

Chapter 5

Building Wireless Sensor Network Applications with LooCI

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ABSTRACT

Considerable research has been performed in applying run-time reconfigurable component models to the domain of wireless sensor networks. The ability to dynamically deploy and reconfigure software components has clear advantages in sensor networks, which are typically large in scale and expected to operate for long periods in the face of node mobility, dynamic environmental conditions, and changing application requirements. LooCI is a component and binding model that is optimized for use in resource-constrained environments such as Wireless Sensor Networks. LooCI components use a novel event-based binding model that allows developers to model rich component interactions, while providing support for run-time reconfiguration, reflection, and policy-based management. This paper reports on the design of LooCI and describes a prototype implementation for the Sun SPOT. This platform is then evaluated in context of a real-world river monitoring and warning scenario in the city of São Carlos, Brazil.

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1. INTRODUCTION

Wireless Sensor Networks (WSNs), composed of embedded computers equipped with low power radios and low-cost sensors are being employed to support a growing range of fixed and mobile applications such as habitat monitoring (Mainwaring, Polastre, Szewczyk, & Anderson, 2002), flood warning (Hughes, Greenwood, Coulson, Blair, Pappenberger, Smith, & Beven, 2007), industrial process control (Pohl, Krumm, Holland, Stewing, & Lueck, 2008a), disaster management (Costa et al., 2007) and in particular environmental monitoring (Smith et al., 2009). WSNs are typically large in scale, subject to unreliable networking, node mobility, high risk of node failure and are expected to operate unattended for long periods. Recently, lightweight component models (Costa et al., 2007; Rellermeyer & Alonso, 2007; Gay, Levis, Von Behren, Welsh, Brewer, & Culler, 2003; Coulson et al., 2008) have emerged as a promising approach to managing complexity in WSN environments.

This paper describes the Loosely-coupled Component Infrastructure (LooCI), which features a loosely-coupled, event-based binding model inspired by event-driven programming models (Gay, Levis, Von Behren, Welsh, Brewer, & Culler, 2003), Service Oriented Architectures (SOA) (Bell, 2008), publish-subscribe interaction models (Eugster, Felber, Guerraoui, & Kermarrec, 2003) and pluggable networking support (Grace, Hughes, Porter, Blair, Coulson, & Taiani, 2008). The resulting architecture is light-weight and promotes a loose coupling between software components while facilitating advanced features such as policy-based management, generic fault tolerance and distributed garbage collection.

We have evaluated LooCI in a real-world river monitoring case-study in the city of São Carlos in São Paulo state, Brazil. In this scenario, four WSN motes were deployed to monitor river health and build a better understanding of the relationship between two related creeks (one is a tributary of

the other). This case-study allowed for a detailed evaluation of our WSN platform and provided valuable data to our local environmental science partners. In this study four environmental factors were monitored over a two-week period:

- **Water depth** is monitored using a hydrostatic level sensor in order to provide early warning of flood events.
- **Water conductivity** levels are monitored using a standard conductivity sensor in order to infer pollution levels.
- **Methane levels** are monitored using a simple CH₄ sensor in order to detect decaying organic matter.
- **Tamper detection** is implemented using a three dimensional accelerometer.

The remainder of this paper is structured as follows. Section 2 discusses related work in the field of middleware for WSNs. Section 3 presents the LooCI middleware. Section 4 provides a static evaluation of the footprint and performance of the LooCI middleware. Section 5 evaluates the benefits of LooCI in a river monitoring case-study. Section 6 discusses directions for future work. Finally, Section 7 concludes.

2. RELATED WORK

A number of lightweight component models have been proposed for networked embedded scenarios. Each of these component models is discussed in Section 2.1. Related work on interaction models for WSN is then discussed in Section 2.3. Finally, Section 2.3 concludes by discussing other significant and related middleware approaches for WSN.

2.1 Component Models for Wireless Sensor Networks

NesC (Gay, Levis, Von Behren, Welsh, Brewer, & Culler, 2003) is perhaps the best known and

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