RP-232867

December 2023

Ambient IoT Devices Complexity and Power Comparison

3GPP RAN-102

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RAN AIoT Device Categorization

TR 38.848 V18.0.0 Section 4.3

- "RAN study considers that a device has either:
  - No storage at all or
  - Limited energy storage
- Relying on these storage capacities, the study considers the following set of Ambient IoT devices:
  - **Device A**: No energy storage, no independent signal generation/amplification, i.e. backscattering transmission.
  - **Device B**: Has energy storage, no independent signal generation, i.e. backscattering transmission. Use of stored energy can include amplification for reflected signals.
  - **Device C**: Has energy storage, has independent signal generation, i.e., active RF components for transmission."

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Ambient IoT Device Architectures

- Wiliot is a Si vendor of Ambient IoT tags, currently offering tags based on Bluetooth standards
- The purpose of this contribution is to present Wiliot's experience for devices with tens of meters range and ~100uW power consumption using Type B and Type C architectures.

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AIoT Device Categorization

Item	Passive device	Active/Passive device		Active device
	Type A	Type B	Type C	Type C
Communication range	< 10 meters	Tens of meters	Tens of meters	Hundreds of meters
Power consumption	~1 uW, Powered by RF energy	~100 uW, Powered by RF	~100 uW, Powered by RF	~500 uW, powered by e.g. solar, heat etc.
Device cost	Similar to UHF RFID	RFID ballpark	RFID ballpark	Order of magnitude lower than NB-IoT
Form factor	Small, ultra-thin	Small, ultra-thin	Small, ultra-thin	Small, thin
EIRP	-25dBm	-25dBm	-25dBm	-5dBm
Reader	Requires Full duplex	Requires Full duplex	May use Half duplex	May use Half duplex

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Architecture Complexity Comparison

Common Architecture/ Building blocks

- Assuming Type B and C transmit the same data
- Type B and Type C Main blocks:
  - Power management
  - RF Harvesting
  - CPU + Memory
  - Digital processing logic
  - RFE

Main difference between Type B and C

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RFE Complexity Comparison

Architecture Differences between Type B and Type C

- Targeting EIRP of -25dBm
- Type B and Type C Si sizes are at similar ballpark numbers as passive RFID Si.
- Type C requires:
  - The main RFE difference is the additional clock generation HW.
  - Wiliot's experience using Bluetooth requirements, the clock generation Si size turns out to be <15% of the total Si size. BT is a simpler solution compared to expected 3GPP Ambient IoT devices and therefore we estimate the clock generation Si size will be less than 5% of the total size.
- Type B requires:
  - Power amplification circuitry complexity is higher compared to type C.
    - ➔ Increase complexity without substantially increasing Si size
  - Clock dividers and the full duplex circuitry are more complex than Type C
    - ➔ Increase complexity without substantially increasing Si size
- **Type C Si size is bigger than type B by less than 5%**

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AIoT Device Power Consumption Definitions

From TR 38.848 V18.0.0 Section 5.1

- "For Device A, the power consumption target during transmitting/receiving is ≤ 1 μW or ≤ 10 μW,
- For Device B, the target during transmitting/receiving is such that:
  - Device A power consumption ≪ Device B power consumption < Device C power consumption; or
  - Device A power consumption ≤ Device B power consumption < Device C power consumption.
- The device power consumption during transmitting/receiving for **Device C is ≤ 1 mW** to ≤ 10 mW."
- **A device using architecture Type C, consuming 100 μW is within the agreed targets of 38.848 section 5.1**

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Energy Consumption Comparison

- Type B and Type C Main blocks:
  - Power management
  - RF Harvesting
  - CPU+Memory
  - Digital processing logic
  - RFE

  } Consume the same energy/power

- RFE energy/power consumption
  - Type B with 10-30dB amplification requires calibrations ➔ with the same total energy consumption as Type C
  - Type B with 0-10dB (limited coverage) amplification can avoid calibration ➔ total energy is 95-99% of Type C

➔ **Type-B/Type-C energy consumption is similar**

➔ **Type C can facilitate more energy-efficient modulations than Type B, which was not included in this energy consumption comparison**

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Summary and Conclusion

- **Summary**:

  Wiliot's implementation experience is that :

  1. Type B and Type C architecture complexity is at a similar level
  2. Type C Si Size is bigger than Type B by less than 5%
  3. Type B and Type C Energy consumption are similar

- **Conclusion**:

  Type C can operate with <100uW, has the same ballpark Si size as RFID, and can fit in any Indoor use case