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Adaptive Physical Resource Block Design for Enhancing Voice Capacity over LTE in PMR Context

Manh-Cuong Nguyen and Hang Nguyen¹

Eric Georgeaux, Philippe Mege and Laurent Martinod²

Abstract—In this paper, we introduce a new Adaptive Physical Resource Block Design for Enhancing Voice Capacity over Long-Term Evolution (LTE) Downlink in Professional Mobile Radio (PMR) Context. In this method, we reorganize the structure of the Physical Resource Block (PRB) to optimize the voice capacity of LTE downlink in the PMR Context. Available PRBs in each subframe is reorganized into a number Sub Physical Resource Blocks. The number of control symbols can be selected flexibility. The proposed method allows reducing both data overhead and control overhead issues for Voice over LTE downlink in PMR context. On average, the voice capacity gain were shown to have about 117.2% in comparison with the standard LTE.

Index Terms—Adaptive PRB, control symbol, voice capacity, control overhead, data overhead, LTE, PMR

I. INTRODUCTION

The current Professional Mobile Radio (PMR) systems which are used for public safety, such as TETRA, APCO25 suffer from slow data transfer [11], [9]. Long Term Evolution (LTE) technology takes its place as the choice for the broadband PMR to satisfy the user demands of public safety in the future. In the public safety systems, the performance in terms of voice capacity is one of the strict requirements. However, LTE is not yet optimal for low bit rate voice communication in PMR context because of the data overhead and control overhead issues [5]. Therefore, the voice capacity is not increased as expected of the PMR service providers. In order to deploy LTE as the solution for the next generation of PMR network, some adaptations have to be considered to reduce both data and control overhead.

Factors thought to be influencing voice capacity of VoLTE have been explored in several studies. The current solutions on data overhead of voice over LTE pays particular attention to reduce the size of header protocols (e.g. [4], [12]). However, in the PMR context the difference between the LTE packet size and the PMR voice payload is the main factor that causes the data overhead. Our research shows that the average size of the LTE packet is about three times greater than the PMR voice payload. In addition, state-of-the-art methods expose many

difficulties to obtain the improvement of the Voice over LTE (VoLTE) capacity in PMR context. The solutions for reducing data overhead do not take into account the signal overhead whenever evaluating the system performance and on the other hand, the existing researches on control overhead such as Semi-persistent scheduling (SPS) [8], TTI-bundling [6], packet bundling [10] do not take into account the data overhead. Therefore, we propose a new Adaptive Physical Resource Block Design for Enhancing Voice Capacity over Long-Term Evolution (LTE) Downlink in Private Mobile Radio (PMR) Context. In this method, we reorganize the structure of the Physical Resource Block (PRB) to optimize the voice capacity of LTE downlink in the PMR Context. The available PRBs in each subframe is reorganized into a number Sub Physical Resource Blocks (subPRBs). The number of control symbols can be selected flexibility. The proposed method allows reducing both data overhead and control overhead issues for VoLTE downlink in PMR context. The details of this method is presented in section II. The performance of our method is evaluated in section III. Section IV will give the conclusion and some perspectives.

II. PROPOSED ADAPTIVE PHYSICAL RESOURCE DESIGN

A. Proposed Sub Physical Resource structure

In LTE [3], [7], [2], [1] one pair of Physical Resource Blocks (PRBs) is the smallest User Assignment Unit. However, the smallest LTE packet size is still too large in case that low bit rate voice communication is transmitted in high Modulation and Coding Scheme (MCS). This is the main factor that affects the data overhead of VoLTE in PMR context. Therefore, the main idea of the proposed method is to reorganize the structure of the PRB of LTE to optimize the voice capacity of VoLTE in case of PMR context but not affect the operations of the system.

In order to ensure the integrity of processing for control signals such as Reference Signal (RS), Primary Synchronization Channel (PSS), Secondary Synchronization Channel (SSS)...These control signals are organized in the same way with LTE standards. It means that one radio frame still includes 10 subframes of 1ms. Each subframe consists of two slots. Each slot in turn consists seven (normal cyclic prefix) or six symbols (extended cyclic prefix). The number and location of control channels such as PSS, SSS, RS.. are unchanged. The difference is that in the new design, the available REs for data in each subframe is reorganized into a number Sub Physical

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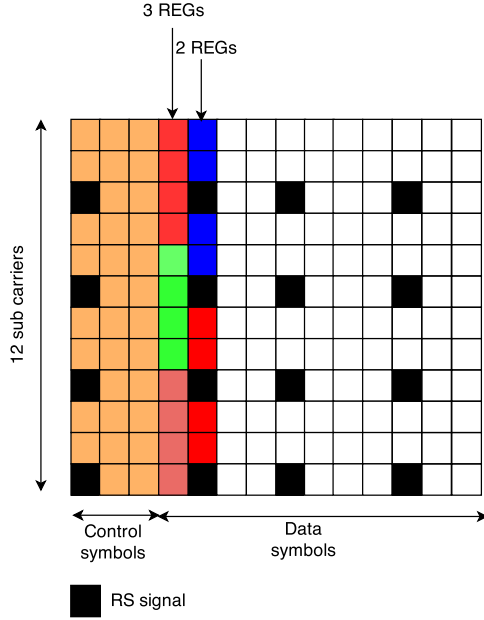


Fig. 1. REG structure

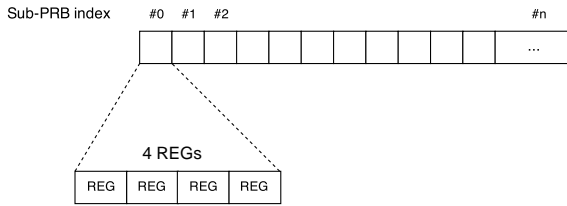


Fig. 2. Adaptive Physical Resource Block

Resource Blocks (SubPRBs). Each SubPRB consists of four Resource Element Group (REG). Each Resource Element Group (REG) contains four consecutive Resource Elements (RE) or four REs separated by a cell-specific Reference Signal (RS). The structure of SubPRB is similar to the structure of Control Channel Element (CCE) for the control channel with adaptations. SubPRB structure is illustrated in Figure 1.

In addition, in the new design, instead of limiting the number of symbols for control channels from 1 to 3 symbols, the new design allows a flexible choice of the number of symbols so that the system can obtain the maximum voice capacity. Figure 3 illustrates the model of our proposed system. There is a slight change in the last step. The symbols after passing the Layer mapping/precoding are mapped into subPRBs instead of PRBs. Therefore, the major issues to be considered is how to determine the size of SubPRB and the number of symbols used for control channel to maximize the voice capacity. In LTE, the base scheduler is Fully Dynamic (FD) scheduler. In the FD scheduler, each data packet needs to associate with a Layer 1 (L1) control signaling (a Physical Downlink Control Channel). LTE uses Physical Downlink

Control Channel (PDCCH) to carry all allocation information for both downlink and uplink shared channels. These symbols for control channels are organized in Resource Element Group and Control Channel Element (CCE). One REG consists of four consecutive REs or four REs separated by one Reference Signal. One CCE comprises nine REGs. To build the PDCCH, LTE uses a number of consecutive CCEs called CCE aggregation level. The CCE aggregation level can be one, two, four or eight. The aggregation level depends on the DCI size and the effective coding rate. There are four PDCCH formats (PDCCH format 0, PDCCH format 1, PDCCH format 2, PDCCH format 3) that correspond to four aggregation levels. PDCCH carries Downlink Control Information (DCI). We know that the number of control channels depends on the size of the DCI and the code rate. The size of DCI in turn depends on the number of available PRBs (in case of LTE) or available SubPRB (in our case). Therefore, the choice of size SubPRB influences the number of available control channels. If the size of SubPRB is too small, the number of bits need to be used for resource allocation in the corresponding DCI is increased. However, if the size of SubPRB is too big, the gap between LTE packet size and the PMR voice payload will be increased. In case of PMR with voice target codec 2450 bps, the optimal value of subPRB size is about four REGs. Therefore, in the proposed SubPRB design, we propose that the one SubPRB can consist of four REGs (see Figure 2). The number of symbols for control channel are chosen to optimize the voice capacity of VoLTE in PMR context.

B. System Model

We consider the number of available control channel (N_C) is a function of the number of allowed resource blocks of a defined bandwidth N_{BW} , the number of symbols used for PDCCH channels n_c , number of active UEs in the cell with the aggregation level A_{ij} that is need to be used to transmit PDCCH for UE_i at j^{th} TTI, voice payload of UE S_p ,

$$N_C = f(N_{BW}, n_c, S_p, [A_{ij}]) \quad (1)$$

We consider the number of available data channels (N_D) is a function of N_{BW} , n_c , S_p number of active UEs in the cell with Modulation and Coding Scheme assigned MCS_{ij}

$$N_D = f(N_{BW}, n_c, S_p, CP, [MCS_{ij}]) \quad (2)$$

The voice capacity N_V at the j^{th} TTI is defined as:

$$N_V = \min(N_C, N_D) \quad (3)$$

At the j^{th} TTI, choose n_c so that:

$$\operatorname{argmax}_{n_c, n_k} f(n_c) = \{n_c | \forall x : f(x) \leq f(n_c)\} \quad (4)$$

The voice capacity in a period $\{t_1, t_2\}$ is defined as:

$$\text{Voicecapacity} = \sum_{t_1}^{t_2} N_V \quad (5)$$

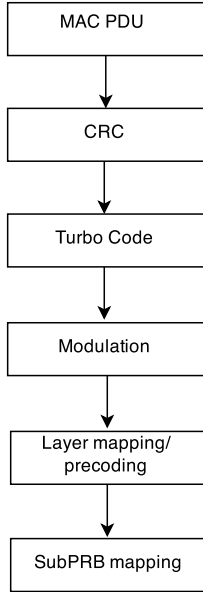


Fig. 3. SubPRB mapping

The number of OFDM symbols in a sub-frame is indicated by the Physical Control Format Indicator Channel (PCFICH) like in case of LTE standard. In order to determine the size of subPRB, the UEs have to read the field SRBS (Size of SubPRB) in new Adaptive DCI structure. The structure of Adaptive DCI structure is presented in table I. In this case, the field SRBA (Sub Physical Resource Block assignment) is used in stead of RBA (Physical Resource Block assignment) in LTE standard.

TABLE I
ADAPTIVE DCI STRUCTURE

Field Name	Length (bits)	Comment
SRBA	8 (1.4 MHz) 10 (3 MHz) 12 (5 MHz)	SubPRB assignment
MCS	5	Modulation and Coding Scheme

III. PERFORMANCE EVALUATION

A. Simulation Parameters

In this section we will present simulation results of our proposed method. In our simulation, we use the target codec of PMR context AMBE with code rate 2450 bps for three lower bandwidths 1.4 MHz, 3MHz, 5 MHz. UEs take random values MCS and Aggregation level for PDCCH channel. The other parameters for simulation are presented in table II.

B. Simulation Results

Table III compares the average voice capacity obtained from Physical Resource Block design (standard LTE) and from Adaptive Physical Resource Block design (our method) for

TABLE II
SIMULATION PARAMETERS

Parameter	Value
Bandwidth	1.4 MHz, 3MHz, 5 MHz
LTE	Type 1 FDD
Codec	AMBE 2450 bps
Ng	1
CRC	24 bits
Cyclic Prefix	Normal
Number of antenna	2

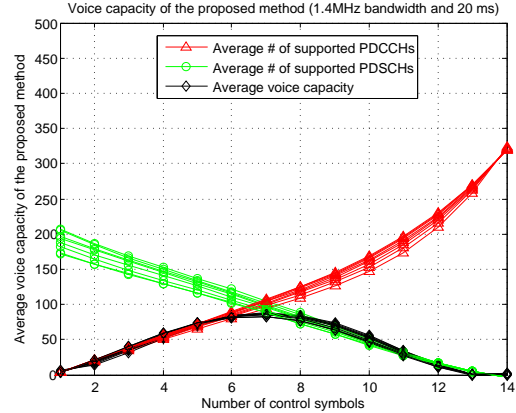


Fig. 4. Control capacity of the proposed method (1.4 MHz bandwidth and 20ms)

1.4 MHz bandwidth in 20 ms simulation. As Table III shows, there is a significant voice capacity gain (54 for standard LTE and 91 for the proposed method) between the two methods. Comparing the two results, it can be seen that the proposed method allows a more flexible and optimal LTE packet size than the existent standard LTE. The standard LTE is not optimal the packet size in case of PMR context. This leads to a decrease number of available data packets and control packets. Meanwhile, the proposed method allows a choice packet size and the number of symbols for control channel more flexible so that the proposed method can chose an optimal value for improving voice capacity.

Table IV and Table V present the voice capacity gain for the case of 3 MHz, 5 MHz bandwidths. For the 3 MHz bandwidth, the voice capacity gain is about 134.7% and for the 5 MHz bandwidth the voice capacity gain is about 133.3%.

In our simulation, we also apply several SubPRB sizes (from one to eight REGs) get the optimal value of SubPRB size for the PMR voice codec of 2450 bps. Figures 4, 5 and 6 show the relation between the number of symbols for control channel with the number of average supported data packets average supported control packets and the voice capacity for the three corresponding 1.4 MHz, 3 MHz, 5 MHz bandwidths for different SubPRB sizes. The results show that the optimal value number of symbols for control channel is about 5 to 7 symbols and the SubPRB contains about four REGs.

TABLE III
VOICE CAPACITY GAIN OF THE PROPOSED METHOD FOR 1.4 MHz IN 20 MS

Number of control symbols	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Average supported control packets of FD	7	31	54	X	X	X	X	X	X	X	X	X	X	X
Average supported data packets of FD	84	84	84	X	X	X	X	X	X	X	X	X	X	X
Average supported control packets of new method	6	26	46	67	87	107	127	148	168	188	208	229	249	269
Average supported data packets of new method	169	157	140	129	115	99	86	72	57	44	28	14	7	0
Average voice capacity of FD	54													
Average voice capacity of new method	99													
Gain	83.5%													

X: Standard LTE not support

TABLE IV
VOICE CAPACITY GAIN OF THE PROPOSED METHOD FOR 3 MHz IN 20 MS

Number of control symbols	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Average supported control packets of FD	16	54	92	X	X	X	X	X	X	X	X	X	X	X
Average supported data packets of FD	208	208	208	X	X	X	X	X	X	X	X	X	X	X
Average supported control packets of new method	13	46	79	112	146	181	216	253	290	331	375	431	631	681
Average supported data packets of new method	481	446	397	360	325	279	241	201	159	120	80	41	0	0
Average voice capacity of FD	92													
Average voice capacity of new method	216													
Gain	134.7%													

X: Standard LTE not support

TABLE V
VOICE CAPACITY GAIN OF THE PROPOSED METHOD FOR 5 MHz IN 20 MS

Number of control symbols	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Average supported control packets of FD	27	88	150	X	X	X	X	X	X	X	X	X	X	X
Average supported data packets of FD	347	347	347	X	X	X	X	X	X	X	X	X	X	X
Average supported control packets of new method	23	75	129	182	237	293	350	410	470	536	608	695	1052	1137
Average supported data packets of new method	805	737	672	597	535	470	403	337	269	202	134	69	0	0
Average voice capacity of FD	150													
Average voice capacity of new method	350													
Gain	133.3%													

X: Standard LTE not support

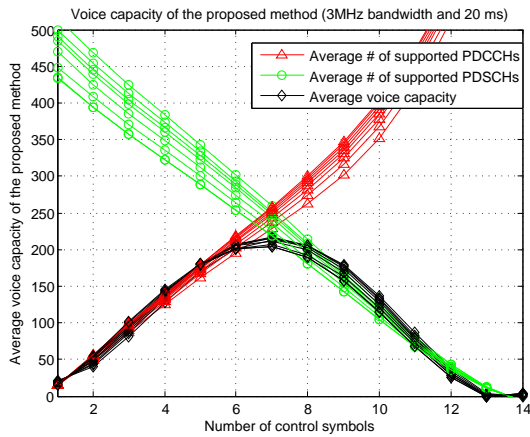


Fig. 5. Control capacity of the proposed method (3 MHz bandwidth and 20ms)

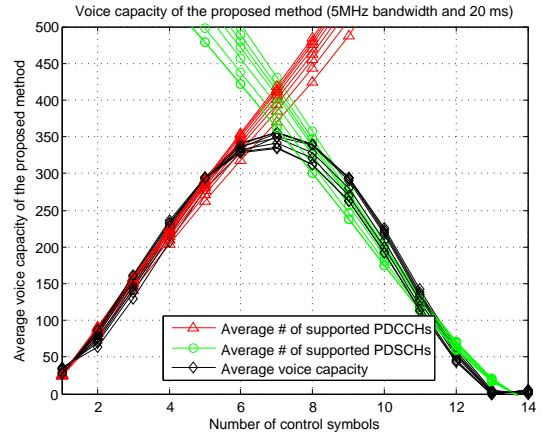


Fig. 6. Control capacity of the proposed method (5 MHz bandwidth and 20ms)

IV. CONCLUSION

In this paper, we proposed a new Adaptive Physical Resource Design for improving control capacity of LTE Downlink in the PMR context. In this design, the available PRBs in each subframe is reorganized into a number of subPRBs.

In addition, the number of symbols for control channel are chosen flexibility to maximize the voice capacity. On average, the voice capacity gain were shown to have about 117.2% in comparison with the standard LTE. Finally, a number of important limitations need to be considered. First, the

complexity assessment and the energy consumption issue of the new design has not been studied. Second, an assessment of the of Bit Error Rate (BER) should also be considered when the number of supported voice calls is increased.

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