A Firefly-inspired project:

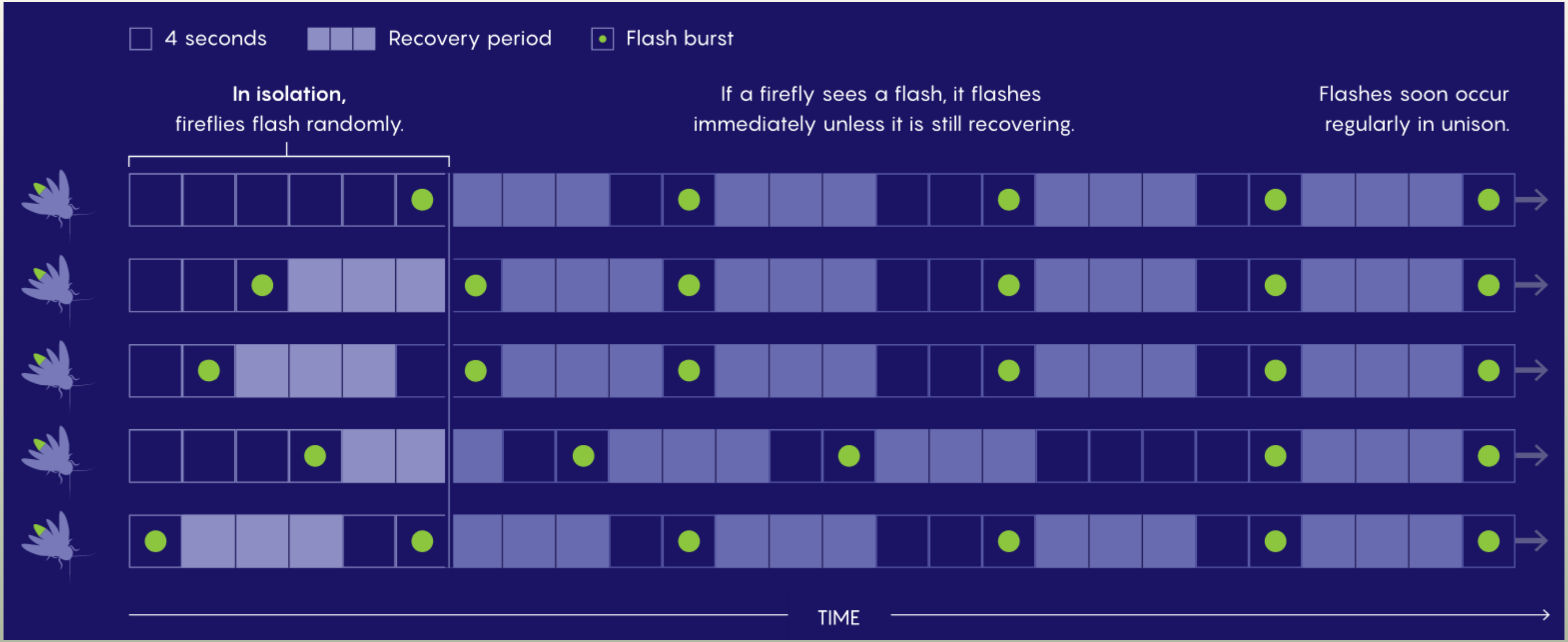
Heartbeat Synchronization in Small World Networks

Swarm Intelligence for Distributed AI systems

Synchronous Flashing!

Some species of fireflies like *Pteroptyx (South Asia)* or *Photinus pyralis (North America)* can flash in a synchronous way.

How?


4 seconds
Recovery period
Flash burst
In isolation,
fireflies flash randomly.
If a firefly sees a flash, it flashes
immediately unless it is still recovering.
Flashes soon occur
regularly in unison.
TIME

Firefly-inspired Heartbeat Synchronization in Overlay Networks*

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Abstract

Heartbeat synchronization strives to have nodes in a distributed system generate periodic, local "heartbeat" events approximately at the same time. Many useful distributed protocols rely on the existence of such heartbeats for driving their cycle-based execution. Yet, solving the problem in environments where nodes are unreliable and messages are subject to delays and failures is non-trivial. We present a heartbeat synchronization protocol for overlay networks inspired by mathematical models of flash synchronization in certain species of fireflies. In our protocol, nodes send flash messages to their neighbors when a local heartbeat triggers. They adjust the phase of their next heartbeat based on incoming flash messages using an algorithm inspired by mathematical models of firefly synchronization. We report simulation results of the protocol in various realistic failure scenarios typical in overlay networks and show that synchronization emerges even when messages can have significant delay subject to large jitter.

1. Introduction

In cycle- or round-based distributed protocols (such as gossip protocols), it is often necessary that all nodes agree on when a new cycle starts. In other words, the local perceptions at nodes as to when cycles begin and end need to be synchronized so that we can talk about "cycles" of the system as a whole. For example, if the protocol requires periodic restarts (that is, all nodes need to be re-initialized), it is important that this event be synchronized [7, 9].

Heartbeat synchronization strives to have nodes in a distributed system generate periodic, local "heartbeat" events approximately at the same time. It differs from classical clock synchronization in that nodes are not interested in counting cycles and agreeing on the ID of the current cycle. Furthermore, there is no requirement regarding the length of a cycle with respect to real time as long as the length is bounded and all nodes agree on it eventually. What we are interested in guaranteeing is that all nodes start and end their cycles at the same time, with an error that is at least one, but preferably more, orders of magnitude smaller than the chosen cycle length.

This problem is rather difficult to solve in peer-to-peer overlay networks due to dynamism, failures and scale. In overlay networks, message delay can vary over a wide range [10] and churn can be significant with nodes leaving and joining the network continuously. In addition, overlay networks can be extremely large, containing millions of nodes. This implies that any proposed solution must be highly scalable. And finally, the solution needs to be decentralized for it to be usable in overlay networks where nodes have only partial information regarding the system as a whole.

Our approach to achieving robust, scalable and decentralized heartbeat synchronization is based on biological inspiration drawn from the flashing of fireflies. It is well know that in certain firefly species, male mem-

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In this paper Ozalp Babaoglu took inspiration from fireflies to synchronize Overlay Networks

by exploiting the
Ermentrout Model

Let's apply it in
Small World Networks

Small World Networks

Short Charateristic Path Length

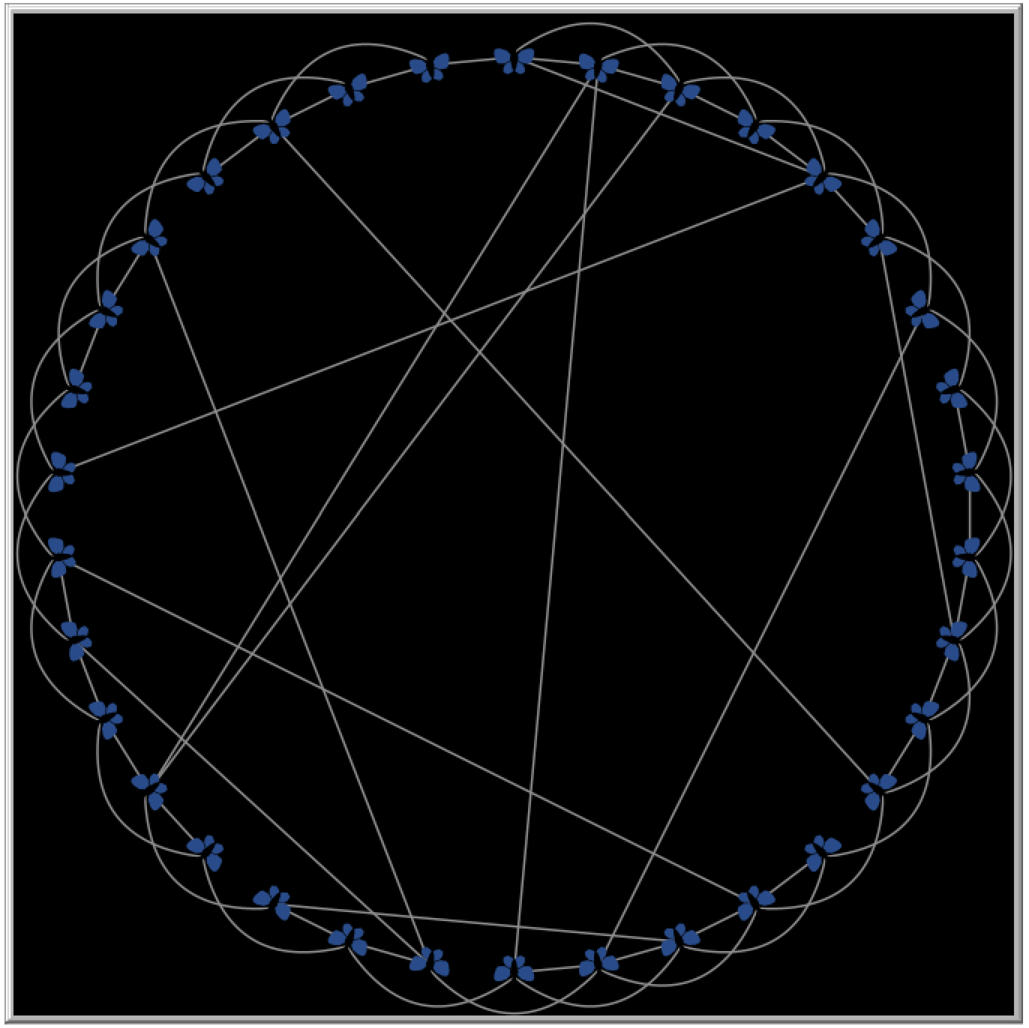
Short path distance distance between any two nodes in the social network

High Clustering factor

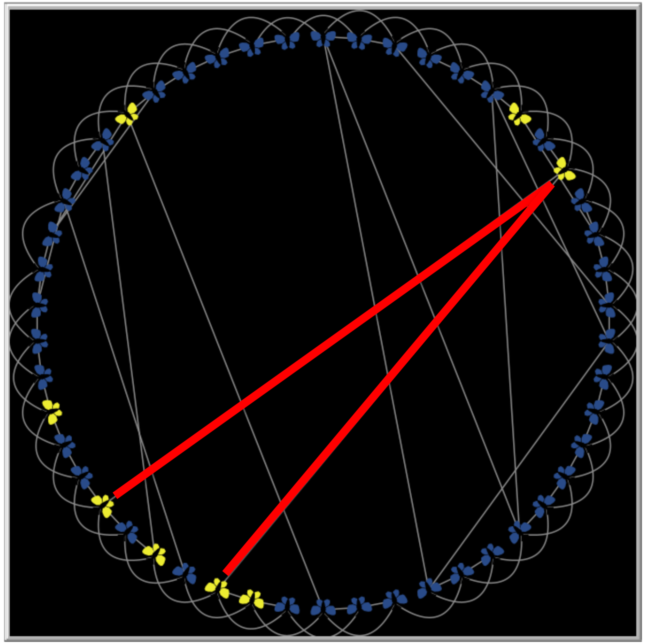
Node’s friends in a social network tend to be friend each other.

Small World Network of virtual fireflies

The program will automatically design a Small World Network, starting each time from a Lattice and checking APL and CC parameters to be in good ranges.



Fireflies → Nodes



Firefly's neighborhood

b
e
c
o
m
e
s

Node's adiacents

The Ermentrout Model

- init cycle_length δi between Δl and Δu, initial δi corresponds to the natural cycle_length Δ.
- express them in terms of frequencies: $\omega i = 1/\delta i$, $\Omega l = 1/\Delta l$, $\Omega u = 1/\Delta u$, $\Omega = 1/\Delta$.
- Φ is the phase (growing excitement of each firefly).

- WE NEVER CHANGE Φ! WE ONLY CHANGE ωi!
- Based on another firefly that flashes in my neighborhood, I can establish if I'm flashing too late or too early!
- By looking at Φ:
- $\Phi < ½$? too late | too early

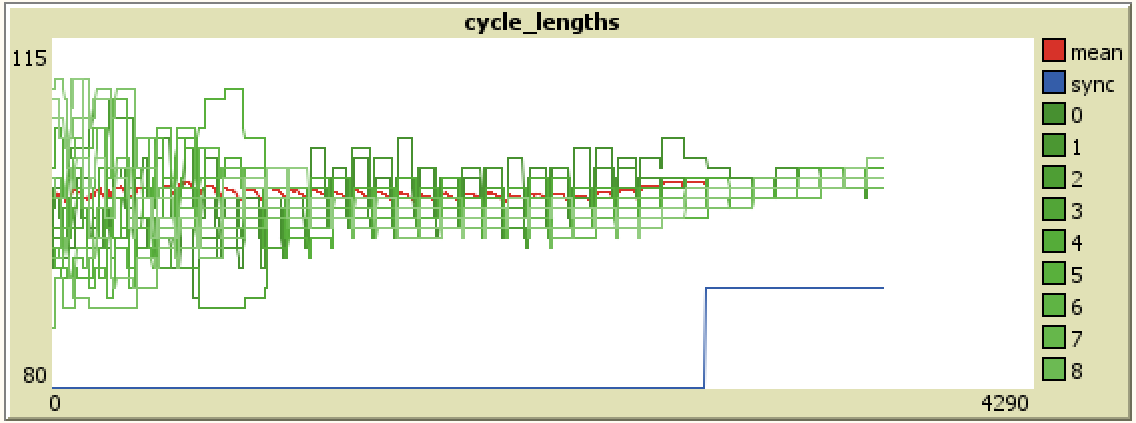
Updating ω

$$
\begin{aligned}
g^{+}(\phi) &= \max\left(\frac{\sin 2\pi\phi}{2\pi}, 0\right) \\
g^{-}(\phi) &= -\min\left(\frac{\sin 2\pi\phi}{2\pi}, 0\right).
\end{aligned}
$$

$$
\omega' = \omega + \varepsilon(\Omega - \omega) + \underbrace{g^{+}(\phi)(\Omega_l - \omega)}_{\text{Lengthening Term}} + \underbrace{g^{-}(\phi)(\Omega_u - \omega)}_{\text{Shortening Term}}
$$

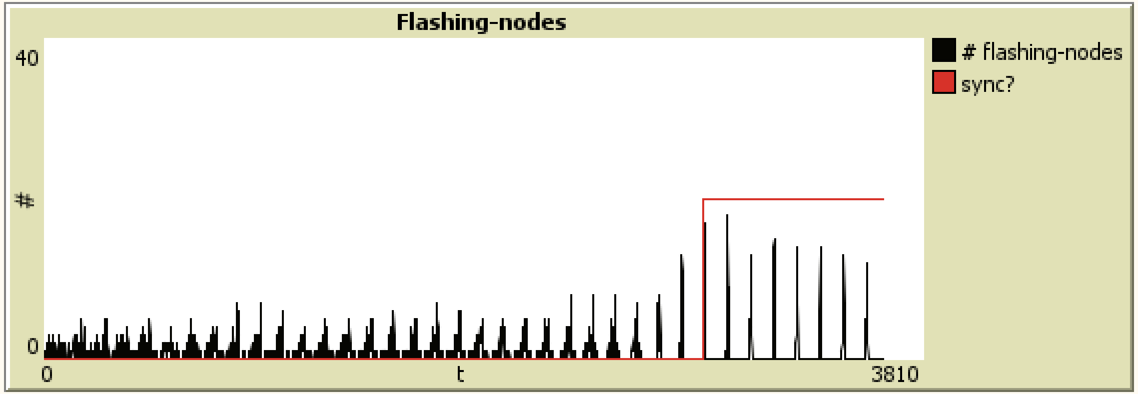
Synchronization

```
to check_sync
  if ticks > 150 [
    ifelse count turtles with [color = yellow or color = green - 0.5] = 0 [
      set silence_time silence_time + 1
    ]
    [
      ifelse silence_time > sync_silence_time [
        if sync = 0 [
          set sync 1
          set sync-tick ticks
        ]
      ]
      [
        set silence_time 0
      ]
    ]
  ]
end
```

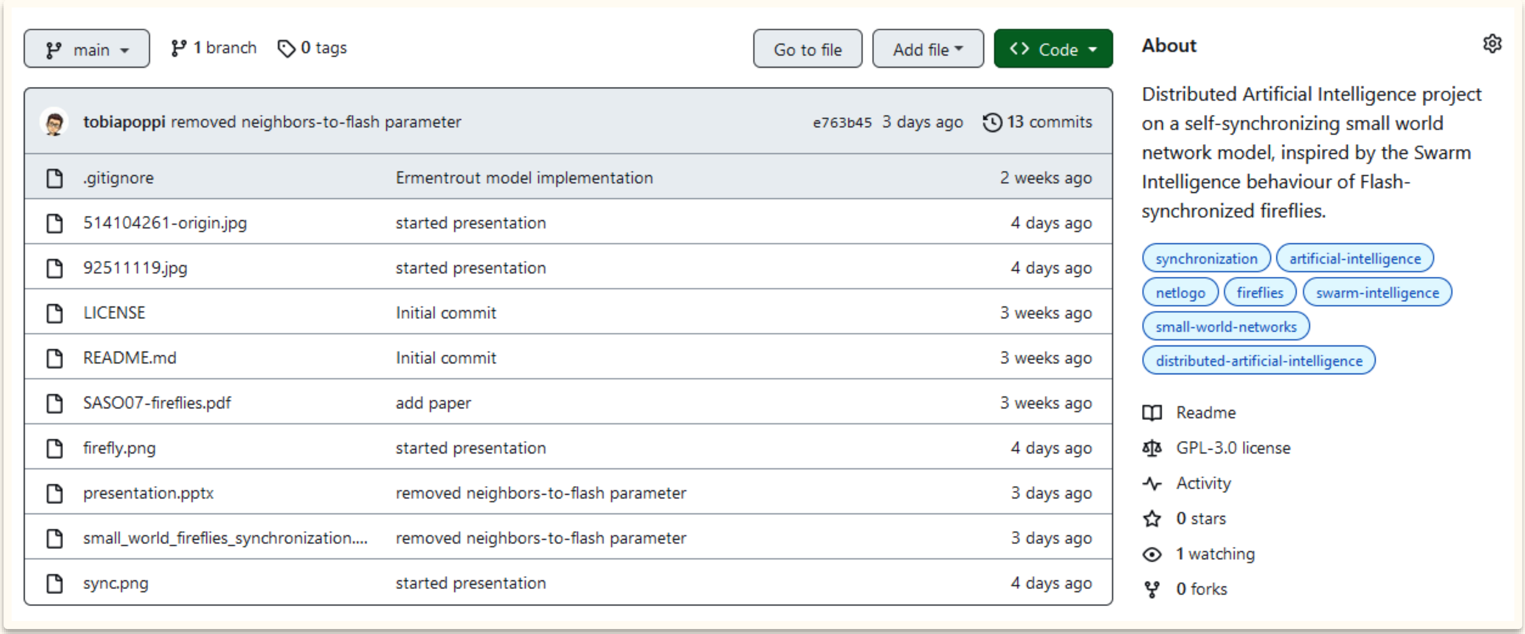


Gradually converging Cycle Length of nodes

Number of Flashes happening at the same time



Go Open Source!



https://github.com/tobiapoppi/Firefly-inspired-heartbeat-sync-in-Small-World-Networks

Thanks!

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Tobia Poppi