Cluster 3: Networked Software Systems

Coordinating Shared Media Access through Counter-Phase Coupling

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Background: Peskin's Model for Self-Synchronization [1]

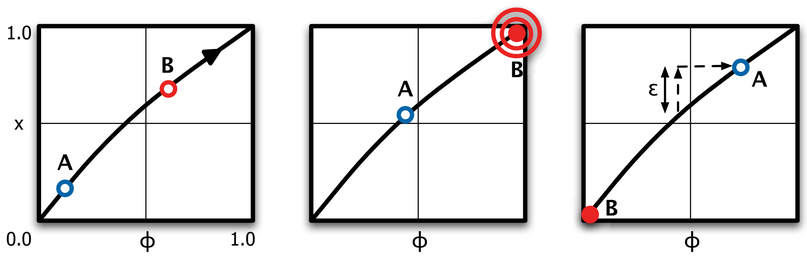

Figure 1: A system of two oscillators interacting by the pulse-coupling rule (see [1])

- Network of N integrate-and-fire oscillators.
- Voltage-like state variable x_i with dynamics:

$$\frac{dx_i}{dt} = S_0 - \gamma x_i, \qquad 0 \le x_i \le 1, \quad i = 1,\ldots,N$$

- When $x_i = 1$, the i-th oscillator fires and $x_i \rightarrow 0$

- Pulse (or phase) coupling: a firing oscillator pulls other oscillators up by an amount ε or to firing:

$$x_i(t) = 1 \Rightarrow x_j(t^+) = min(1, x_j(t) + \varepsilon) \quad \forall j \neq i$$

- For arbitrary initial conditions: system approaches a state in which all oscillators are firing synchronously.

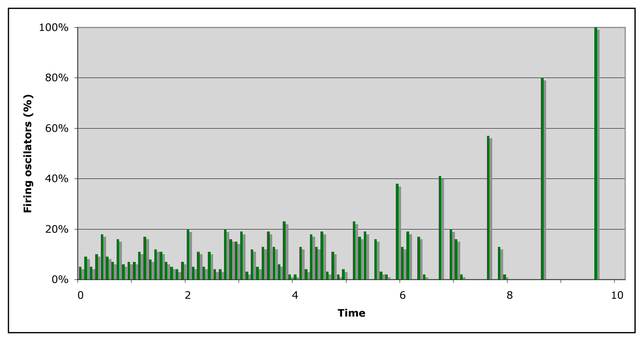

Figure 2: Number of oscillators firing over time; N=100, S0=2, γ=1, ε=0.3 (see [1])

Application to Wireless Networks [2]

- Problem: transmission delays cause "blind spots" where no mutual coupling between nodes can occur.
  Here, lower bound for synchronization accuracy is: $T_{del} = T_0 + T_{Tx} + T_{dec}$
  T_0: propagation delay
  T_{Tx}: transmitting delay (Message length)
  T_{dec}: decoding delay

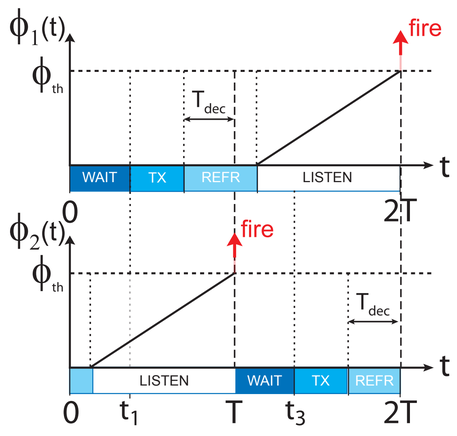

Figure 3: Timing advance strategy for two periods (see [2])

- Solution:
  nodes delay sending the synchronization burst by:
  $T_{wait} = T - (T_{Tx} + T_{dec})$

- Oscillators split into two groups, firing *T* seconds apart, synchronizing each other.
- Accuracy only bounded by T_0.

Plan: Counter-Phase Coupling for Coordinated Media Access

- Idea: "counter"-phase coupling creates groups that access the shared medium simultaneously without interference.

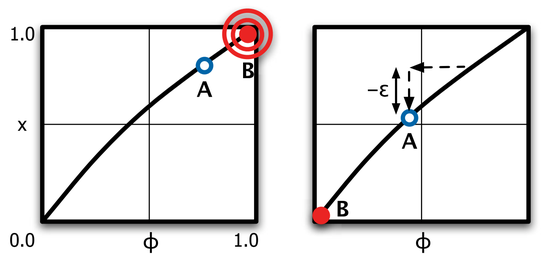

Figure 4: Two oscillators interacting by the counter-phase-coupling rule

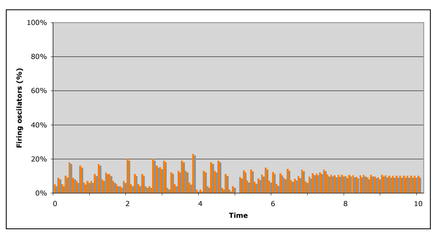

Figure 5: Oscillators firing with counter-phase-coupling

- Goal: more "coordinated" alternative to randomized backoff strategies with no communication overhead.
- Hypothesis: Pro-active collision avoidance increases throughput and fairness under high load.
- Plan: Realization as MAC-layer add-on; evaluation on NS-2 and on our testbed.
- Other potential applications: accessing shared media with expensive collision handling; e.g., memory, databases.

[1] R.E. Mirollo, S.H. Strogatz, Synchronization of Pulse-Coupled Biological Oscillators, SIAM J. APPL. Math, Vol 50, 1990
[2] A. Tyrrell, G. Auer, C. Bettstetter, Firefly Synchronization in Ad Hoc Networks, Proc. MINEMA workshop, Belgium, 2006

FNSNF
Fonds national suisse
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Swiss National Science Foundation

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