Towards Highly Scalable Hardware-Based Implementation of Low-Power Wide-Area Networks

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Motivation

- ***Low-Power Wide-Area Network*** (LPWAN) is one of the key enabling technologies for wide-area Internet of Things (IoT) applications with several thousand sensors, including sensing and monitoring, smart cities, and smart farming.
- ***Sensor Network Over White Spaces*** (SNOW) is an LPWAN technology that operates in the free *TV white spaces* (470—698 MHz in the US).
- Our goal is to provide a **hardware-based implementation** for enabling massive scalability in SNOW, where **hundreds to thousands** of sensors may transmit to a base station (BS) both **asynchronously** and **concurrently.**

Limitations of LPWAN Tech.

Long Range (LoRa) [1]

- LoRa performance drops exponentially as the number of sensors grows.
- LoRa city deployment can support only 120 sensors per 3.8 hectors.
- LoRa most often uses a large spreading factor that reduces the bit rate.

SIGFOX [1]

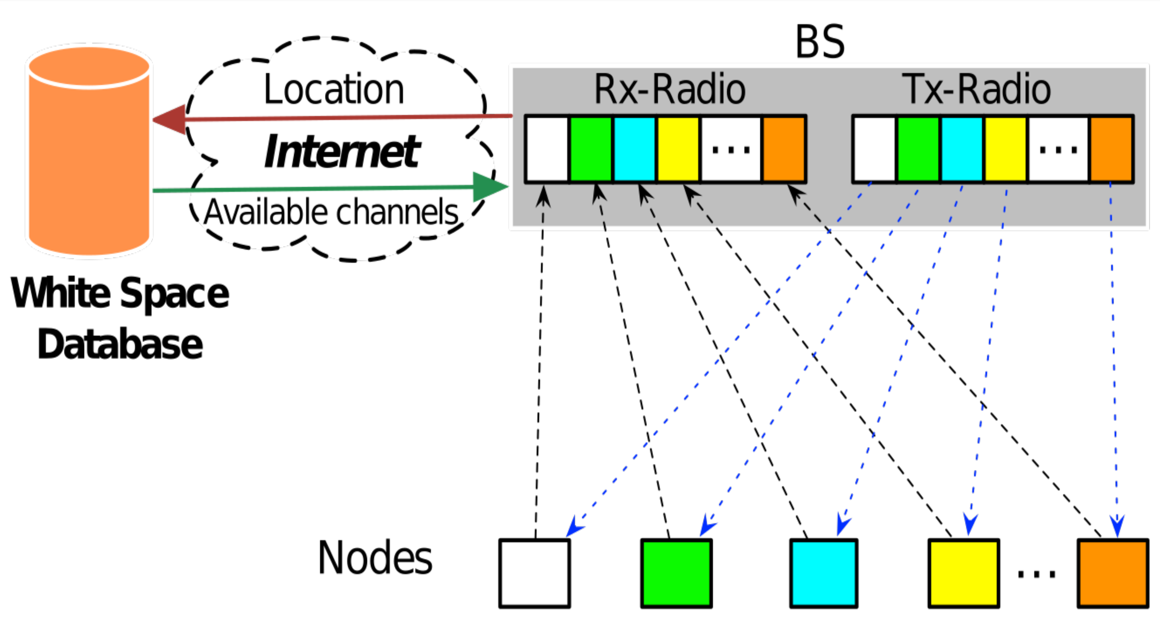
- SIGFOX's maximum data rate is **1kbps** and its packet size is **12 bytes**.
- A Limited number of messages per day (140 messages) from each sensor node. **Limited scalability.**

Limitations of LPWAN Tech. (Cont.)

Other LPWANs [1]

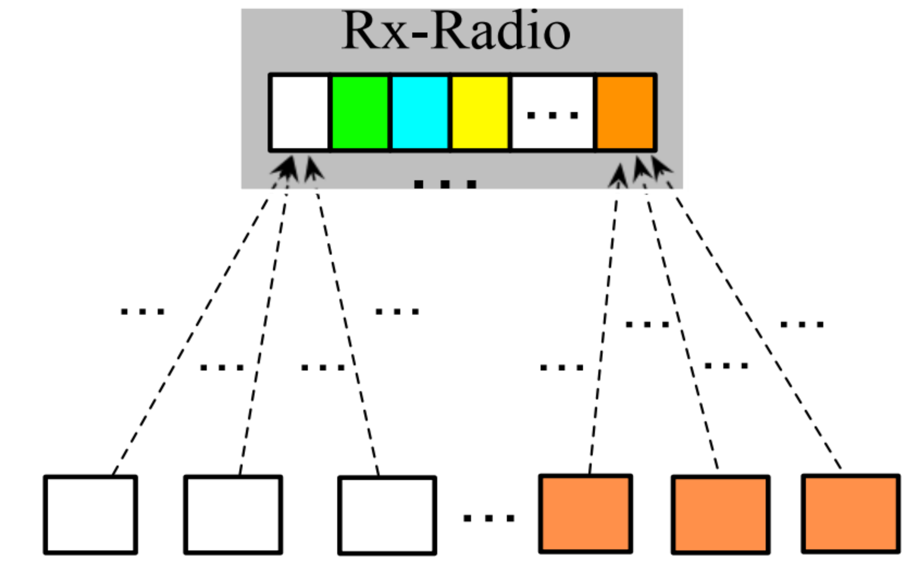
- **Cellular-based** LPWANs (EC-GSM-IoT, NB-IoT, LTE Cat M1, 5G) rely on **wired infrastructure** for enhanced scalability.
- Lack of infrastructure and connectivity hinders rural IoT applications.

SNOW Overview



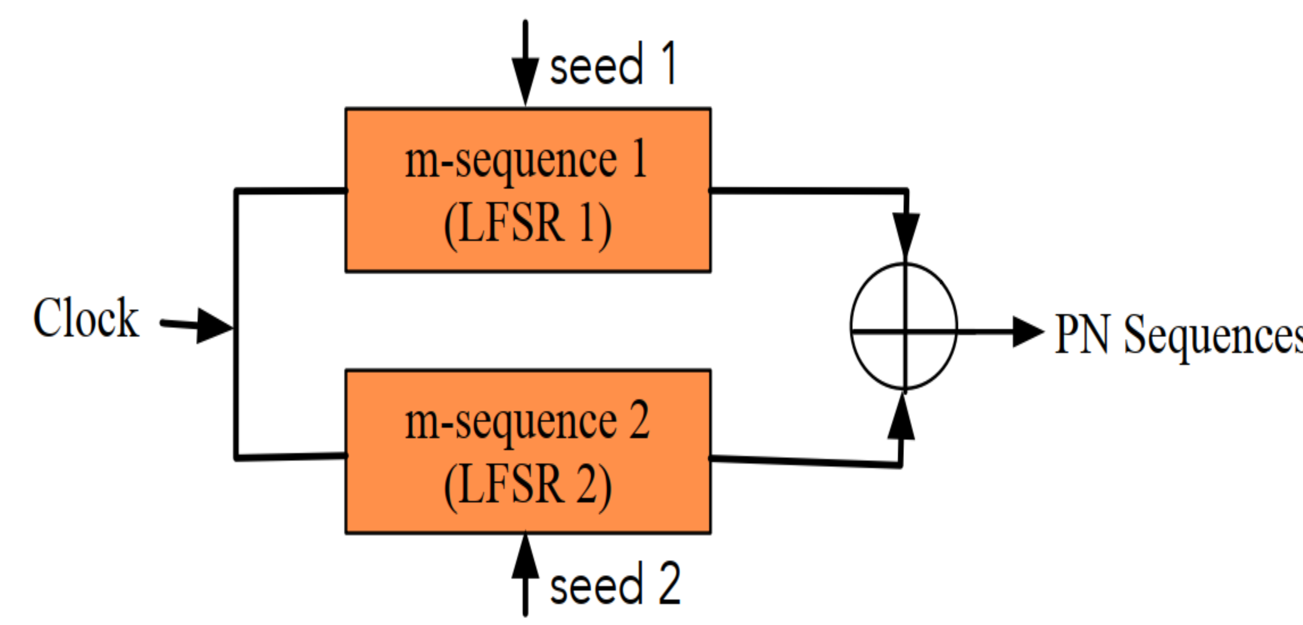
- SNOW has a star network topology **[2]**.
- A sensor is equipped with a single half-duplex narrowband white space radio.
- BS is equipped with two half-duplex radios. **Tx-Radio** and **Rx-Radio**.
- The BS uses a wide channel split into orthogonal subcarriers of equal width.
- The PHY-layer uses *Distributed OFDM* (**D-OFDM**), allowing multi-user access.
- BS can transmit to and receive from many sensors asynchronously and concurrently using different subcarriers, while no subcarrier is shared by more than one sensor at any instance.

System Model



- **Proposed concurrency in uplink communication in our hardware-based implementation.**
- **Numerous sensors** transmit at the same time **on and across** the D-OFDM subcarriers with different spreading codes or PN (pseudorandom noise) sequences (e.g., those similar to *Gold code*).

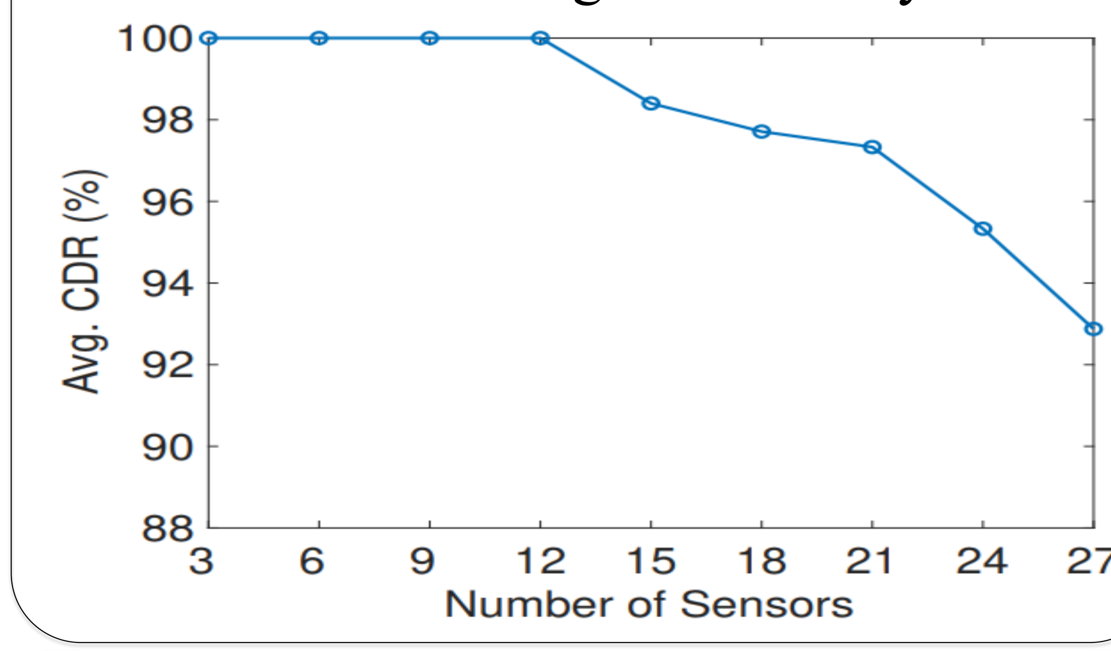
Spreading Code Generation



- We aim to enable multiple sensors to send at the same time using the same D-OFDM subcarrier by using a set of PN sequences that do not interfere with each other on or across the subcarriers.
- Two *Linear Feedback Shift Registers* (LFSRs) with two non-zero seeds: *seed 1 and seed 2* (each of length n), generate two different m-sequences, each of length $N = 2^n - 1$.

Implementation

- Our goal is to implement the proposed concurrency in hardware using URSP or other commercial off-the-shelf sensors.
- We already built a SNOW simulation platform using the Python programming language. In the simulation, we used 64 overlapping subcarriers **[3].** The figure below shows the reliability in each D-OFDM subcarrier for various number of sensors transmitting concurrently.



Conclusion

Through the proposed hardware-based implementation, we aim to significantly advance SNOW and enable very wide-area rural and urban IoT applications with hundreds to thousands of sensors.

References

[1] https://phantom.cs.qc.cuny.edu/rahman/scc18.pdf

[2] https://phantom.cs.qc.cuny.edu/rahman/ton_snow.pdf

[3] https://phantom.cs.qc.cuny.edu/rahman/icess22.pdf