An Efficient Method For n_{DMRS} Selection*

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Abstract - In LTE uplink scheduling system, the Physical Hybrid_ARQ Indicator Channel(PHICH) in the downlink carries Hybrid ARQ(HARQ) acknowledgments (ACK/NACK) for uplink data transfers. So it is important to allocate resource to PHICH. Although the two parameters which identify PHICH have been given in section 6.9 in 3GPP 36.211, when we use them in our real life according to these formulas, PHICH resource conflicts often happen in one TTI, or too much PHICH resource has been allocated which results in wasting of resource. In this paper, we can consider to introduce n_{DMRS} selection to guarantee PHICH resource never conflicts between UEs in the same TTI even if only allocating minimum physical time_frequency resource to PHICH. When the number of UE per TTI less than 8, we just get n_{DMRS} from physical resource block index ignoring PHICH group number.

Index Terms - PHICH ; n_{PHICH}^{group} ; n_{DMRS} ; n_{PHICH}^{seq} .

1. Introduction

Recently, LTE has been so popular in our daily life, and more and more research has been done by hundreds of people. There are several basic concepts we are better to know at first. The first one is the frame mode in LTE system, and the second one is the physical resource in LTE system.

*(A) The frame mode in LTE system :*There are two types of modes can be supported in LTE system: FDD and TDD. Each of them support different frame structure: Type1 and Type2. The radio frame is 10ms and the radio frame structure of TDD is shown in Fig.1.

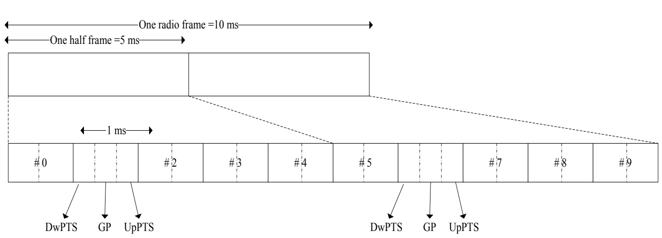

Fig.1 The Frame Structure Of TDD

1 RE= 1 sub-carry ＊1 symbol

RB: Resource Block. Describe the field between the physical channels and the resource element.

1 RB= 12 sub-carries ＊1 slot

1 slot= 7 symbols

1RB= 12 sub-carries ＊7 symbols= 84 REs.

REG: Resource Element Group. Define the field between the control channel and the RE.

1 REG= 4 REs

CCE: Control Channel Element.

1 CCE= 9 REGs= 9 ＊4 REs= 36 REs

In LTE uplink scheduling system [1], the parameter n_{DMRS} is used to differentiate Physical Hybrid_ARQ Indicator Channel (PHICH) resource for different user equipments (UEs) in the same transmission time interval (TTI). The PHICH in the downlink carries Hybrid_ARQ (HARQ) acknowledgements (ACK/NACK) for uplink data transfer. PHICHs are located in the first symbol of each subframe, as shown in Fig. 2. A PHICH is carried by 3 Resource Element Groups (REGs), and multiple PHICHs can share the same set of REGs and can be differentiated by orthogonal covers. PHICHs that share the same resource are called a PHICH group. Each PHICH group contains 8 PHICHs in it [2].

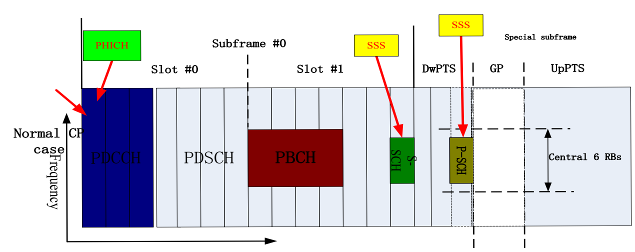

Fig. 2 The physic channel and the subframe

In one system, the actual number of the PHICH groups can be derived from the downlink bandwidth of the system and the parameter N_g . Both of which are broadcast in the Master Information Block (MIB). The fomula is defined in 3GPP TS 36.211 section 6.9 as shown below [3]:

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$N_{\text{PHICH}}^{\text{group}} = \lceil N_{\text{g}}\left(N_{\text{RB}}^{\text{DL}}/8\right)\rceil$ for normal cycle prefix, with $N_{\text{g}} \in \{1/6, 1/2, 1, 2\}$.

What is more, according to 3GPP TS 36.213 section 9.1.2, the PHICH resource is identified by the index pair [4] $(n_{PHICH}^{group}, n_{PHICH}^{seq})$, where n_{PHICH}^{group} is the PHICH group number and n_{PHICH}^{seq} is the orthogonal sequence index within the group. These two parameters are defined as:

$$n_{PHICH}^{group} = (I_{PRB\_RA}^{lowest\_index} + n_{DMRS}) \bmod N_{PHICH}^{group} + I_{PHICH} N_{PHICH}^{group}$$
$$n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA}^{lowest\_index} / N_{PHICH}^{group} \rfloor + n_{DMRS}) \bmod 2N_{SF}^{PHICH}$$

where:

(A) n_{DMRS} is mapped from the cyclic shift for DMRS field in the most recent DCI format 0 [4] for the transport block associated with the corresponding PUSCH transmission. n_{DMRS} shall be set to zero, if there is no PDCCH with DCI format 0 for the same transport block, and

(a) if the initial PUSCH for the same transport block is semi-persistently scheduled, or

(b) if the initial PUSCH for the same transport block is scheduled by the random access response grant .

(B) $N_{SF}^{PHICH} = 4$ for normal cycle prefix, which can satidfy the current environment.

(C) $I_{PRB\_RA}^{lowest\_index}$ is the lowest PRB index in the first slot of the corresponding PUSCH transmission, , usually we can use an internal parameter RB_start to express it.

(D) N_{PHICH}^{group} is the number of PHICH groups configured by higher layers as described before.

(E) $I_{PHICH} = \begin{cases} 1 & \text{for TDD UL/DL configuration 0 with PUSCH transmission in subframe } n = 4 \text{ or } 9 \\ 0 & \text{otherwise} \end{cases}$.

According to current environment, TDD UL/DL configuration 0 is not needed, so I_{PHICH} should always be 0.

Nowadays, there are two ways to allocate the PHICH resources. Both of them set the parameter $n_{DMRS} = 0$. In one scheme, the parameter PHICH resource in MIB message N_{g} is configured to be 1/6, which results in the collision of PHICH resource between two UEs [6]. The other scheme sets the $N_{\text{g}} = 1$, which results in the waste of the PHICH resources. In this paper, we propose a new scheme that considers introducing n_{DMRS} selection to guarantee PHICH resource never conflicts between UEs in the same TTI, even if only allocating minimum physical time_frequency resource to PHICH. When the number of UE per TTI less than 8, we just get n_{DMRS} from physical resource block index ignoring PHICH group number.

2. Two schemes in details

Scheme 1:

We set the parameter PHICH resource in MIB message $N_{\text{g}} = 1/6$, and bandwidth is configured to be 20 MHz, so the total PHICH groups: $N_{PHICH}^{group} = \lceil N_g(N_{RB}^{DL}/8) \rceil = \left\lceil \frac{1}{6}(100/8) \right\rceil = 3$, because each PHICH group contains 8PHICHs, the total PHICH resource is 3*8=24. As we know, in this scheme, another key parameter n_{DMRS} is hardcoded as 0 in uplink grant for all of the UEs, which will cause the following two problems:

(A) At this moment, $n_{PHICH}^{group} = I_{PRB\_RA}^{lowest\_index} \bmod 3$, $n_{PHICH}^{seq} = (\lfloor I_{PRB\_RA}^{lowest\_index} / 3 \rfloor) \bmod 8$. We can discover from these two formulas that once the difference of the first PRB index of two UEs in the same TTI is integer multiple of 24, uplink scheduler cannot guarantee that collision of PHICH resource between two UEs will not happen. So eNodeB can only send ACK report on PHICH. In this situation, non-adaptive UL HARQ retransmission cannot be supported. For uplink HARQ retransmission, only one option can be used: adaptive uplink HARQ retransmission [9]. But such retransmission mechanism has apparent disadvantages as below:

(a) Uplink HARQ retransmission depends on DCI 0 carried on PDCCH, so in this situation, retransmission UE will still occupy the limited CCEs as well as new transmission UE, and due to its higher priority compared to new transmission UE, it's very possible to cause that some new transmission UEs cannot be scheduled.

(b) Usually retransmission will occur in poor radio environment so that it's possible that the DCI 0 message cannot be received by UE successfully in some extreme poor radio environment, then the adaptive uplink HARQ retransmission may fail.

(B) According to customer requirement, some capacity test, e.g. 1200 UEs performance test must be executed with the help of UE simulator rather than real 1200 UEs. Different from independent real UE, in UE simulator, different sim-UEs may have some dependency with each other. For example: once UE1 is allocated one physical time-frequency resource, UE2 cannot receive/transmit any information using the same physical time-frequency resource because the UE simulator will consider such resource allocation illegal and impossible. So from this point of view, the collision of PHICH resource

can be detected by UE simulator and then cause a serial of other problems.

Scheme 2:

The parameter $N_g = 1$, so the total PHICH groups: $N^{group}_{PHICH} = \lceil N_g \left(N^{DL}_{RB} / 8 \right) \rceil = \lceil 1 \left(100/8 \right) \rceil = 13$, then the total PHICH resource is 13*8=104, which is larger than the uplink physical resource block number. Such configuration and implementation can guarantee that the PHICH resource collision can never happen, no matter which value the parameter n_{DMRS} is set to. So the non-adaptive uplink HARQ retransmission can be supported in this system, even if the parameter n_{DMRS} is hardcoded to be 0 as same as before.

However, such configuration for PHICH group number must occupy more physical time-frequency resource for PHICH so that the physical resource reserved for another important channel---PDCCH will be less [10]. Detailed comparison is as below:

Take 20MHz bandwidth, TDD 1 and CFI 3 as an example.

In *scheme 1*: $N^{group}_{PHICH} = 3$

Subframe 4 and 9 with PHICH

$$N_{CCE} = \lfloor (2*100+3*100+3*100-4-3*3) \div 9 \rfloor = 87$$

Special subframe 1and 6 with PHICH (CFI=2)

$$N_{CCE} = \lfloor (2*100+3*100-4-3*3) \div 9 \rfloor = 54$$

In *scheme 2*: $N^{group}_{PHICH} = 13$

Subframe 4 and 9 with PHICH

$$N_{CCE} = \lfloor (2*100+3*100+3*100-4-13*3) \div 9 \rfloor = 84$$

Special subframe 1and 6 with PHICH (CFI=2)

$$N_{CCE} = \lfloor (2*100+3*100-4-13*3) \div 9 \rfloor = 50$$

So we can find that the CCE resource for PDCCH will be decreased by 3 in subframe 4 and 9 and be decreased by 4 in special subframe 1 and 6 because of more physical resource allocated to PHICH. However, eNodeB doesn't need to allocate so many resource (8*13=104) to PHICH, because eNodeB cannot schedule so many UEs in each TTI, Actually, minimum resource (8*3=24) allocation for PHICH is enough to meet current requirement.

3. New scheme

Based on the two schemes being analysed above, a new scheme is proposed to guarantee PHICH resource never conflicts between UEs in the same TTI, even if only allocating minimum physical time-frequency resource to PHICH. We can consider to introduce n_{DMRS} selection in each DCI 0. Detailed algorithm flowchart is shown as below in Fig. 3:

After uplink physical resource block (PRB) allocation for all of the UEs in one TTI is completed, including that both of their PRB number and PRB position have been determined, this new algorithm can be executed.

Step1: For the first 8 UEs in one TTI, eNodeB's uplink scheduler can allocate 8 different PHICH sequences to them, regardless of PHICH group allocation. With this difference of PHICH sequence for each UE, eNodeB's uplink scheduler can guarantee no PHICH collisions will happen in these first 8 scheduled UEs. The detailed implementation method of this step is as below:

Step 1.1: For the 1st scheduled UE, select n_{DMRS} from 0 to 7 to make $n^{seq}_{PHICH} = \left(\left\lfloor \frac{RB\_start}{3} \right\rfloor + n_{DMRS} \right) \bmod 8 = 0$, so the

$$n_{DMRS} = \left(8 * \left\lceil \frac{\lfloor RB\_start/3 \rfloor}{8} \right\rceil - \lfloor RB\_start/3 \rfloor \right) \bmod 8 \cdot$$

Step 1.2: For the 2nd scheduled UE, select n_{DMRS} from 0 to 7 to make $n^{seq}_{PHICH} = \left(\left\lfloor \frac{RB\_start}{3} \right\rfloor + n_{DMRS} \right) \bmod 8 = 1$, so the

$$n_{DMRS} = \left(8 * \left\lceil \frac{\lfloor RB\_start/3 \rfloor}{8} \right\rceil - \lfloor RB\_start/3 \rfloor + 1 \right) \bmod 8 \cdot$$

Then we can summarize a general formula to calculate n_{DMRS} for each UE in step 1 as below:

$$n_{DMRS} = \left(8 * \left\lceil \frac{\lfloor RB\_start/3 \rfloor}{8} \right\rceil - \lfloor RB\_start/3 \rfloor + n^{seq}_{PHICH} \right) \bmod 8 \quad ,$$

where $n^{seq}_{PHICH} = 0, 1 \cdots, 7$.

Step 2: If the scheduled user number exceed 8, from the 9th scheduled UE, eNodeB needs to execute *step 2* of this n_{DMRS} selection algorithm, detailed procedure is as below:

Step 2.1: At the beginning of this step, uplink scheduler needs to calculate and record the PHICH resource occurpied by the previous 8 scheduled UEs, including both n^{group}_{PHICH} and n^{seq}_{PHICH} based on their RB_start and n_{DMRS}.

Step 2.2: If there are another available PHICH groups, eNodeB can configure $n_{DMRS} = \left(3 * \lceil RB\_start/3 \rceil - RB\_start + available\_n^{group}_{PHICH} \right) \bmod 3$ for the UE to make the available PHICH group as: $n^{group}_{PHICH} = \left(RB\_start + n_{DMRS} \right) \bmod 3 \cdot$

Step 3: If there is no available PHICH groups for a new UE, *step 3* needs to be executed for the rest UEs, detailed procedure is as below:

Step 3.1: Similar as *step 2.1*, uplink scheduler needs to calculate and record the PHICH resource occurpied by the previous 8 scheduled UEs, including both n_{PHICH}^{group} and n_{PHICH}^{seq} based on their RB_start and n_{DMRS}.

Step 3.2: Traverse all n_{DMRS} from 0 to 7 to find a proper n_{DMRS}, which can satisfy the UE's PHICH resource to be an available PHICH resource.

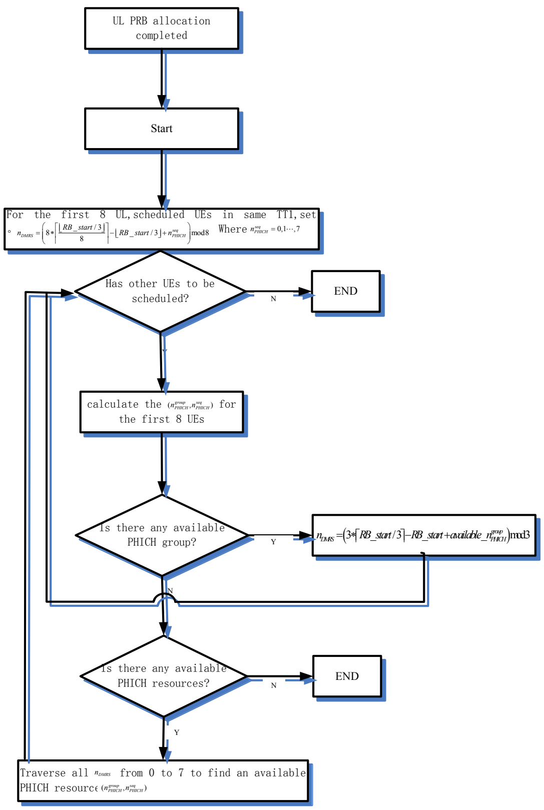

Fig. 3 Algorithm Flowchart Of The New Scheme

4. Conclusion

Apparently, the *step 1* of this n_{DMRS} selection algorithm is very simple, and we can only use one formula to calculate the n_{DMRS} for the first 8 UEs. So it's very high efficient and the cost should be very low to adapt current requirement and system capability. The *step 2* is very simple and efficient as well as *step 1*. Similarly, only one formula is enough to calculate the n_{DMRS}. The *step 3* is a little complex compared to the former steps, but its complexity should be still acceptable and reasonable.

For the first 8 UEs in one TTI, we can 100% get n_{DMRS} from the physical resource block regardless of n_{PHICH}^{group} allocation, because the n_{PHICH}^{seq} has been set different from each other. After that, when the number of UEs is from 9 to 16, and if there is one (or two) PHICH group(s) is still available, the probability that we can get the n_{DMRS} in this new scheme is 11.7%, just like throwing eight balls into three baskets, and at least one basket is empty. When the UEs number is more than 16, we cannot use *step 3* only, which is traverse all n_{DMRS} from 0 to 7 to find a proper n_{DMRS} to satisfy the UE's PHICH resource to be an available PHICH, because the efficiency is very low.

So this new scheme is proposed to guarantee PHICH resources from no conflicts between UEs in the same TTI, even if only allocating minimum physical time-frequency resource to PHICH. In reality, especially in commercial, the nember of UE will not be a lot, so the algorithm is practical and feasible.

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