BW-REQ channel design recommendations for IEEE 802.16m

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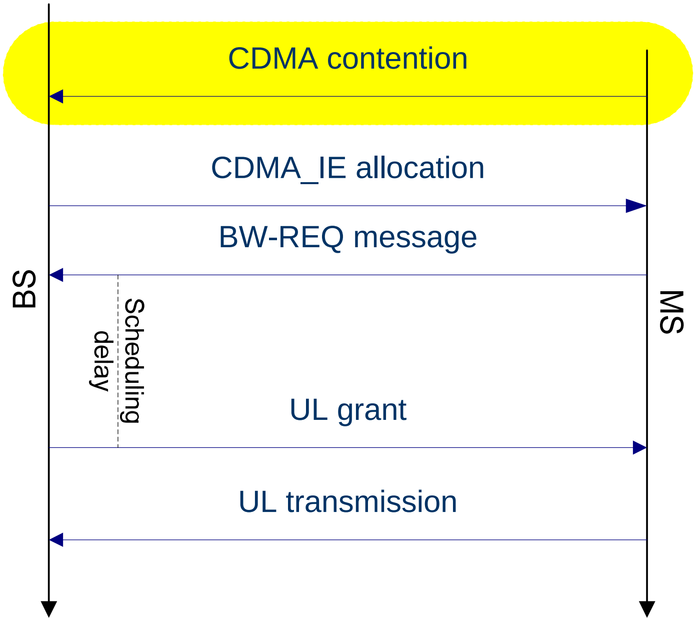
Venue: IEEE C802.16m-UL_ctrl-08/003r4 Intermediate Draft of Rapporteur Group Contribution: SDD Text on the 802.16m Uplink Control Structure, UL_ctrl Rapporteur Group discussion.

Base Contribution:

Purpose: Discussion and approval of the proposal into the IEEE 802.16m System Description Document

Bandwidth Request in the reference system

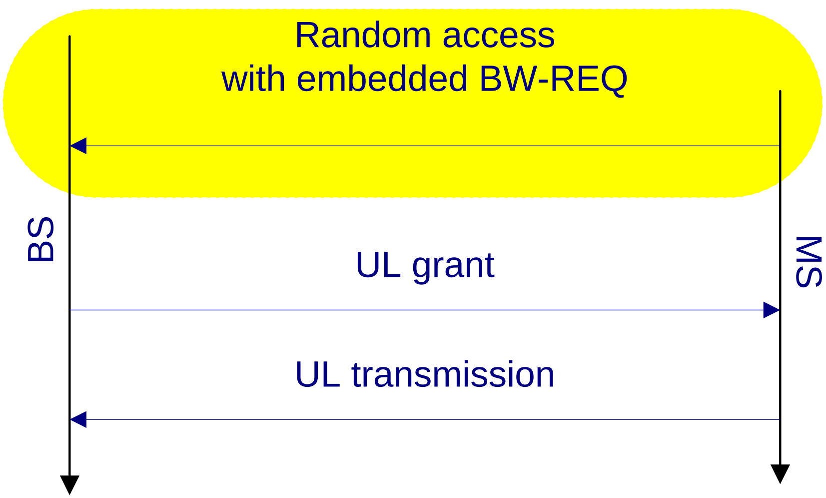
- Bandwidth Request (BW-REQ) procedure
  - CDMA (truncated 144-bit PN code) contention
  - CDMA_IE allocation for BW-REQ message
  - BW-REQ message
  - UL grant allocation for UL data
- IEEE 802.16m has more demanding requirement on BW-REQ [3]
- What can be improved?
  - Initial Ranging and BW-REQ use the same code design in the reference system although they have different requirements.
  - The 3-step BW-REQ procedure has high latency and is not suitable for delay-sensitive signaling/traffic.
  - There is no acknowledgement by the BS of the reception of the BW-REQ message, MS uses timer expiry to detect failed Bandwidth Request and restart CDMA contention



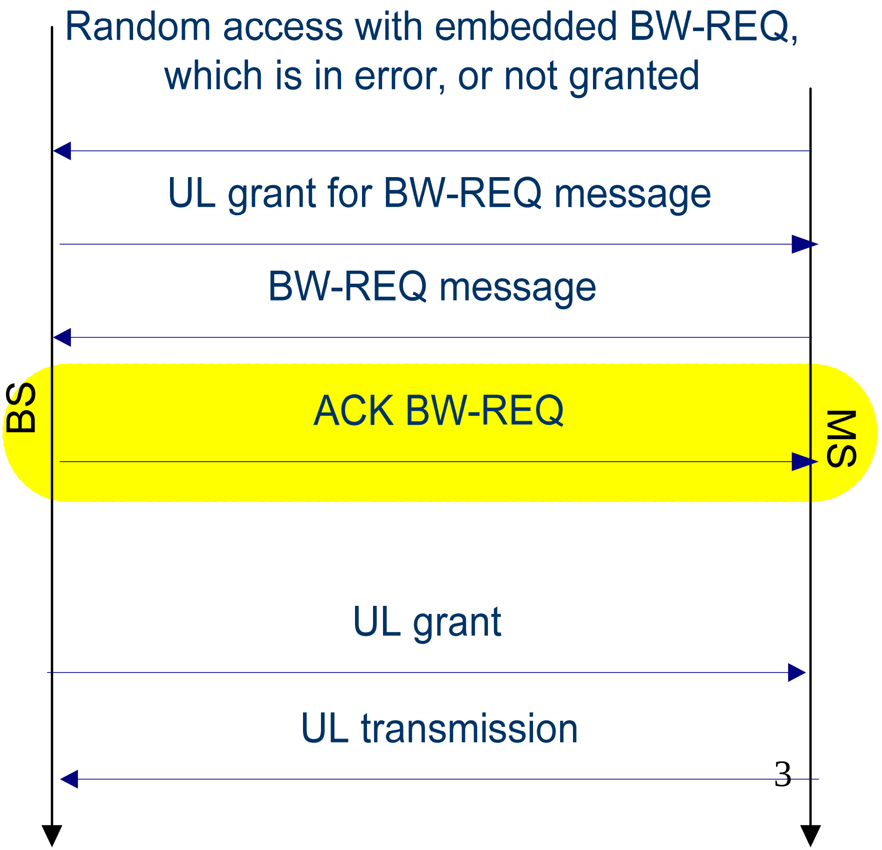
BW-REQ Design for IEEE 802.16m

Proposed improvements to current protocols

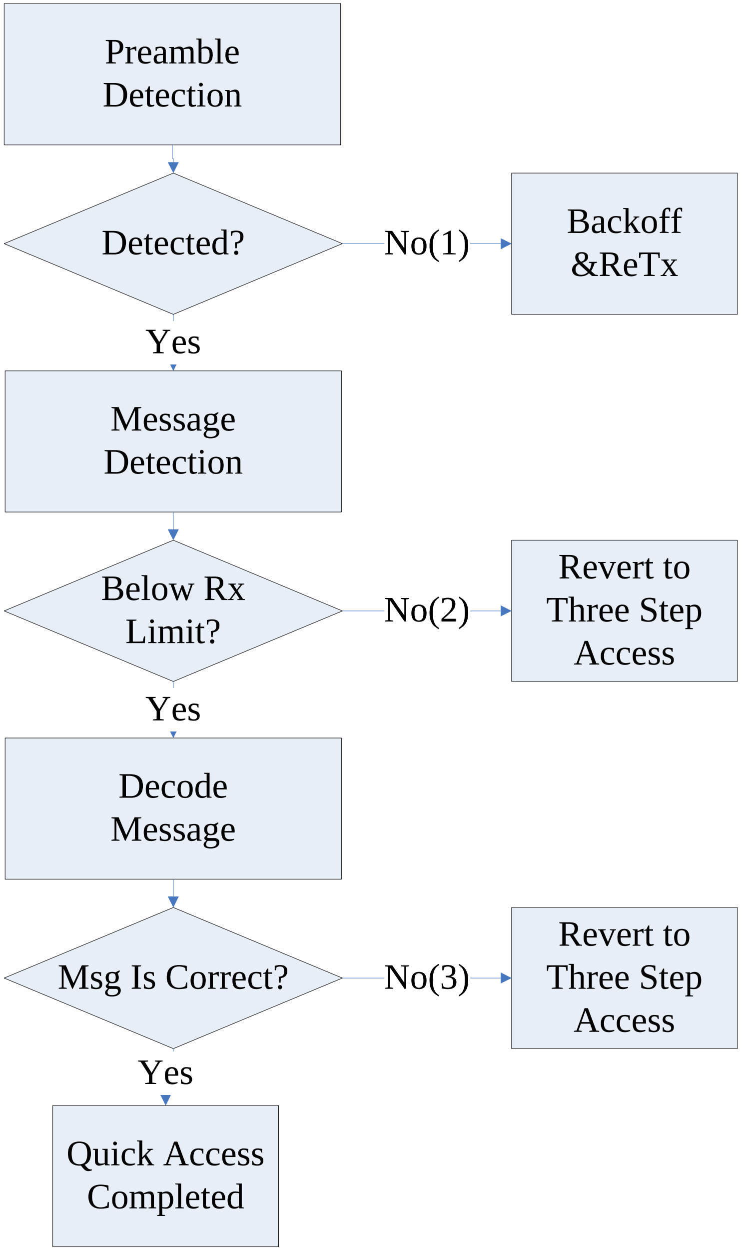
- 2-step quick access
  - Avoid one round-trip
  - Reduce signaling overhead



- 3-step regular access
  - Serves as fall-back mode for quick access
  - Explicit acknowledgment of Bandwidth Request message, enables early restart of random access

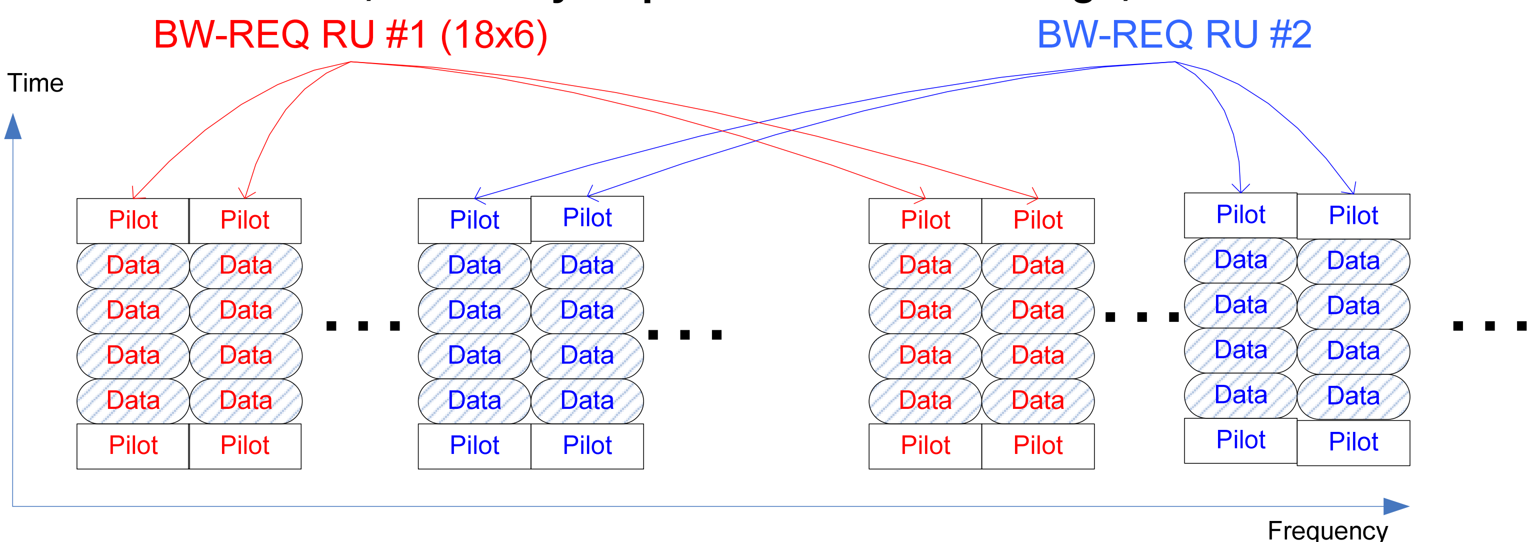


Proposed IEEE 802.16m BW-REQ Procedure



Quick Access in BW-REQ Channel

- **Short-spreading contention code (in the pilot tile)**
  - Multiple BW-REQ resource units (BW-REQ RU), e.g., each of 1 RB size (18x6)
  - BW-REQ RU may split in time/frequency for diversity gain
  - One BW-REQ RU contains one pilot tile, where MSs send in contention codes
  - Non-coherent energy detection for the contention code
  - Short-spreading facilitates channel estimation for decoding embedded BW-REQ message
- **Associated BW-REQ message (encoded in data tiles)**
  - Each BW-REQ RU contains a few BW-REQ data tiles, for example 4
  - BW-REQ info bits contains MS-ID (e.g. 10 bits) and buffer report (e.g. 6 bits)
  - Coherent detection of BW-REQ message using detected contention code as pilot
  - If BW-REQ message in error, fall back to regular 3-step BW-REQ procedure
- **Parameters are FFS, to satisfy requirements on coverage, overhead etc.**



An example of embedding BW-REQ message (in Data symbol) with contention code (in Pilot symbol)

Short Spreading Contention Code

- Sequence and length are FFS
  - Spreading length is around 16-32 bit
- Time-domain or frequency-domain spreading FFS
  - Frequency-domain spreading allows simple frequency-domain correlation receiver design and less latency
  - Time-domain spreading provides good coverage
- Under the same resource usage, short-spreading code allows multiple contention slots, and thus yields better overall performance when multiple MSs perform contention-based BW-REQ
- Short-spreading code facilitates coherent detection of short BW-REQ message
- Short-spreading SNR performance meets coverage requirement. Addition improvement may come from
  - repetition (time or frequency domain)
  - moderate power boosting on active sub-carriers

Design Concept of Embedded BW-REQ Messages

- PHY design aspect of BW-REQ message (i.e. data tile)
  - Channel coding uses convolution code for short message
  - QPSK or BPSK modulation
  - Coherent detection of BW-REQ message in data subcarriers using pilots which carry contention code

- MAC design aspect of BW-REQ message
  - Tradeoff between collision and detection
    - Less data tiles per BW-REQ RU, large data tile size allows lower rate CC with better detection
    - Less data tiles per BW-REQ RU, collisions in the data tiles are more likely even if preambles are successfully decoded.
  - Resource ratio between preamble and message tiles is FFS

Conclusions

- BW-REQ channel contains multiple BW-REQ RUs
  - Each BW-REQ RU fits in 18x6 RB
  - Each BW-REQ RU contains one pilot title for sending in contention codes and one or more data titles for sending in BW-REQ associated information
- Contention code design based on short-spreading sequences
  - Better contention channel throughput
  - Suitable for simple frequency-domain non-coherent detection
  - Flexible resource allocation for contention channel
- Quick access via embedded BW-REQ message
  - Feasible via coherent detection and channel coding
  - Enable quick access
  - When BW-REQ message is in error, fall back to regular 3-step BW-REQ procedure

Text Proposal #1 to IEEE 802.16m SDD

Insert the following text into PHY Layer clause (Chapter 11 in [IEEE 802.16m-UL_ctrl-08/003r4])

------------------------------ Text Start ------------------------------

10.x.2.5 Bandwidth request channel

The contention-based bandwidth request procedure for bandwidth requests is described in Figure 10.x.1. A 3-step procedure (step 1 to 3) or an optional quick access procedure (step 1) may be used to transmit a UL grant (step 5) for the requested bandwidth and subsequent UL transmission (step 6). Following the 3-step access procedure, the BS provides an acknowledgement (step 4) for the bandwidth request message transmitted by the MS to enable a information for the MS to restart of the random access procedure (from step 1) to recover quickly from a failed bandwidth request.

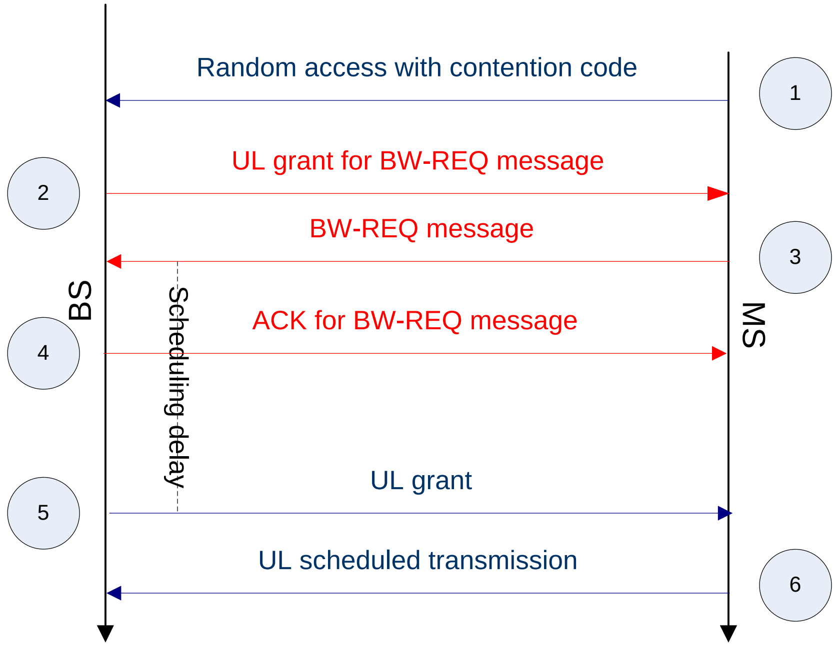


Figure 11.x.1 Contention-based BW-REQ procedure

------------------------------ Text End ------------------------------

Text Proposal #2 to IEEE 802.16m SDD

Insert the following text into Physical Layer clause (Chapter 11 in [IEEE 802.16m-UL_ctrl-08/003r4])

------------------------------- Text Start -------------------------------

11.x.2.5.1 Multiplexing with other control channels and data channels

The BS can configure the frequency and location of random access opportunities for bandwidth requests.

------------------------------- Text End -------------------------------

Text Proposal #3 to IEEE 802.16m SDD

Insert the following text into Physical Layer clause (Chapter 11 in [IEEE 802.16m-UL_ctrl-08/003r4])

------------------------------ Text Start ------------------------------

11.x.2.5.2 PHY structure

BW-REQ channel contains multiple BW-REQ resource units (RUs), in which a MS can send in a contention code along with a BW-REW message for quick access.

------------------------------ Text End ------------------------------

References

[1] IEEE 802.16m-07/002r4, “TGm System Requirements Document (SRD)”

[2] IEEE 802.16m-08/004r1, “Project 802.16m Evaluation Methodology Document (EMD)”

[3] IEEE 802.16m-08/368r1, “BW-REQ channel requirements and design recommendations for IEEE 802.16m”, Intel Corporation

Appendix

BW-REQ Requirements

in C80216m-08/368r1

Higher IEEE 802.16m requirement on BW-REQ

IEEE 802.16m system requirements from SRD [1]

- High application capacity
  - Lead to high UL signaling load from L2/L3, which likely needs BW-REQ
  - BW-REQ generates higher load to contention channel
- Low latency
  - Tight requirement on state transition or handover latency
  - Good E2E performance and SE desire low UL access latency
- High mobility support: upto 350Km/hr
  - Small channel coherence time, timing/frequency offset and power control errors
  - Robust contention detection performance

Our view, IEEE 802.16m requirements on BW-REQ are in two aspects

- Contention channel (PHY)
  - Sufficient contention capacity
  - Good detection performance in various loads
  - Robust detection performance in various channel conditions
- Contention-based BW-REQ protocol (MAC)
  - Allow simpler/faster UL access
  - Provide fast recovery from contention failure or collision
  - Contention management is necessary to handle bursty contention loads

Application scenario examples

- Use SRD [1]
  - 10MHz/10MHz FDD
  - 60 VoIP calls/MHz/sector,
  - 2.6bps/Hz/sector DL SE requirement (TCP), 75% loading

- Use EMD [2] to define the following traffic patterns

  - Call setup for VoIP application session
    - BW-REQ only at the beginning of each session
    - At most 40ms UL access delay to meet 50ms delay bound (10ms budget for HARQ latency)

  - UL access for on-off applications
    - BW-REQ when off$\rightarrow$on switch to obtain UL grant
    - Assume push-to-talk type of traffic
    - At most 40ms UL access delay to meet 50ms delay bound

  - UL L3 signaling for DL TCP applications
    - BW-REQ when TCP ACK sent in uplink
    - Assume no opportunity for piggybacking BW-REQ
    - 500ms UL access delay to avoid TCP timeout (100ms downlink, 400ms backbone RTT)

BW-REQ contention channel PHY design targets and recommendations

Design targets for BW-REQ contention channel

- handle 0.1~0.15/ms/FDD-MHz contention load
- <1% overhead for BW-REQ contention channel excluding extra embedded MAC information such as buffer size (comparable to the reference system)
- Below target load, success probability >90%

SDD Recommendations

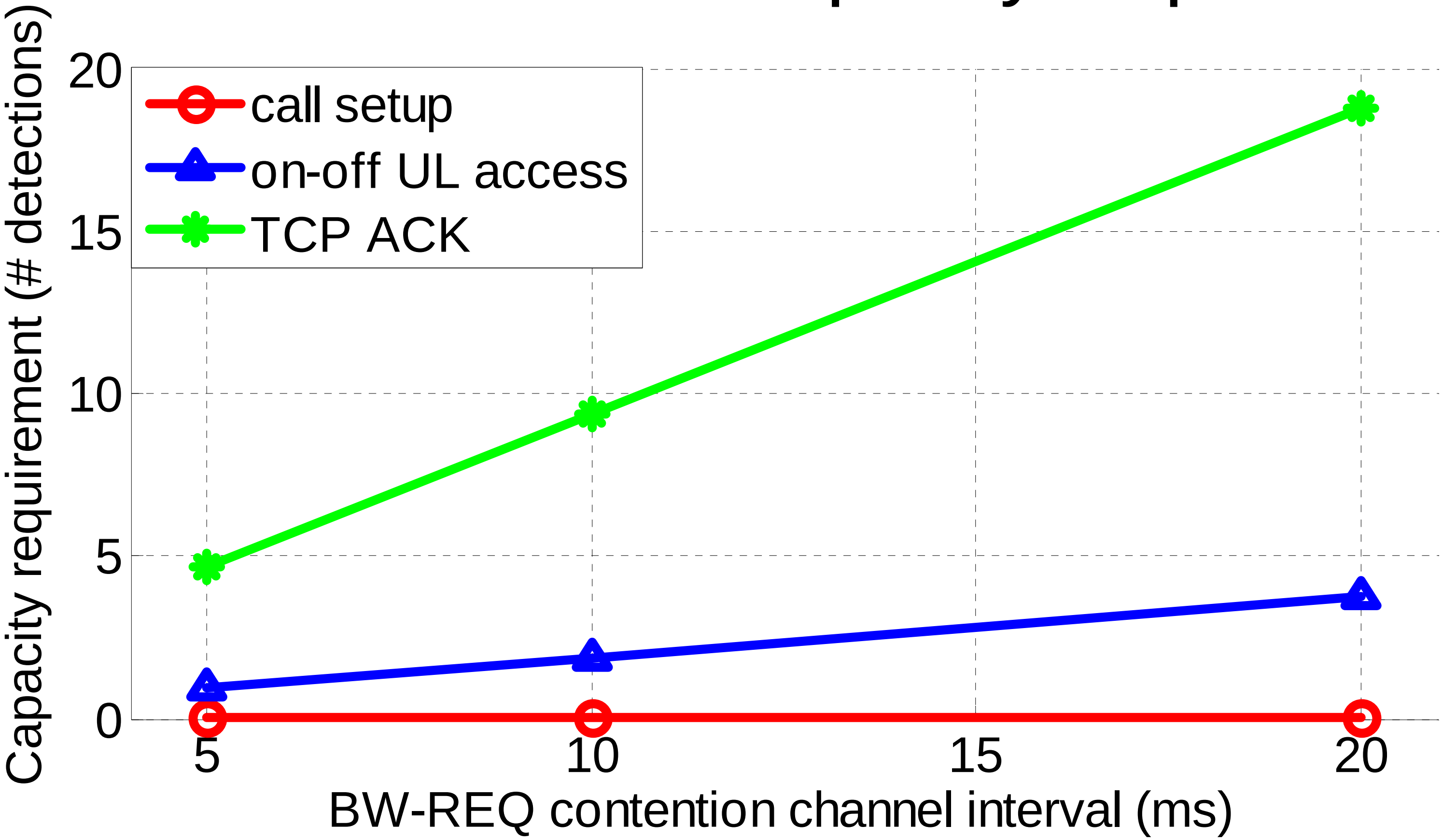
- Use a BW-REQ design different from initial ranging
  - Detection performance optimized for relatively low timing/frequency offset
  - Good performance in frequency-selective or fast fading channels
  - A channel design suitable for large dynamic range of contention loads

- Contention channel allows flexible allocation of logical contention resources
  - Scalable to different bandwidth
  - Robust/adaptive to traffic dynamics

BW-REQ MAC protocol design target

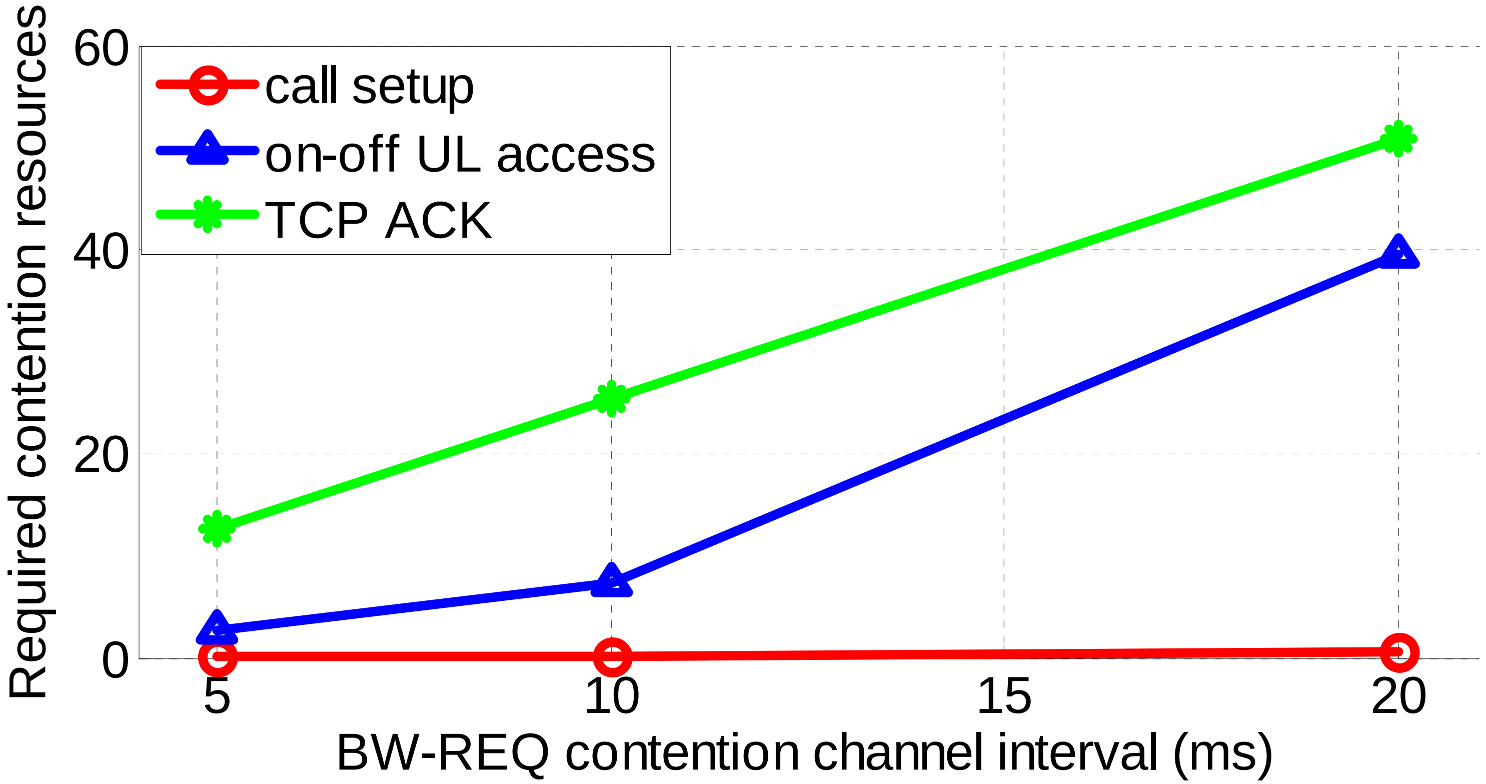
- Min UL access delay
  - Definition: from contention to UL transmission
  - Desire to achieve the fast turn-around
  - Target: 10ms in IEEE 802.16m frame structure defined in SDD[1], suitable for delay-sensitive bursty traffic and signaling
- Average UL access delay
  - Guaranteed by PHY contention success probability
- Max recovery delay
  - Definition: from failed contention to retry
  - 40ms, allowed by the delay bound of delay-sensitive traffic/signaling
  - MS can retry 2nd time within 40ms, making overall failure probability <1%

Contention channel capacity requirement



- Call setup offers marginal contention load
- Challenging to support On-off UL access in the reference system
  - allocation is required every <10ms
- Heavy downlink TCP data traffic causes huge contention load
- Required contention resource depends on both:
  - contention channel capacity requirement
  - Latency requirement

Contention channel resource requirement



- contention resource measures
  - # of separated physical (time/frequency) allocations
  - # of (quasi-)orthogonal code words
- Assume a multi-slot ALOHA model, contention resource measured in slots.
  - Assume all contenders, will be detected.
  - Collision happens if >1 MSS pick the same slot.
- Practically, detection probability is <1 and decreases in load, thus the requirement is much more stringent!

Lesson learned from the application examples

- When delay or success probability is a concern (e.g., see on-off UL access case)
  - Tight QoS constraint causes required contention resource increase non-linearly in BW-REQ interval
  - Better allocate more frequently to reduce overhead
- TCP case has relaxed QoS requirement but it has high load
  - In any case, require sufficient allocation for contention
  - When consider practical detection performance drops in load, required allocation will be more and increase non-linearly
- Generally
  - Much more demanding in capacity and latency than the reference system!
  - To be scalable to traffic mix and bandwidth, the design should be flexible