

3GPP RAN#102

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Agenda Item: 9.1.1.4

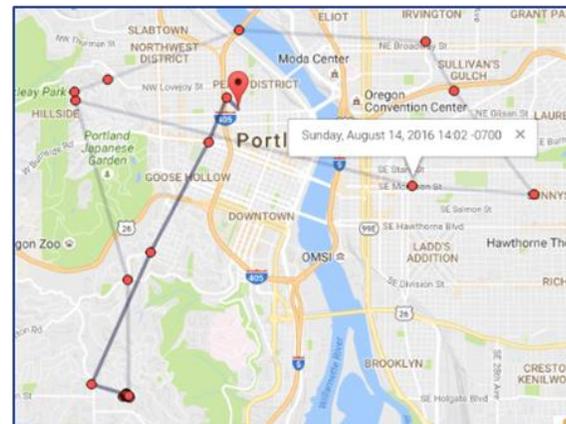
# Views on Ambient IoT in Rel-19

Qualcomm Incorporated

# Ambient IoT

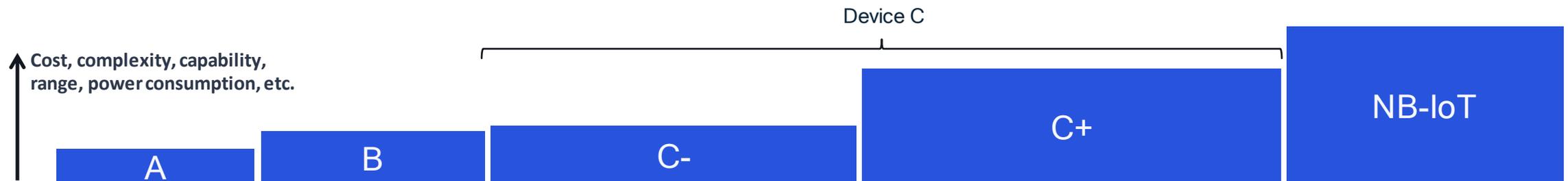
## Motivation

- Current LPWA IoT device does not fully cover use cases in logistics, retail, smart home, smart factory, smart farm, etc. due to battery replacement requirement, high device cost, high power consumption
- Ambient IoT (A-IoT) is new device type(s) targeting low cost/low complexity/low power consumption, which could potentially operate with harvested ambient energy only, which removes the requirement of battery replacement.
- Use cases: **inventory/logistics, tracking/positioning, sensor reporting**



# Device Types

- Three device types defined in 3GPP RAN SI; A, B, C.
- **Device type A/B**
  - Device A is pure passive device. Device operates based in instantaneously received RF signal energy.
  - Device B is semi-passive device having energy harvesting capability. Harvested energy can be stored in device and used later to power up IC or to power active RF component to improve Rx/Tx performance.
- **Device type C**
  - Device C generates Tx signal based on active RF component using harvested energy. Energy storage size, receiver architecture choice (e.g., mixer, filter, LNA, ADC, etc) could have significant impact on receiver sensitivity, and accordingly, range/coverage. The size of energy storage also determines the functions/capability of device, e.g., 5G PHY/MAC/UL protocols is to be leveraged or not.
  - Having larger energy storage also means higher cost due to required energy storage cost.
  - **Device C includes different sub-types**, in terms of complexity, capability, cost, range, power, etc. For example, we see the following two sub-types:
    - **C-** : This is similar to A/B in terms of form factors, but with slightly higher complexity/cost/power, and accordingly has slightly better capability than B. RF signal energy could be the main source of energy for device C- consuming lower power.
    - **C+**: This is more complex than C-, closer to NB-IoT in terms of form factor, cost, complexity, power consumption, protocols, etc. With larger energy storage and higher transmit power, C+ could achieve larger coverage and longer continuous operation time before recharge is needed. Utilizing energy source (e.g., solar) other than RF signal could be suitable for device type C+.
- **Proposal : Support device type C- with power consumption of < 1mW, e.g., in the order of 100s uW.**



# Deployment Scenarios and Topologies

- Rel-18 RAN SI identified 5 pairs of deployment scenario and topology and recommendation is to down-select from (A), (B), (C), (D), and (E).
- The choice of desired pair has strong dependency on device type. For C-, we see the following choices.

	Case		Analysis
Indoor	(A)	Deployment scenario 1 (indoor) with Topology 1	This is the case where new set of indoor BSs can be deployed for A-IoT in e.g., private network. Warehouse, automated factory for inventory/tracking could be strong use cases.
Outdoor to Indoor (O2I)	(B)	Deployment scenario 2 (O2I) with Topology 1	This is the best effort scenario for device type C- leveraging outdoor BS.
	(C)	Deployment scenario 2 (O2I) with Topology 2	Intermediate node communicating with A-IoT device could be useful for 1) consumer use case such as smart home use case - connecting retail use case and end user use case based on smart phone reader 2) use case where existing outdoor infra (BS) can be used with minimal modification only (e.g., SW change only).
Outdoor	(D)	Deployment scenario 4 (outdoor) with Topology 1	This is for outdoor long range supported A-IoT, e.g., asset tracking, long range wireless sensors. Since it is for outdoor BS direct access, device C+ works better in this case than C-.
	(E)	Deployment scenario 4 (outdoor) with Topology 3	Using assisting node could enhance the coverage enabling Topology 1 in outdoor.

## Proposal: Focus on following deployment scenario and topologies for device C-.

- For Indoor, (A) deployment scenario 1 with Topology 1
- For O2I, (C) deployment scenario 2 with Topology 2
- For Outdoor, (E) deployment scenario 4 with Topology 3

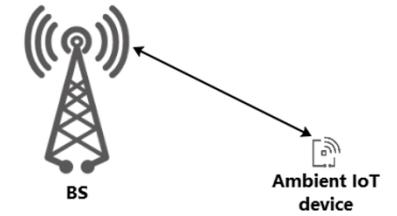


Figure 4.2.1.1-1: Topology 1

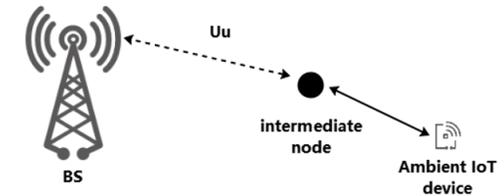


Figure 4.2.1.2-1: Topology 2

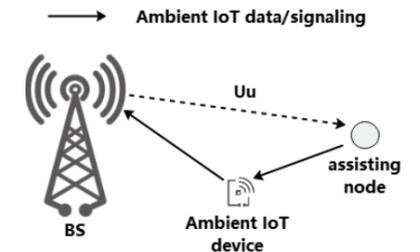


Figure 4.2.1.3-1: Topology 3 with downlink assistance

# FR1 Licensed Spectrum: FDD vs FDD/TDD

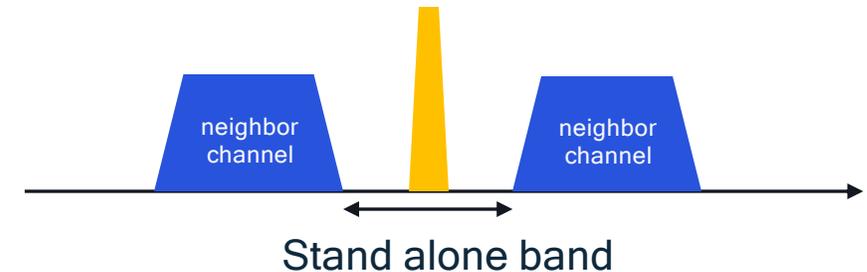
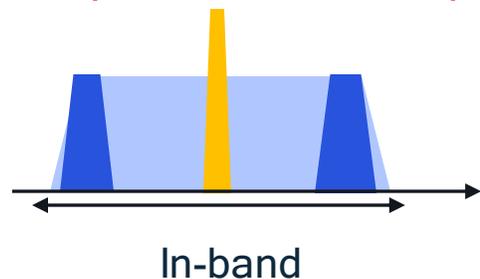
- Conclusion from Rel-18 RAN SI recommended FR1 licensed spectrum with potential selection or prioritization between FDD and FDD/TDD.
- FDD band frequency is lower than that of TDD band (e.g., 3-4GHz) leading to lower pathloss and accordingly larger coverage/range of A-IoT.
- System design for FDD band would be less challenging than that for TDD band due to contiguous nature of DL/UL slots in FDD frame.
- **Proposal: Focus on FR1 licensed FDD spectrum in Rel-19.**

# Spectrum deployment options

- Rel-18 RAN SI 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)
- The choice of deployment depends on RF filtering capability of device types A/B/C.
  - A/B have poor RF selectivity (e.g., tens of MHz) due to lack of selective RF filter.
  - C should have better filtering capability than A/B (through RF filter, down conversion and filtering at BB).

	Device A/B w/ poor RF selectivity	Device C w/ better RF selectivity
<b>in-band to NR</b>	For A/B, BS can easily allocate large guard RBs around A-IoT DL signal by scheduling in order to reduce co-channel/in-band interference.	For C w/ RF filtering capability, the necessary guard RBs could be smaller than that required for A/B. So, in-band option will work more efficiently.
<b>Guard-band to LTE/NR</b>	For A/B, the interference from in-band RBs or neighboring channels could be high, if not controlled.	For C w/ RF filtering capability, guard band deployment should be fine as long as it provides enough selectivity and possible interference management/control as in-band case.
<b>Standalone band</b>	For A/B, allocating large chunk (w/ enough guard band) of spectrum only for A-IoT might be less efficient than other cases when spectrum is under utilized.	For C w/ RF filtering capability, narrower stand alone band become possible than A/B case, which will improve efficiency.

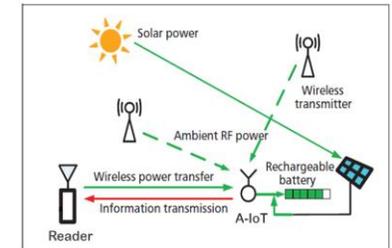
**Proposal: Consider all deployment scenarios for device type C-.**



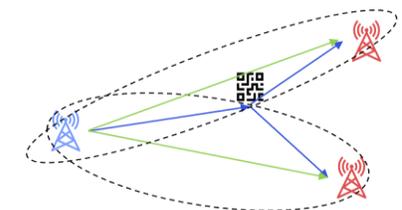
# R19 RAN Study on Ambient IoT

## SI Scope (1/2)

- RAN1 focuses on study on new air interface design - L1/L2 procedures/protocols to support A-IoT devices operation based on harvested energy.
  - Confirm **target use cases of interest** including inventory/logistics, positioning/tracking, sensor reporting considering RAN SI outcome [RAN1].
  - Study and confirm **topologies** of interest at least including **BS to A-IoT device** and **BS to UE to A-IoT device (including topology 1/2/3)** in terms of feasibility (e.g. limited full duplex capability, limited coverage, etc.) [RAN1].
  - Focus on **device type C with limited pwr (<1mW, e.g., in the order of 100s uW)** to support target use cases [RAN1].
  - Define the **evaluation methodology** including use cases, traffic model, target deployment scenarios (including topologies, frequency, base station/device characteristics, etc.) and KPI for the identified use cases [RAN1]
  - Study **DL/UL communication techniques** between gNB/UE and above mentioned A-IoT devices covering identified use cases and deployment scenarios [RAN1]
    - Study **coding and modulation, multiple access, coverage extension techniques** for A-IoT devices
    - Study the **feasibility** of stand-alone and **co-deployment** (considering co-source interference) considering NR frame structure [RAN1]
    - Study **RF energy harvesting techniques** including waveform, signal, beamforming, and procedures [RAN1/4]
    - Study **positioning/ranging techniques** for Ambient IoT device at least including passive positioning [RAN1/4]



Source: IEEE Wireless Comm., April 2016



Passive positioning

# R19 RAN Study on Ambient IoT

## SI Scope (2/2)

- RAN2 study the **AS protocol and procedures simplification/enhancements** and connection control for A-IoT device in coordination with SA2.
  - Study upper layer procedures to support A-IoT device in NR system, e.g., reusing existing NR features, [RAN2]
- RAN3 study RAN Architecture and interfaces impact taking Access Stratum and 5GC enhancements into consideration [RAN3]
- Data/signaling/communication should consider the limitations due to energy harvesting of the A-IoT device [RAN2/1]



# Thank you

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