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Athens, Greece, 22 - 26 August 2011

Agenda Item: **6.6.2.2**

Souce: **Samsung**

Title: **Discussion on ePDCCH Design Issues**

Document for: **Discussion**

1 Introduction

As the development of DL MIMO enhancements and coordinated multi-point (CoMP) techniques is evolving, it has been broadly observed that the legacy DL control channel could become a bottleneck and impose significant limitation in terms of number of UEs that can be scheduled in a subframe [1]. Extending the capacity of the DL control channel is therefore necessary.

To preserve backward compatibility with the legacy DL control channel, the use of resources in the legacy PDSCH region, similar to the R-PDCCH, is needed to design the enhanced DL control channel and the associated design aspects will include resource allocation, multiplexing, RS utilization, etc.

This contribution continues on the discussion from RAN1#65 on the enhanced DL control channel aspects and explores several design issues. Preliminary comparisons are presented among possible design alternatives.

2 Enhanced DL Control Channel Design Issues

Resource Allocation

UE-specific Region

Similar to the R-PDCCH VRB configuration, the eNB can individually configure each UE with a set of PRBs via RRC signalling (e.g. based on the long-term channel statistics). By using a separate VRB configuration for each UE, the eNB can separate the search space for each UE and thus potentially reduce the number of required blind decoding operations.

Cell-specific Region

Similar to the legacy control region, the eNB assigns a common set of RBs to all UEs for the transmission of enhanced DL control channels. The assignment can be dynamic, as for the legacy control region, or semi-static. As UE scheduling is substantially more dynamic than RN scheduling, a cell-specific region can potentially require less resources (overhead) in case of common RS-based ePDCCH demodulation.

Enhanced DL Control Region Granularity and Multiplexing

In the legacy DL control region design, four consecutive REs are grouped into a REG. The PCFICH and PHICH granularity is in REGs while the PDCCH granularity is in multiple of nine REGs which define a CCE. As frequency diversity is critical for the transmission of DL control channels, the REGs are distributed substantially over the entire system bandwidth. The R-PDCCH with interleaving mode also follows the same design as the legacy PDCCH on a configured virtual bandwidth. As the RNs can be non-mobile, as considered in Rel.10, the R-PDCCH transmission also supports a non-interleaved mode where the assignment granularity is one PRB and the DL grants are FDM multiplexed in the first slot while the UL grants are FDM multiplexed in the second slot.

For the enhanced DL control channels, the terms eCCE and eREG can be used with the same utilization and meaning as for the legacy control channels. .

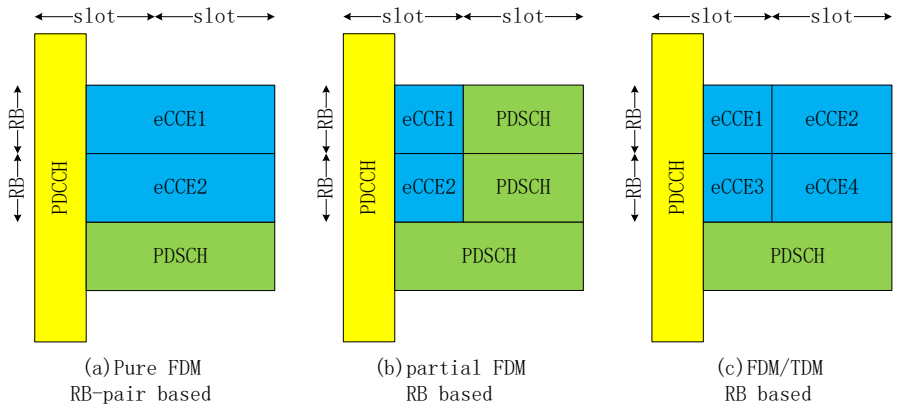

Fig. 1: Examples for RB-based ePDCCH Multiplexing

RB(pair)-based eCCE with non-interleaved multiplexing

Fig.1 illustrates a few examples for RB(pair)-based enhanced PDCCH (ePDCCH) multiplexing.
In Fig.1(a), an eCCE is defined on a PRB pair. Such a design simplifies PDSCH scheduling since the legacy granularity for PDSCH is a PRB-pair. However, as one PRB-pair contains many more REs than a legacy CCE, the multiplexing in Fig.1(a) may lead to significant and unnecessary overhead.

In Fig.1(b), only the PRB in the first slot is used for transmission of eCCEs while the PRB in the second slot is used for transmission of a PDSCH. The number of REs in an eCCE is similar to that of the legacy CCE. Such a design will also shorten the decoding time of an ePDCCH and PDSCH decoding can start from the second slot once a DL grant is detected.

In Fig.1(c), PRBs in both the first and second slots can be allocated for an ePDCCH transmission. It is FFS how the eCCEs are aggregated into an ePDCCH, e.g., whether an ePDCCH can have multiple eCCEs confined in one slot, as for the R-PDCCH aggregation, or have eCCEs in both slots. The impact of different eCCE sizes depending on the slot position is also FFS.

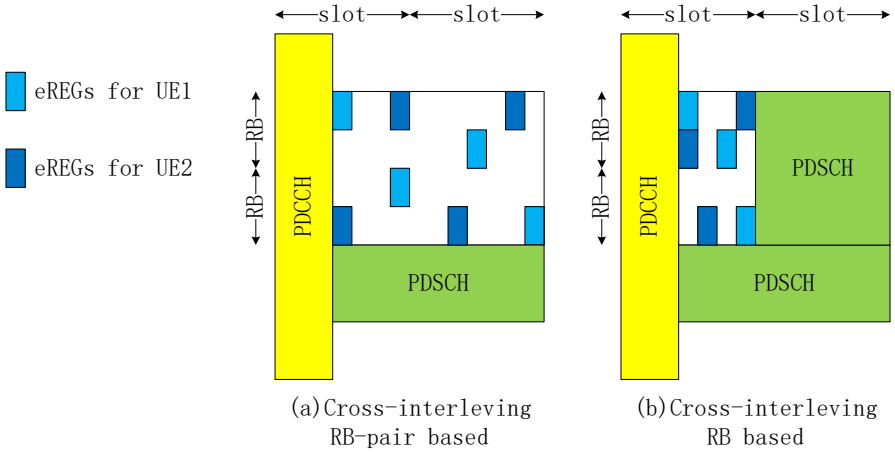

Fig.2: Interleaved ePDDCH multiplexing.

eREG based eCCE with interleaved multiplexing

Similar to legacy PDCCH and interleaved R-PDCCH, another alternative for ePDCCH multiplexing is to multiplex multiple UEs within a common set of PRBs with the resources for each UE being interleaved in the frequency and/or time domains. Fig.2 illustrates two examples for RB-pair (Fig.2(a)) and for RB based interleaved multiplexing (Fig.2(b)). Interleaved multiplexing of eREGs can benefit from the frequency diversity gain as subband feedback cannot be always assumed to be available or have the reliability required for transmission of DL control channels. However, since the ePDCCH region for interleaving-mode is exclusive of PDSCH transmission, there could be potential un-utilized REs in the region (depending on whether the ePDCCH region can be dynamically configured).

The eCCEs in the two examples of Fig.2 are mutually orthogonal in the time-frequency domain. It is also possible that eCCEs can be orthogonal in the spatial domain by using precoding (FFS whether this is possible in practice considering the reliability requirements and absence of HARQ for DL control channels).

Reference Signals

CRS or DMRS can be used for demodulation of enhanced DL control channels. As for the R-PDCCH, the selection will be practically determined by the multiplexing mode (interleaved or non-interleaved). In additional, it is also possible to define a new RS type optimized for ePDCCH.

CRS-based ePDCCH

The ePDCCH demodulation can be based on the legacy wideband CRS (WB-CRS) when an ePDCCH is transmitted, for example, using transmit diversity, or with multiple UEs multiplexed in the same RBs, or with a known precoder for beamforming transmit mode. As the legacy WB-CRS is widely and densely distributed, channel estimation performance based on WB-CRS will be better comparing to using other RS. However, WB-CRS based ePDCCH demodulation cannot achieve cell-splitting which is important for CoMP scenario 4.

DMRS-based ePDCCH

A UE-specific DMRS is transmitted per PRB and can be optimised for an ePDCCH transmission with beamforming (assuming UE feedback is available and appropriately accurate) as no additional precoding configuration is needed. The gain of beamforming can be significant comparing to that of transmit diversity in some channel scenarios. A DL/UL grant can be multiplexed with an UL/DL grant or with PDSCH for the same UE in the same RB pair in a subframe for better resource utilization. With DMRS, it is possible but complex to multiplex several UEs in one PRB using different DMRS ports as it may be necessary to avoid unnecessary overhead (such a necessity is FFS).

Other RS-based ePDCCH

In addition to the legacy WB-CRS and DMRS, a narrowband CRS (NB-Common RS) over a set of RBs can be considered (as it was also considered for the R-PDCCH design). The NB-CRS can be common for all UEs in a cell, or can be common for a group of UEs configured by the network. The NB-CRS may or may not be precoded and the precoding may change between RBs. The primary motivation for a NB-CRS is to provide cell-splitting gains for CoMP scenario 4.

Search Space Design

Since enhanced DL control channels can only be recognized by Rel-11 UEs, it should be considered whether Rel-11 UEs should monitor both the legacy DL control channels and enhanced DL control channels or only the latter. In the former case, a UE can be configured a number of PDCCH candidates per CCE aggregation level for the legacy DL control region and another number of ePDCCH candidates per eCCE aggregation level in the enhanced DL control region so that the maximum number of blind decoding operations per cell is similar to that in Rel.10. For example, the common search space may be in the legacy PDCCH region and the UE-specific search space may be only in the enhanced DL control region or the number of candidates for the UE-specific search space may be split between the legacy and extended DL control regions. In case a UE is configured to monitor only the enhanced DL control region, there may be some additional overhead as some broadcast/multicast DL control signalling may need to be also transmitted in the enhanced DL control region.

3 Other Enhanced Downlink Control Channel Design Issues

In the R-PDCCH design, the R-PDCCH region (VRBs) is configured by RRC signaling for both interleaved and non-interleaved mode. This is meaningful as the variation of the number and size of R-PDCCH transmissions per subframe is small or none. Using a semi-static configuration also for the enhanced DL control region is one possibility. For ePDCCH multiplexing using CCE interleaving (as for legacy PDCCH multiplexing), another possibility is to follow the design of the legacy DL control region and use an ePCFICH to dynamically indicate size of the enhanced DL control region. This can be meaningful for the same reason as for the size of the legacy DL control region; namely to avoid DL throughput loss associated with variations in the total size of the enhanced DL control region.

In CoMP scenario 3, the control channel will have to either suffer more interference from other cells, or be blanked in an almost-blank subframe. It needs further study if the legacy PHICH design can suffice for Release-11.An enhanced PHICH may also be needed (FFS) to provide interference protection for CoMP scenario 3 and collision avoidance for CoMP scenario 4 as SPS PUSCH can be transmitted in both the macro cell and the pico cells and legacy PHICH resource collisions are very likely to occur particularly considering the absence of PHICH resource indexing for SPS PUSCH transmission (no cyclic shift index for the UL DMRS).

4 Conclusions

This contribution provided an overview for the following aspects related to the design of enhanced DL control channels:

- Region Allocation: Cell specific or UE-specific configuration
- ePDCCH Granularity and Multiplexing: whether or not to keep a similar granularity with the legacy CCE and whether or not to have interleaving
- Reference Signals: Legacy wideband CRS, DMRS, or narrowband CRS
- Search Space Design: Distribution of blind decoding operations between legacy DL control region and enhanced DL control region
- Use of ePCFICH or ePHICH is FFS.

5 References

[1] R1-111471 Discussion on Downlink Control Channel enhancement, Samsung