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Considerations on Ambient IoT

EURECOM

Agenda Item: 9.1.1.4

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Background

The Rel-18 report on Ambient IoT TR 38.848 (V18.0.0) recommends the following to RAN:

- RAN is recommended to down-select further starting from
  - Deployment scenario 1 with Topology 1
  - Deployment scenario 2 with Topology 1
  - Deployment scenario 2 with Topology 2
  - Deployment scenario 4 with Topology 1
  - Deployment scenario 4 with Topology 3
- FR1 licensed spectrum is recommended
  - Note: selection or prioritization between FDD and FDD/TDD is to be decided
- RAN is recommended to down-select to one or more of:
  - Spectrum in-band to NR, in guard-band to LTE/NR, and in standalone band(s)

Deployment Scenarios and Topology

- "Simple" topologies 1 and 2 require the BS or the intermediate node to simultaneously generate a carrier wave (CW) for backscattering and to receive the back-scattered signal (Devices A&B)
- This will require some HW modifications, e.g. isolated TX and RX antennas to recover the faint back-scattered signal from the strong CW
- Technologies to achieve that exist (e.g. in RFID Readers) and are easier to implement than topologies requiring complex backhaul procedures (Topology 3 & 4)

Proposal: Focus on Topologies 1 & 2 and associated deployment scenarios

Spectrum

- Devices A and B require back-scattering transmission for UL communication
- Back-scattering requires a time-continuous carrier wave
- Thus, TDD is not able to support back-scattering without the device knowing the exact UL/DL pattern
- In addition, device A needs to extract power from the DL transmission to operate its circuitry and decode the DL data
- Without continuous DL transmission, device A cannot operate
- Low carrier frequencies can achieve better coverage (especially important for devices A & B)
- Unlicensed operation requires additional procedures (LBT) and can be considered in the future

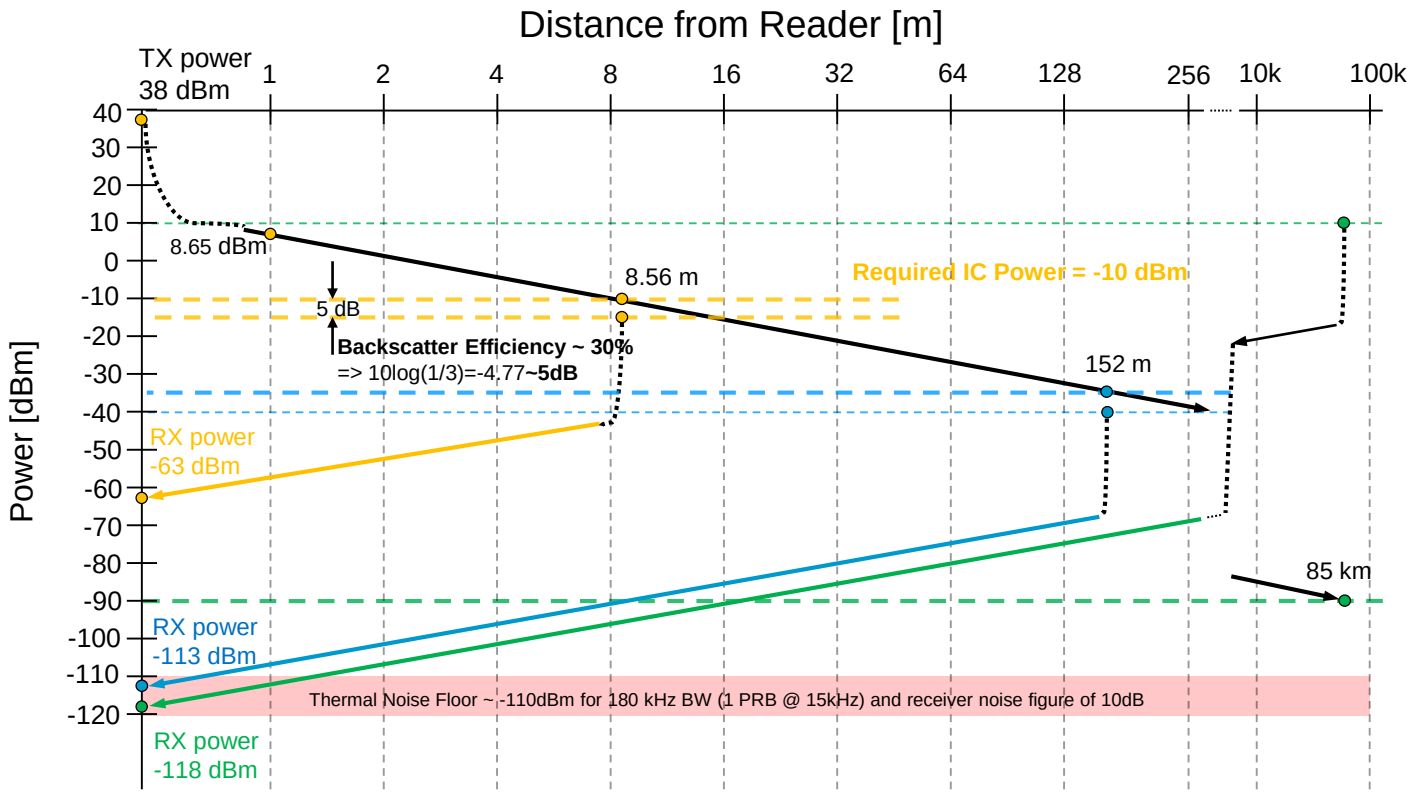
Proposal: Focus on sub-GHz spectrum and licensed FDD (in-band, guard-band or standalone bands)

Three Very Different Device Types…

Property	Device A (passive)	Device B (semi-passive)	Device C (active)
Complexity	Ultra-low	Low	Low/Medium
Energy storage	None	E1	E2 (E2>E1)
Reception	• Low-complexity • Energy from incoming signal required for powering circuitry	• Increased receiver sensitivity • Independent power from ambient sources	• Full low-complexity receiver • Independent power from ambient sources
Independent Tx	No (back-scattering)	No (back-scattering)	Yes (but limited TX power)
Power consumption	<[1-10]μW	Hundreds of μW	<[1-10] mW
Link Budget and Range (see next slide)	DL-limited ~5-10m	Balanced link possible ~100m	UL-limited ~depends on tx power

- Different characteristics require **specific physical layer design** for each device type
- Study needs to evaluate if and **how the different devices can co-exist**

Example Link Budget



Device A (Passive)
- ~10-30 µW IC power consumption to read tag
- ~30% rectifier efficiency → 100 µW = -10dB at tag
- -63dBm at reader

➔ *Forward-link (DL) limited*

Free Space Pathloss @ 700MHz, PL (dB) = 29.35 + 20log(d)
Near Field @ 700MHz, until 2*lambda ~ 0.86m → 28dB

Device B (Semi-Passive)
- Rx power only large enough to decode data
- Rx sensitivity ~ -30 to -40 dBm

➔ Range of ~100m, high quality reader required
➔ Adding LNA at tag requires even more RX sensitivity at reader
➔ *Balanced link possible but usually UL-limited*

Device C (Active)
- Rx sensitivity of (cheap) radio ~90dBm
- Able to read tag from ~85km ! LOS conditions
- Limited by TX power of tag, e.g. 10dBm (10mW)

➔ *Unbalanced link* (read the tag but not hear it)

Directional antennas can improve link budget

Proposals

- **Study UL/DL PHY design for all three Ambient IoT device types A,B,C**
  - DL (A): Received signal needs to power receiver circuitry
  - UL (A/B/(C)): Back-scattering transmission design
  - UL (C): UL waveform enabling power-efficient transmitter design
  - DL (B/C): For in-band operation, WUS design can be starting point
    → Different device types require different waveforms/coding in UL and DL
  - If prioritization among device types required → focus on A & B
- **Study PHY procedures**
  - Multiple access schemes (TX/RX of multiple devices of different type)
  - Co-existence of all three device types (unified design to support all three device types)
  - Potential measurements performed by devices
  - Include energy harvesting in the evaluation methodology (communication uncertainty, does device have enough energy to receive/transmit)
- Given amount of novelty in the air interface → **SI only in Rel-19**