Chapter 6

On the Use of Stochastic Activity Networks for an Energy-Aware Simulation of Automatic Weather Stations

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ABSTRACT

Automatic Weather Stations (AWSs) are embedded systems equipped with a number of sensors used to monitor harsh environments: glaciers and deserts. AWSs may also be equipped with some communication interfaces in order to enable remote access to data. These systems are generally far from power sources, and thus they are equipped with energy harvesting devices, wind turbines and solar panels, and storage devices, batteries. The design of an AWS represents a challenge, since designers have to maximize the sampled and transmitted data while considering the energy needs. We designed and implemented an energy-aware simulator of AWSs to support designers in the definition of the configuration of the system. The simulator relies on the Stochastic Activity Networks (SANs) formalism and has been developed using the Möbius tool. In this chapter we first show how we used SANs to model the components of an AWS, we then report results from validation experiments carried out by comparing the results of the simulator against a real-world AWS and finally show examples of its usage.

INTRODUCTION

Automatic Weather Stations (AWSs) (Sharan, 2014) are employed as sensing systems in extreme environments, such as desert, Antarctica (Reijmer, 2001), glaciers (Abbate et al., 2013) and deserts (Hobby et al., 2013). An AWS is normally composed of a number of sensors (humidity, wind speed, solar radiation, snow height) connected to a processing unit (CPU and memory). Since AWSs are usually far from

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mains power sources, they are often powered by batteries and exploit energy harvesting (solar panels or wind turbines, typically) to provide perpetual operation (Priya et al., 2009). AWSs can use communication interfaces, for example WiFi links, Radio bridges, GSM, or satellite links, to implement telemetry (Cesarini et al., 2013).

AWS deployments are built to last, in the order of years. Since after-deployment maintenance is generally difficult, expensive, or even impossible, designing an AWS is a critical task, the requirements being long-lived continuous operation, possibly in any working condition (Box et al., 2004). To address them, designers tend to over-provision energy related sub-systems, although this leads to higher costs and bigger size of the AWS.

Designers should be provided with computer aided design tools to study how hardware choices, e.g., battery and solar panel size, impact on the energy state and evolution of the system (Sabharwal et al., 2013). These class of tools, if used early during the design cycle, can help minimizing AWS design errors. Multiple approaches to analyse energy evolution of wireless systems have been proposed, in particular referred to Wireless Sensor Networks (WSN), which do share some features with AWSs. However, the following important differences hold:

- AWSs are generally larger and more complex than WSN nodes.
- The ratio between the energy stored in the battery and the energy spent during operation may be very different (up to two orders of magnitude) between AWSs and WSN nodes.
- WSN nodes typically have a reduced set of sensors, while an AWS is normally equipped with a broad range of sensors.
- Even though during the last 10/15 years a large number of research platforms for WSNs have been proposed, only few HW (telos, mica) and SW (TinyOS, Contiki) platforms are currently used in research, with an even lower industrial adoption. Instead, a wider and more heterogeneous panorama of industrial legacy platforms exists for AWSs (Cesarini et al., 2013), motivated by a broader range of different manufacturers, each one delivering it's own hardware and software.

Considering the exposed differences, we believe that approaches focusing on WSNs cannot be easily adapted to effectively analyse AWSs. Thus, specific tools for AWSs are needed in order to design and install such systems with a higher degree of efficiency and accuracy.

In this chapter it is shown how to use the Stochastic Activity Networks (SAN) formalism (Sanders et al., 2001) to model the energy behaviour of an AWS system. Furthermore, an energy-aware simulator implemented starting from the SAN models is described. The simulator allows designers to perform an evaluation of the energy feasibility of the system early in the development process. Both the hardware components and applications running on the AWS can be modeled, following the approach that has been first proposed in (Cesarini et al., 2014a). Using the simulator, AWSs designers can study the energy behaviour of the system and tune the system parameters more quickly and easily than with a prototype-based analysis. As the different parameters of an AWS are not independent (e.g., battery size vs. cost, sampling and communication rates vs. transmission energy), several trade-offs have to be constantly considered during the design of the system. The proposed simulator empowers the designer in finding the most satisfactory functioning parameters and choosing the best hardware components to maximize the amount of collected data while ensuring the survival of the AWS.

Considering the existing techniques and tools, our proposal represents one of the first approaches for an holistic modelling, analysis and simulation of AWS systems' energy issues. Indeed, our simulator is