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Considerations for Ambient IoT Devices

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Abstract

- We present an analysis of several limitations that should be considered when designing a standard for ultra-low power and low-complexity energy harvesting-based Ambient IoT devices

- These are not physical or mathematical limitations, but rather some common, current technology features that were found by our analysis with significance to Ambient IoT devices

- We suggest taking such analysis into consideration when choosing between several options for the Ambient IoT standard

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Ambient IoT Device Have Small Energy Reserves

- For Ambient IoT devices, energy is extremely limited
  - Scarce light conditions (PV within a building or on a very cloudy day)
  - Small capacitor for RF energy harvester (nJ-uJ)
- An example of a transmission of 30us with EIRP=-10dBm:
  - The energy spread to the air = 3nJ
  - In order to transmit, an actual device's total energy consumption of about 30nJ is reasonable
- Ambient IoT devices are ultra-low complexity as well as ultra-low power
  - In order to fit cost and size of sticker form factor, requirements for several external components should be limited
  - This is especially true for external components that consume energy

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Impact of Clock Generation on an Active Transmitter Ambient IoT device

- For active transmitter Ambient IoT devices, we would like to reduce the need for a stable clock with accuracies in the orders of 0.1ppm
- Stable crystal-based clocks usually consume non-negligible power and also take some time to turn on, until reaching stability
- In addition, they require an external component on top of the silicon chip. This increases the bill of material (BOM) of the product and also limits massive deployments with a sticker form factor
- Depending on the exact system design, it is possible to use much simpler, lower-power, internal oscillators [1-3]. Such oscillators are usually characterized by lower clock accuracies. However, by using various low-power calibrations, they can reach an accuracy of 1000ppm
- We recommend to reduce the clock accuracy required from an Ambient IoT device to 1000ppm

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Impact of Memory Retention

- Ambient IoT devices are required to support energy harvesting power delivery.
- This means these devices are not always powered on, and most of the time are either powered off or work on the remaining energy from the last energizing
- One of the biggest energy-consuming blocks is memory.
- While on a dynamic power regime, the memory power consumption is comparable to the rest of the circuitry operating within the Ambient IoT devices.
- But while staying non-active/standby (meaning no transmit or receive) any requirement to retain memory values is energetically expensive - especially if this is required for long times [4].
- Various SRAM technologies with low retention power consumption exist, but between 20-200fW/bit are achievable in commercial products.
- So, holding 1Kbyte for 1 minute takes 10nJ, which is comparable to the transmission energy as seen in slide 3.

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Impact of Non-Volatile Memory

- An alternative to retaining memory is the use of non-volatile memory.
- One such component is OTP, which allows for a device to write once and then read multiple times.
- This component can be integrated into the Si, without the need to increase the complexity of the end device.
- Between the write and read, there is no need for energizing, and the written values stay written without any energy consumption.
- However, it is basically a one-time write, so multiple writes can be done only a few predetermined times.
- Our analysis revealed that such components can consume as much as 50-500uJ per writing of 32 bits. This is orders of magnitude more energy compared to the energy used by the transmission as seen in slide 3

Impact of Idle/Wait Times

- While the Ambient IoT device is non-active, during either idle or wait times, it is desirable that the device will consume the minimum amount of energy possible.
- Since these times can be much longer than active times (depending on the system architecture), the power consumption during these times is non-negligible.

- For Example, by using a lower-accuracy clock, we can minimize energy consumption. This clock can be used for either operating a low-power receiver (WUR) or as a synchronizer for waking up.
- Our analysis suggests that such a clock can operate with an accuracy of 10,000ppm for a 100KHz clock, this analysis estimates 100nJ per 1 second Idle time[2].

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Summary

- An analysis for few possible limitations of Ambient IoT devices was presented
- Only mainstream technology was analyzed on each of the suggested parameters, so these limitations can be further updated
- We suggest considering these limitations when comparing between different options and features for adoption in the standard
- By limiting the requirements from Ambient IoT devices according to the analysis, Ambient IoT devices can reach lower costs and be based on energy harvesting.
- Additionally, it will provide significant differentiation from devices implementing other existing low-power standards.

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References

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