Evaluation on interference averaging of 16m DL/UL inner permutation

IEEE 802.16 Presentation Submission Template (Rev. 9)

Document Number:

IEEE C802.16m-09/0260r1

Date Submitted:

2008-01-07

Source:

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Nokia Siemens Networks

Venue:

Re: 802.16m amendment working document

Base Contribution:

This is the base contribution.

Purpose:

To be discussed and adopted by TGm for the 802.16m SDD

Notice:

Release:

Patent Policy:

Outline

- Introduction
- Simulation Model
- Evaluation on DL subcarrier permutation
- Evaluation on UL CRU/DRU allocation and inner permutation

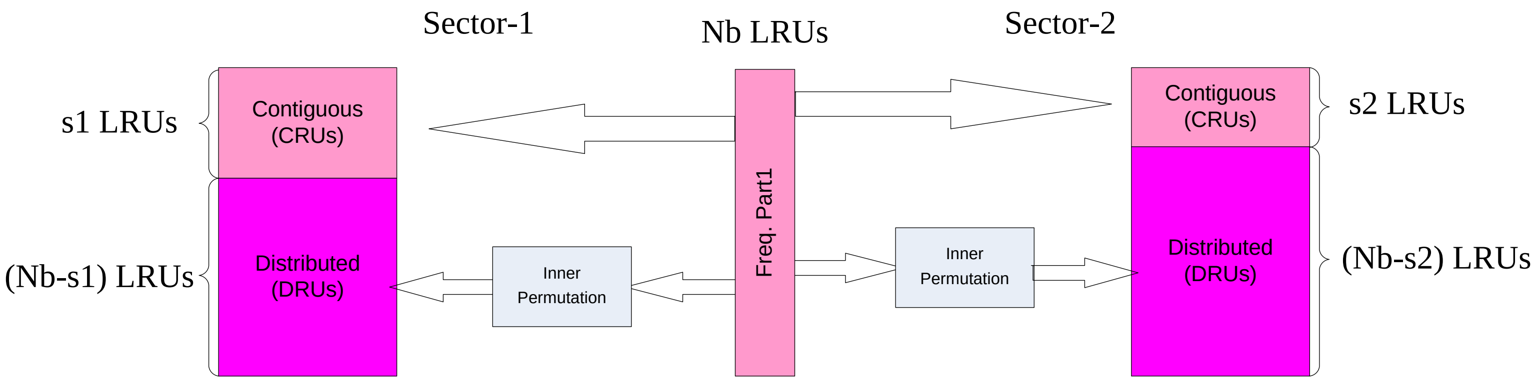
Introduction

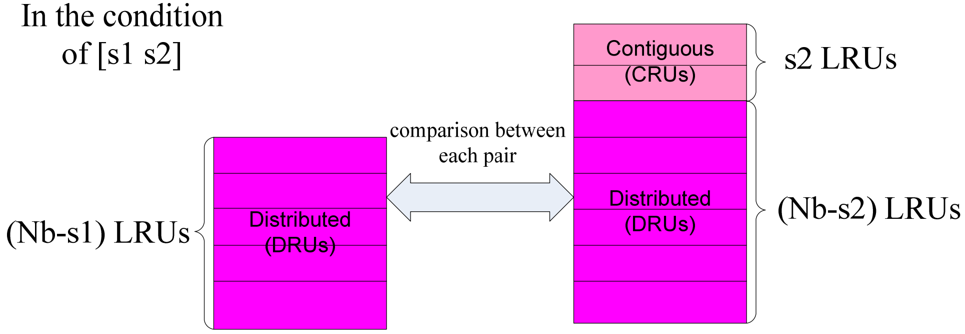
- In Dallas meeting, a number of contributions proposed different DL and UL inner permutation schemes.
  - DL subcarrier permutations proposals are consolidated into C80216m-08_1508r1 as different options. Basically, four options are proposed: Intel, LGe, Samsung and NSN. ITRI and ZTE proposed the same permutation equation with Intel, but with different permutation sequence.
  - UL tile permutations were proposed by Intel, LGe, Samsung and NSN.
- This contribution provides evaluation on the interference averaging performance of different inner permutation schemes.

Simulation Model

- The subcarrier (tile) collision is used as the metric in DL (UL) to evaluate the interference averaging of different proposals.
- The simulation model (illustrated in the figures in the next slide)
  - Assume there are two adjacent sectors. They have the same configuration of frequency partition (FP). The collision probability is examined within one FP. Denote the size of the FP as Nb.
  - Denote the number of CRUs in the FP of sector i as si, respectively, i=1,2.
    - Thus, the number of DRUs in sector i can be easily calculated as Nb-si.
    - The two sectors may have different CRU/DRU allocations: s1 could be different with s2.
    - Even if s1=s2, the CRUs could be different in different sectors.
  - In one simulation scenario, Nb and (s1,s2) are set for the two sectors.
    - Set different perm_base (permutation base number, or Cell_ID) for the two sectors
    - M (e.g. M = 1000) cases are simulated. In each case
      - In each sector, si PRUs are randomly selected from the Nb PRUs to form the CRU region. The remainders of PRUs form DRU region.
      - After the CRU/DRU allocation is done, inner permutation is performed to the DRUs. The Nb-s1 distributed LRUs and Nb-s2 distributed LRUs are formed in the two sectors, respectively. The CRUs are mapped directly to be localized LRUs.
      - Take one **distributed LRU** from sector1 (Nb-s1 distributed LRUs); take one **LRU** from sector2 (Nb LRUs). Calculated how many subcarriers (tiles) of the LRU-pair collide.
      - Exhaust all the LRU-pairs in the previous step and calculate all the collisions. We have (Nb-s1)*Nb LRU-pairs in all.
    - Go to the starting step until all the perm_base pairs are exhausted.
  - The final output from the simulation is a denoted as *rslt(). rslt(i)* means the percentage of LRU-pairs who have *i* subcarriers (tiles) collided.

Simulation Model

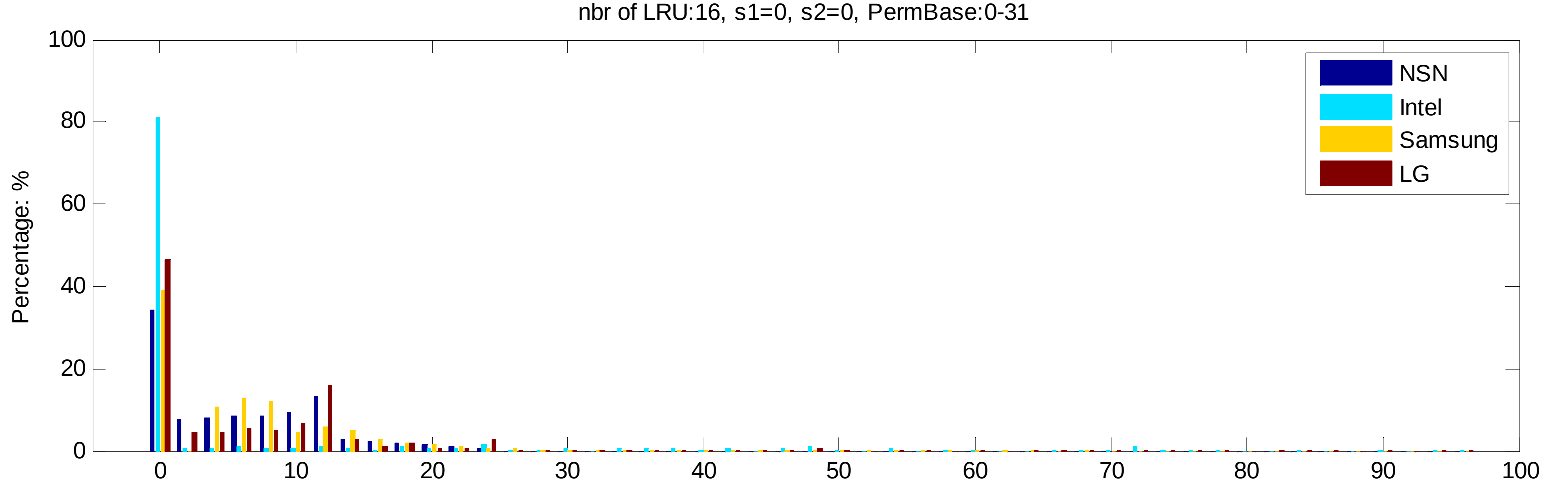


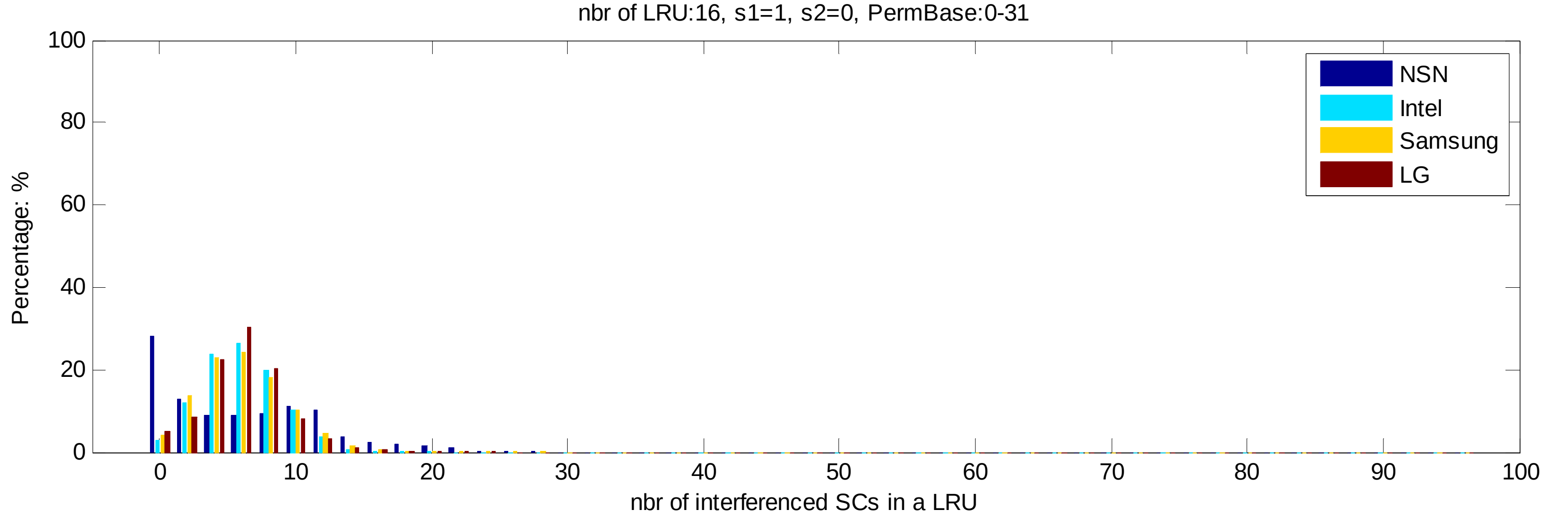


Evaluation on DL subcarrier permutation

Simulation Scenario: Nb=16; (s1,s2)=(0,0)/(1,0); Perm_Base=0~31

Observation: NSN's proposal shows different performance with other proposals. When s1 is not equal to s2, the hitting probability PDF curve of NSN proposal remains similar to the case s1=s2=0. While, the PDF curves of other companies change a lot.

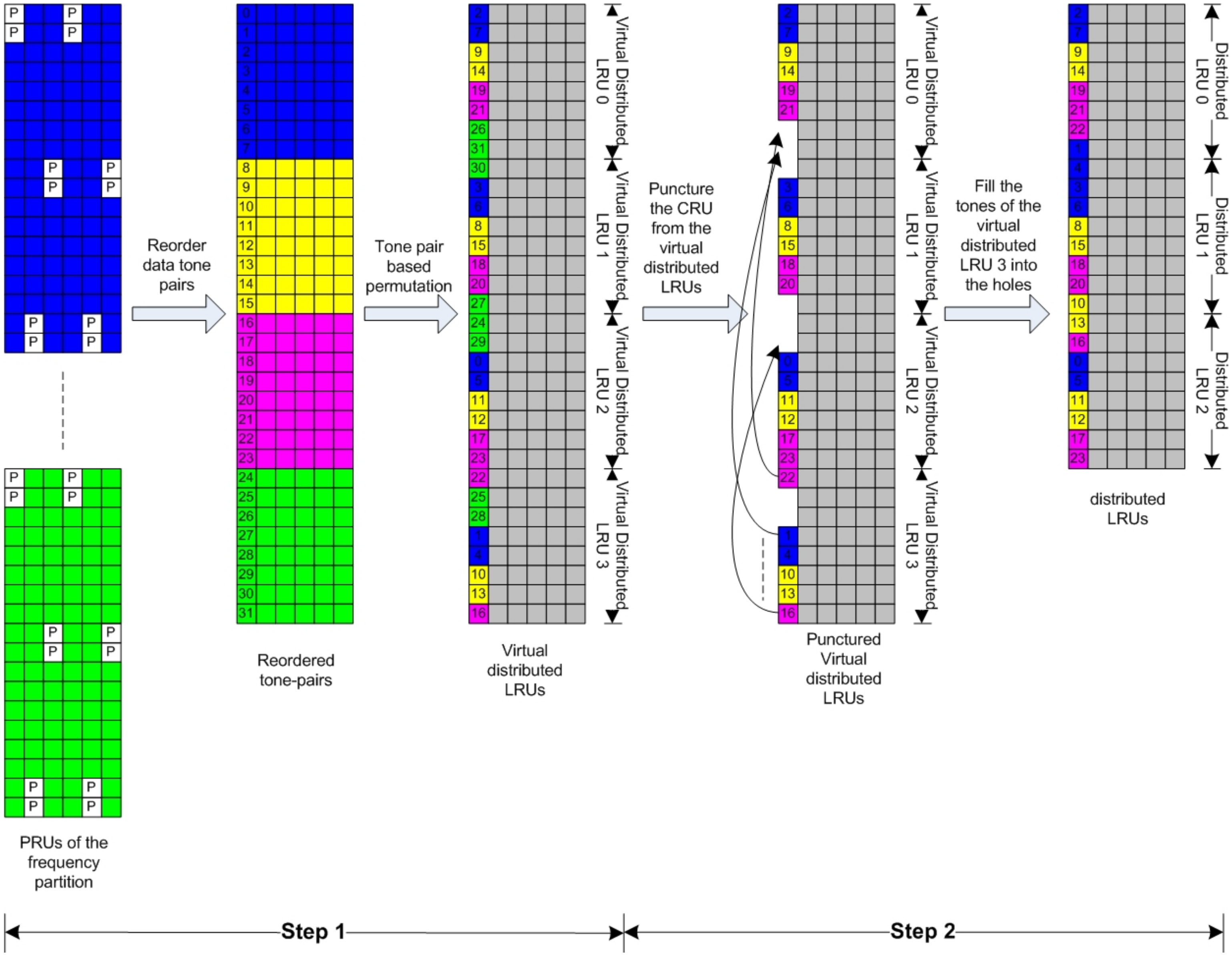




DL subcarrier permutation proposal

- In 16e, subcarrier permutation (i.e. OFUSC) is designed based on RS code.
  - Adjacent sectors used the same RS code as the basic permutation sequence to perform the subcarrier permutation.
  - The benefit are good frequency diversity and interference averaging.
- In 16m, CRU/DRU allocation is a sector-specific operation.
  - Adjacent sectors may not have the same DRU region. Then, adjacent sectors may not be able to use the same basic permutation sequence. The permutation sequences in adjacent sectors may even have different length. The interference averaging property of subcarrier permutation is difficult to keep.
  - NSN proposal tries to solve the issue.
- NSN proposal, the "two-step" subcarrier permutation
  - 1st step: The 16e OFUSC permutation is performed to the subcarriers of **all the PRUs** (including CRU and DRU) of the frequency partition. In this way, the same permutation sequence could be used in adjacent sectors, and interference averaging is gained. After this step, we get the so-called "**virtual distributed LRUs**". The number of virtual distributed LRUs equals the number of PRUs in the frequency partition.
  - 2nd step: The tone-pairs of the CRUs are **punctured** from the virtual distributed LRUs. The subcarriers of the virtual distributed LRUs with highest indexes are filled in the "holes" (the punctured subcarriers) in the other virtual distributed LRUs. Finally, we get the distributed LRUs.
  - The detailed description could be found in C80216m-08_1508r1. An example is provided in the following slide.

An example of our proposal



An example of our proposal

- Assumptions of the example
  - The frequency partition is made up of 4 PRUs. The highest-indexed PRU is selected as the localized resource. The other 3 PRUs are distributed resource.
- Step 1, for each the *l*-th OFDMA symbol:
  - n_l Pilots are allocated in all the 4 PRUs in the frequency partition.
  - The data tones are reordered from 0 to 31, in the unit of tone-pair.
  - An equation is used to permute the tone-pairs. E.g. for the 1st OFDMA symbol, after permutation we get $pair(0,0:7,0)=[2,7,9,14,19,21,26,31]$; $pair(1,0:7,0)=[30,3,6,8,15,18,20,27]$; $pair(2,0:7,0)=[24,29,0,5,11,12,17,23]$; $pair(3,0:7,0)=[22,25,28,1,4,10,13,16]$, as the 4 virtual distributed LRUs. $pair(s,0:7,0)$ means the indexes of the 8 tone-pairs of virtual distributed LRU *s* in OFDMA symbol 0.
- Step 2, for each the *l*-th OFDMA symbol:
  - The data subcarriers of the PRU for localized resource are punctured from virtual distributed LRUs. E.g. for the 1st OFDMA symbol, we get $pair(0,0:7,0)=[2,7,9,14,19,21,\ ,\ ]$; $pair(1,0:7,0)=[\ ,3,6,8,15,18,20,\ ]$; $pair(2,0:7,0)=[\ ,\ ,0,5,11,12,17,23]$; $pair(3,0:7,0)=[22,\ ,\ ,1,4,10,13,16]$, for the 4 punctured virtual distributed LRUs.
  - The tone-pairs of the 4-th virtual distributed LRUs are filled in the other virtual distributed LRUs. E.g. for the 1st OFDMA symbol, we get $pair(0,0:7,0)=[2,7,9,14,19,21,22,1]$; $pair(1,0:7,0)=[4,3,6,8,15,18,20,10]$; $pair(2,0:7,0)=[13,16,0,5,11,12,17,23]$, to form the 3 distributed LRUs.

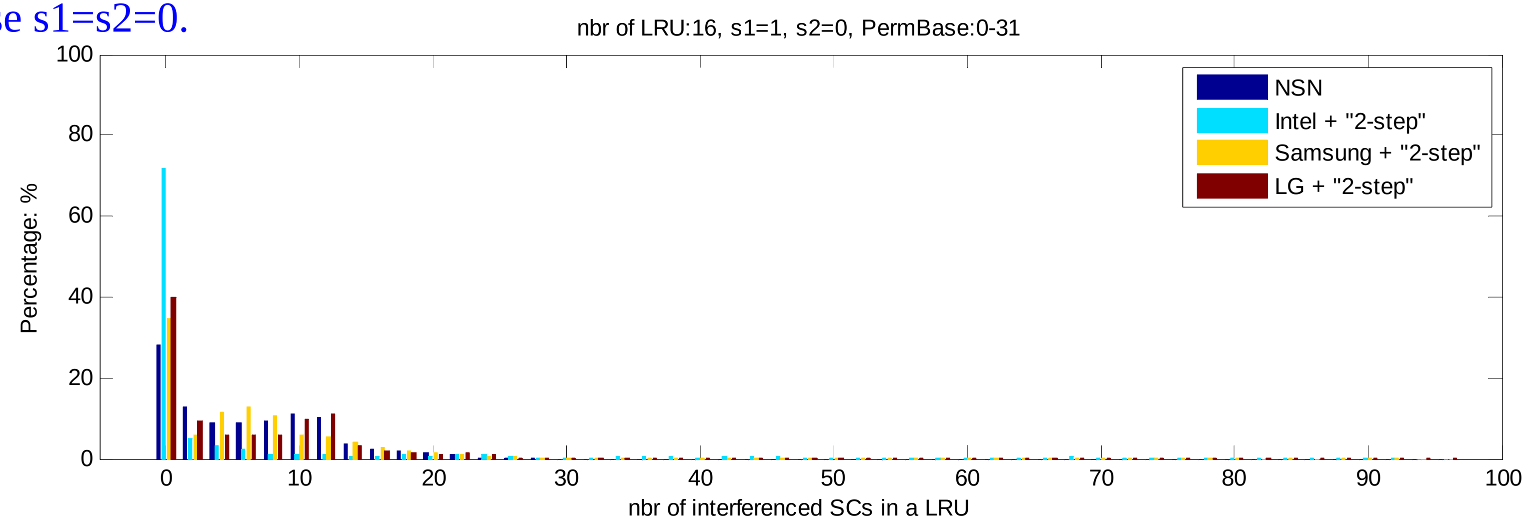
Apply the 2-step permutation to other permutation equations

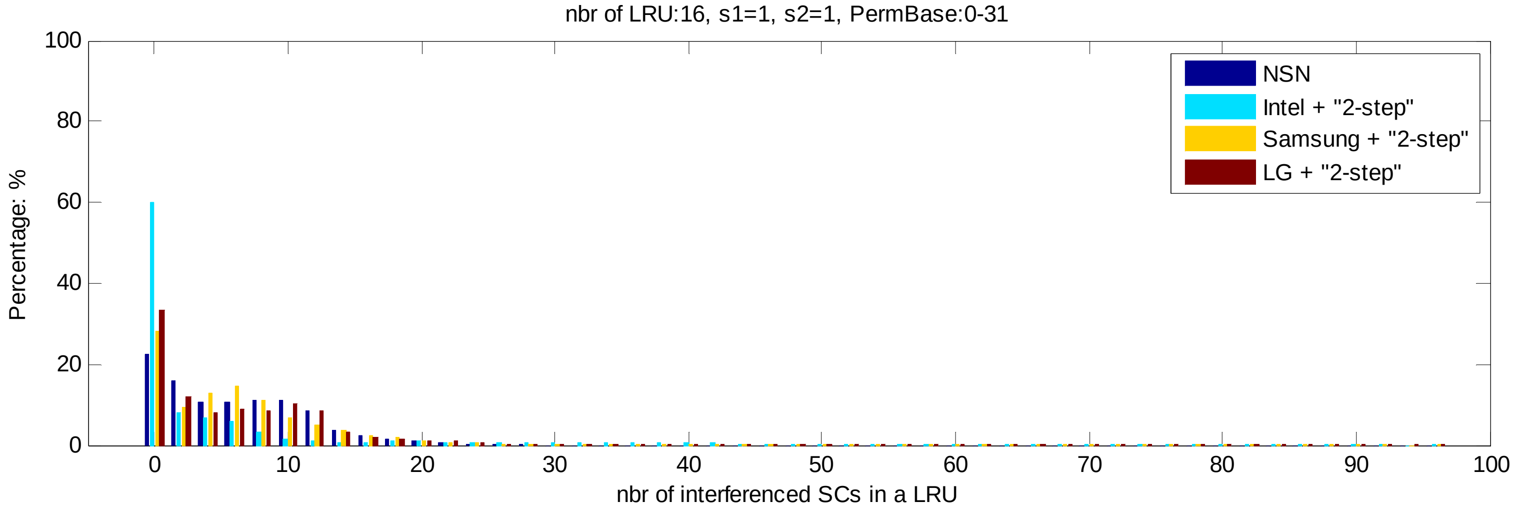
- The 2-step subcarrier permutation proposed by NSN could be used with any permutation equation.
- From the performance evaluation we can observe:
  - In case of s1=s2 (i.e. adjacent sectors have same number of DRUs), the performance of different proposals are similar to each other.
  - In case of s1!=s2, NSN proposal (OFUSC + “2-step perm.”) shows some benefit.
- One question is:
  - What is the performance of combining “2-step perm.” with permutation equations other than OFUSC?
  - In the following evaluation, we **combine the 2-step permutation with the permutation formula proposed by other companies**.

2-step subcarrier permutation is combined with permutation equations proposed by different companies.

Simulation Scenario: Nb=16; (s1,s2)=(1,0)/(1,1); Perm_Base=0~31

Observation: Different proposals have very similar interference averaging performance, regardingless whether s1 equals s2 or not. The hitting probability PDF curves are similar to the case s1=s2=0.

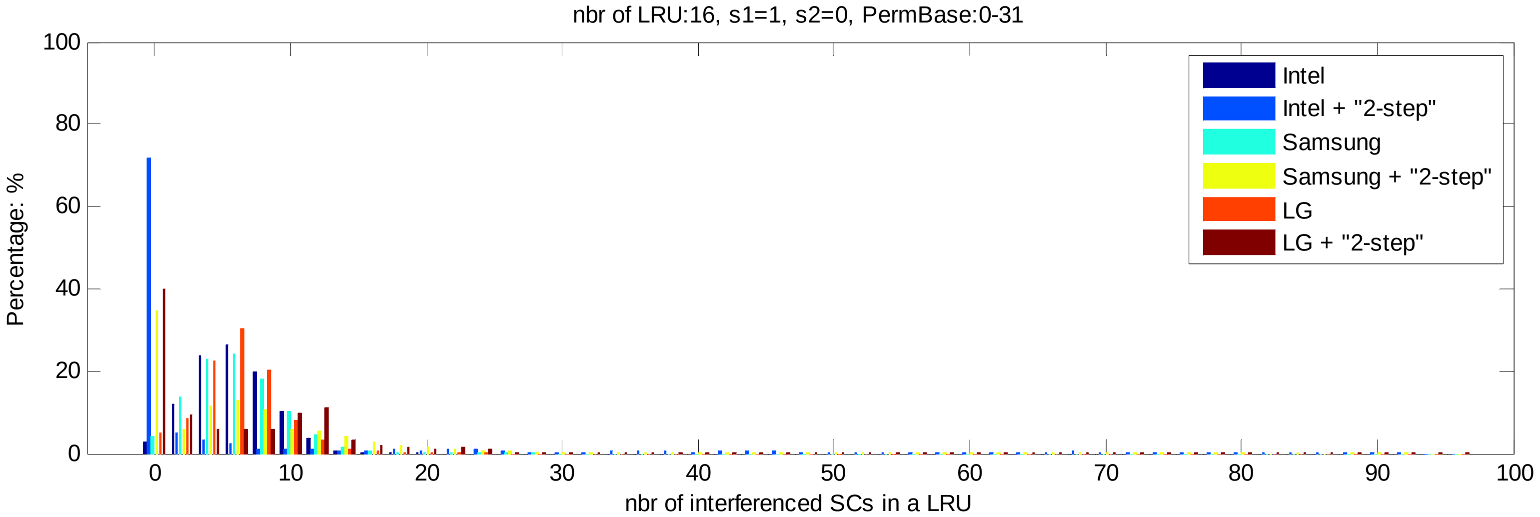


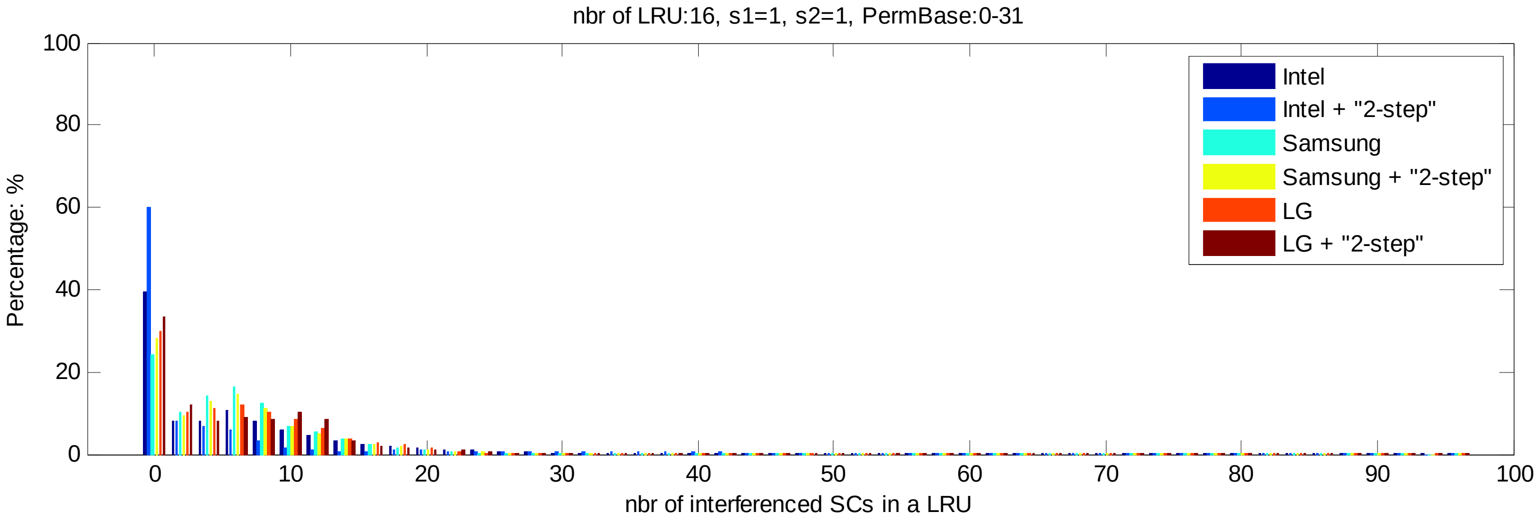


Two cases are compared: the proposals without and with the 2-step permutation.

Simulation Scenario: Nb=16; (s1,s2)=(1,0)/(1,1); Perm_Base=0~31

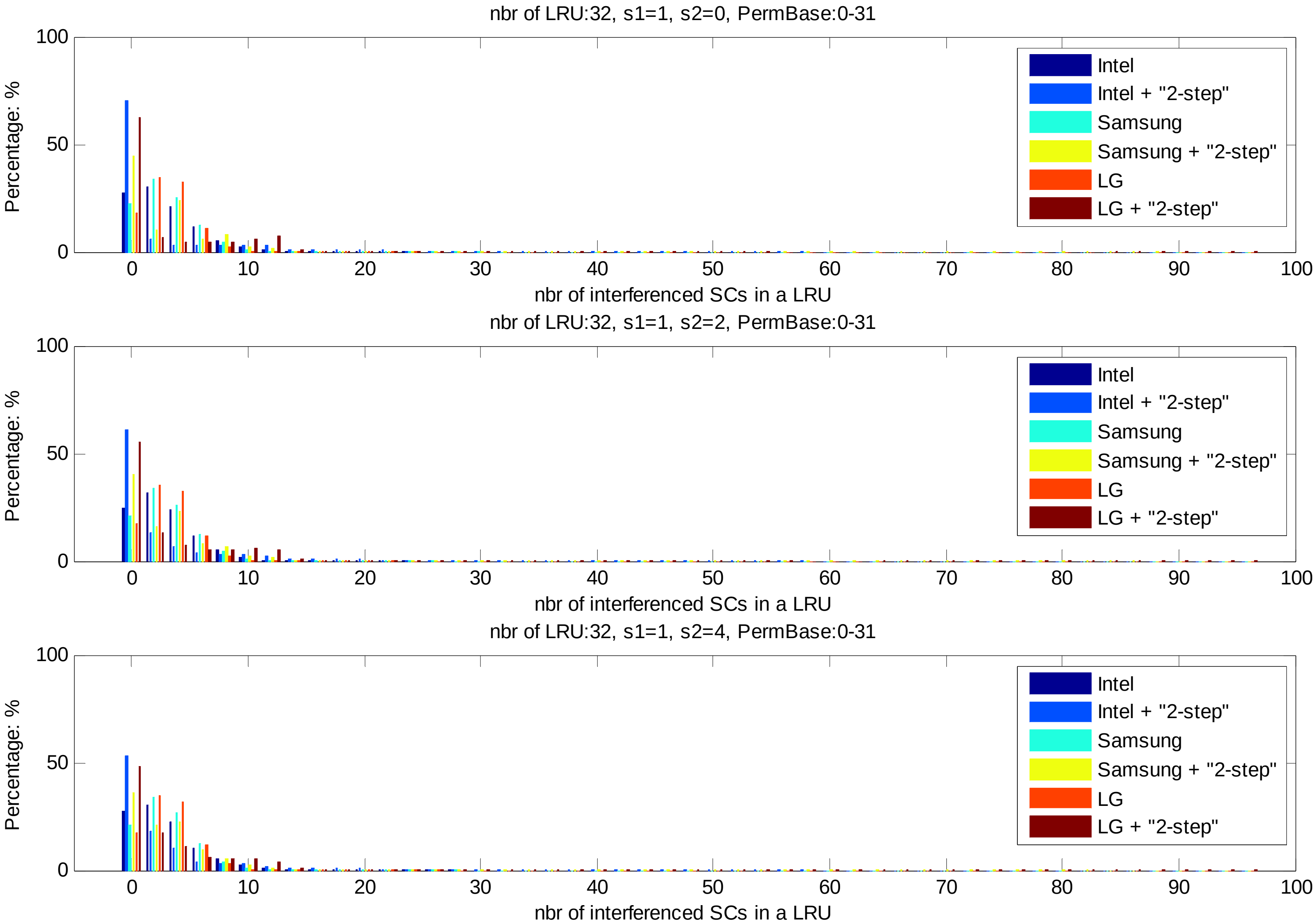
Observation: The 2-step subcarrier permutation improves the interference averaging performance of all proposals. When s1 is not equal to s2, the value of rslt(0) is increased significantly; and the PDF curve of hitting probability remains similar to the case s1=s2.





Simulation Scenario: Nb=32; (s1,s2)=(1,0)/(1,1); Perm_Base=0~31

Observation is similar to the results of Nb=16 in the previous slide.



Conclusion for DL subcarrier permutation

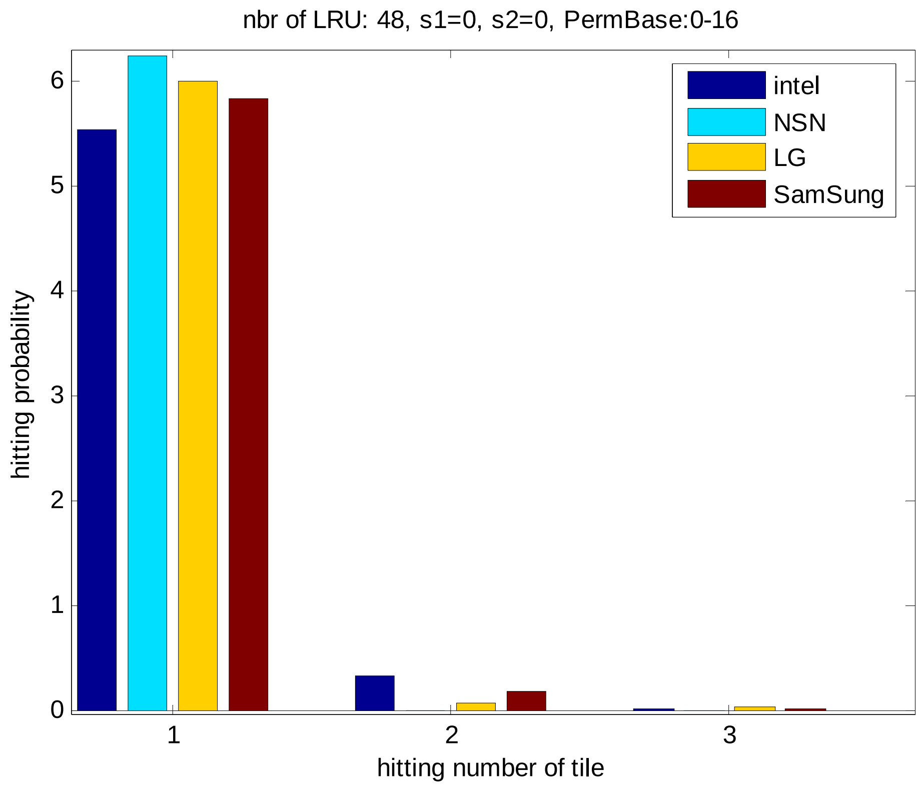
- Subcarrier permutation should be designed to improve frequency diversity and interference averaging.
- When adjacent sectors have same number of DRUs, proposals from different companies have similar performance in terms of interference averaging.
- When adjacent sectors have different number of DRUs, the 2-step subcarrier permutation could be used to improve the interference averaging performance of all the proposals.
  - By combining the 2-step permutation with all the permutation formulas from different companies, **the hitting probability PDF curve remains the similar shape** with the PDF curve of the case when adjacent sectors have same number of DRUs.
- **We recommend to consider the the 2-step subcarrier permutation in the 16m DL subchannelization.**

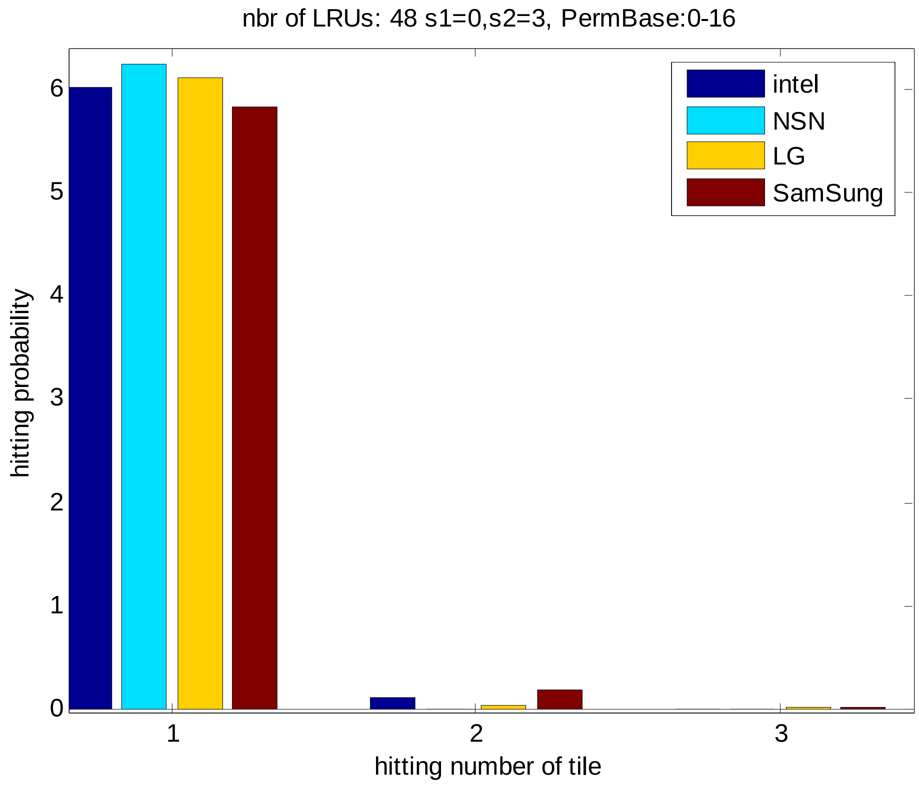
Evaluation on UL CRU/DRU allocation and inner permutation

Hitting probability evaluation for UL

Simulation Scenario: Nb=48; (s1,s2)=(0,0)/(0,3); Perm_Base=0~15

Observation 1: When the range of permutation base is small, NSN proposal has the least hitting probability for 2 and 3 tiles hitting.

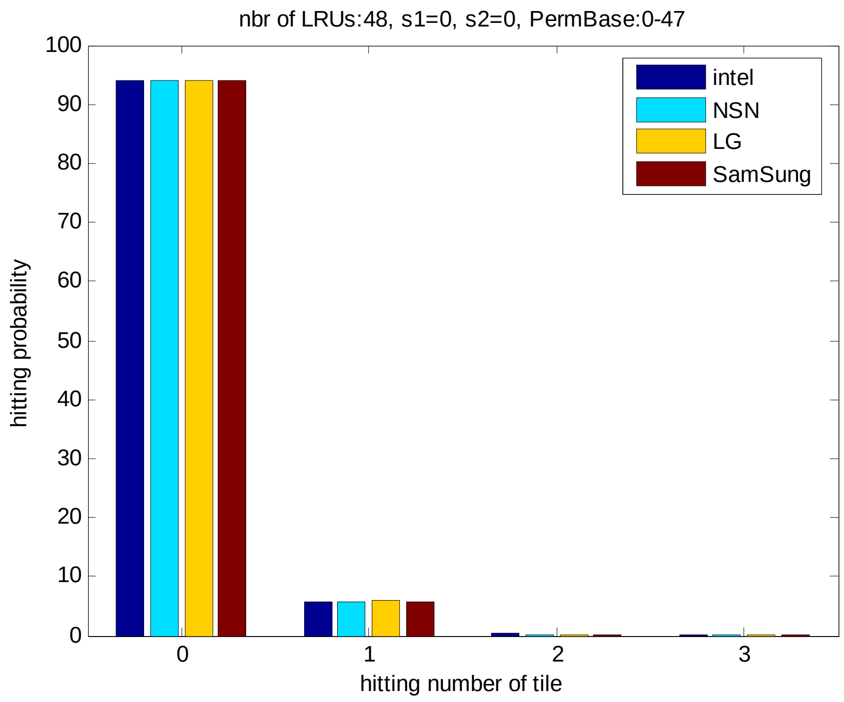


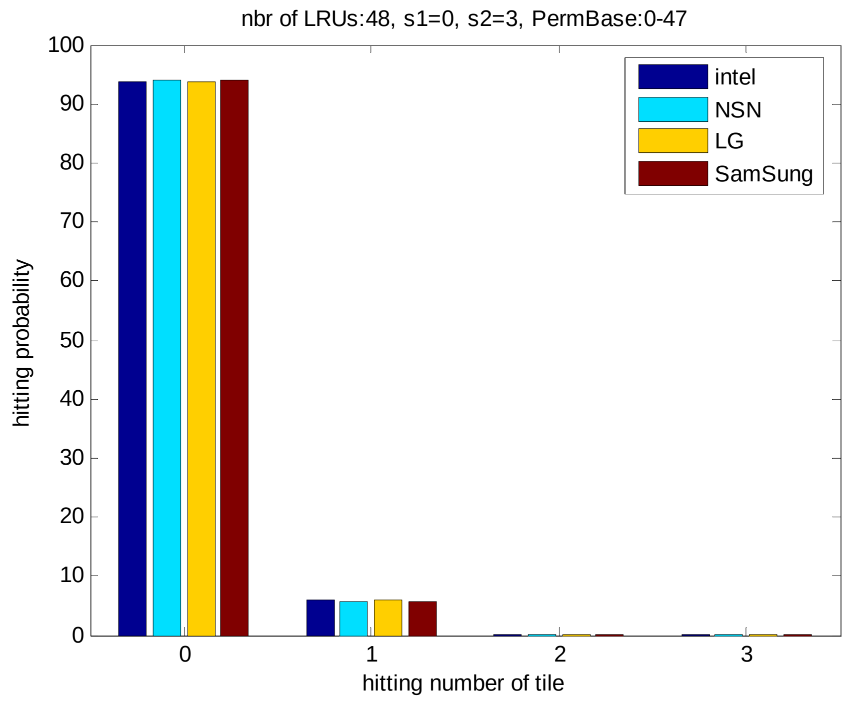


Hitting probability evaluation for UL

Simulation Scenario: Nb=48; (s1,s2)=(0,0)/(0,3); Perm_Base=0~47

Observation 1: When the range of permutation base is larger, all the schemes have very similar hitting probability.

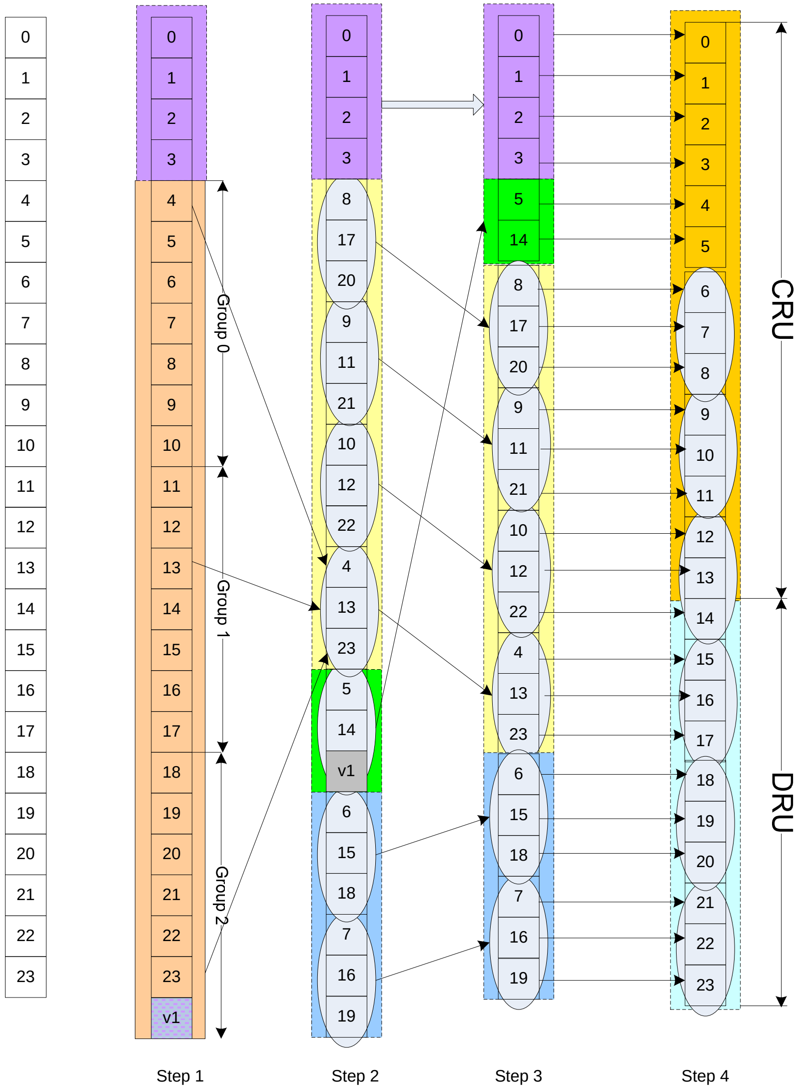




UL permutation proposal

- In 16e, tile permutation is designed based on RS code.
  - Adjacent sectors used the same RS code as the basic permutation sequence to perform the tile permutation.
  - The benefit are good frequency diversity and interference averaging.
- In 16m, CRU/DRU allocation is a sector-specific operation.
  - Adjacent sectors may not have the same DRU region. Then, adjacent sectors may not be able to use the same basic permutation sequence. The permutation sequences in adjacent sectors may even have different length. The interference averaging property of tile permutation is difficult to keep.
  - Our proposal tries to solve the issue.

An example of CRU/DRU allocation



CRU/DRU allocation

Step 1: Divide the PRUs in the FP except the reserved subbands into 3 groups. When the number of PRUs is not multiple times of 3, virtual PRUs are added.

Step 2: Permute PRUs and form PRU-blocks. Each PRU-block includes 3 PRUs. The block is named regular block when virtual PRUs are not included, otherwise, it is named irregular block.

Step 3: Change the order of the PRU-blocks. Move the irregular blocks to the front of regular blocks.

Step 4: Renumber the PRUs and take the first $L_{CRU,FPi}$ PRUs as CRU, and the other PRUs are taken as DRUs.

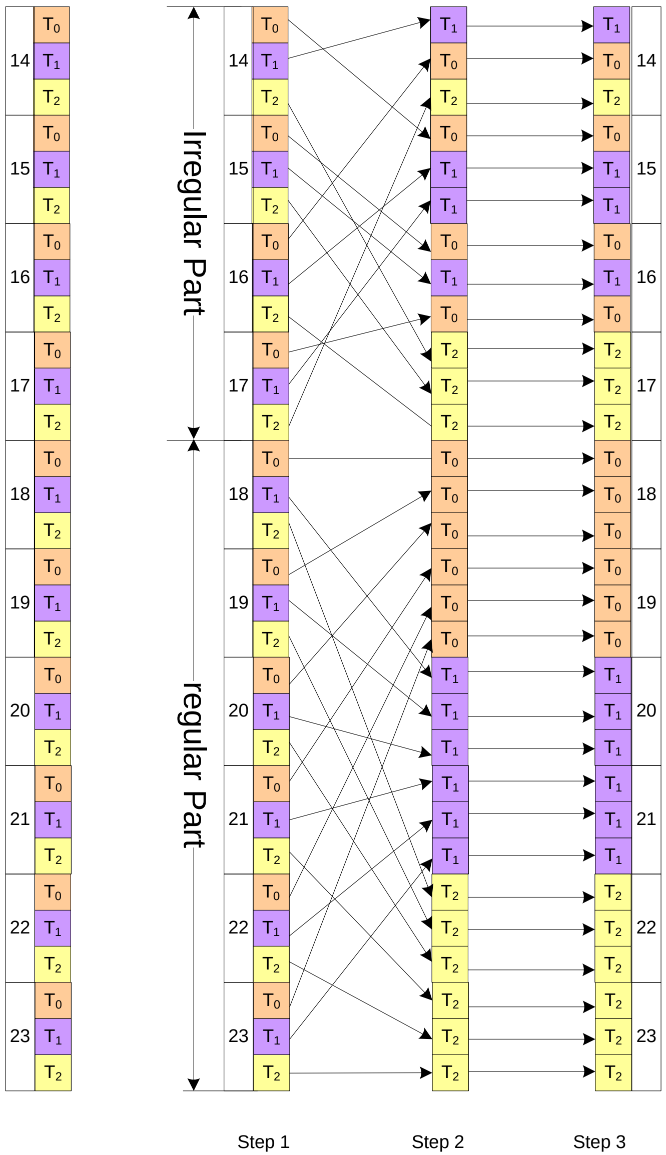
The whole procedure can be describe with the following equations:

$$CRU_{FP_i}[j] = PRU'_{FP_i}[j] \qquad 0 \le i < FPCT, and\ 0 \le j < L_{CRU,FP_i}$$

$$DRU_{FP_i}[j] = PRU'_{FP_i}[j + L_{CRU,FP_i}], \qquad 0 \le i < FPCT, and\ 0 \le j < L_{DRU,FP_i}$$

$$PRU'_{FP_i}(k) = \begin{cases} PRU_{FP_i}[k], & k < Z \\ PRU_{FP_i}\left[Z + s\left[\left\lfloor \frac{v_{\left(\left\lfloor \frac{k-Z}{2} \right\rfloor + 1\right)}}{3} \right\rfloor * 3 + \left(v_{\left(\left\lfloor \frac{k-Z}{2} \right\rfloor + 1\right)} + ((k-Z) \bmod 2) + 1\right) \bmod 3\right]\right], & Z \le k < L + Z \\ PRU_{FP_i}\left[Z + s\left[\left(\left\lfloor \frac{k-Z-L}{3} \right\rfloor + m_{k-Z-L}\right) * 3 + (k-Z-L) \bmod 3\right]\right], & L + Z \le k < FPS_i * N_2 \end{cases}$$

Inner Permutation



Inner permutation example

Step 1: Divide the PRUs in the distributed-LRUs into irregular part and regular part.

If there are irregular blocks in CRU/DRU allocation, regular part includes the intact regular blocks except the first regular block. The remaining is irregular part.

If there are no irregular blocks, all the PRUs are in regular part.

Step 2: Inner permutation is given by the following equation. For irregular part, the first equation is used. For regular part, the second equation is used.

$$Tiles(s,n) = \begin{cases} L_0 * n + \left[s \oplus P_{L_0,c_2}\left(n \bmod (L_0 - 1)\right) \right] & s < L_0 \\ L_0 * 3 + \left(9*(s - L_0) + 3*n + \left(\left\lfloor \dfrac{\text{UL\_Permbase}}{U_{FP_i}} \right\rfloor * n + \left\lfloor \dfrac{s - L_0}{\left(L_{DRU,FP_i} - L_0\right)/3} \right\rfloor \right) \bmod 3 \right) \bmod \left(3*\left(L_{DRU,FP_i} - L_0\right)\right) & s \geq L_0 \end{cases}$$

Step 3: Renumber the distributed LRUs

Conclusion for UL permutation

- From hitting probability point of view, our permutation schemes is better than other schemes.
- We recommend to adopt our schemes as proposed in C802.l6m-09_261 into the amendment document.