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RP-160304

Discussion on NB-IoT UE capabilities

Huawei, HiSilicon, Neul

Background

- At RAN#70 it was decided (RP-152297) that “RAN will make the decision on capability/interoperability testing at RAN#71”.

- At RAN1#84 meeting there are relevant agreements achieved which are helpful for making the decision

Multi-tone capability indication (1)

- **Proposal 1: Single-tone transmission support is a mandatory part of the NB-IoT UE category, and multi-tone transmission is an optional capability:**
  - WID approved at RAN#70 says: "*The UE shall indicate the support [of] single-tone and/or multi-tone*"
    - Clearly, there would be no reason for the UE to indicate support if both single-tone and multi-tone were mandatory
    - Single-tone UE support is required to meet the 164 dB coverage objective, since multi-tone transmissions are only useful for UEs in relatively good coverage
  - Agreements at RAN1#84 meeting:
    - In R1-161522 was close to agreement to make the recommendation in the feature groups:
      - Single-tone is mandatory component of NB-IoT UE category, multi-tone is optional feature; single-tone is the Prerequisite feature group of multi-tone
  - Technical reasons:
    1. Single-tone-only UE support is essential for ultra-low cost and very energy efficient UE transmitter architectures (modulation is constant envelope) and rapid TTM
    2. Single-tone-only UEs meet the objectives of the GERAN study item for coverage, battery life and latency (at extended coverage all UE transmissions will be single-tone anyway)
    3. Single-tone-only UEs meet the requirements of a large segment of IoT applications which do not require higher peak data rates, but do require ultra-low cost

Multi-tone capability indication (2)

- **Proposal 2: Msg3 includes a capability bit to indicate whether UE supports multi-tone transmission:**
  - This supports RAN1#84 agreements related to Msg3 transmission:
    - "*RAN1 specifications will support the existence of UEs that do not support multi-tone Msg3*"
      - i.e. to allow UEs that only support single-tone transmissions to connect to the network and send a capability bit in Msg3 to ensure that all subsequent transmissions are also single-tone
    - "*For at least one number of repetitions of NB-PRACH, multi-tone Msg3 transmission is not allowed by the specifications*"
    - NPRACH resources may be split to distinguish single-tone vs. multi-tone UEs, but this up to the operator depending on their capacity needs, so a later chance to indicate capability is also required.

Subcarrier spacings

- **Proposal 3: Both subcarrier spacings, 3.75 kHz and 15 kHz, are mandatory components of NB-IoT UE category based on:**
  - WID approved at RAN#70 says "*Two numerologies should be configurable by the network for single-tone transmission: 3.75 kHz and 15 kHz*"
    - The numerologies are only optional for the network and UE needs to implement both. Otherwise UEs may fail to access to the network.
  - RAN1 related agreements:
    - *Subcarrier spacing for Msg3 and subsequent NPUSCH is indicated in RAR*
      - i.e. in RAR the network will indicate either of the subcarrier spacing without knowing UE-specific capability (there is no chance before RAR for the UE to indicate its capability), therefore to make both 3.75KHz and 15KHz mandatory is the appropriate way forward
      - Otherwise if either subcarrier spacing is optional, RAN plenary has created unnecessary error cases in a technical WG agreement
  - Technical reasons:
    1. 3.75 kHz subcarrier spacing provides improved uplink capacity when many UEs require extended coverage (because more UEs can transmit simultaneously as there are more distinct subcarriers)
    2. There is negligible UE cost impact for supporting both subcarrier spacings:
       - 3.75 kHz is an integer division of 15 kHz, so it is simple for a UE capable of 15 kHz single-tone transmissions to also support 3.75 kHz
       - The peak data rate for a 3.75 kHz subcarrier is lower than for a 15 kHz subcarrier, so the processing load on the UE must be lower