# <u>Intermittent Distributed Hash Tables</u>

Manisha Mukherjee (mmukherj), Emily Ruppel (eruppel), Milijana Surbatovich (milijans)

## Introduction

Batteryless, energy harvesting devices (EHDs) allow computing to break away from power supplies and take on applications that would be impossible with a battery. However, the applications built for EHDs must be robust to the *intermittent* execution model, where the device power frequently fails and restarts. While the existing body of support for intermittent execution enables sophisticated applications in the single node case, no prior work supports even basic cooperation among intermittent devices. Our goal is to simulate a cooperative system of intermittent devices by simulating a distributed hash table (DHT) composed of data allocated across intermittent nodes. More generally, we want to show that it is reasonable to program an application that creates and updates shared data structures with data stored and replicated across multiple batteryless devices.

For a system to be useful to an application developer, it should be able to provide data availability, eventually consistent updates to shared data, and robustness in the event of failures. It is challenging to ensure these characteristics in any distributed system, but it is particularly challenging for a system of intermittent devices where power failure is an intrinsic part of the device execution model. Rather than implementing an application on embedded devices, we simulated a system of intermittent nodes using the Simpy discrete event simulator. The advantage of simulating an application is that it provides data omniscience to study system wide characteristics. For instance, using the simulator, we can test different data replication strategies and consensus protocols to determine the important design bottlenecks for distributed systems of intermittent devices.

EHDs' extended lifetimes and low maintenance requirements make them well suited to unobtrusively collect data over long periods of time. By sharing data and computational resources, cooperative deployments of EHDs will extend the advantages of single intermittent devices to cyber-physical systems. This positions systems of EHDs at the cusp of new branches of research exploring long term, intelligent, distributed monitoring applications. Our project focused on body area networks (BANs) of EHDs because systems of wearable EHDs represent a logical extension of existing work in BANs with continuously powered wireless sensor nodes and system support for intermittent devices.

## Background & Motivation

Distributed systems implemented on intermittently powered devices is a new area of research. The compute devices we are interested in are energy harvesting, batteryless systems that exhibit an intermittent execution pattern. The devices harvest energy into a capacitor and when the capacitor reaches a threshold voltage, the on board MCU is turned on and begins running code and exercising peripherals, which uses energy. When the energy in the device's capacitor is depleted, the MCU powers off and the device's capacitor again begins to charge. Typically, there are no guarantees about how much time the recharge takes, but when the MCU powers back on it will continue to make progress in the application code thanks to recent work that extends program execution across reboots[1,2,3].

The first generation of intermittent devices operate using small energy reservoirs, ~50uF of capacitance, that are only capable of running a low power microcontroller and several internal sensors [5]. However, recent work has demonstrated that the intermittent execution model can be used with larger capacitors to perform relatively power hungry operations such as sending a bluetooth packet [6,7,8]. While intermittent devices have many of the same capabilities as traditional wireless sensors, the tradeoffs between device lifetime and device workload are fundamentally different. A primary challenge in sensor networks is improving network lifetime by efficiently using the static energy capacity of a battery,