2025 START Program
CFP Brief

THEME: **01. Wireless Communication**

SUB-THEME: **1.2. Low-power circuit and energy harvesting for future Smart Home and IoT**

Context/ Overview

Samsung has a diverse range of home products that can leverage data for enhancing user experiences and enabling automation. Deploying these products with sensors that can wirelessly communicate can enable a fully connected IoT experience. Ambient IoT can lead to opening of new markets since they can enable increased range and better interreference management to tackle problems faced by current low-complexity RFID systems. These markets can range from smart home applications; smart warehouses for asset tracking, wide-area networks enabled with wireless sensor networks, environmental monitoring, smart cities infrastructure, and connected vehicle systems. To facilitate the anticipated experience in these new markets, ambient IoT device connectivity must be able to replace existing less-connected incumbent solutions while minimizing the cost to operating duration and price point. By harvesting ambient energy, the span of operation can be improved while reducing the size and cost of the product. The key innovation required is to detect and capture small amounts of energy to charge rechargeable batteries without manual intervention for long shelf life.

Problem Statement

There are two architectures for ambient IoT devices based on operating power – 1 µW devices, few 100 µW devices [1]. Focusing on the former, the current standard for commercial RF harvesters is a lowest operating power of ~-30 dBm at 10% efficiency [2], resulting in 10s to power a 1 µW device. This setup only works when there is a dedicated energizing source near the RF harvester. In order for ambient IoT devices to be widely adopted, harvesters need to be more sensitive to sense much lower power levels. For context, ambient Wi-Fi signals in typical home and office are lower than -50 dBm. The RF energy is so low that normally it cannot be harvested unless the receiver is 100x more sensitive than the current benchmark. Other ways to harvest signals (thermal, mechanical and optical) should also be considered. Innovations in charging device with ultra-low leakage storage devices are also necessary to keep accumulating the harvested energy.

From a small amount of energy harvested, a power management IC (PMIC) is used to generate constant voltage either for battery-less operation or charging of battery. An innovative design of PMIC is needed which can generate constant voltage from limited stored energy. The traditional approach to RF circuit and system design assumes a battery supply and continuous usage. The design chain is also optimized for maximum data transfer. For low power IoT, the amount of data transmitted may be limited. New transmitter circuits which operate in high efficiency when the data load is less are needed, so as efficient wake-up receiver.

Objectives & Scope

The key objective is to power on ultra-low power transmitters and receivers for sending packets at intermittent intervals. The idea is to keep gathering and storing ambient energy which over time will be much larger than few micro-joules. Then depending on the application, the low power transmitter will send one-or more packets of arbitrary durations when it is triggered, to use part of the stored energy while the harvester keeps accumulating more. In this way, an instantaneous transmission can occur upon trigger, which is superior to the long charging time currently experienced.

Specific Topics & focus areas*

Five main focus areas are identified to achieve the above objectives

1. **Harvester sensitivity and efficiency**
   Sensitivity improvement to sense -50 dBm or lower power levels at ~10% efficiency. New materials/ processes may be required to improve the SNR of the harvesting device.

2. **Low leakage energy storage device**

   Two solutions are needed – Low leakage capacitor or similar after harvester with ability to cold start from 0V. Another solution after the PMIC, to store fixed voltage variable current output of PMIC and power on the transmitter. This can be a small rechargeable battery or something similar.

3. **Fusion of multiple harvesting methods and bands**

   The motivation is to use any method possible to harvest energy, for faster time to store few micro-joules of energy

4. **High sensitivity PMIC design**

   PMIC which is able to charge battery from the trickle amount of energy harvested. PMIC should be able to boost <50mV input to battery charging voltage of > 2.5V.

5. **Low power circuit and system**

   In traditional RF circuits, significant energy is spent in the frequency generation block. This block is essential for high fidelity coherent transmission. New circuits need to be developed to achieve this without consuming lot of power. The circuit should be able to go in the sleep mode and quickly recover from it to achieve coherent transmission. Also, the circuit should have high DC-to-RF efficiency while adhering to existing standards such as BLE.

※ The topics are not limited to the above examples and the participants are encouraged to propose other original ideas.

References

[1] 3GPP, "3rd Generation Partnership Project; Technical Reports; Study on solutions for Ambient IoT (Internet of Things) in NR," 3GPP TR 38.769, version 2.0.0, 3GPP, 12th Dec, 2024, https://www.3gpp.org/ftp/Specs/archive/38_series/38.769/

[2]] H. P. D. Paz, et. al., "Temperature Analysis of Schottky Diodes Rectifiers for Low-Power RF Energy Harvesting Applications," in *IEEE Access*, vol. 11, pp. 54122-54132, 2023, doi: 10.1109/ACCESS.2023.3281794

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