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Athens, Greece, February 13-17, 2017
Agenda Item: 7.1.1
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Document for: Discussion and decision

R1-1703087

Motivation for change to scrambling of NB-IoT MIB/SIB transmission

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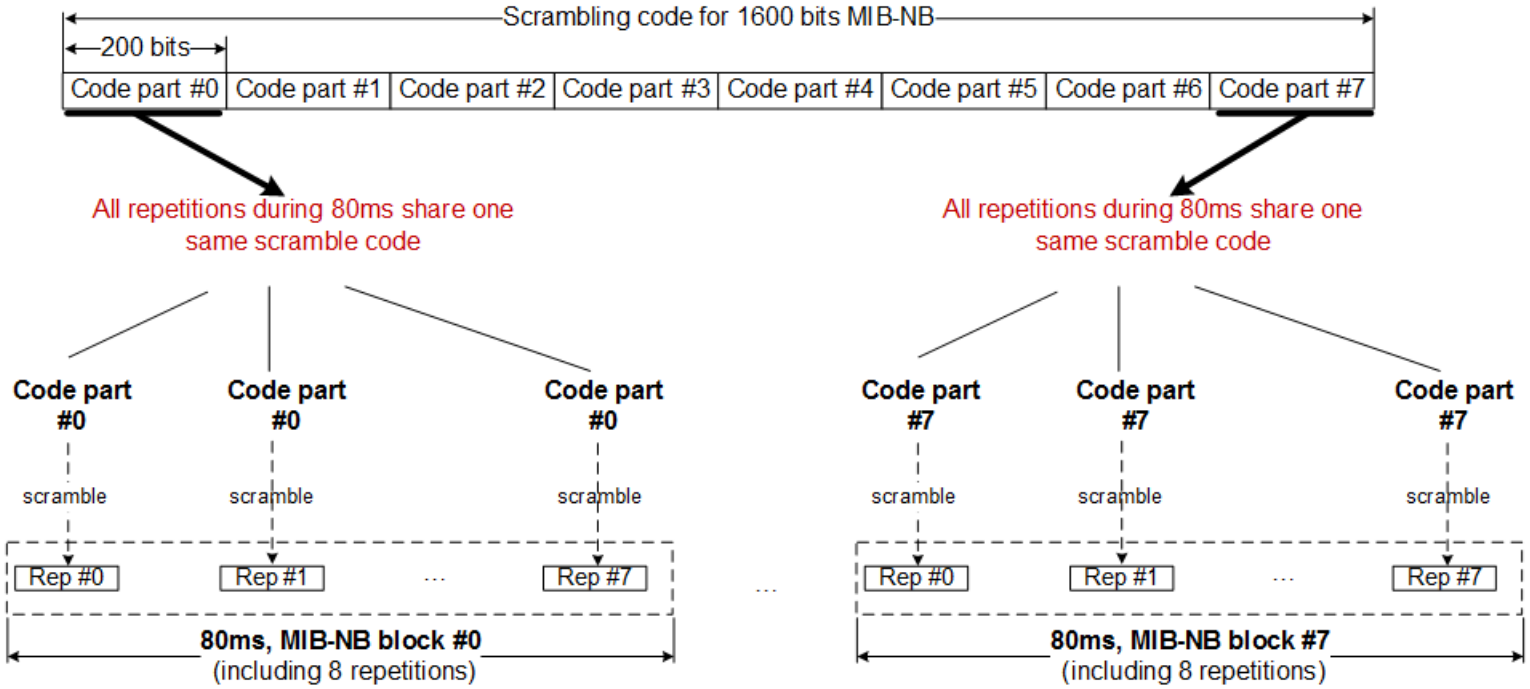
Background of MIB-NB scrambling

- **Current specification**

NMIB scrambling code initialization:

$$c_{\text{init}} = N_{\text{ID}}^{\text{Ncell}}$$



- **Observation**

Scrambled MIB-NB bits between repetitions within each 80ms block are same.

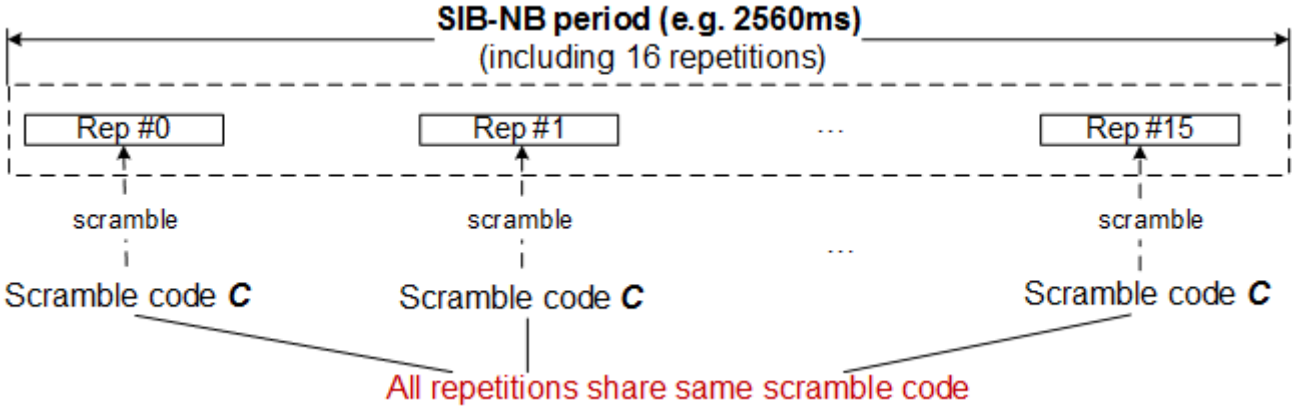
Background of SIB-NB scrambling

- **Current specification**

NSIB scrambling code initialization:

$$c_{init} = n_{RNTI} \cdot 2^{14} + (n_f \bmod 2) \cdot 2^{13} + \lfloor n_s / 2 \rfloor \cdot 2^9 + N_{ID}^{Ncell}$$

Fixed | Unchanged between SIB-NB repetitions | Unchanged between SIB-NB repetitions | Fixed

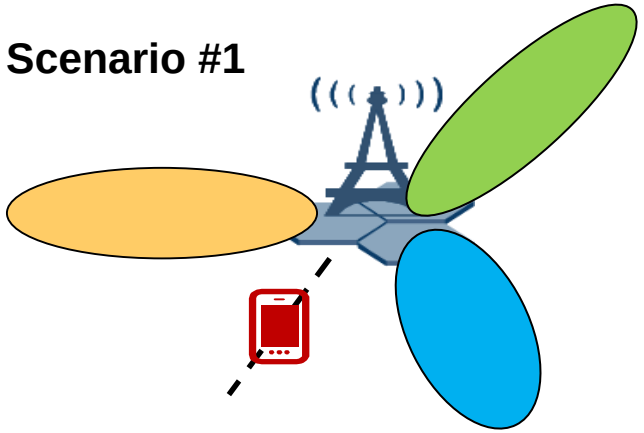


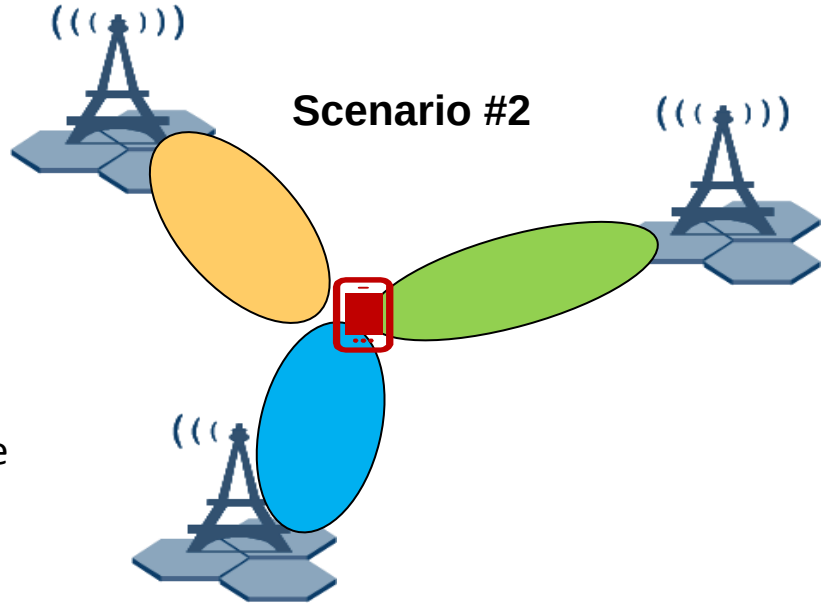
- **Observation**

Scrambled SIB-NB bits between repetitions within SI period are same.

Problem of MIB-NB/SIB-NB scrambling

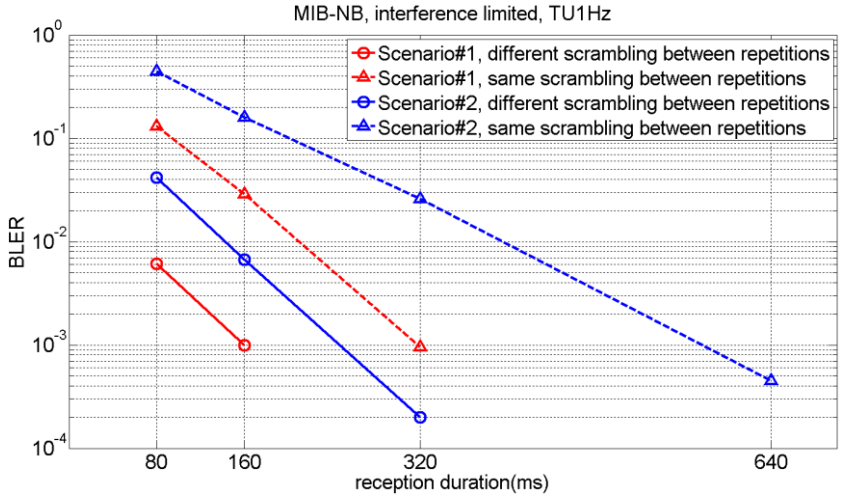
- **MIB-NB/SIB-NB scrambled bits are the same between repetitions, which leads to coherent combining of interference from neighbor cells in the following configuration**
  - MIB-NB/SIB1-NB transmissions are time aligned between cells
  - Some configurations of other SIBs result in time alignment
- **In a synchronous network, this time alignment will often occur**
  - MIB-NB transmitting on same pre-defined sub-frames for all cells
  - SIB1-NB has only 2~4 frame offset options to stagger transmission between cells depending on repetition number, but there may be many more neighbor cells
- **In a non-synchronized network, intra-site cells are typically synchronized**
- **The performance impact can be large especially under interference limited scenarios**
  - As Doppler reduces, UE more often fails to access the cell because it cannot receive SIB1-NB even though it is within the coverage of the cell
  - This leads to real-world cases where very large proportion of UE battery life is consumed by failed cell accesses, and in very low Doppler, the UE cannot access the network at all – even though it is within cell coverage

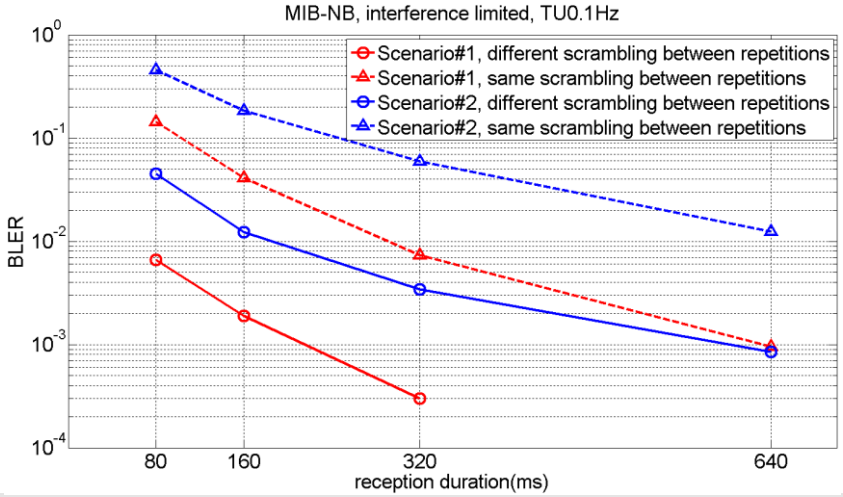




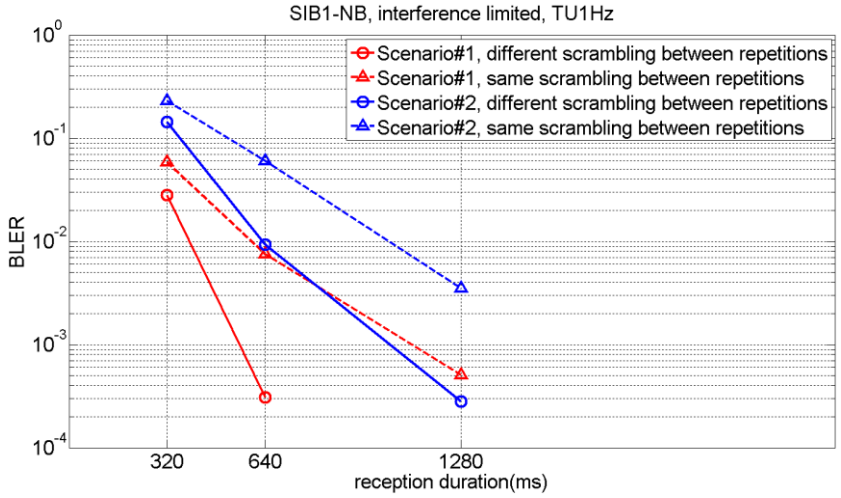
Performance evaluation

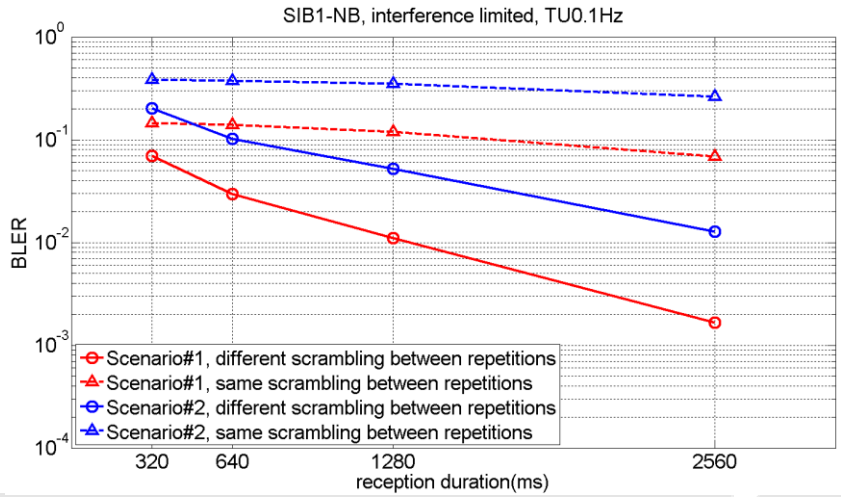
MIB-NB





SIB1-NB





- **900 MHz**
- **SNR = 30 dB**
- **SIR**

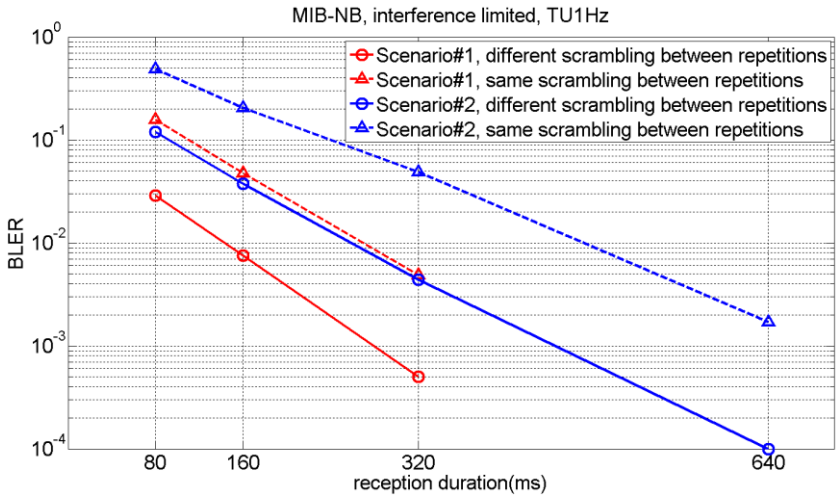
Scenario #1 : 0 dB

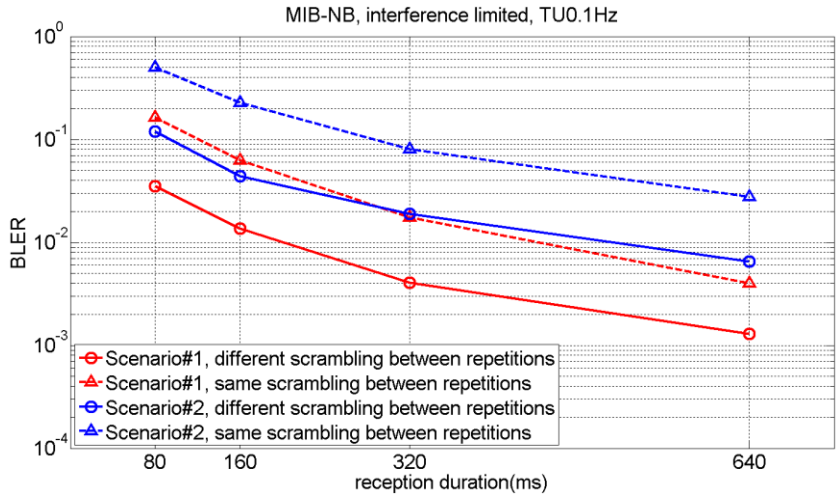
Scenario #2: -3 dB

- **SIB1 TBS: 208 bits**
- **Synchronous between cells**
- **MIB-NB/SIB-NB have same t-f resources in each cell**
- **Realistic channel estimation across 5 sub-frames**

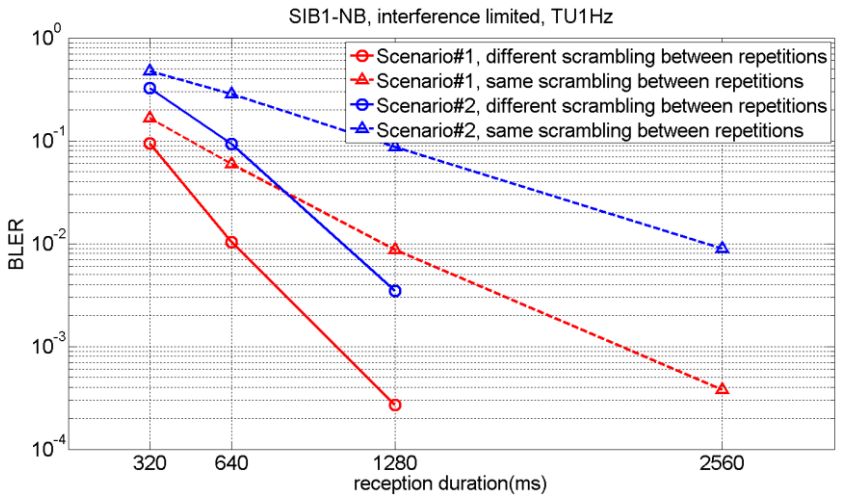
Performance evaluation

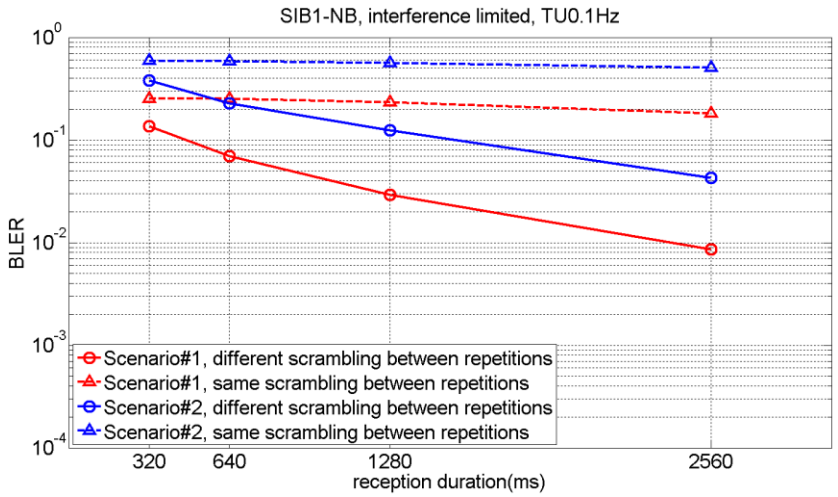
MIB-NB





SIB1-NB





- **900 MHz**
- **SNR = 30 dB**
- **SIR**

Scenario #1 : 0 dB

Scenario #2: -3 dB

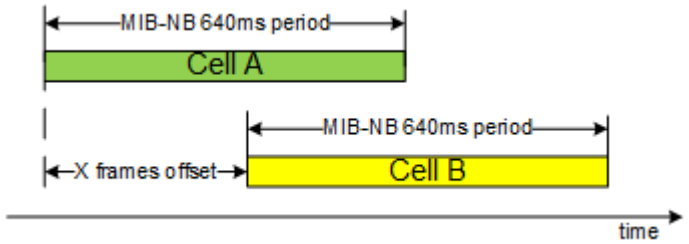
- **SIB1 TBS: 208 bits**
- **Synchronous between cells**
- **MIB-NB/SIB-NB have same t-f resources in each cell**
- **Realistic channel estimation in 1 sub-frame**

Observations

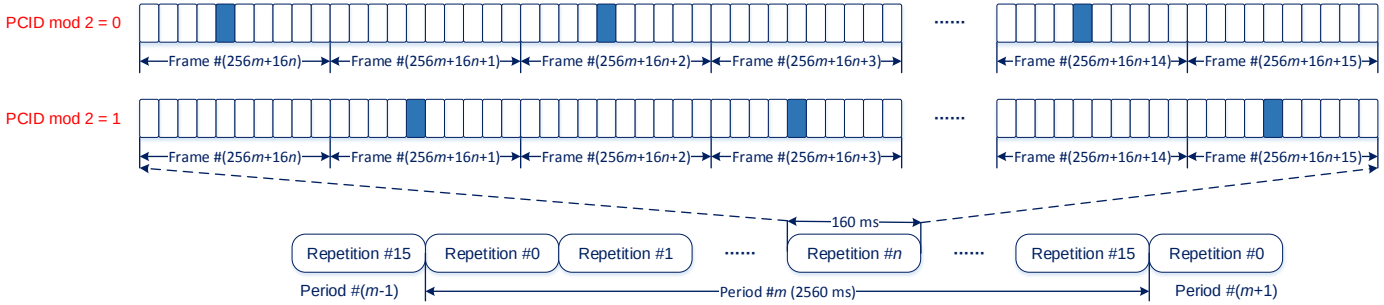
- **Performance impact on SIB1-NB is serious within the cell's coverage when interference limited**
  - SIB1-NB decoding needs 2560ms reception @1%BLER
  - SIB1-NB almost can be un-decodable in low Doppler channel.
- **Introducing different scrambling between repetitions of MIB-NB/SIB1-NB has significant gain in interference limited scenarios**
  - MIB-NB
    - More than 3 dB gain in TU 1Hz
    - Around 6 dB gain in TU 0.1Hz.
  - SIB1-NB
    - Several dB gain in TU 1Hz
    - Gain enough in TU 0.1 Hz to restore cell access to the UE
  - These lead to benefits for latency of cell acquisition, and restore access to the network for those UEs which can otherwise be lost even within network coverage

Configuration not useful in synchronous cells

- **Different synchronous cell configures different SFN can not solve MIB-NB issue**
  - MIB-NB content changes every 640ms
  - Different cell can stagger SFN by configuration
  - Coherent combining of interference from neighbor cells partially relieved
  - This is not sufficient to solve the problem thoroughly
  - Intra-site cells cannot perform such configuration particularly for NB-IoT in-band operation



- **SIB1-NB issue cannot be solved by configuration**
  - In the case repetition number of SIB1-NB is 16, only two offsets can be configured
  - At least 2 cells have SIB1-NB collision within intra-site 3 sectors
  - Also not sufficient for inter-site cells



$R_{SIB1-NB}$	PCID	Starting radio frame number
4	PCID mod 4 = 0	SFN mod 256 = 0
	PCID mod 4 = 1	SFN mod 256 = 16
	PCID mod 4 = 2	SFN mod 256 = 32
	PCID mod 4 = 3	SFN mod 256 = 48
8	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 16
16	PCID mod 2 = 0	SFN mod 256 = 0
	PCID mod 2 = 1	SFN mod 256 = 1

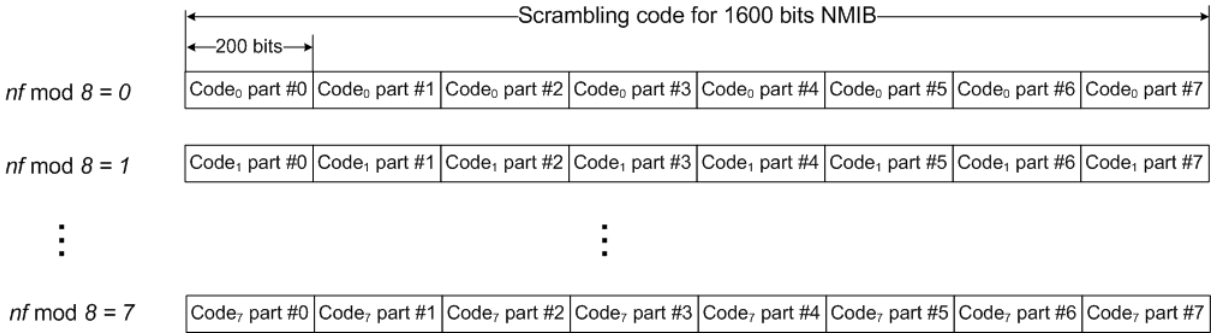
Why MIB-NB/SIB-NB needs robust scrambling

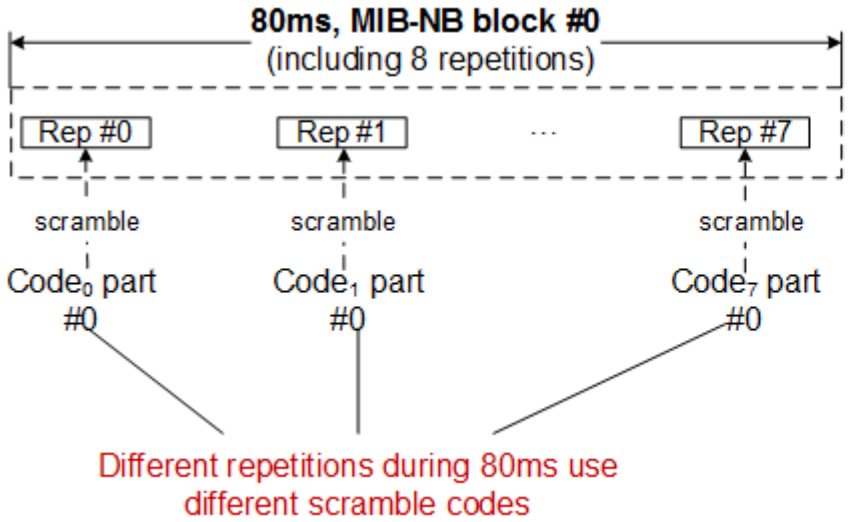
- **Synchronous network deployment is the trend**
  - Some operators' networks are already time synchronous, e.g., TD-LTE, CDMA. NB-IoT may evolve from the existing TD-LTE and CDMA sites
  - TDD is a very important 5G duplex mode, which requires a tightly synchronous network
  - Many features, e.g., NB-IoT TDOA, eDRX requires the network to be synchronous
  - Many LTE features, e.g., CoMP, MBSFN, requires the network to be synchronous. NB-IoT in-band operation will be subject to coexistence with LTE configurations for such features.
- **Intra-site cells are synchronous even when a network is not synchronous inter-site**
- **In real networks, the deployment is less regular (non-hexagonal) than in a simulation analysis**
  - Interference can appear in more locations in the field, especially as networks become denser
- **The gain by introducing robust scrambling is valuable for NB-IoT eco-system**
  - In many IoT applications, UEs are installed in fixed locations so any poor performance will be prevalent for long periods.
  - If UEs cannot camp in the network despite being within coverage, there is an unexpected network and device behavior for the customer

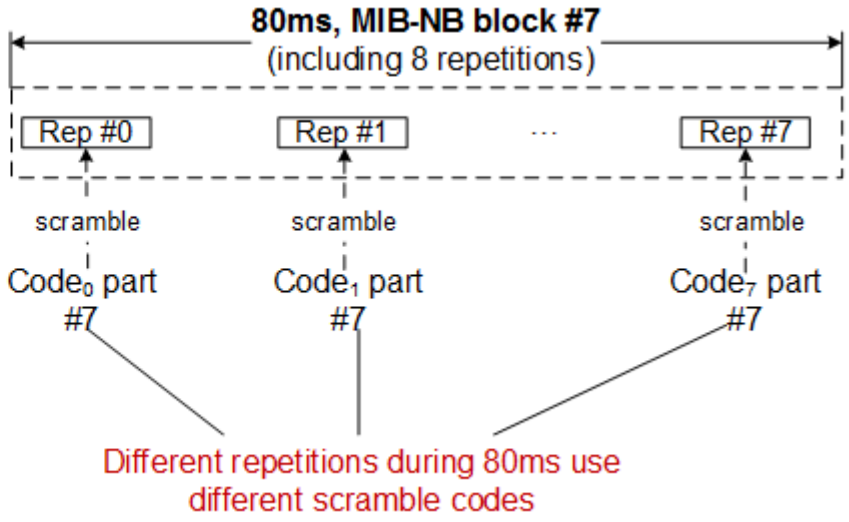
Robust MIB-NB scrambling

- **Change scrambling initialization:**

$$c_{\text{init}} = (n_{\text{f}} \bmod 8) \cdot 2^9 + N_{\text{ID}}^{\text{Ncell}}$$







Robust SIB-NB scrambling

- **Change scrambling initialization:**

Option 1:
Replace the *SI-RNTI* field by system frame number

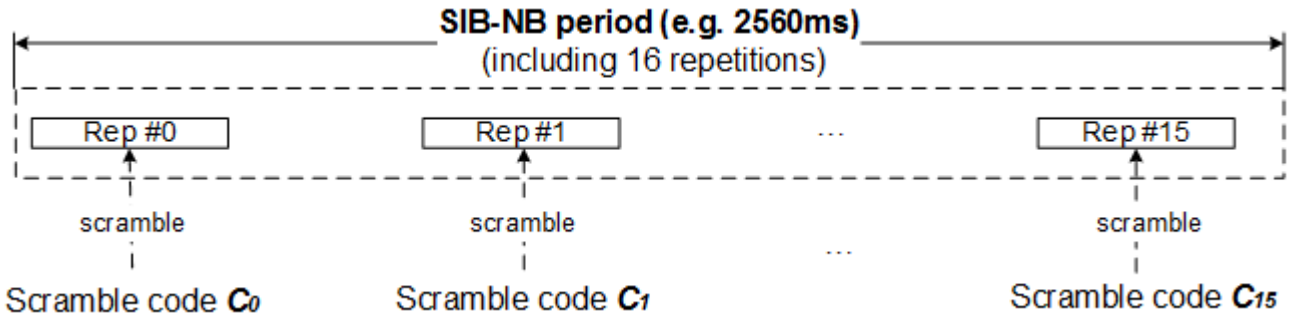
$$c_{\text{init}} = n_{\text{f}} \cdot 2^{13} + \lfloor n_s / 2 \rfloor \cdot 2^9 + N_{\text{ID}}^{\text{Ncell}}$$

Option 2:
Remove the *slot number* field and use SFN mod prime

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{15} + (n_{\text{f}} \bmod 61) \cdot 2^9 + N_{\text{ID}}^{\text{Ncell}}$$

or

$$c_{\text{init}} = n_{RNTI} \cdot 2^{14} + (n_{\text{f}} \bmod 31) \cdot 2^9 + N_{\text{ID}}^{\text{Ncell}}$$



Summary

Problem

- **MIB-NB/SIB-NB scrambling initialization is the same for each repetition, which can lead to coherent combining of interference from neighbor cells in intra-site scenarios and synchronized inter-site scenarios**
- **In some interference-limited cases, UE cannot access the cell even though it is within the cell's coverage**

Solution

- **Scrambling initialization needs to be different for each repetition of the codeword**
- **Differently-scrambled repetitions of MIB-NB need to be interleaved**

➢ **MIB-NB scrambling code initialization change:**

$$c_{\text{init}} = (n_{\text{f}} \bmod 8) \cdot 2^{9} + N_{\text{ID}}^{\text{Ncell}}$$

One 1600-bit repetition is transmitted in sf#0 of 8 radio frames distributed across 640 ms TTI

➢ **SIB-NB scrambling code initialization change:**

$$c_{\text{init}} = \cancel{n_{\text{RNTI}} \cdot 2^{14} + (}n_{\text{f}} \cancel{\bmod 2)} \cdot 2^{13} + \lfloor n_{\text{s}}/2 \rfloor \cdot 2^{9} + N_{\text{ID}}^{\text{Ncell}}$$

OR

$$c_{\text{init}} = n_{\text{RNTI}} \cdot 2^{\cancel{14}13} + (n_{\text{f}} \bmod 6\cancel{12}) \cdot 2^{\cancel{9}13} + \cancel{\lfloor n_{\text{s}}/2 \rfloor \cdot 2^{9} +} N_{\text{ID}}^{\text{Ncell}}$$

(example using a particular prime number)

Thank You

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