A Tiny and Light-weight Autonomic Element for Wireless Sensor Networks

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Abstract

Autonomic networks are able to monitor and control themselves without direct human intervention. The smallest unit of an autonomic network is the autonomic element (AE). This work presents the model and evaluation of a specific wireless sensor network (WSNs) AE, called autonomic sensor element (ASE). The ASE has been proposed considering WSNs hardware, software, communication and energy restrictions.

1 Introduction

A Wireless Sensor Network (WSN) [5] can be considered a special kind of ad hoc network composed in most cases by hundreds to thousands of network elements called sensor nodes, which are deployed in remote environments where maintenance by technicians and local administration could be difficult or even impossible.

The autonomic computing paradigm defines computational systems that are able to manage themselves with none or minimal human intervention [3]. This management paradigm can be applied in many contexts, from simple hardware or software components to information technology (IT) systems of high complexity and different kinds of networks. Considering specially WSNs that in most cases are designed to operate in hostile environments with elements that presents severe resources restrictions, it is interesting to use hardware and software that allow self-management. Therefore, the use of the autonomic computing paradigm will be in some cases the best way of implementing and using management services and functions in WSNs.

The construction of a complete autonomic solution to any kind of system demands the development of an specific autonomic element (AE), which is the smallest part of an autonomic system and should be embedded into each of its components. The AE allows the execution of autonomic services, representation and efficient management of manageable resources and continuous improvement of control and supervision services through the implementation of machine learning techniques. The design of particular AEs to each devices or components collections can be considered one of the main research challenge in the autonomic computing field [2]. This work deals with this challenge: to propose an AE specific for WSNs. The design of this AE uses a generic autonomic element model proposed in [3] and a specific WSN management architecture called Manna [5].

2 Autonomic Sensor Element

According to the format of a generic AE proposed in [3], an autonomic element is comprised of five parts: monitoring, analysis, planning , execution and a Knowledge Base (KB).

The monitoring service of an AE is responsible for the implementation of self-knowledge and self-awareness. These parameters can be divided into two categories: internal and external. Internal parameters are connected to the self-knowledge concept and reflect the current state of the managed element hardware and software. External parameters are those connected to self-awareness and construct the managed element vision related to the network condition of the network, its connectivity with neighbors and their state.

The verification of internal and external parameters of an AE will be performed by the analysis service. It is this service responsibility to transform input data acquired by the monitoring service into useful information that will be analyzed and that lead to conclusions on performance, pro-

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ductivity, desired quality of service level accomplishment and established service negotiation agreements aspects for example, to different funcional areas, management levels and considering one or more WSNs functionalities. The autonomic concept connected to this service is the self-diagnosis. The planning service of an AE has as its main goal to chose or elaborate an actions plan to be followed according to the results of the analysis performed by the previous service.

The execution service is related to one of the main aspects of the autonomic computing paradigm: self-configuration. It is through this aspect that the AE can act on the managed element hardware and software, trying to configure them the best way possible to the needs of this element and to the conditions of the surrounding environment. The KB stores data, information, policies, thresholds, among other items. The main tradeoff observed by the ASE in this case is between memory space consumption and precision.

3 Results Analysis

In this work, besides proposing an autonomic element to WSNs (ASEs), we have instantiated the proposed model to the Mica Motes 2 sensor node platform [1]. The implementations have been done using the Network Simulator [4] simulator. Real experiments with Mica Motes 2 sensor nodes have also been done. We have simulated scenarios with autonomic and non-autonomic WSNs. Besides, we have considered localized and distributed versions of the autonomic WSNs.

Memory Consumption: In order to verify the amount of memory demanded by the ASE instance elaborated in this work, it has been implement in conjunction with a luminosity data sensing application already available in the TinyOS [6] operating system. The autonomic cycle represented an increase of only approximately 1KB to ROM memory and 290 Bytes to RAM memory (see Table 1).

Table 1. ROM and RAM memory consumption(in Bytes).

Service	ROM (Bytes)	RAM (Bytes)
Application	15960	1847
ASE Total	1026	290

Varying the ASE Complexity: Table 2 presents average total and percentage with processing energy consumption (white lines) and their respective standard deviations (gray lines). It also shows the number of relevant data sent by localized and distributed ASE. We have considered iterations with 40,000 and 120,000 instructions. Each autonomic cycle iteration corresponds to a determined machine instructions set to be executed by the sensor node.

Table 2. Sensor nodes average total energy consumption in Joules and number of relevant sent data.

	Distributed ASE		Localized ASE	
# Inst.	**40**	**120**	**40**	**120**
Proc. (%)	1.84	4.74	11.86	24.18
	0.09	0.26	0.84	10.03
Relevant Data	5775.92	5771.27	7243.41	7118.73
	421.01	377.74	503.19	685.48

4 Conclusion

The implementation of the autonomic networking paradigm in WSNs will be frequently the solely way to promote control and supervision to this kind of network. In this work, we have proposed the Autonomic Sensor Element (ASE) based on the generic model proposed and on the concepts of the WSN management architecture called Manna. The development and studies described in this paper have been made possible due to financial support granted by CAPES.

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