Towards Robust and Scalable Battery-Free Group Communication

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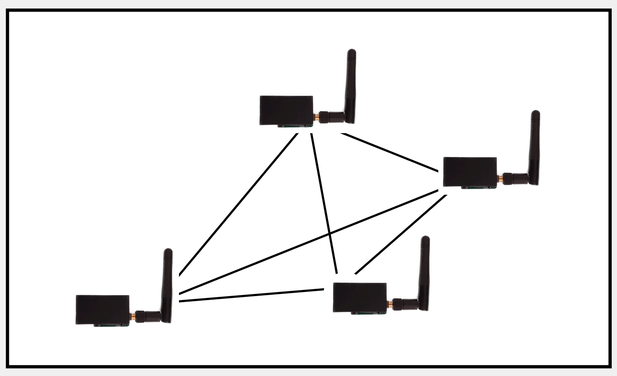
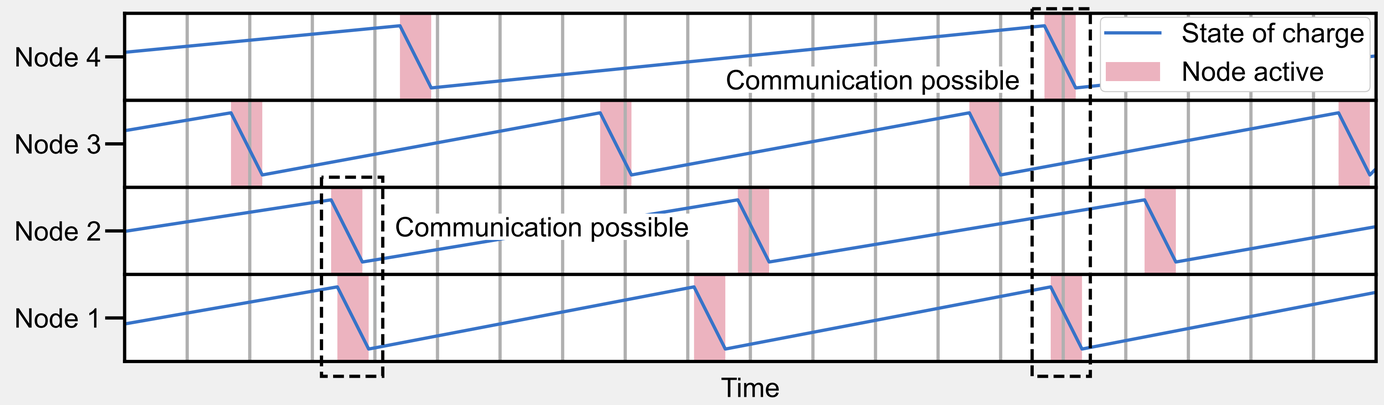
Motivation



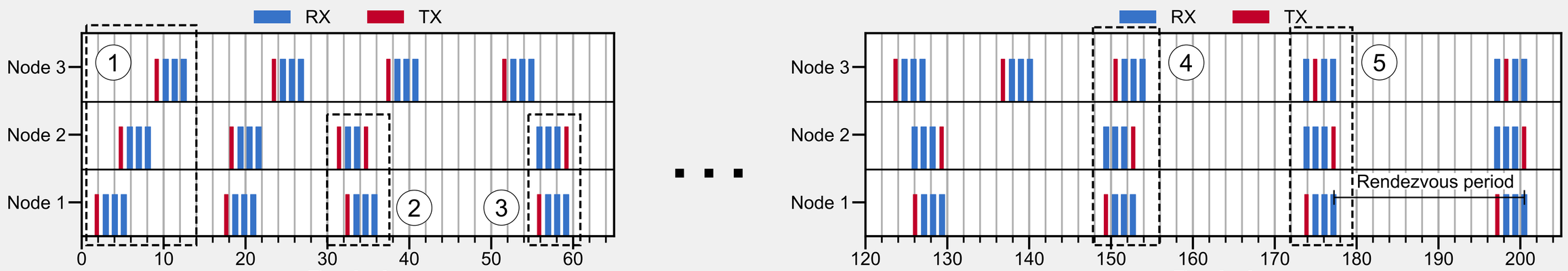
Goal: Decentralized all-to-all communication in fully connected networks of battery-free devices. Previous work is limited to two nodes [1].

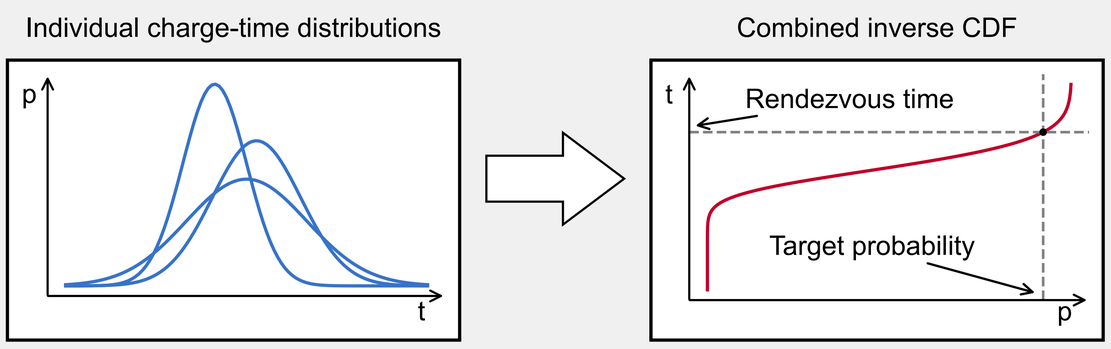


Problem: Battery-free devices operate intermittently. In uncoordinated systems, communication depends on multiple nodes coincidentally being active. This results in inefficient and unreliable communication.

Approach

Sample experiment on the Shepherd Nova [2] testbed using 3 nodes with a slot count of 4.





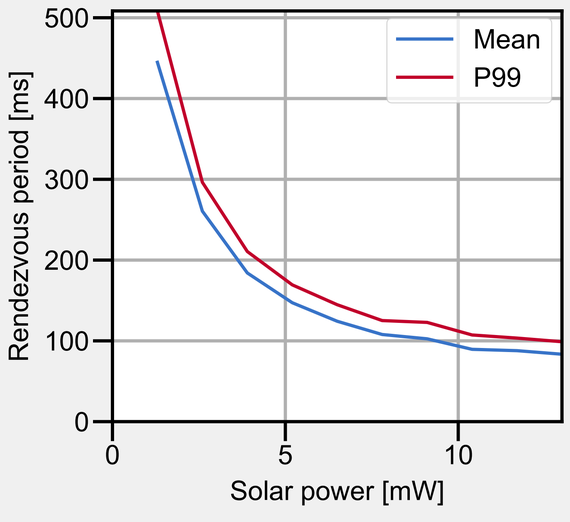
Nodes determine their charge-time distribution at runtime. Distributions are shared with the group and combined. All nodes in the group then choose the same rendezvous time independently. This is a generalization of *Bonito's* approach [1] for two nodes.

1. Nodes are initially uncoordinated and run the *Find* [3] neighbor discovery protocol.
2. Nodes 1 and 2 encounter eachother. The two nodes form a coordinated group.
3. Nodes 1 and 2 have their first coordinated rendezvous.
4. Node 3 encounters and joins the previously established group. The network is now unified in a single group.
5. The group continues to coordinate periodic rendezvous.

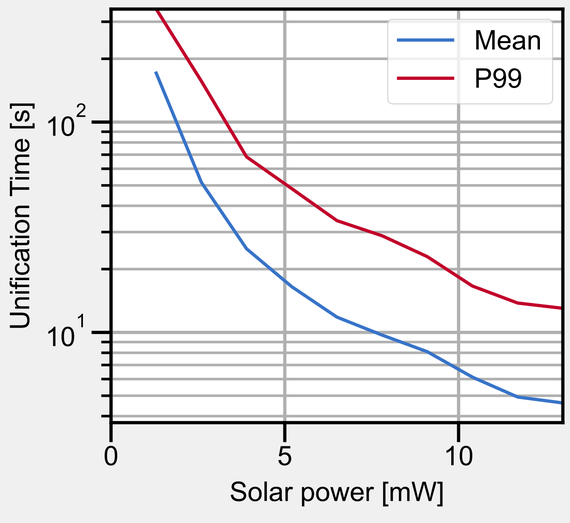
Preliminary Results

Performance

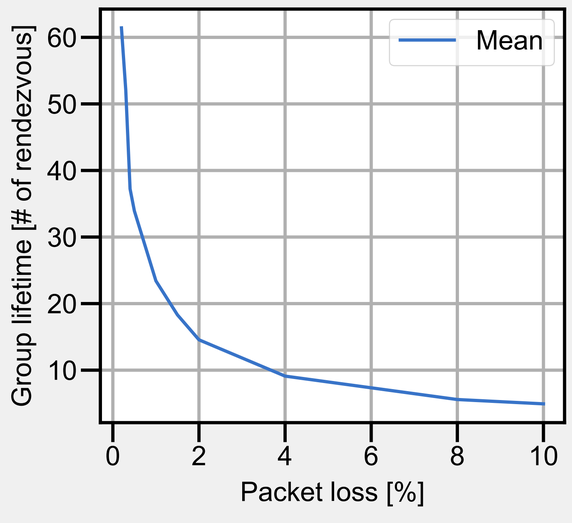
Setup: 3 nodes configured with a slot count of 4 in a controlled lightbox



Rendezvous period decreases with higher harvesting power, increasing throughput and reducing latency.



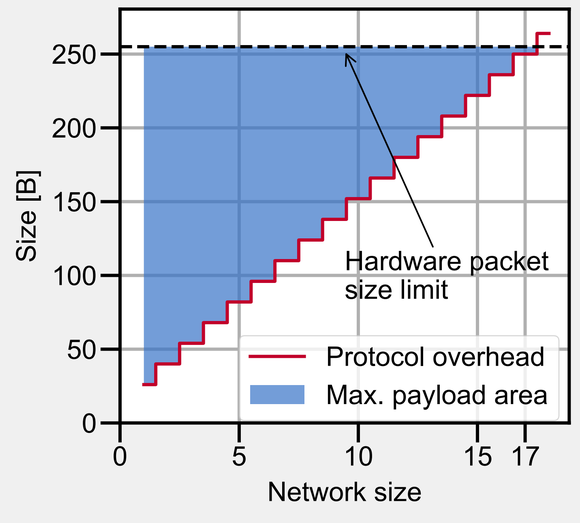
Initial group formation is much slower and less consistent compared to the rendezvous period.



Lost packets can break existing groups, requiring them to be re-established.

Scalability

For solar charge-time distributions



Packet header includes distribution parameters of all group members, reducing efficiency and limiting network size.

[1] K. Geissdoerfer and M. Zimmerling, "Learning to Communicate Effectively Between Battery-free Devices," in *19th USENIX NSDI*, 2022, pp. 419–435.
[2] K. Geissdoerfer *et al.*, "Shepherd Nova: A public testbed for rigorous experiments under repeatable energy-harvesting conditions," in *Proc. 23rd MobiSys*, 2025, pp. 236–248.
[3] K. Geissdoerfer and M. Zimmerling, "Bootstrapping Battery-free Wireless Networks: Efficient Neighbor Discovery and Synchronization in the Face of Intermittency," in *18th USENIX NSDI*, 2021, pp. 439–455.

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