

Research Paper Presentation

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Title and Author

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Performance comparison of DTX detection schemes for 5G NR PUCCH

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Abstract

- The detection of discontinuous transmission (DTX) at the receiver
- Demodulation of the uplink control information (UCI) that is transmitted on the 5G New Radio (NR) Physical Uplink Control Channel (PUCCH)
- Two feasible detection schemes of the DTX for 5G NR PUCCH format 0 are considered.
- The performance comparisons of these are carried out by the computer simulations under several situations.
- The simulation results show that these meet the performance metrics described in the 3GPP standards.

Keywords

DTX

Discontinuous transmission (DTX) is a method of momentarily powering-down a mobile or portable wireless telephone set when there is no voice input. This optimizes the overall efficiency of a wireless voice communication system.

Physical uplink control channel(PUCCH)

PUCCH is an uplink physical channel that carries UCI (Uplink Control Information). UCI consists of HARQ (Hybrid Automatic Repeat Request) feedback, CSI (Channel State Information) and SR (Scheduling Request).

PUCCH Format

Depending on what kind of information the UCI in PUCCH contains, PUCCH is classified into various formats.

Keywords

UE

A device carries the uplink control information (UCI) on the Physical Uplink Control Channel (PUCCH).

TX and RX

TX and RX are abbreviations for Transmit and Receive, respectively.

gNB

The gNB is a 3GPP 5G Next Generation base station which supports the 5G New Radio.

SNR

The Signal to noise ratio(SNR) is the difference between the received wireless signal and the noise floor.

Introduction

- 5G NR (New radio) is latest cellular wireless technology which follows 3GPP specifications.
- UCI can be transmitted on PUCCH using five different formats for various situations and scenarios
- Short-PUCCH such as format 0 and format 2 can be transmitted in short-duration (1 or 2 OFDM symbols).
- On the other hand, long-PUCCH such as format 1,3 and 4 can be transmitted occupying from 4 to 14 OFDM symbols.

Introduction

- Whenever the number of bits of UCI is less than equal to 2, format 0 and 1 should be used to carry only HARQ and Scheduling Request (SR). The other formats can be used to transmit UCI more than 2 bits for carrying CSI.
- In this paper, we focus only on the detection of 5G NR PUCCH format 0 that is quite different from the other formats.

Introduction

PUCCH format	Number of OFDM symbols	Number of UCI bits
0	1 ~ 2	≤ 2
1	4 ~ 14	≤ 2
2	1 ~ 2	> 2
3	4 ~ 14	> 2
4	4 ~ 14	> 2

Figure: Table regarding 5G PUCCH formats

System Description

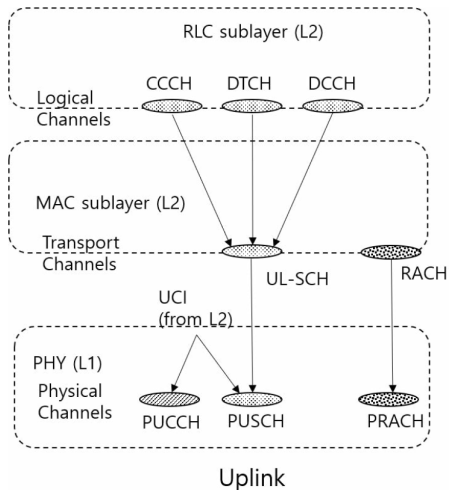


Figure: Mapping between UL channels

System Description

- A PUCCH format for a UE can be configured by the Radio Resource Control (RRC) signaling from gNB (Next generation nodeB).
- The resource configuration for the UE PUCCH format can be defined by several RRC parameters such as intraSlot Frequency Hopping, starting PRB, second Hop-PRB, no of Symbols, and starting Symbol Index.
- A PUCCH format 0 can be used during RRC connection, because the UE has only HARQ-ACK information bit and can be used under the situation when the low latency is needed.

System Description

- PUCCH format 0 sequence is generated according to

$$x(l.N_{sc}^{RB} + n) = r_{u,v}^{(\alpha,\delta)}(n) \quad (1)$$

$$n = 0, 1, 2, \dots, N_{sc}^{RB} - 1$$

$$l = \begin{cases} 0 & \text{for 1 OFDM symbol,} \\ 0, 1 & \text{for 2 OFDM symbols} \end{cases}$$

- Where $r_{u,v}^{(\alpha,\delta)}(n)$ is low peak-to-average power ratio (PAPR) sequence with m_{CS} depending on UCI bits.
- N_{sc}^{RB} is the number of subcarriers per resource block.

System Description

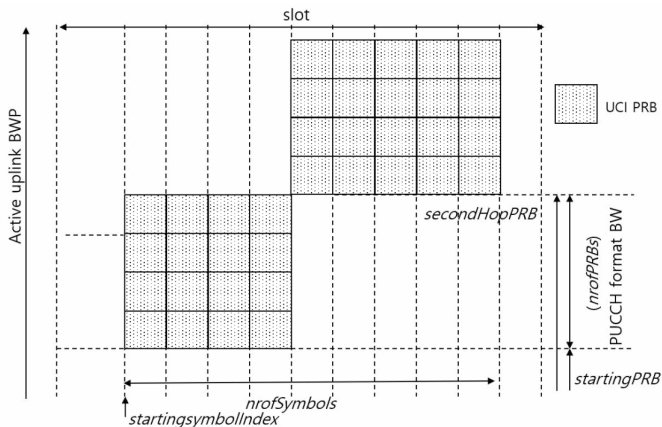


Figure: PUCCH resource allocation and related RRC parameters

System Description

Transmission Type	HARQ value			
	$\{0,0\}$	$\{0,1\}$	$\{1,0\}$	$\{1,1\}$
No SR/1 bit HARQ	0	6	-	-
SR/1 bit HARQ	3	9	-	-
No SR/2 bits HARQ	0	3	6	9
SR/2 bits HARQ	1	4	7	10

Figure: m_{CS} VALUE FOR HARQ/SR TRANSMISSION OF FORMAT 0

System description

- There are 4 possible different Low-PAPR sequences for one OFDM symbol transmission and 8 orthogonal candidates for two OFDM symbol transmission at the receiver side of gNB.
- The received sequences are correlated with these sequences:

$$C_m = \frac{1}{N_r} \sum_{r=0}^{N_r-1} \left| \frac{1}{N_{sc}^{RB}} \sum_{k=0}^{N_{sc}^{RB}-1} R_r(k) \times X_m^*(k) \right| \quad (2)$$

- N_r : no of RX branch.
- $R_r(k)$: received PUCCH sequence in the frequency domain
- $X_m^*(k)$: conjugated sequence that $m = m_{CS}$
- The demodulated UCI bits can be obtained by finding m that provides the maximum of C_m .

Performance Metrics

- There are two performance metrics for NR PUCCH format 0.

DTX to ACK probability

It is the probability that ACK is detected when nothing was transmitted to gNB.

- Performance requirement: DTX to ACK probability $< 1\%$

Missed ACK probability

The missed ACK probability is the probability of not detecting an ACK when an ACK was sent.

- Performance requirement: Missed ACK probability $< 1\%$

TX and RX processing

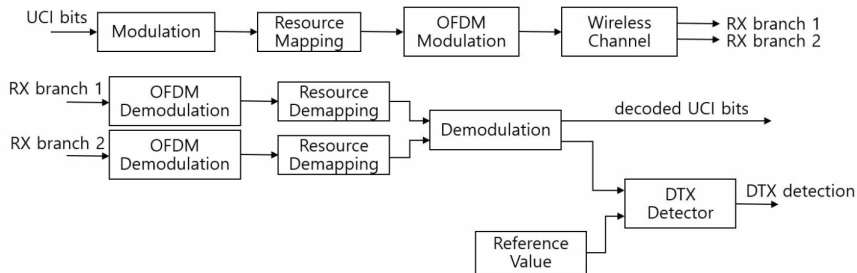


Figure: TX and RX processing for PUCCH format 0

Simulation results

- In this section, two detection schemes of the DTX for PUCCH format 0 have been simulated.
- . In this link level simulation, DTX threshold values for two detection algorithms are chosen to maintain at below 0.01 for DTX to ACK probability.
- The performances of two algorithms of alg0 (based on the power) and alg1 (based on the correlation) with 1 RX branch and 2 RX branch cases are compared.
- Both algorithms can get the diversity gain, however the required SNR for the power based scheme does not meet the required SNR 3.8dB.
- The reason for the better performance of the correlation based algorithm is due to the processing gain of the Low-PAPR sequence correlation under the fading channel.

Simulation results

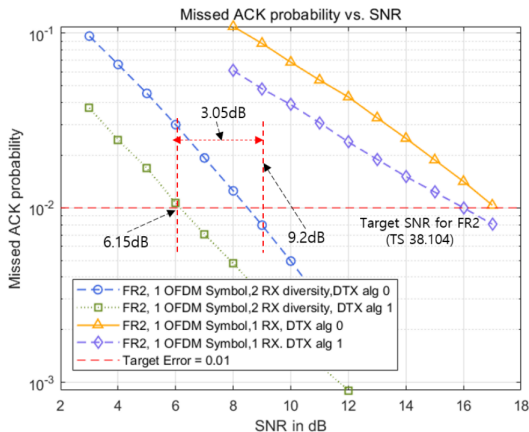


Figure: Missed ACK detection probability for 1 OFDM symbol

Simulation results

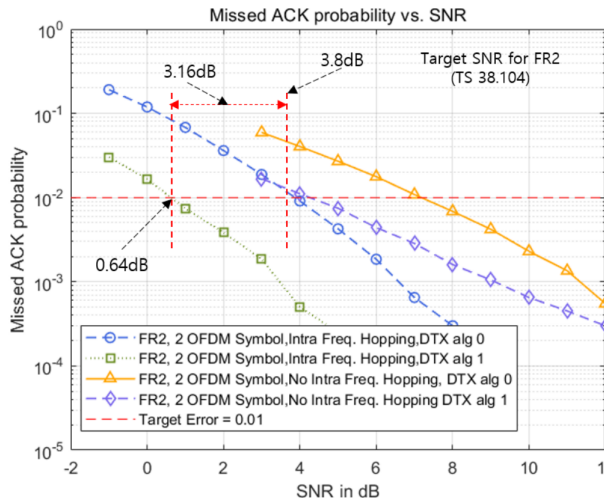


Figure: Missed ACK detection probability for 2 OFDM symbol

Conclusion

- The DTX is one of the most important functionality to save the battery life for a UE.
- The detection of DTX is essential at the receiver side of the gNB.
- Simulation results shows above two schemes for the 5G NR PUCCH format 0 satisfy the performance requirements.
- Two schemes are feasible and promising for the various deployments of 5G NR gNB such as the regular gNB, DU and IAB.