A cross-layer integration prototype for wireless sensor networks

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***Abstract*—Nowadays, the cross layer integration of the different elements composing a wireless sensor network is seen as the most effective approach towards the deployment of long-lasting operating and self-configuring networks. In this work, we undertake the task of developing and integrating a smart and power-aware protocol architecture. We focus our efforts on the physical, MAC protocol and self-configuring and maintaining operations which are at the base on the design and deployment of long-lasting operating and self-configuring wireless sensor networks.**

Keywords: protocol integration, power management, synchronization, self-organization.

I. INTRODUCTION

Wireless sensor networks (WSN) are composed of a large number of smart devices aimed to work autonomosly. In order to enable the long-lasting operation of such networks, the proper integration of power-efficient hardware entities and protocols is one of the major challenges to be addressed. In this work, we undertake the design and development of a power- efficient protocol architecture using as main source of energy a solar energy harvesting approach. Our protocol architecture comprises the underlying control mechanisms enabling the auto-configuration and medium access control mechanism.

In the following, the paper is organized as follows. We start by reviewing the design principles of ATON, an energy harvesting device recently designed in our labs. We then proceed with the design of a set of power-efficient protocol mechanisms built on top of ATON. Throughout our description, we position the main features of our proposal within the main current trends in the area of power-efficient protocols.

II. ENERGY HARVESTING

Our cross-layer protocol architecture has been developed bearing in mind that wireless sensor nodes are energy contrained devices. We then make use of a battery-less system supply recently developed in our labs and reported in [1]. The design of our battery-less system has been based on solar-energy harvesting techniques and particularly customized for low power wireless sensor networks (see Figure 1). The proposed system is made up of: 1) a set of low-power solar cells connected in series forming a photovoltaic panel of 60x40mm with an optimum voltage work of 3.3V and 24mA of current; 2) a supercapacitor or high density capacitor as energy storage; 3) a power control unit responsible of properly coupling the supercapacitor voltage to the sensor node electrical characteristics; and 4) a filter stage connected to Telosb mote to avoid electromagnetic interferences and possible noise produced by the power unit.

Figure 1. ATON.

III. CROSS-LAYER APPROACH

The protocol architecture proposed herein follows a cross-layer approach. We address the following three main communication mechanisms: medium access control mechanims, transmission scheduling and network (auto) configuration.

A. *Medium Access Control Mechanism*

It is widely known that one of the main sources of energy wastage is due to the operation of the radio system. In turn, the operation of the radio is highly dependent on the medium access control (MAC) mechanism. Among the various paradigms, MAC based on Time Division Multiplexing Access (TDMA) principles have been recognized as one of the preferred alterantives. In the framework of power-constrained

(1) http://www.i3a.uclm.es

MACs, the main idea relies on the assignment of a given time slot to each one of the nodes composing the network. In this way, each node gets to know the time and period length during which it must be on to realize the communication operations (send/receive). Various TDMA-based MAC proposals have already been reported in the literature [2][3][4].

In this work, we adapt the operation mode of SA-MAC [4], a synchronous TDMA MAC protocol recently developed in our labs. It is worth to note that any other TDMA-based MAC protocol could be easily interfaced to ATON. Figure 2 depicts the scheduling process of SA-MAC. As depicted in the figure, depending on the capacitor load, the duty cycle of SA-MAC will be adapted accordingly. The SA-MAC protocol entity gets to know the actual time periodicty by integrating into the header of the protocol data unit. In order to keep the proper synchronization among the communicatins nodes, the duty cycle should be adapted in multiples derived from the primary period.

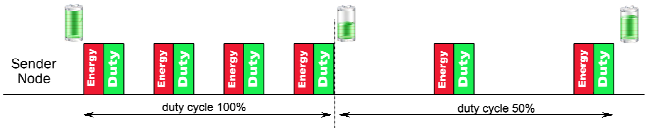

Figure 2. Adaptive Duty Cycle

B. *Network Self-Configuration*

In order to self-configure the network, we propose NORIA, a novel self-organization intelligent algorithm which uses a rule-based approach to create minimum paths. NORIA performs role assignment where nodes with higher resources are in charge of forwarding data in multihop network configurations. Different to previous configuration mechanisms, such as CTP [5], NORIA makes use of simple fuzzy rules in the decision process to periodically balance the traffic load among nodes (see Figure 3). In our design, NORIA takes into account the energy-level as one of the key parameters to ensure a reliable and self-adaptive operation of networks consisting on a large number of energy-constrained nodes.

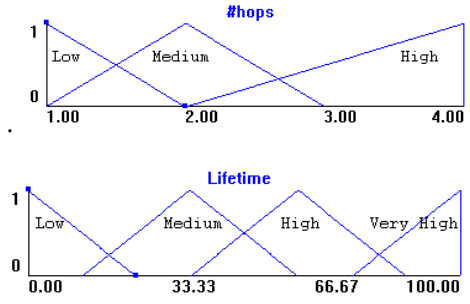

Figure 3. Fuzzy sets.

In NORIA, input parameters are classified in customizable data sets to perform fuzzy-rule evaluation among them. These fuzzy rules are solved by a simple inference engine to get conclusions like parent node or chosen role.

IV. System Integration

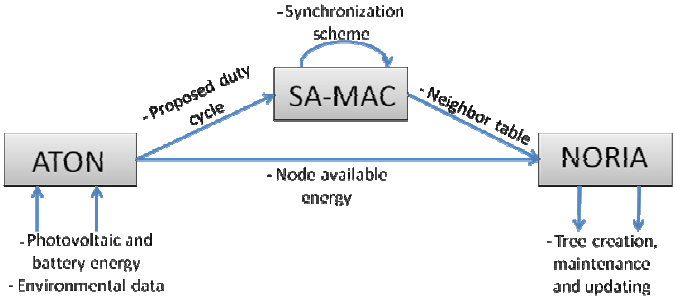

Figure 4. Integration of Architecture Components.

Figure 4 shows the relation among the various components of the proposed power-aware protocol architecture. A protoype of our system has been preliminary tested in our labs. In particular, we have been able to validate the operation of our TDMA-based MAC protocol, SA-MAC. In fact, our experimental lab tests have shown that it is in fact possible the long-lasting operation of the battery-less solar-powered device using a Telosb mote assuming that the weather condition provides enough energy during the day-hours. However, we are further developing a protoype incoporating a rechargeable battery to be used as a backup facility. About the rule based auto-configuration mechanism, NORIA, our simulation results show that our approach should effective toward the configuration of a dense network. Our future plans comprise the deployment of a prototype for an environmental application [6].

Acknowledgments

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