Firefly-Inspired Sensor Network Synchronicity with Realistic Radio Effects

1 Simulation Results

We have implemented the Firefly algorithm in TinyOS [1] using the TOSSIM [2] simulator environment. This simulator has several limitations. It does not model radio delay correctly, and nor does it take into account clock skew that occurs from variations in clock crystals in individual wireless sensors. Despite these limitations, the simulator is useful for exploring the parameter space of our algorithm. This can help us determine optimal parameter settings for the algorithm on a real testbed as well as better understand the impact of the parameter values on the level of synchronicity achieved.

In our simulator experiments, we explore the impact of varying:

1. **Node topology**: *all-to-all* where each node can communicate with every other node, and a *regular grid* topology where a node can directly exchange messages with at most four other nodes.
2. **Firing function constant value**: ranging from 10-1000. Recall from the theoretical discussion of the algorithm that the time to synchronize is proportional to the firing function constant value.
3. **Number of nodes**: We examine whether the impact of the firing function constant and node topology varies with the number of nodes. The size of the all-to-all topologies is varied between 2-20 nodes with 2 node increments, and grid topologies are varied from 16, 64, to 100 nodes.

We evaluate these simulations using the two metrics defined in the previous section: **Time to sync** and **50th and 90th percentile group spread** and use them to determine the impact of the parameters on the time taken to achieve synchronicity as well as the tightness of the synchronization.

1.1 Simulation Results

Fig. 2- 4 show the results of simulations on the all-to-all topology. Each data point is averaged over several experimental runs. Although not shown here, error bars for all the data points are also computed. Each experiment was run for 3600 seconds of simulation time with a unique random seed to start the nodes at different times. We ran simulations for firing function constant values ranging from 10,20,50,70,100,150,300,500,750 and 1000, repeating this combination for number of nodes ranging from 2-20 with 2 node increments. Figure **??** shows the percentage of cases that did not sync for these experiments. Most experiments with firing function constant values of 10,2050 and 150 did not achieve synchronicity. Consequently, we have suppressed the results for these experiments from the graphs displaying the trends for the all-to-all topology. One reason the simulation results for firing function constant values in this range have this behavior this could be that the firing function constant value is too small, causing nodes to make extremely large jumps, and thus to miss firing at the times that their neighboring nodes are firing.

Topology	Number of Nodes	Firing Function Constant
all-to-all	2	1000
all-to-all	6	10
all-to-all	8	20
all-to-all	10	10
all-to-all	10	20
all-to-all	12	20
all-to-all	12	50
all-to-all	14	10
all-to-all	14	20
all-to-all	14	50
all-to-all	16	20
all-to-all	18	20
all-to-all	20	20
grid	64	10
grid	64	750
grid	64	1000
grid	100	750
grid	100	1000

Table 1: Cases that did not achieve synchronicity consistently across all experimental runs.

Fig. 2 shows the time to sync for 2-20 nodes when the firing function constant is varied between 70-750. Overall, the graph shows that the best (lowest) time to sync for different number of nodes in an all-to-all topology can be achieved for firing constant values between 500-750. While the time to sync does increase (for more than 2 motes) when the firing function constant value is varied from 500 to 750, the increase is less than 100 units of time and thus not significant.

XXX: GT: This last para is crap. Needs to be rewritten. Fig. 3 and Fig. 4 show the extent of group spread in the 50th and 90th percentiles respectively for 2-20 nodes in an all-to-all topology. The graphs show that in most cases the tightness of the synchronicity decreases with large values of the firing function constant. The extent of this variation in group spread, however is not very large. For instance the maximum change in the group spread when the firing function constant values changes from 10 to 750 is on the order of 2000 μseconds.

Fig. 5- 7 show the corresponding results for regular grid topologies. Not suprisingly, the behavior of nodes in a grid topology changes dramatically from an all-to-all topology particularly when the firing function constant is increased. In the grid topology, large values of the firing function constant increase the time taken to achieve synchronicity and also decrease the tightness of synchroncity. Nevertheless, Fig. 7 shows that relatively tight synchronicity can be achieved 90% of the time even in the grid topology for any firing function constant value between 10 and 200.

The simulation experiments proved beneficial in selecting parameter values for the experiments on the actual testbed of wireless sensors.

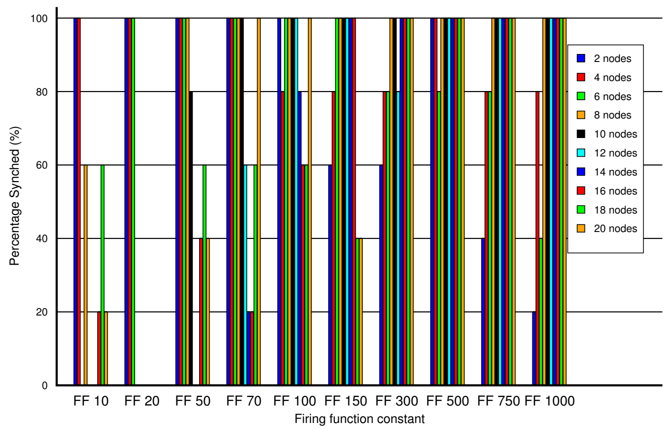

Figure 1: **Most experiments involving small firing function constants (E.g. 10,20,50,150) did not achieve synchronicity.**

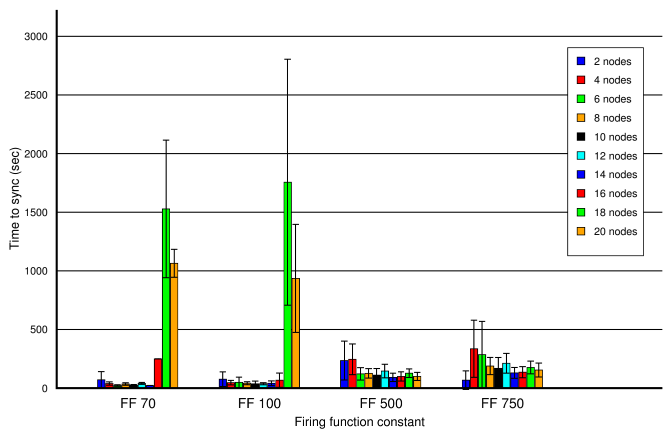

Figure 2: **Firing function constant values ranging between 500 and 750 produce the smallest time to synch for nodes in an all-to-all topology.**

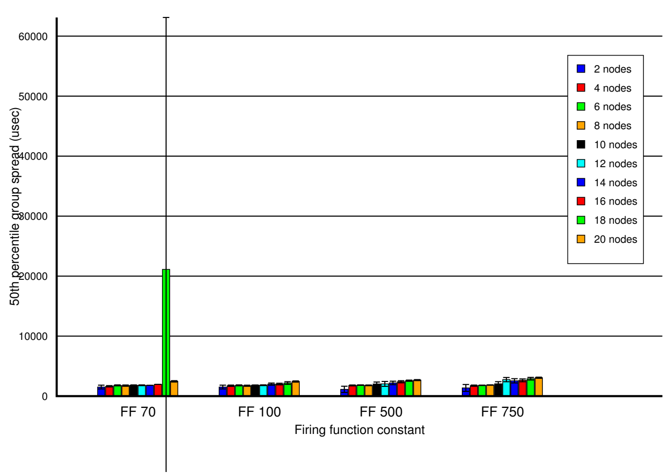

Figure 3: **The tightness of synchronicity for half of the groups does not vary dramatically across different firing function constant values, but does increase with the number of nodes in an all-to-all topology. The magnitude of the increase however is quite small.**

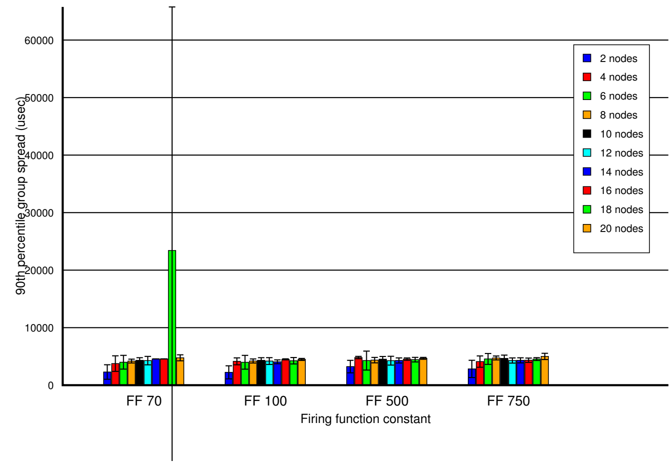

Figure 4: **90th percentile group spread for different number of nodes in the all-to-all topology**

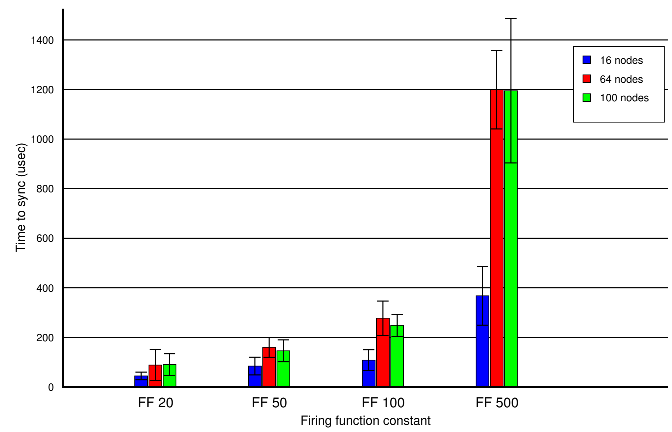

Figure 5: **The relationship between the firing function constant and the time to synch follows the theoretical predictions near-perfectly in a grid topology. In most cases the time to synch consistently increases as the firing function constant increases causing the nodes to make smaller jumps, thus converging to synchrony more slowly.**

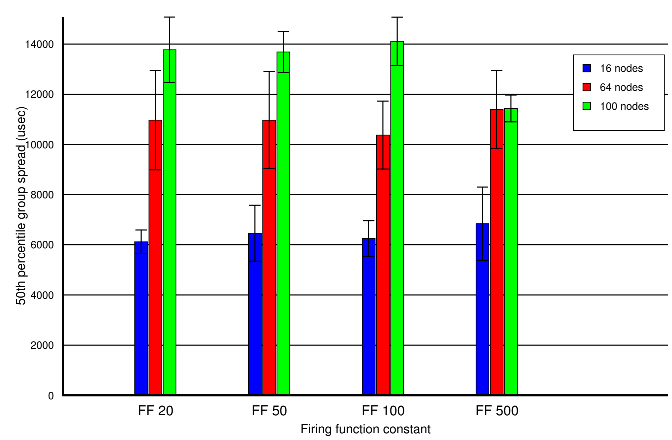

Figure 6: **The tightness of the synchronicity decreases with the number of nodes in the grid topology regardless of the number of nodes. Furthermore, the firing function constant does not have a significant impact on the tightness of synchronicity in this topology. These trends are retained in the 90th percentile group spread.**

References

[1] J. Hill, R. Szewczyk, A. Woo, S. Hollar, D. E. Culler, and K. S. J. Pister. System architecture directions for networked sensors. In *Proc. the 9th International Conference on Architectural Support for Programming Languages and Operating Systems*, pages 93–104, Boston, MA, USA, Nov. 2000.

[2] P. Levis, N. Lee, M. Welsh, and D. Culler. TOSSIM: Accurate and scalable simulation of entire TinyOS applications. In *Proc. the First ACM Conference on Embedded Networked Sensor Systems (SenSys 2003)*, November 2003.

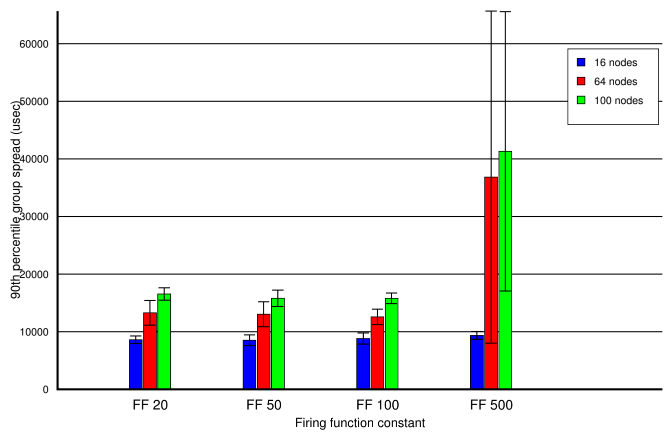

Figure 7: **90th percentile group spread in the grid topology for different number of nodes**