3GPP TSG-RAN WG1 NR Ad Hoc Meeting #2 **R1-1711252**
Qingdao, China, 27th-30th June 2017

Source: **Cohere Technologies**
Title: **Support of Long-PUCCH over Multiple Slots**
Agenda item: **5.1.3.2.2.2**
Document for: **Discussion/Decision**

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1 Introduction

In recent past 3GPP RAN 1 meetings, the structure of PUCCH in long duration (PUCCH-LD) was discussed, and the following relevant agreements were reached [1-4], as detailed in Appendix A. In a separate contribution, we propose a format for PUCCH in long duration and provide simulation results [5]. In this contribution, we discuss the applicability of the format described in [5] to PUCCH-LD transmitted over multiple slots. Note that several aspects regarding PUCCH-LD transmission over multiple symbols and regarding frequency hopping were also discussed in [6].

2 PUCCH-LD Transmission over Multiple Slots

In [6], a format for PUCCH-LD based on phase rotations or cyclic shifts of a base sequence, combined with DFT spreading codes, was proposed for small payloads (1 or 2 bits). In [5], an extension of this format was proposed for larger payloads of multiple symbols, whereby different shifts and/or DFT codes are used for different symbols of a given payload.

An illustration of the proposed PUCCH-LD format is provided in **Error! Reference source not found.**. A QPSK symbol $b_{k,l}$ is first multiplied by a DFT spreading code $[v_k(0) \dots v_k(M-1)]$, i.e. the k-th column of a size M DFT matrix. Each symbol is then multiplied by a length N sequence $[s(0) \dots s(N-1)]$, and subsequently by a length N orthogonal phase rotation $[w_l(0) \dots w_l(N-1)]$. Note that phase rotation vectors are also columns of a size N DFT matrix. Alternatively, cyclic shifts of a base sequence may also be used. As a base sequence, a CAZAC sequence, such as Zadoff-Chu, may be chosen. The resulting symbols are then loaded on a size N*M grid of PUCCH-LD resources. This method allows transmitting multiple symbols of one PUCCH-LD by selecting different indices k,l.

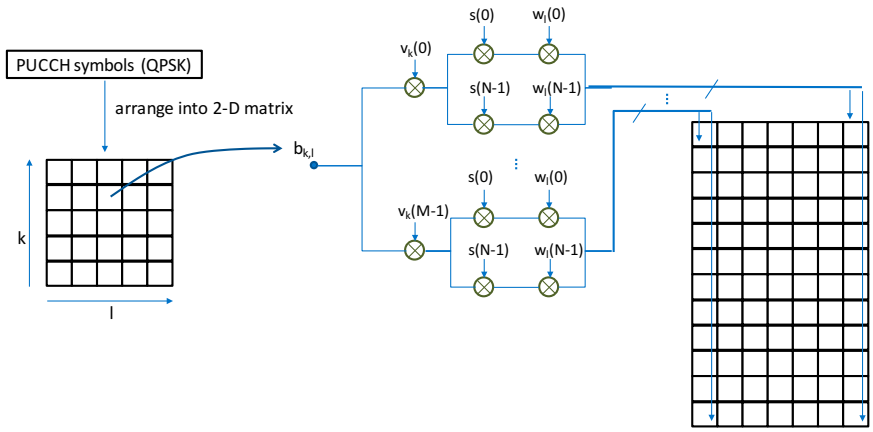

Figure 1. Illustration of 2-dimensional spreading for PUCCH.

PUCCH-LD transmission over multiple slots has two distinct advantages. First, it allows a better link budget to support extended range or larger payloads. Second, it may provide additional diversity, if frequency hopping is used, or due to mobility and Doppler spread in the channel.

Regarding the PUCCH-LD format described above, and in [5] in more detail, there are two fundamental ways to extend it:

- *Method 1: Repetition*. A first approach (Figure 2) consists in applying the same structure to every slot, using different payload symbols. This structure relies on channel coding and interleaving to extract the potential diversity in multiple slots.
- *Method 2: Extension.* A second approach (Figure 3) consists in extending the length of DFT codes over multiple slots. With this approach, the energy of each symbol is evenly spread over all channel states, allowing a higher degree of diversity regardless of the properties of the channel code and interleaver. The number of code

combinations is the same as for method 1, since the length of the code is doubled, as well as the number of codes available.

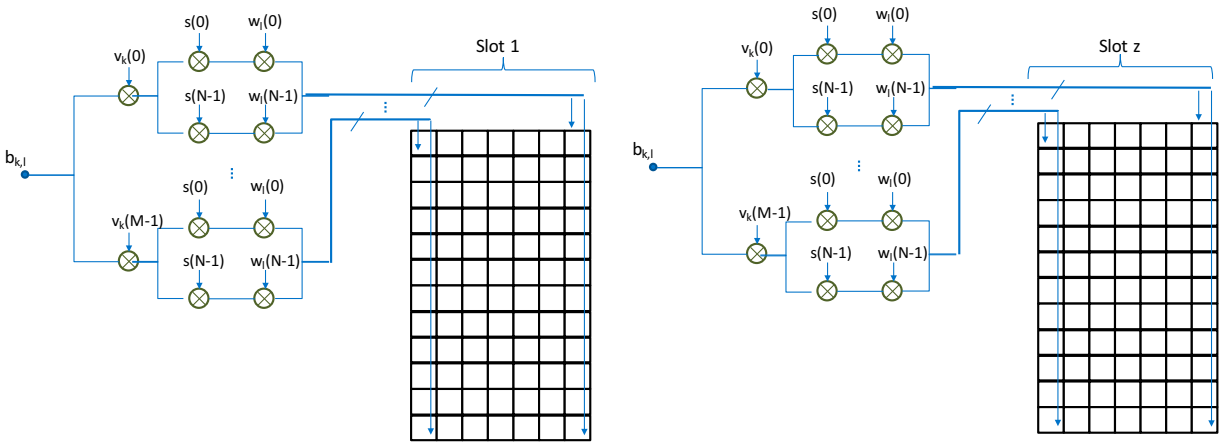

Figure 2. Method 1: independent PUCCH-LD structure per slot.

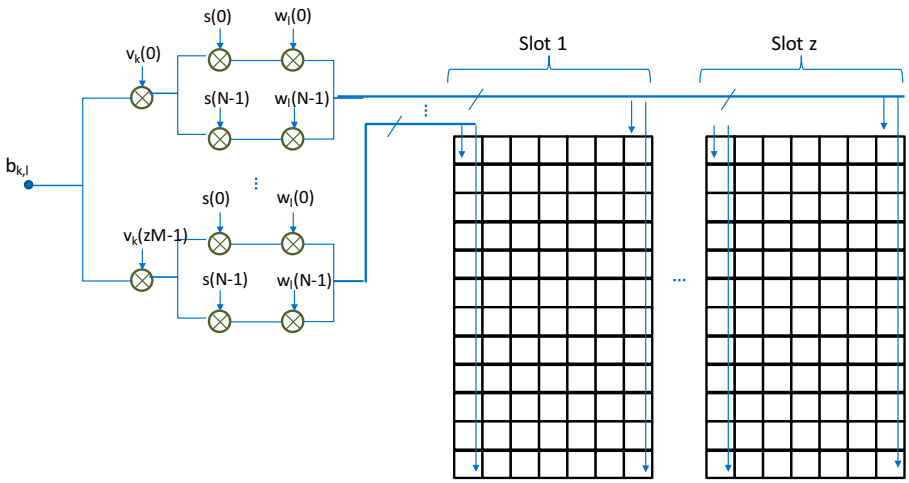

Figure 3. Method 2: single PUCCH-LD structure spanning multiple slots.

3 Conclusion

In this contribution two methods for the transmission of PUCCH-LD over multiple slots were proposed.

4 References

[1]. Draft Report of 3GPP TSG RAN WG1 #89 v1.0.0 (Hangzhou, China, 15th – 19th May 2017).
[2]. Final Report of 3GPP TSG RAN WG1 #88bis v1.0.0 (Spokane, USA, 3rd – 7th April 2017).
[3]. Final Report of 3GPP TSG RAN WG1 #88 v1.0.0 (Athens, Greece, 13th – 17th February 2017).
[4]. Final Report of 3GPP TSG RAN WG1 #AH1_NR v1.0.0 (Spokane, USA, 16th – 20th January 2017).
[5]. R1-1711251, "Design of Long-PUCCH for UCI of more than 2 bits", 3GPP TSG-RAN WG1 NR Ad Hoc Meeting #2, Qingdao, China, 27th-30th June 2017.
[6]. R1-1708314 "Structure of PUCCH in long-duration, Cohere Technologies," 3GPP TSG RAN WG1 #89, Hangzhou, China, May 15th – 19th 2017.

5 Appendix A: Relevant RAN1 Agreements

RAN1#89 (Hangzhou)

Agreements:

- Long duration NR-PUCCH for up to 2 bits in a given slot is composed as the followings:

- HARQ ACK by BPSK or QPSK modulation is repeated in time domain and multiplied with sequence(s)
  - FFS: pi/2 BPSK usage
- Two states SR is based on on-off-keying
- Time domain OCC can be applied over multiple UCI/DMRS symbols per frequency hop

Agreements:

- NR supports following long-PUCCH:
  - One PUCCH format for UCI with up to 2 bits with high multiplexing capacity
  - One PUCCH format for UCI with large payload with no multiplexing capacity
- FFS: One PUCCH format for UCI with moderate payload with some multiplexing capacity
  - Note: this could be a variation of one of the former PUCCH formats.

RAN1#88b (Spokane)

Agreements:

- For long duration NR-PUCCH in a given slot, FFS the detailed NR PUCCH formats. Companies are encouraged to provide the corresponding details.
  - Some examples as a starting point:
    - For small UCI payload with 1 or 2 bit(s), LTE PUCCH 1a/1b especially in light of # of symbols available for NR-PUCCH
      - FFS: Time domain OCC is applied over allocated multiple symbols.
    - For large UCI payload with X bits, LTE PUCCH format 4, or PUSCH
      - FFS on applicability of (virtual) frequency domain OCC
    - FFS for the value of X
    - FFS for medium UCI payload with less than X bits
    - Scalability of NR-PUCCH for different number of symbols available for NR-PUCCH
- The set of the number of symbols for long duration NR-PUCCH in a slot includes {4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14}
  - FFS whether or not it depends on the slot type, # of symbols per slot, etc.

Agreements:

- For DFTsOFDM in long-PUCCH, the following schemes are candidates for transmit diversity:
  - Low PAPR Alamouti-based transmit diversity applied in frequency or time domain, transparent transmit diversity (e.g. short delay CDD), time domain beam/precoder cycling or SORTD
  - FFS: for which PUCCH format and/or payload size
  - Other schemes with low PAPR are not precluded.
- Companies proposing a certain transmit diversity scheme are encouraged to jointly propose PUCCH structure and the transmit diversity scheme.

RAN1#88 (Athens)

Agreement: Both TDM and FDM between short duration PUCCH and long duration PUCCH are supported at least for different UEs in one slot

Agreements:

- For a given UCI payload, short-PUCCH is designed such that:
  - UE multiplexing capacity can be less than that of long-PUCCH
  - Performance including at least the following:
    - Frequency-diversity
    - Interference-diversity
    - PAPR/CM and emission
    - RS overhead
  - Interference randomization should be enabled
  - For more than 2 UCI bits, strive for scalable design with short-PUCCH
- For a given UCI payload, long-PUCCH is designed such that:
  - FFS: UE multiplexing capacity should be same/similar to LTE PUCCH
  - PAPR/CM should be same/similar to LTE PUCCH except for NR CP-OFDM case (if supported)
  - Frequency-diversity gain should be same/similar to LTE PUCCH
  - Interference randomization should be enabled
  - For more than 2 UCI bits, strive for scalable design with long-PUCCH with respect to the number of UCI bits
  - Strive for scalable design with long-PUCCH with respect to the number of symbols

Agreement:

- For PUCCH in long-duration, it may have variable number of symbols with a minimum of 4 symbols in a given slot
    - FFS the set of supported values

Agreements:

- For PUCCH in long duration,
    - At least for 1 or 2 UCI bits, the UCI can be repeated within N slots (N>1)
        - The N slots may or may not be adjacent in slots where PUCCH in long duration is allowed
        - Details are FFS, including repetition scheme including same or different formats, the possible value(s) N, the mechanism to determine the value of N, etc.
    - FFS for >2 UCI bits
    - FFS the case of within a slot

RAN1#AH1-NR (Spokane)

Agreements:

- For PUCCH in long-duration,
    - Long UL-part of a slot can be used for transmission of PUCCH in long-duration.
        - i.e., PUCCH in long-duration is supported for both UL-only slot and a slot with the number of uplink symbols greater than X (X >= 2).
            - FFS exact value of X
    - In addition to simultaneous PUCCH-PUSCH transmission, UCI on PUSCH is supported.
    - Intra-slot frequency-hopping is supported

Agreements:

- For further discussion of PUCCH in short-duration, UCI payload of 1 – at least a few tens of bits (or SR) is assumed.
- For further discussion of PUCCH in long-duration, UCI payload of 1 – at least a few hundreds of bits (or SR) is assumed.
- For PUCCH in long-duration, DFT-s-OFDM waveform is supported.
- For PUCCH in long-duration, transmit antenna diversity is supported.
    - FFS: PUCCH in short-duration

Agreements (updating RAN1 #87 agreements):

- A combination of semi-static configuration and (at least for some types of UCI information) dynamic signaling is used to determine the PUCCH resource both for the ‘long and short PUCCH formats’
    - The PUCCH resource includes time, frequency and, when applicable, code domains.
        - FFS details e.g., if the time in the PUCCH resource includes both slot and symbol, or only symbol in a slot