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Technical Report

Poster: EMMON - A WSN System Architecture and Toolset for Large-Scale and Dense Real-Time Embedded Monitoring

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Abstract

Wireless sensor networks (WSNs) have attracted growinginterest in the last decade as an infrastructure to support a diversityof ubiquitous computing and cyber-physical systems.However, most research work has focused on protocols or onspecific applications. As a result, there remains a clear lackof effective and usable WSN system architectures that addressboth functional and non-functional requirements in anintegrated fashion. This poster outlines the EMMON systemarchitecture for large-scale, dense, real-time embedded monitoring.It provides a hierarchical communication architecturetogether with integrated middleware and command andcontrol software. It has been designed to maintain as muchas flexibility as possible while meeting specific applicationsrequirements. EMMON has been validated through extensiveanalytical, simulation and experimental evaluations, includingthrough a 300+ nodes test-bed the largest single-siteWSN test-bed in Europe.

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Abstract

Wireless sensor networks (WSNs) have attracted growing interest in the last decade as an infrastructure to support a diversity of ubiquitous computing and cyber-physical systems. However, most research work has focused on protocols or on specific applications. As a result, there remains a clear lack of effective and usable WSN system architectures that address both functional and non-functional requirements in an integrated fashion. This poster outlines the EMMON system architecture for large-scale, dense, real-time embedded monitoring. It provides a hierarchical communication architecture together with integrated middleware and command and control software. It has been designed to maintain as much as flexibility as possible while meeting specific applications requirements. EMMON has been validated through extensive analytical, simulation and experimental evaluations, including through a 300+ nodes test-bed the largest single-site WSN test-bed in Europe.

Categories and Subject Descriptors

B.4.4 [**Performance Analysis and Design Aids**]: [Simulation, Verification, Worst-case analysis]

General Terms

Design, Experimentation

Keywords

Large Scale WSNs, System Design, Testbed

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1 Introduction

Wireless Sensor Networks (WSNs) have been emerging as underlying infrastructures for new classes of large-scale and dense (real-time) networked embedded systems. However, despite relevant work proposed so far (e.g., [3]), none fulfills all the requirements imposed by such systems [5]. The EMMON system architecture [1] outlined in this poster abstract pushes today's state-of-the-art, since: (i) it encompasses all system components: a Command and Control (C&C) subsystem, a middleware and a WSN communication architecture; (ii) it considers several Quality-of-Service (QoS) properties simultaneously, i.e., scalability, timeliness, energy-efficiency and reliability; (iii) it builds upon a thorough analysis of specific user/application requirements [4], of problems to address [2] and of previous work [5]; (iv) it is based on the most widely-used standard and COTS technologies for WSNs - ZigBee/IEEE 802.15.4, but (v) augments it with important add-ons, such as time-division cluster scheduling and downstream geographical routing; (vi) the baseline protocol stack is supported by a solid critical mass, designed and implemented in synergy with the TinyOS 15.4 and ZigBee Working Groups [6]; (vii) it is supported by a unique and complete planning, dimensioning, simulation and analysis toolset (Section 3); (viii) it has been tested and validated by extensive simulation and experimental evaluation, including through a 300+ nodes test-bed [1].

2 System Architecture

The EMMON system architecture supports scalability and QoS through a hierarchical network, middleware and C&C design. Fig. 1 highlights its main components, as listed in what follows. (i) Tier-0 consists of simple wireless Sensor Nodes (SNs) with a minimum set of functionalities to be deployed in large quantities, performing sensing tasks. (ii) Multiple SNs are grouped to form a WSN Cluster at Tier-1, where a Cluster Head (CH) incorporates functionalities such as data aggregation, distributed synchronization, convergecast (upstream) and geographical-based (downstream)

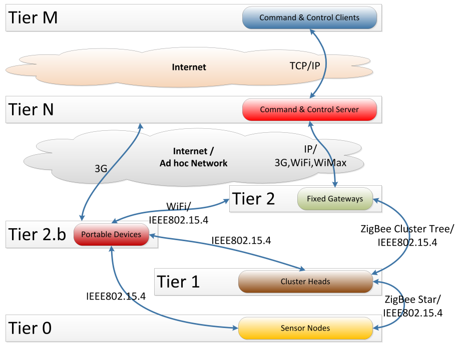

Figure 1. EMMON Multi-Tier System Architecture.

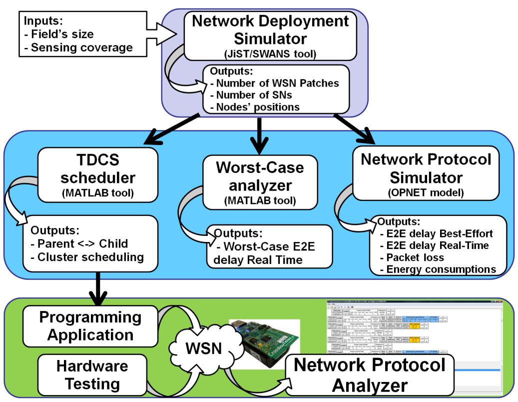

Figure 2. *EM-set* - the EMMON toolset.

routing. (iii) At Tier-2, multiple CHs form a WSN Patch rooted at a gateway (GW). (iv) Multiple WSN Patches can operate in parallel using distinct frequency channels and spatial re-use. Through GWs and IP-based technologies, they are reached by the C&C subsystem, i.e., the most visible part of the system, which collects readings and provides all the functionalities to the end-users. It encompasses a C&C server (Tier-N) and multiple C&C clients (Tier-M), which run a user-friendly graphical interface (GUI). (v) As optional elements at Tier-2.b, Portable Devices act as mobile GWs and support management/diagnosis.

Conversely to traditional C&C applications, instead of interacting with each node individually, a novel EMMON-specific middleware (EMW) facilitates the development of environmental monitoring applications via geographical programming interfaces (geo-APIs). EMW runs on all the elements of the system and glues all the components together, from the powerful C&C Clients to the cheapest SNs, allowing them to work properly and efficiently over the heterogeneous communication technologies (Fig. 1).

3 EM-Set: The EMMON Toolset

In order to help application designers to customize the EMMON system parameters and assess if its expected performance meet the specific requirements, we developed *EM-set* [7], an unified toolset whose overall perspective is sketched in Fig. 2.

Starting from (i) the definition of the size of the area to cover with the SNs, (ii) the sensing coverage of each SN and (iii) assuming the atomic structure of a basic *WSN Patch*, i.e., a GW and N CHs surrounding it, the Network Deployment Planning tool outputs the number of WSN Patches and SNs needed to cover such area, as well as their optimal placement. This output feeds three tools for network dimensioning and performance evaluation: the TDCS scheduler, the Worst-Case analyzer and the Network Protocol simulator. Theoretical upper bounds on the e2e delays of real-time traffic are analytically derived, while e2e delays for both best-effort and real-time traffic classes, packet loss ratio and network lifetime are estimated through simulation. Finally, the TDCS scheduler outputs the topology of a WSN Patch and its clusters' scheduling. This information feeds the Remote Programming and Testing tool to program a physical WSN testbed (via e.g., USB tree). Then the Network Protocol Analyzer tool (i.e., the sniffers and an EMMON customized parser) is able to capture the network behavior to cross-validate the previous analytical and simulation results.

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