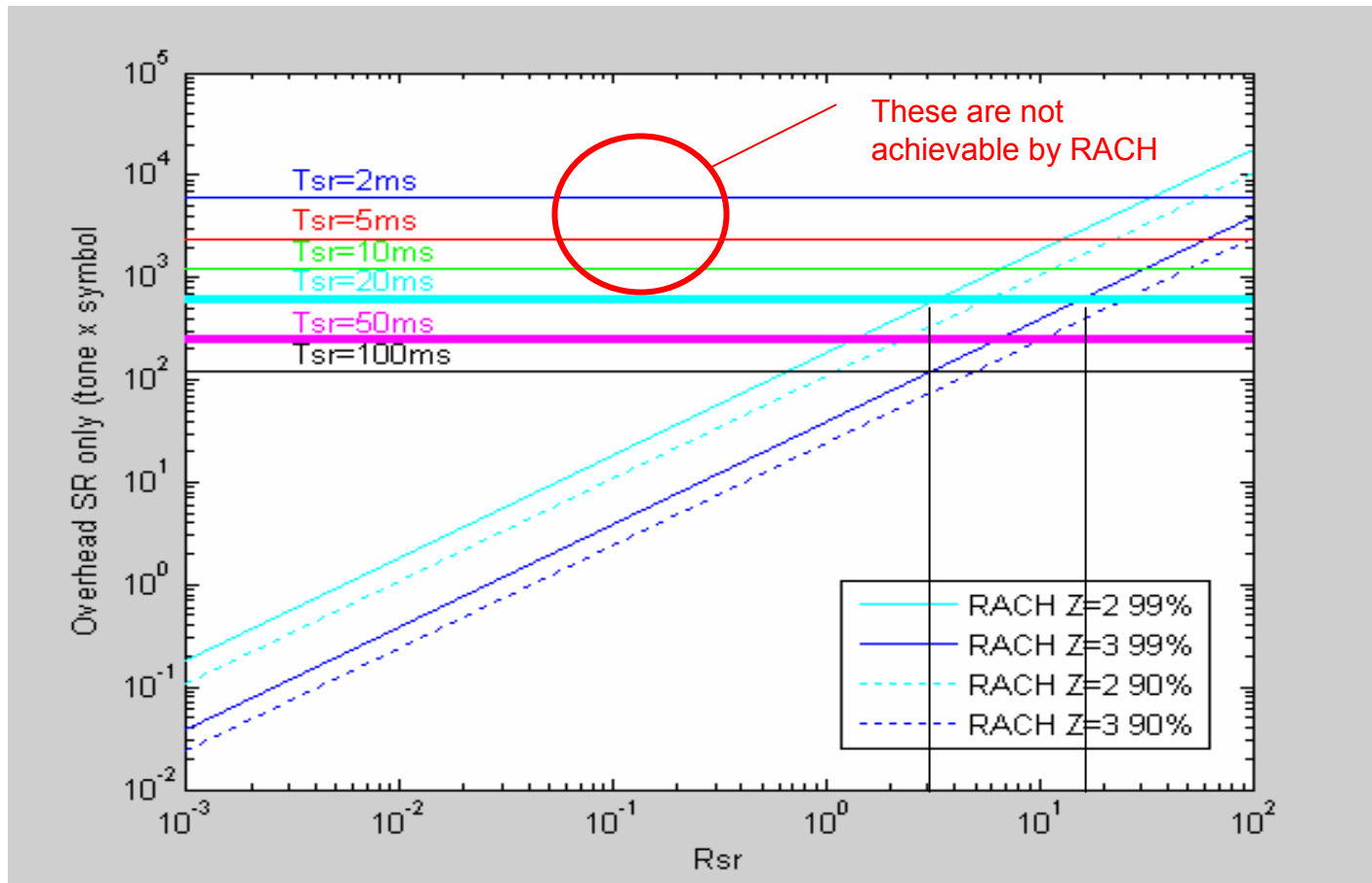
RACH vs. Polling

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



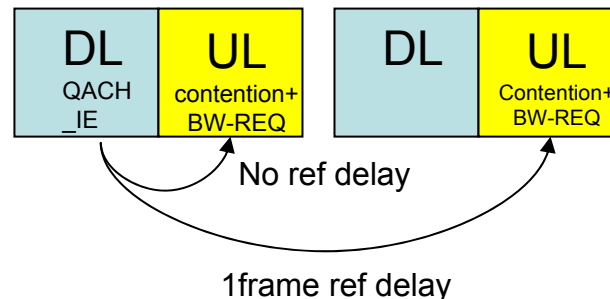
RACH vs Polling

- 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



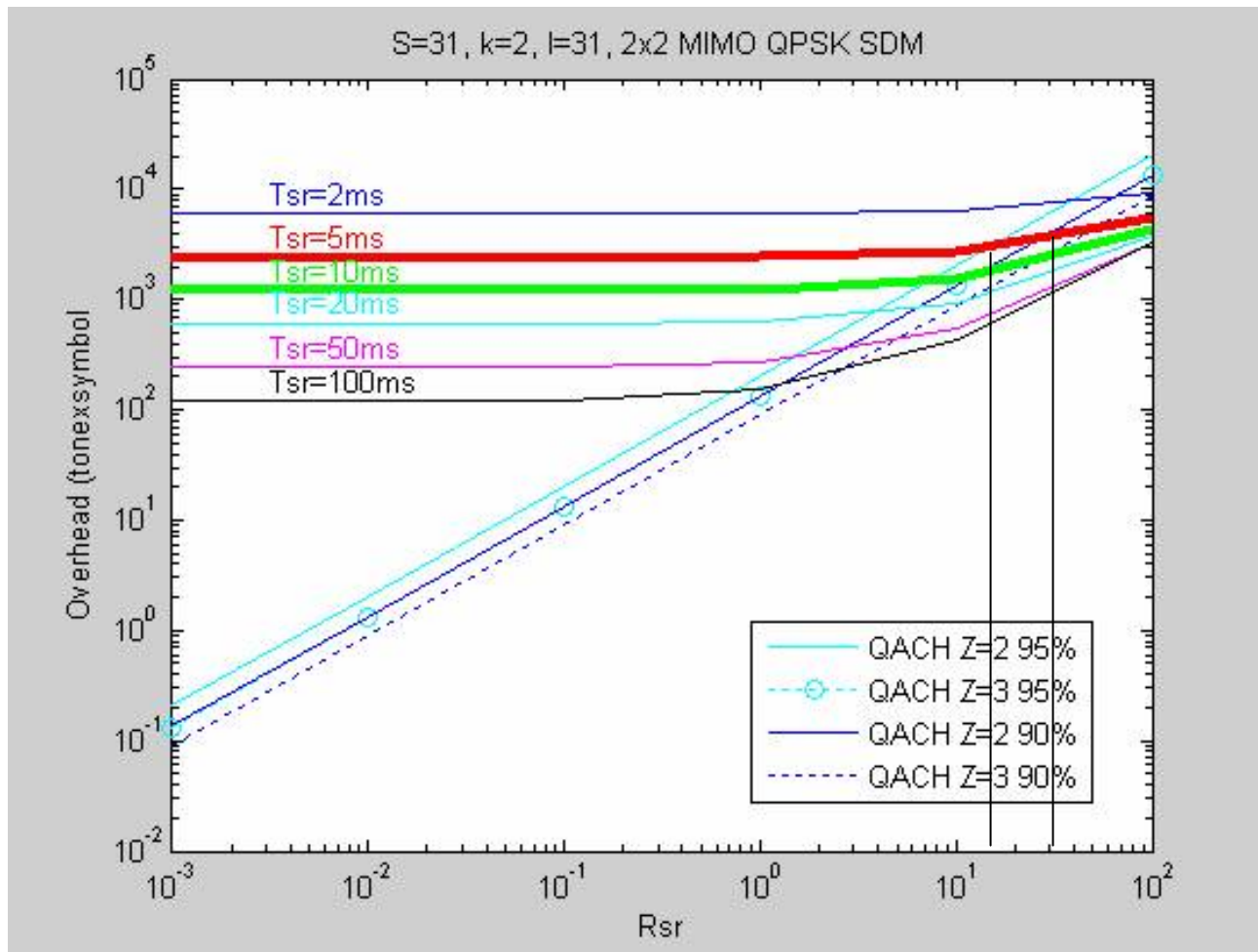
QACH vs Polling

- 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 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 $T_{sr}=5\text{ms}\sim 10\text{ms}$)
- QACH is more efficient when BW-REQ per user is below $10\sim 30/\text{sec}$



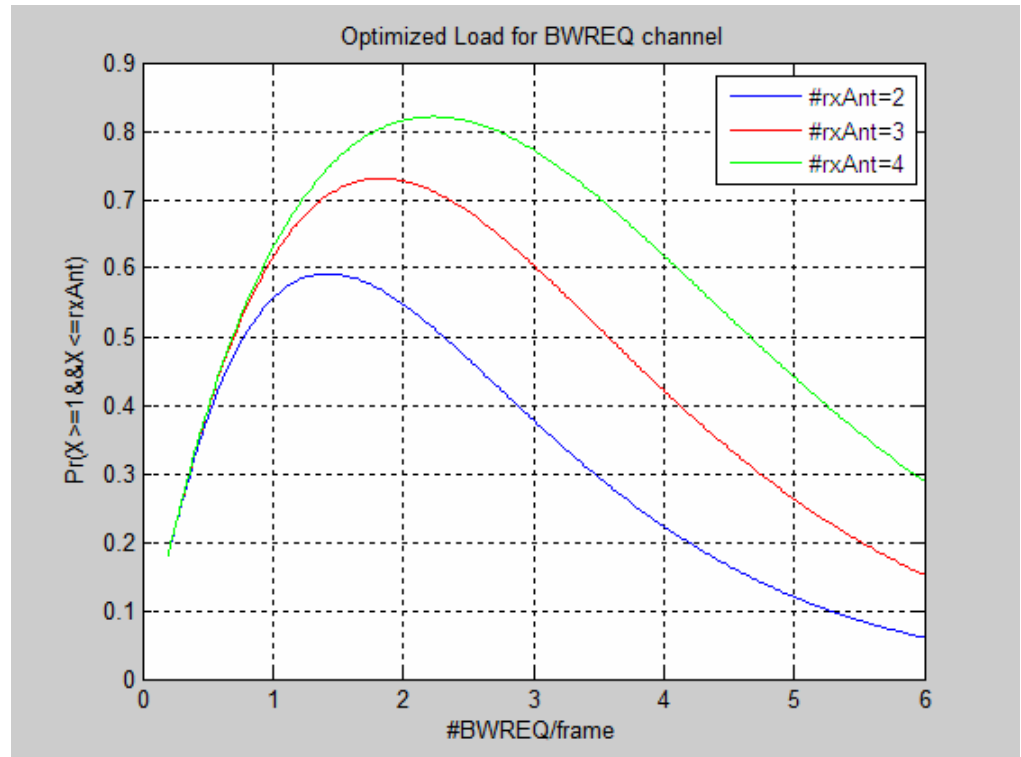
Conclusion on RACH/QACH vs. polling

- 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

SDD text

[insert the following text and figure in section 11.9.2.5.2]

The BW-REQ channel contains three 6x6 sub-tiles as shown in Fig.n. The same contention code is repeated in the preamble part of the tiles. TBD bits of BW-REQ information for quick access procedure is encoded in the data part of the tiles. The receiver performs non-coherent detection for the preamble part. The receiver perform coherent detection for the data part, with channel estimation obtained from the preamble.

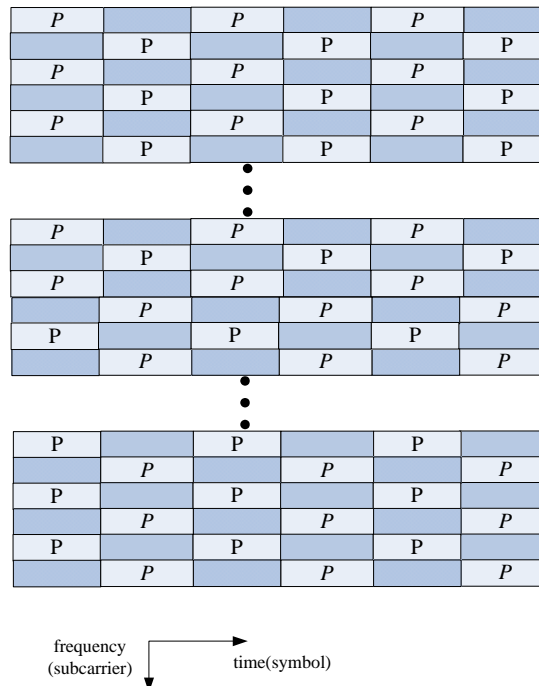


Figure.n PHY structure of BW-REQ channel
