Functional Design and Behavior Simulation of WSN Application

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Abstract

Wireless Sensor Networks (WSN) have become a hot research and application topic, showing much promise to be entitled as the future generation miniature technology. Currently, researchers are developing various applications and infrastructure for different layers of WSNs. Showing correctness before implementation, by behavior simulation and functional verification, is essential for a sound design methodology. However, there is a lack of tools with good modeling and debugging support for this purpose. In order to fill this gap, we propose to extend Stateflow and Simulink [1] libraries to provide parameterized blocks of WSN components which can be used as building blocks to model and simulate a complete multi-node distributed WSN application.

The methodology is depicted at figure 1. The algorithm will be at first modeled by using Simulink and Stateflow blocks. After running simulation, statistical data can be collected for algorithm behavior analysis and also for the validation. The model can be refined if the analysis results suggest to do so. Our contribution is to extend the Stateflow and Simulink libraries by parameterized blocks modeling radios, sensors, device drivers, broadcasting medium, popular Medium Access Control Algorithms etc., thus providing a complete framework for modeling WSN applications. The reason for choosing the Mathworks tools over, for example, TOSSim or OmNet, is that they are well known by most students and they already provide rich libraries for Digital Signal Processing and control algorithm behavior simulation.

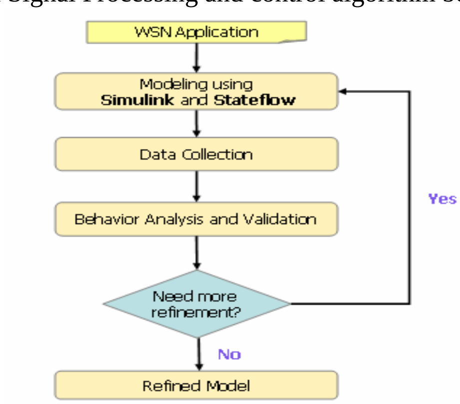

Figure 1: Functional Design Verification of WSN application

As a first step towards this goal we modeled, by using Simulink and Stateflow, all the levels of the E^2RINA [2] (Energy Efficient and Reliable In-Network Aggregation) algorithm, which is an aggregation technique to elect the cluster leader in a sensor network. E^2RINA introduces an approach that combines the efficiency of the cluster-head algorithms with the robustness of the gossip algorithms. Every node plays the same role initially, transmitting and receiving packets randomly. At the end of the initial phase, the cluster leader is selected based on number of packets received from other nodes. The node that has been able to hear from the maximum number of nodes has become the cluster leader. The algorithm is depicted at the Figure 2.

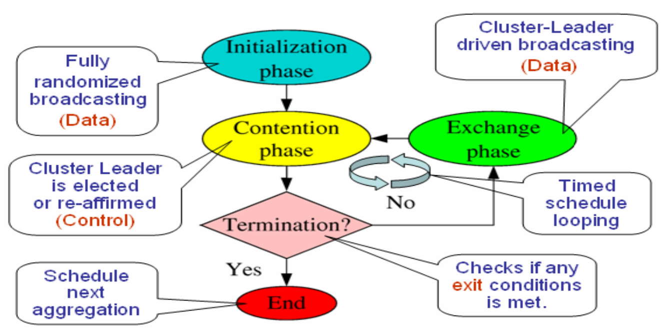

Figure 2: EERINA algorithm to elect the cluster leader

To model the algorithm, a Stateflow block has been designed to model the behavior of EERINA algorithm; Simulink blocks such as pulse generators, uniform random number generators, multiplexers, etc. have been used model the rest of the protocol stack (MAC, radio, channel, etc). Scopes and Stateflow animation were used to analyze the behavior of the algorithm. After completion of behavioral analysis and functional design, the Stateflow model has been used as a reference to drive the implementation of the EERINA in MANTIS [3], which is an OS for wireless sensor network. The whole flow is depicted in Figure 3.

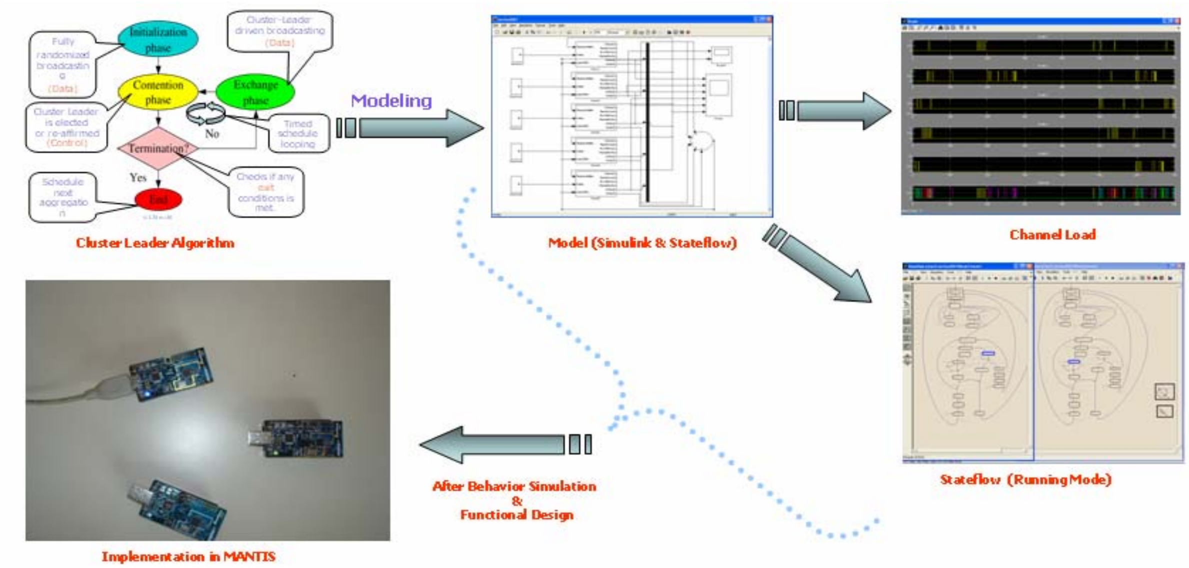

Figure 3: Stateflow/Simulink-based EERINA implementation path

References:

1. The MathWorks - Simulink® - Simulation and Model-Based Design, http://www.mathworks.com/products/simulink/
2. L. Necchi, A. Bonivento, L. Lavagno, L. Vanzago, A. Sangiovanni-Vincentelli, “EERINA: an Energy Efficient and Reliable In-Network Aggregation for Clustered Wireless Sensor Networks, to be presented at WCNC 2007
3. MANTIS OS, http://mantis.cs.colorado.edu/index.php/tiki-index.php