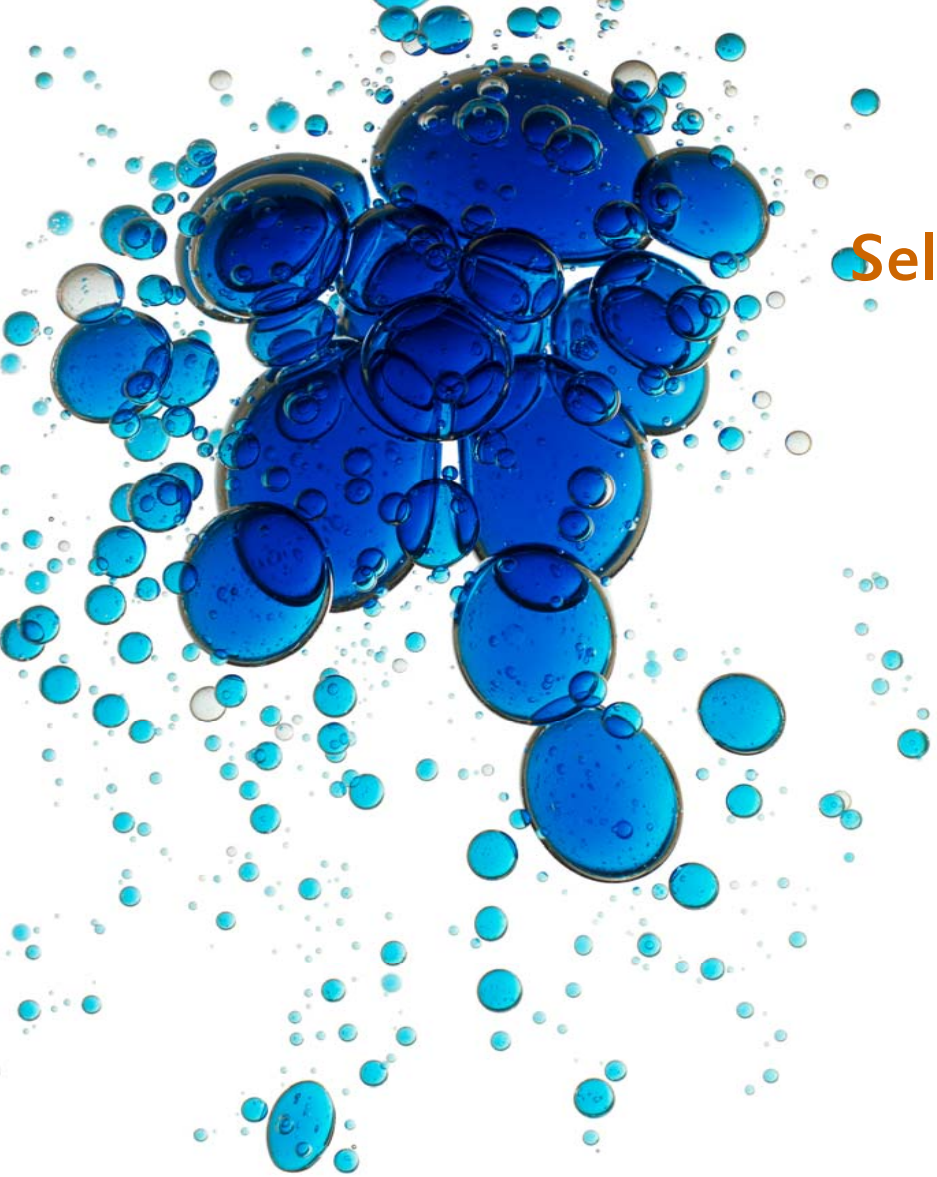


Self-organizing Synchronization in Wireless Networks

Christian Bettstetter

Networked and Embedded Systems
University of Klagenfurt

Lakeside Labs GmbH

Talk at Lakeside Research Days

July 15, 2009

ALPEN-ADRIA UNIVERSITÄT KLAGENFURT

Lakeside Labs

People

Lead

Christian Bettstetter

Professor

Administration

Kornelia Lienbacher

Office

Dominik Egarter

System Administrator

Post Docs

Dr. Wilfried Elmenreich

Senior Researcher

Dr. Evsen Yanmaz

Senior Researcher

People: 9 PhD Candidates

Helmut Adam

Researcher

Günther Brandner

Researcher

Sérgio Crisóstomo

Scholar

István Fehérvári

Researcher

Michael Gyarmati

Researcher

Johannes Klinglmayr

Researcher

Nikolaj Marchenko

Researcher

Udo Schilcher

Researcher

Alexander Tyrrell

Scholar

Research Portfolio

Networked Communication Systems

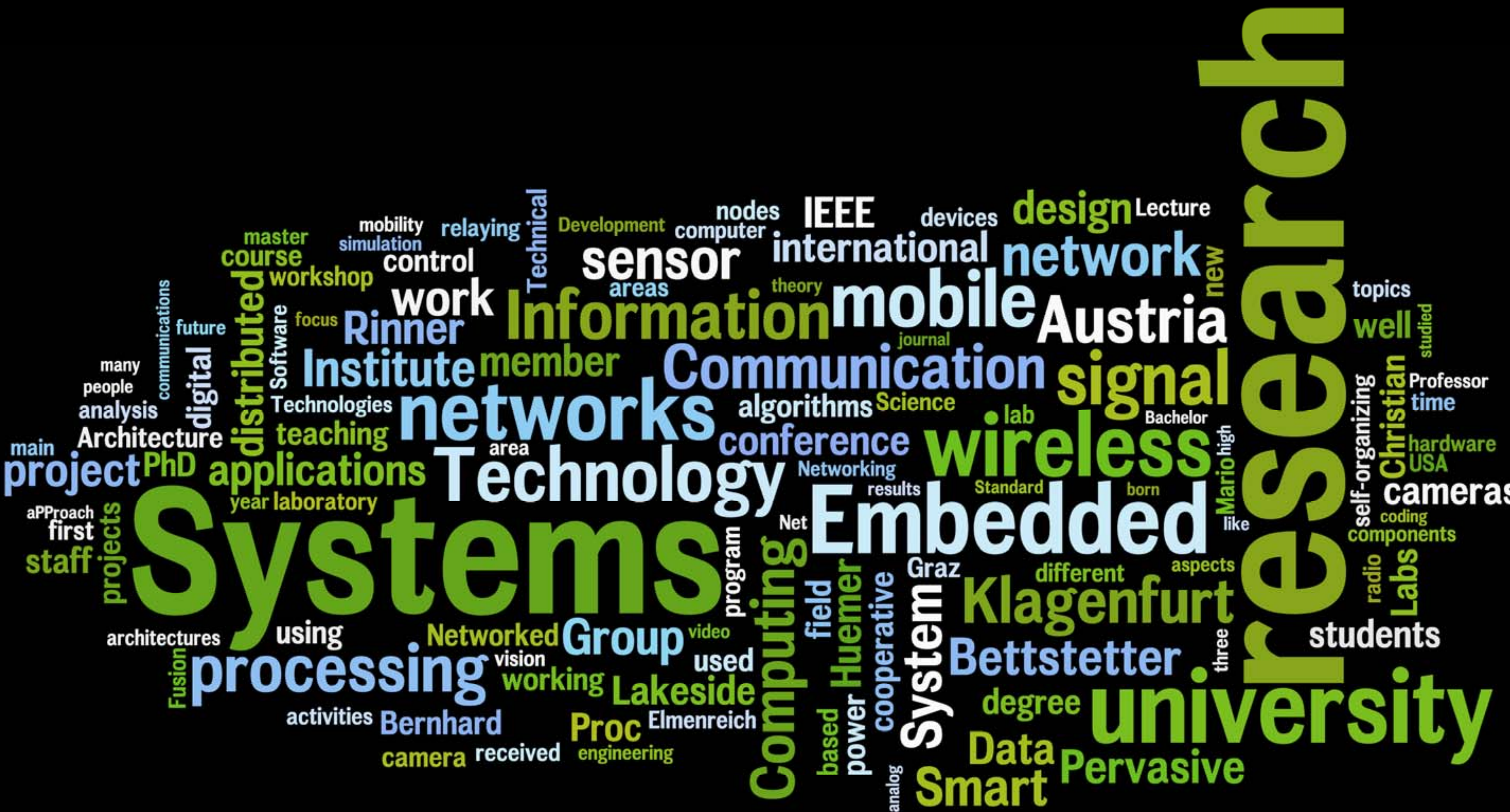
- Algorithms and Protocols
- Network Theory
- Modeling and Simulation
- System and Protocol Architectures

Focus on

Mobile & Wireless Networking

Paradigms

- Self-organization
- Multihop relaying
- Cooperation
- Mobility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Research Activities and Projects

- Cooperative relaying in wireless networks
- Self-organizing synchronization in wireless networks
- Flooding in complex networks
- Collaborative microdrones
- Modeling sparse wireless networks

- Real-time communication for modular robot systems
- Methods for the design of self-organizing networks

- Middleware for network eccentric and mobile applications (MiNEMA)

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Lakeside Labs

NTT docomo

DOCOMO Euro-Labs

SUNRC

U.PORTO

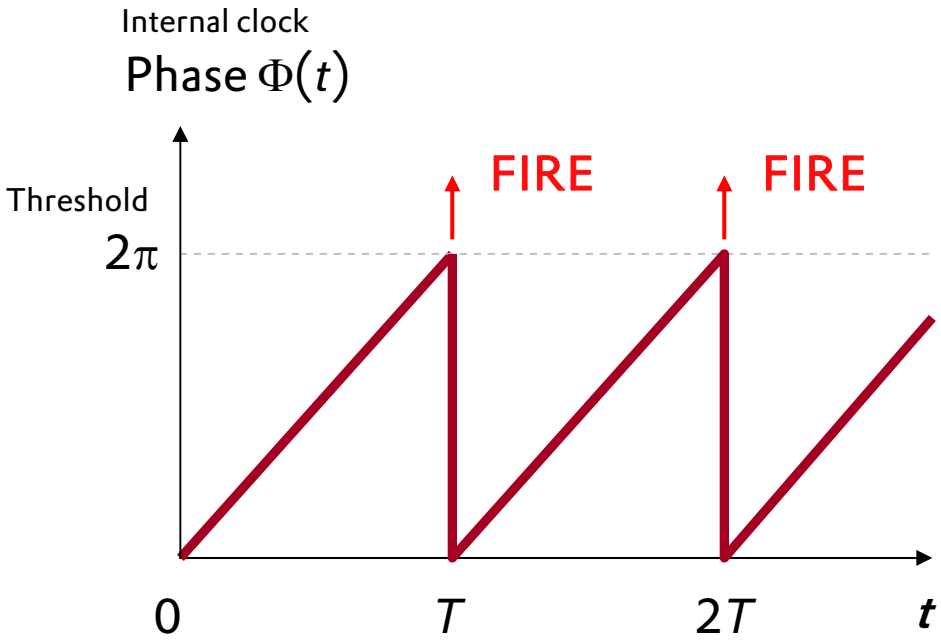
Joint work with Alexander Tyrrell and Gunther Auer

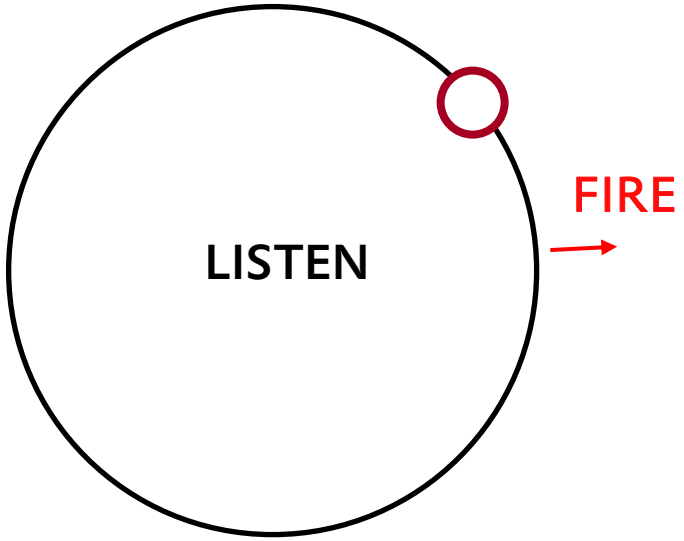
Time Synchronization of Fireflies in South-East Asia

BBC video "Trials of Life"

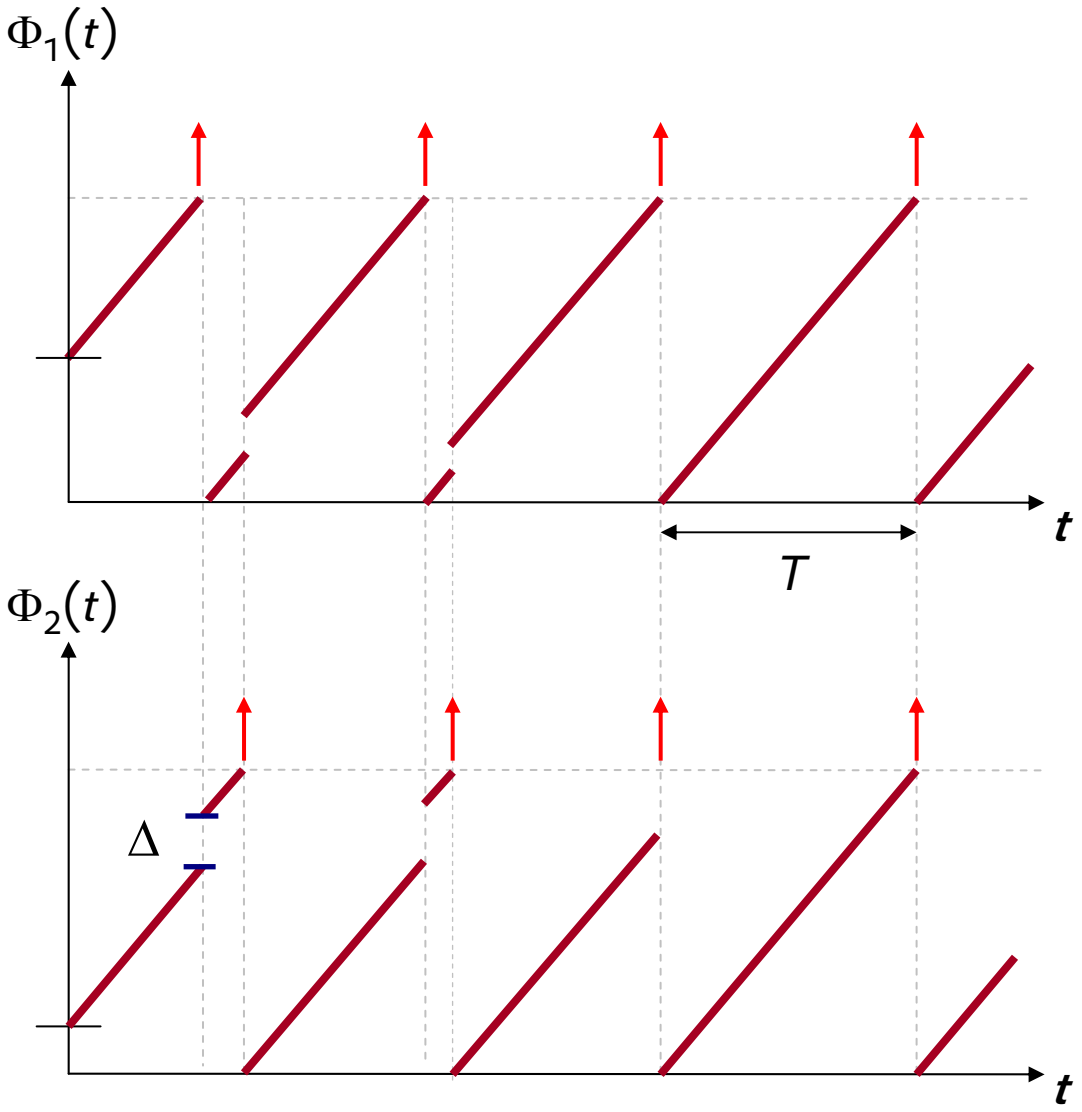
"I could hardly believe my eyes. I saw .. a synchronal .. flashing of fireflies."
(P. Laurent, *Science*, 1917)

Modeling One Firefly: Integrate-and-Fire Oscillator



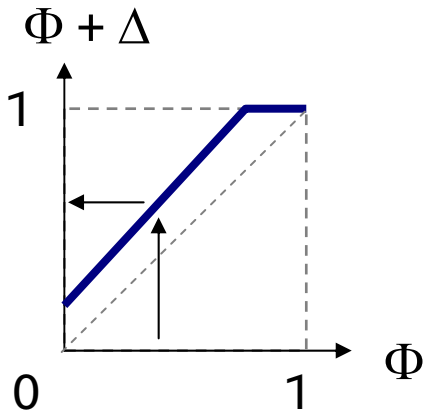


Modeling Two Fireflies: Coupled Integrate-and-Fire Oscillators

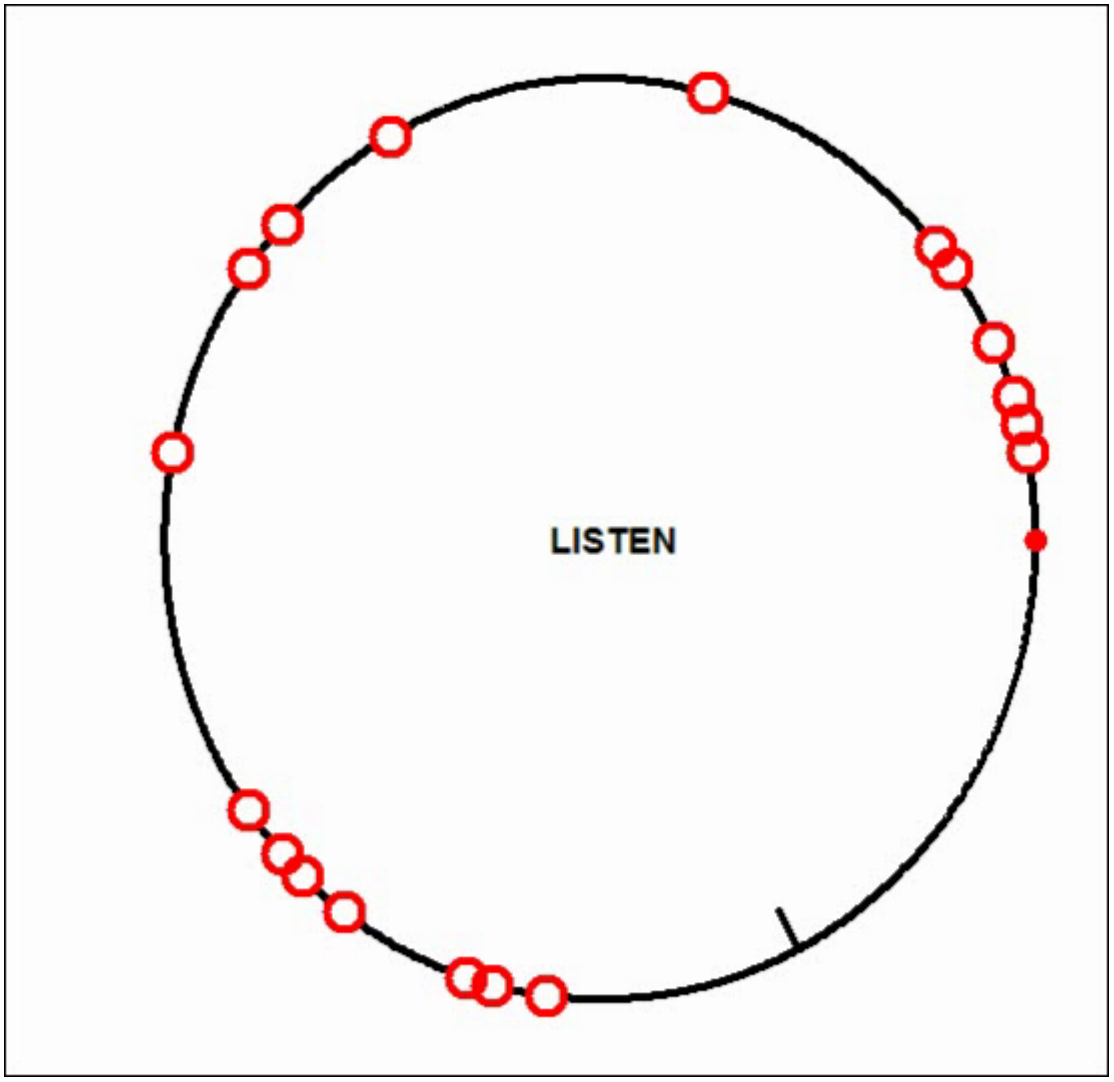


Firing of one oscillator causes other oscillator to increment phase $\Phi(t)$ by a value $\Delta(\Phi(t))$.

Phase jump: $\Phi \rightarrow \Phi + \Delta$



Several Coupled Integrate-and-Fire Oscillators



Mathematically proven to lead to synchronization

Our Research: Application to Wireless Networks

Problem statement: Can we apply this distributed algorithm to achieve slot synchronization in ad hoc networks?

Why is this algorithm appealing?

- Simple local behavior leads to synchronization of the entire network
- Algorithm is scalable and adaptive to changes in the topology
- Nodes do not need to distinguish between transmitters

Why do we need slot synchronization?

- Essential building block for functions in communications and control e.g. for medium access, distributed sensing, scheduling of sleep phases, and cooperative diversity

Can Firefly Synchronization be Applied to Wireless Systems?

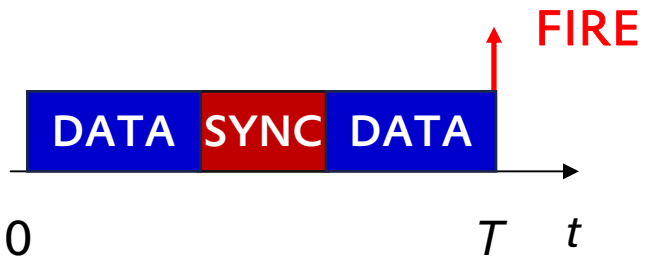
Original Firefly algorithm assumes:

- No delay in transmitting and decoding pulses
- Synchronization pulses are infinitely short
- Nodes listen and transmit at the same time
- All nodes form a fully meshed network

Removing one or more of these assumptions causes severe problems → Direct transfer to wireless systems is **infeasible**

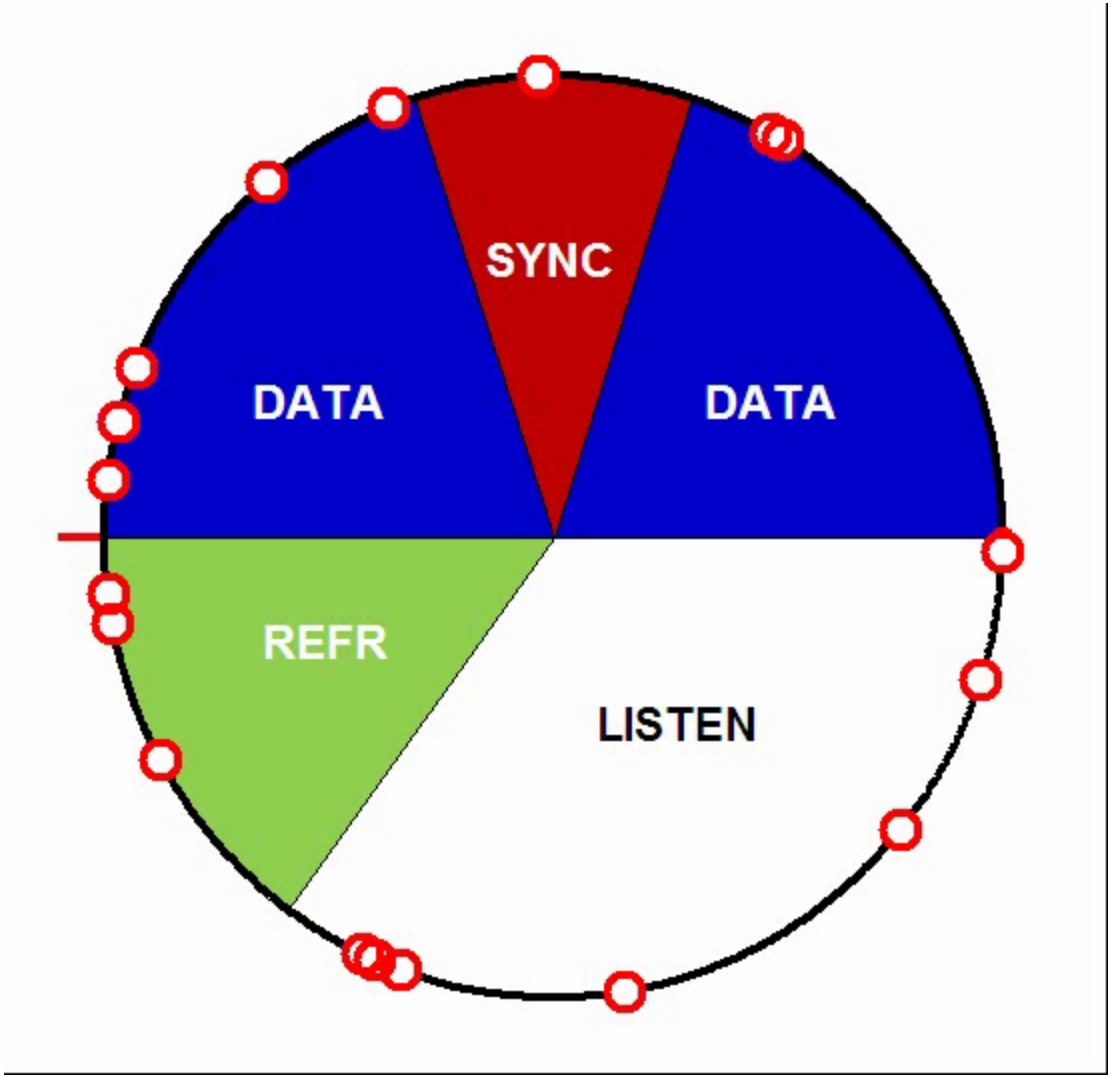
Meshed Emergent Firefly Synchronization (MEMFIS)

- Solution taking into account the **technological constraints** of wireless systems while maintaining nice properties of firefly sync.
- A **synchronization word** that is common to all nodes is **embedded** into each **payload** packet.
- This synchronization word is detected at the receiver using a **correlation receiver** detecting the synchronization word.

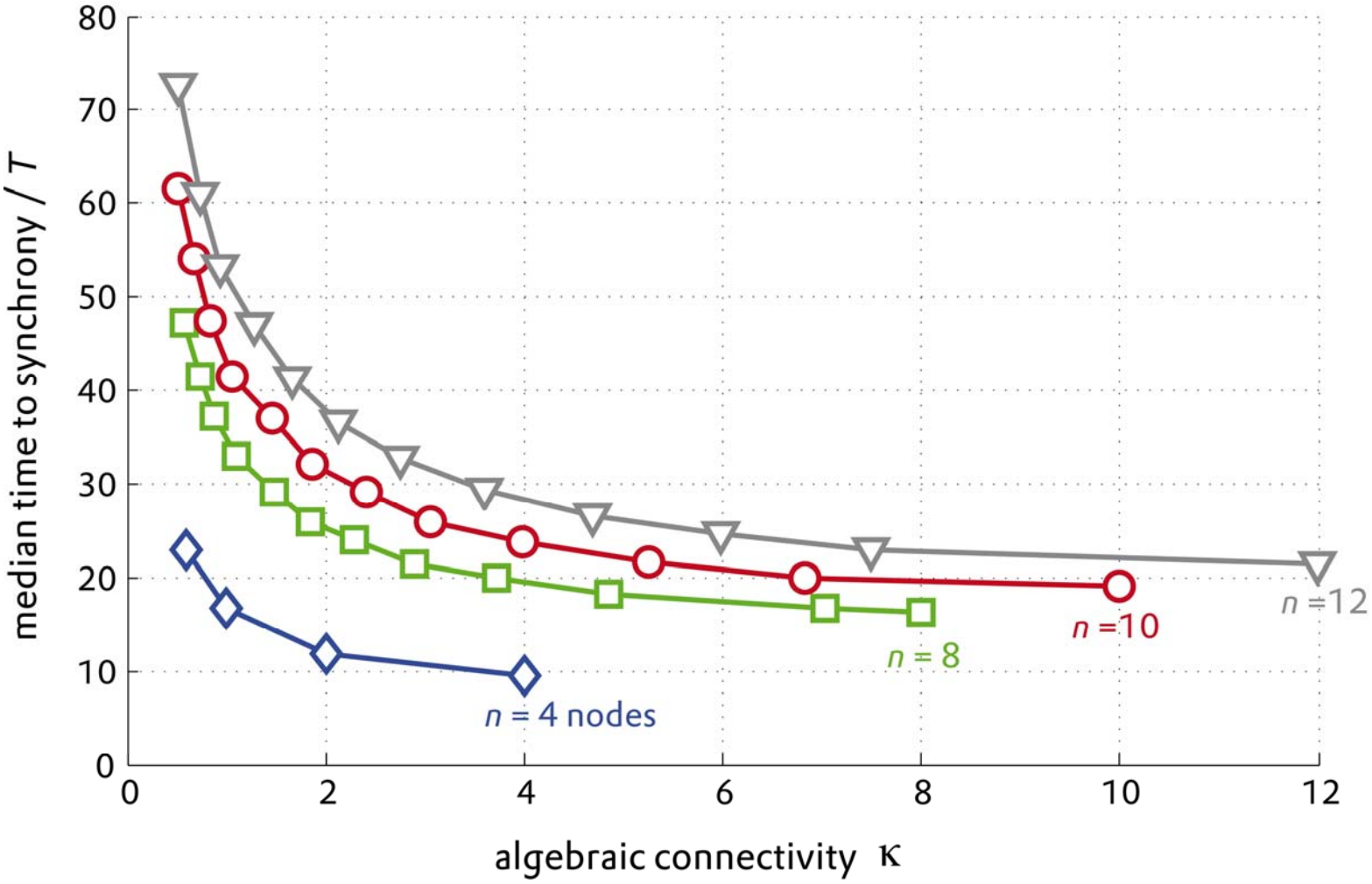


- Synchronization **emerges** as nodes exchange payload packets **randomly**, hence avoiding a dedicated synchronization phase.

Meshed Emergent Firefly Synchronization (MEMFIS)



Meshed Emergent Firefly Synchronization (MEMFIS)



A. Tyrrell, G. Auer, C. Bettstetter. Emergent Slot Synchronization in Wireless Networks. Under minor revision at *IEEE Transactions on Mobile Computing*.

Ongoing and Future Work

Research Issue

- Robustness of self-organizing synchronization against faulty and malicious nodes

Implementation

- Demo applications with light and audio signals
- Prototyping on programmable radio platform