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IDEA1: A study of SystemC based Simulator for WSNs

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Abstract

This paper presents IDEA1, a graphical system-level simulator for wireless sensor networks. It is developed by SystemC and C++. It enables the design space exploration at an early stage of system development. It allows the performance evaluation of sensor networks at high-level, but elaborately takes into account of the hardware and software modeling. SystemC combines advantages of being a widely-used language in micro-electronic systems design flow, and permitting hardware and software co-modeling. The simulator graphical user interface permits to configure easily a network and set the sensor nodes characteristics Simulation gives easy-to-read waveforms and easy-to-process output logs. IDEA1 library contains many hardware devices and the whole IEEE 802.15.4 standard. It is possible to run quick and accurate simulations with different hardware devices on the nodes. Classical network simulators outputs (packet delivery rate (PDR), packet latency) are supported. It is also possible to simulate and compare many scenarios and configurations in order to run design-space exploration for the best-suited and lower power solution.

Keywords: Data, IDEA1, Network, SystemC, Wireless.

Introduction [3]

In recent years, various applications of wireless sensor networks (WSNs) have been developed. Simulation is a cheap and quick way to perform many experiments with different hardware prototypes and network settings thus, a simulation tool is needed to explore the huge design space at an early stage before devoting too much time and resources. In order to extend the network lifetime, many efforts have been taken to reduce the energy consumptions of hardware, software, communication protocols and applications. Therefore, it is necessary to accurately predict the energy consumption of WSN, which requires detailed models of the hardware and software (HW/SW) of sensor nodes. SystemC is a C++ class library for system and hardware design. Four SystemC-based WSN simulators have been developed; however, none of them has been validated with experimental measurements or evaluated comprehensively by comparing with other simulators. To exceed this limitation, a SystemC-based WSN simulator named IDEA1 (hIerarchical DEsign plAtform for WSNs and Architectural Node exploration) is developed. A testbed of 9 sensor nodes has been built to validate the simulation results of IDEA1. The deviation of IDEA1 simulations and the experimental measurements is small enough to be acceptable by the general system-level simulations. IDEA1 allows rapid performance evaluation at system level. The simulation results include packet delivery rate, transmission latency and power consumption. Many commercial off-the-shelf (COTS) hardware components, such as MICAz and MICA2, are modeled. The IEEE 802.15.4 standard is implemented. It has been widely utilized in WSN applications since it is designed for low data rate, short distance and low-power-consumption applications in conformity with the constraints of WSN systems. One important feature of IDEA1 is the accurate prediction of energy consumption of each sensor node and the whole network. It implements a clock-based synchronization mechanism to provide performance evaluation with cycle accurate communication and approximate time computation. The energy model implemented in IDEA1 takes into account the power consumptions of all operation modes of each hardware component and transitions between different modes.

Features of SystemC

SystemC is a C++ class library rather than a truly independent language. SystemC has some aspects that seem to annoy its users (particularly experienced designers from an RTL background). One main aspect is that part of the power of SystemC is the fact that it is C++, and therefore, it is extremely compatible with application software. SystemC started out as a very restrictive cycle-based simulator and “yet another” RTL language. The language has evolved to a true system design language that includes both software and hardware concepts. Although SystemC does not specifically support analog hardware or mechanical components, there is no reason why these aspects of a system cannot be modeled with SystemC constructs or with co-simulation techniques.

Architecture of IDEA1 [1]

In IDEA1 every component is modeled as an individual SystemC module communicating with each other via channels. The node system is a complex model comprising two parts, hardware model and software model. The hardware components of a sensor node generally include a processing unit, a transceiver, several sensors and a battery. The software model consists of protocol stack and application implementations. All nodes are connected to a same network object via their proxies. At the initialization phase, every node registers its information at the network module.

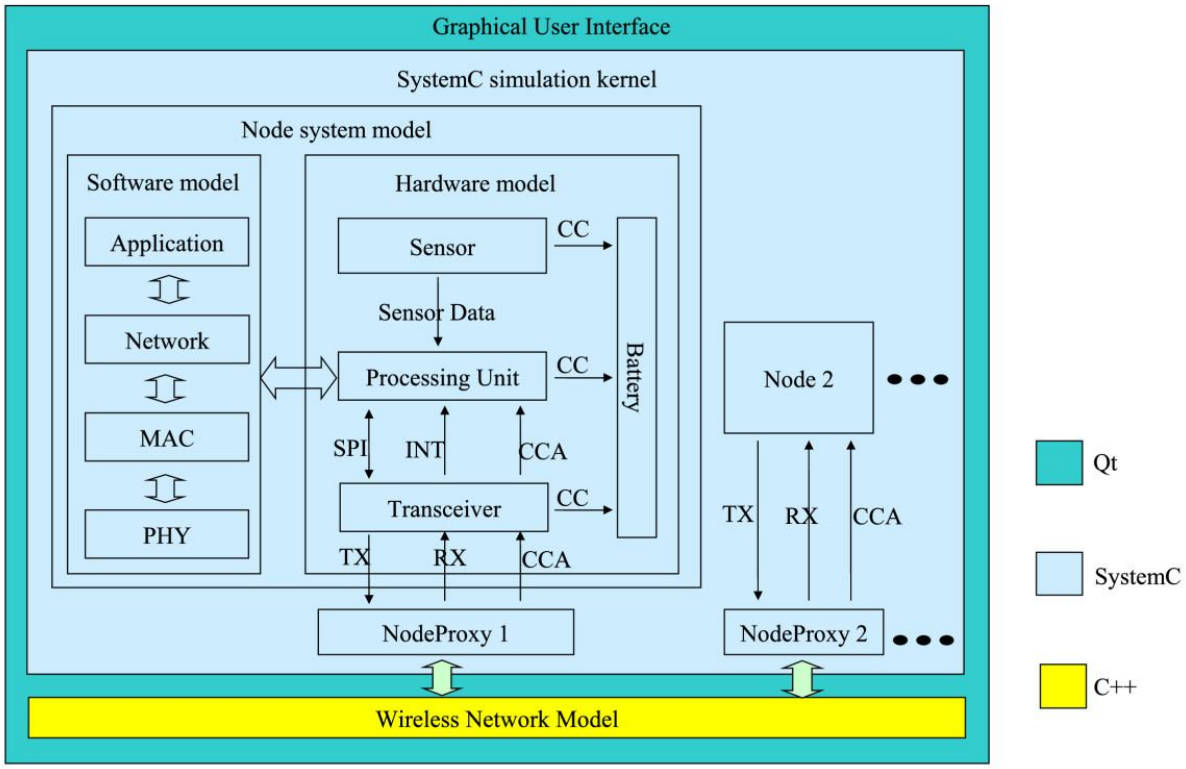

Figure1:- Architecture of IDEA1

The SystemC kernel acts as the simulation engine. It schedules events and updates the states of modules every simulation cycle. A GUI is developed to integrate all parts, which can facilitate the system configuration, network topology visualization, simulation control and result analysis. In the node hardware model, the sensor is simulated as a stimuli generator. The processing unit converts the analog signal generated by the sensor module into digital format by a built-in analog to digital convertor (ADC) and sends the data frame to the transceiver via a serial peripheral interface (SPI) bus. The transceiver emits packets into network by different media access protocols. The transceiver reports the clear channel assessment (CCA) result and some interrupts to the processing unit. During simulation, the state transition traces of each component are recorded. Each state is associated with a current consumption (CC) based on either experimental measurements or values in datasheets. The duration and current consumption of each transition between two states are also identified. Based on this information, the battery module calculates the energy consumption of each component and its residual capacity according to particular battery models during runtime.

Main Features of IDEA1 [2]

IDEA1 is an open source simulator for Wireless Sensor Networks (WSN). It is dedicated to WSN researchers, especially in electronic and computer science fields.IDEA1 is a discrete event simulator, based on SystemC and C++ language.IDEA1 main features are:

- Design space exploration to best fit application to sensor nodes parameters
- Evaluation of node hardware (HW) and software (SW) impact on network metrics (PDR, latency)
- Evaluation of standard (i.e. IEEE 802.15.4), comparisons of algorithms (beacon & non-beacon ones)
- Evaluation of power consumption with hierarchical coarse to fine granularity: node level, HW components (i.e. microcontroller, radiofrequency device), blocs in components (i.e. ADC, SPI in microcontroller, TX, RX, idle, sleep (...) states in radiofrequency device)
- Precise timings (i.e. ADC, SPI timings)

- Interchangeable HW components in order to configure commercial or "lab-made" sensor nodes.
- Official models (provided with IDEA1 in download section) are validated by measurements on real HW.

Conclusion

This paper reflects about the contents of IDEA1. Among all the simulator based on SystemC the only IDEA1 is capable of providing accuracy in the results that matches to the real world. It has only comparison with NS-2. There are various features by which IDEA1 is better than NS-2. It enables the design space exploration at an early stage. It models the sensor node in SystemC, which makes the simulation to be a part of the HW/SW design of sensor nodes. It supports a modular design of sensor nodes and WSN applications The advantages of IDEA1 is that it is SystemC based system level simulation environment that built on SCNSL while NS-2 is widely used as general- purpose network simulator.

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