3GPP TSG RAN Meeting #98-e

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RP-222985

Discussions on Ambient IoT

Agenda Item: 9.2.3

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Use cases & scenarios

- Various use cases and traffic scenarios were identified by SA1 and captured in TR 22.840 for ambient power-enabled IoT solutions. Typical examples include automated warehousing, asset tracking and inventory management, etc.
- A clear understanding of the various use cases/traffic scenarios, practical feasibility, and technical requirements from the perspective of the radio access technology remains to be established
- In general, an ambient IoT device is to compliment the existing IoT devices of eMTC, NB-IoT, and RedCap/eRedCap (with or without support of LP-WUR), potentially characterized by
  - Extreme low complexity and power consumption comparable to incumbent devices. For devices without energy storage, the power consumption can be in level of ~1uW
  - Orders of magnitude higher device density than incumbent use cases
  - Target for larger coverage than incumbent devices, e.g., 20-200m
  - Positioning support may be a key differential factor

Device categorization

- An ambient IoT device can be categorized by energy storage and active/passive transmission
  - Type A: Pure batteryless devices with no energy storage capability
    - It can work using backscatter communication
    - Energy is harvested by the radio waves that is from the reader or an ambient node
    - Extreme low complexity/power consumption but with limited capacity, e.g., data rate, coverage, etc.
  - Type B: Devices with limited energy storage capability that do not need to be replaced or recharged manually
    - A capacitor can be used to store the energy. It is preferred to clarify that using a battery with small size is not in the scope of the study
    - The source for energy harvesting may be radio wave and other non-RF sources
    - It can work with backscatter or active communication
    - Compared with Type A device, more functionalities can be supported with improved coverage and sensitivity but increased complexity.

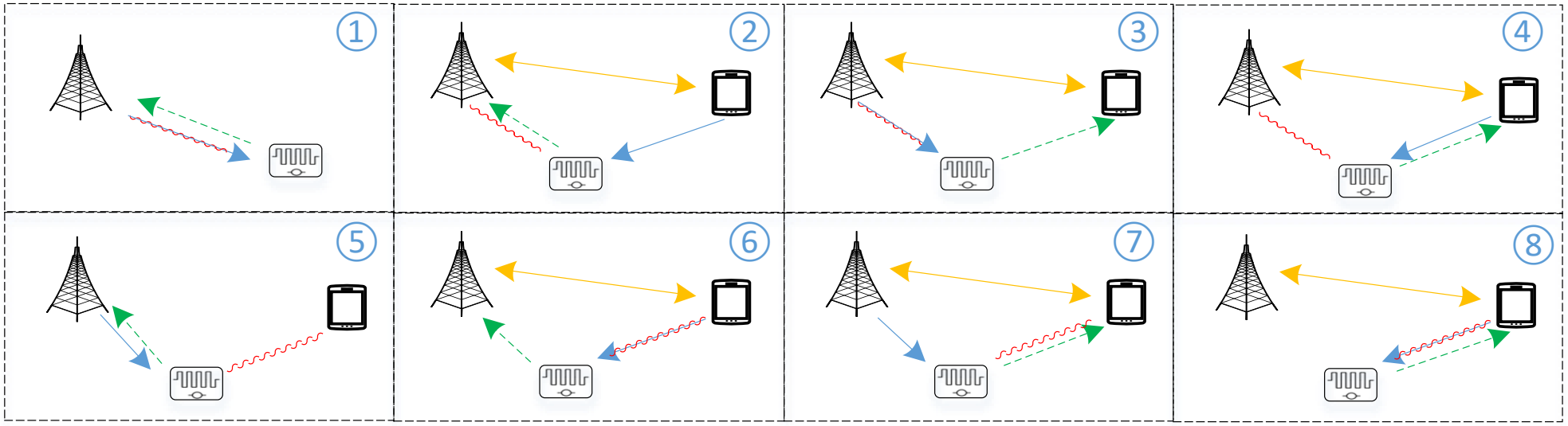
- Source for energy harvesting
  - Radio waves
    - It typically has quite low power density, e.g., ~1uW/cm^2
  - Non-Radio sources, e.g., solar, light, thermal, vibration, etc.
    - The power density depends on the sources. It can be up to 10s of mW/cm^2
- Impact of energy harvesting mechanism on the operation of ambient IoT should be studied

Energy source	Power density	Advantages	Disadvantages
Solar	15 mW/cm^3	Sufficient energy in the daytime, high output voltage	Disappear at night
Vibration (piezoelectric)	200 uW/cm^3	Without voltage source	Brittle materials
Thermoelectric	40 uW/cm^2	Long life, reliable with low maintenance	Low energy conversion efficiency
Acoustic noise	960 nW/cm^3	High energy conversion efficiency	Rare environments with high acoustic noise levels
Airflow	1 mW/cm^2	Sufficient in certain place and time	Big size
Radio frequency	1 uW/cm^2	Sufficient in urban areas	Few in suburbs

[1] Yejun He, et.al, “A Survey of Energy Harvesting Communications: Models and Offline Optimal Policies”, IEEE Communications Magazine, June 2015

RAN topologies

- Ambient IoT device may communicate with gNB directly (Figure 1), however, it may suffer from coverage issue
- Ambient IoT device may communicate with gNB via a node of relay, IAB node, repeater, or a UE (Figure 8)
  - Better coverage can be achieved
- Ambient IoT device may communicate with gNB assisted by a node of relay, IAB node, repeater, or a UE (Figure 2-7)
  - The assisted node may act as the source for energy harvesting, relay a DL transmission/trigger from gNB, and/or forward an UL transmission to gNB
  - Feasibility of different options should be studied



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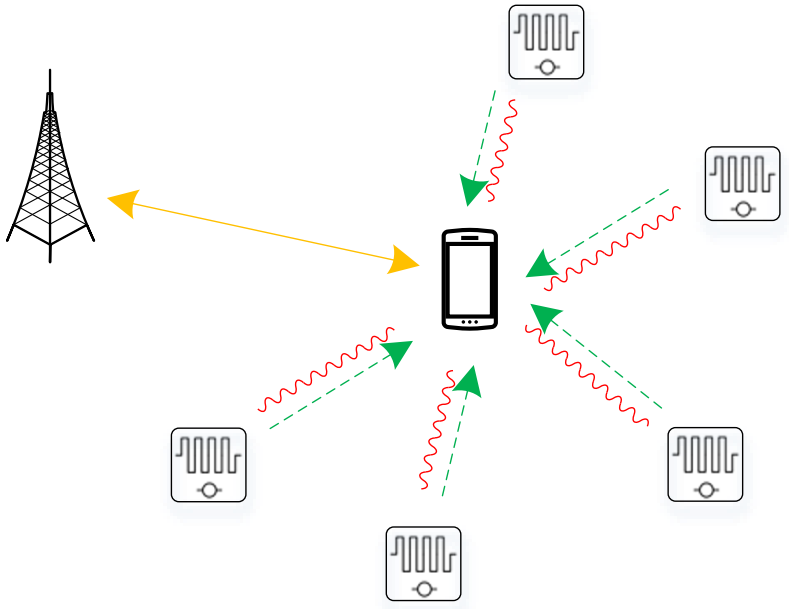
Radio wave for energy havesting

Information/trigger to the ambient IoT device

UL transmission by e.g. backscatter

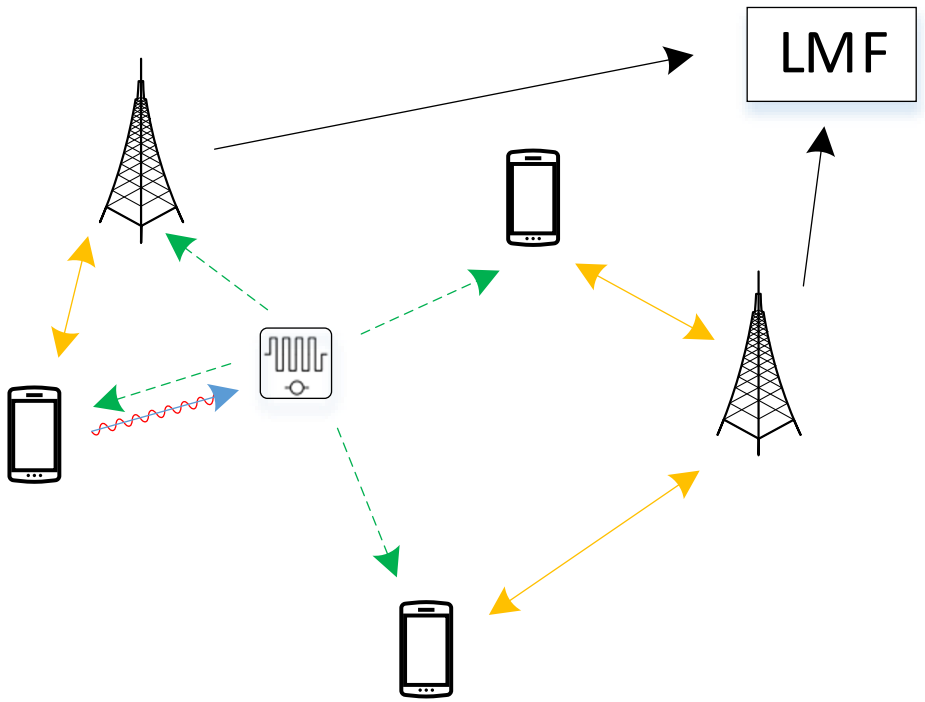
Proactive or reactive operation mode

- An ambient IoT device can work proactively or reactively depending the use cases identified by SA1. Correspondingly, the traffic can be device originated or device terminated
- Device originated use cases
  - In such use cases, how to coordinate the transmissions from multiple ambient IoT devices to avoid severe mutual interference should be studied
  - The ambient IoT device may only have the capability of UL transmission. For example, when the device receive a radio wave being energy source, the device reflects the signal with modulated information, e.g., ID
  - The ambient IoT device may have the capability of both DL transmission and UL transmission too
- Device terminated use cases
  - Operation of DT use cases are under the control of the reader (can be gNB or other nodes) which avoids interference between ambient IoT devices
  - The ambient IoT device must have the capability of both DL transmission and UL transmission



Positioning

- Positioning support is considered in multiple use cases identified by the study in SA1
- Especially considering the number of ambient IoT devices may be order of magnitudes of the existing device density, locating an ambient IoT device may become quite messy
- Difficulties to be overcome
  - Ambient IoT device is of low capability hence may not be capable of positioning related measurements and calculations
  - Ambient IoT device is of short energy supply hence may only transmit positioning signals in limited time duration
  - Ambient IoT device often has a short coverage hence may only communicate with nodes in proximity
- On the other hand, certain use-cases may only require coarse positioning estimates, e.g., whether certain items have been delivered or left in a warehouse, etc.
- The positioning of ambient IoT devices should be study for a balance of the achieved accuracy and complexity/power consumption



Coexistence with existing 3GPP technologies

- NR as baseline for ambient IoT
  - For physical layer
    - Changes in physical layer are inevitable since the existing OFDM waveform and QAM modulation is not efficient for extreme low power consumption
    - LP WUR/WUS studied in a Rel-18 study item can be a reference for physical layer of ambient IoT, e.g., OOK/FSK modulation and envelop detection
  - For high layer
    - Existing NR protocol stack may serve as a starting point
    - Unnecessary protocols/procedures can be removed or simplified.
- Ambient IoT may be operated in a frequency that is different from the cellular network, i.e., out-of-band
- In-band transmission of Ambient IoT devices in a carrier of cellular network should be considered too
- The ambient IoT device should be workable in a TDD and/or FDD cell
- Both licensed carrier and unlicensed carrier can be considered for the study
  - The suitable band for ambient IoT operation should be identified

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