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Technical Report

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Abstract

In spite of the significant amount of scientific workin Wireless Sensor Networks (WSNs), there is a clear lack ofeffective, feasible and usable WSN system architectures thataddress both functional and non-functional requirements in anintegrated fashion. This poster abstract outlines the EMMONsystem architecture for large-scale, dense, real-time embeddedmonitoring. EMMON relies on a hierarchical network architecturetogether with integrated middleware and command&controlmechanisms. It has been designed to use standard commercially–available technologies, while maintaining as much flexibilityas possible to meet specific applications' requirements. TheEMMON WSN architecture has been validated through extensivesimulation and experimental evaluation, including through a300+ node test-bed, the largest WSN test-bed in Europe to date.

Invited Poster: EMMON: A System Architecture for Large-Scale, Dense and Real-Time WSNs

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***Abstract*—In spite of the significant amount of scientific work in Wireless Sensor Networks (WSNs), there is a clear lack of effective, feasible and usable WSN system architectures that address both functional and non-functional requirements in an integrated fashion. This poster abstract outlines the EMMON system architecture for large-scale, dense, real-time embedded monitoring. EMMON relies on a hierarchical network architecture together with integrated middleware and command&control mechanisms. It has been designed to use standard commercially–available technologies, while maintaining as much flexibility as possible to meet specific applications' requirements. The EMMON WSN architecture has been validated through extensive simulation and experimental evaluation, including through a 300+ node test-bed, the largest WSN test-bed in Europe to date.**

I. Introduction

Wireless Sensor Networks (WSNs) have been emerging as underlying infrastructures for new classes of large-scale and dense networked embedded systems. While there has been a plethora of scientific publications on WSNs, the vast majority focuses on protocol design (e.g. medium access control, routing, data aggregation) while only a scarce number of papers report real(istic) applications [1]. This might be due to the following facts: (i) WSN technology is extremely expensive for large-scale systems, contradicting the initial "less than 1$ per node" vision; (ii) WSN technology is still very limited and unreliable, particularly in what concerns communications; (iii) difficulty on finding "killer" applications with a good cost/benefit trade–off; (iv) unavailability of standard, application-adequate, mature and commercially available technology; (v) lack of complete and ready-to-use WSN system architectures, able to fulfill both functional and non-functional applications' and users' requirements.

Despite relevant work on WSN architectures proposed so far (e.g. [2] – [8]), to the best of our knowledge, none of them fulfills all requirements for large–scale and dense real–time monitoring [9], [10]. The EMMON system architecture [11] outlined in this poster abstract pushes the state-of-the-art by combining the following aspects:

- it encompasses all system components: Command and Control (C&C) graphical user interface, communication network architecture, middleware over a standard and commercially available hardware platform;
- it considers several Quality–of–Service (QoS) properties simultaneously, e.g. scalability, timeliness (including real–time support), energy–efficiency and reliability;
- it builds upon a deep analysis of specific user/application requirements [12], problems to address [9] and previous work [10], ranking solutions/technologies according to a set of criteria;
- it is based on the most widely-used standard and COTS technologies for WSNs - IEEE 802.15.4 and ZigBee, which is good for system designers and end–users;
- it augments IEEE 802.15.4 and ZigBee with important add–ons, such as traffic differentiation, time–division cluster scheduling, dynamically adaptable duty-cycling, mitigation of the hidden–node problem and downstream geographical routing;
- the baseline IEEE 802.15.4 and ZigBee protocol stack is supported by a solid critical mass, developed in synergy with the TinyOS 15.4 and ZigBee Working Groups;
- it is supported by a unique and complete planning, dimensioning, simulation and analysis toolset;
- it has been tested and validated by extensive simulation and experimental evaluation, including through a 300+ nodes test-bed (DEMMON1 [11]). This first prototype serves as a baseline pilot experiment to support development of more system functionalities in the near future.

II. Outline of the EMMON system architecture

The EMMON system architecture aims at supporting scalability and QoS support through a hierarchical network, middleware and command and control design, as outlined next.

A. WSN architecture

Building on the alternatives identified in [10], the main features of the WSN architecture are (Fig. 1):

- Tier 0: IEEE 802.15.4 operating in synchronous mode, supporting traffic differentiation (e.g. best-effort and real-time) and duty–cycling.

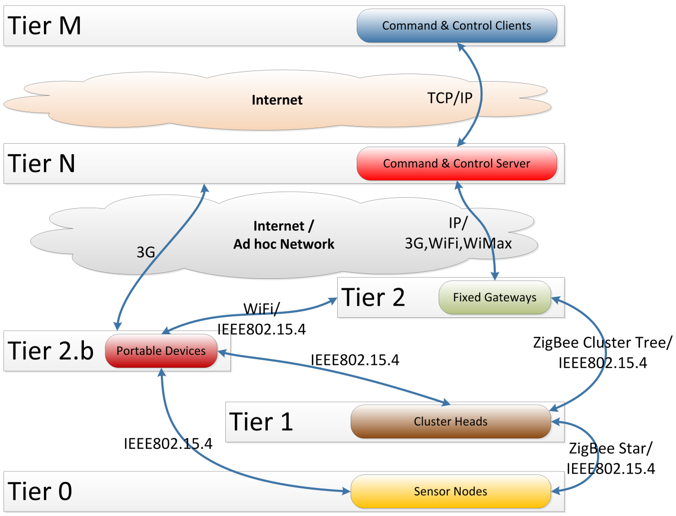

Fig. 1. EMMON High Level Multi–Tiered System Architecture.

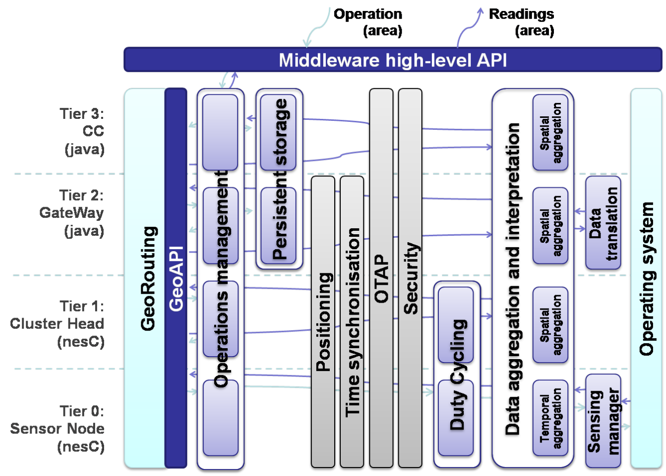

Fig. 2. EMW architecture: the light blue boxes are components from other software layers. White boxes were implemented for DEMMON1.

- Tier 1: Cluster–Tree network model (ZigBee-like) supporting distributed synchronization, time division cluster scheduling, convergecast routing upstream and geographical based routing downstream.
- Tier 2: Fixed gateways enable the interface between the WSN and the command and control over long range IP-based communication technologies.

Fig. 1 also includes an optional element of the EMMON network architecture, the Portable Device (e.g., PDA). It is indicated as belonging to an intermediate Tier2.b, since it plays a special role of mobile gateway and diagnosis element.

B. EMW: EMMON Middleware

A novel EMMON–specific middleware (Fig. 2) facilitates the development of environmental monitoring applications by abstracting away the details of the network via a geographical API. It runs on all the elements of the system and glues all the components together, from the C&C Clients to the Sensor Nodes, allowing them to work properly over the heterogeneous communication technologies (Fig. 1). The middleware distributes intelligence as low as possible in the network (given hardware restrictions) to reduce traffic generated and simplify system management.

C. C&C: EMMON Command and Control

The EMMON C&C subsystem is the most visible part of the whole system. It aims to collect readings and provide all the functionalities to the end-users. It encompasses a C&C server and multiple C&C clients, where the Graphical User Interface is implemented. Conversely to traditional C&C applications, the EMMON C&C Clients do not interact with each node individually, but with monitoring objects (e.g. a room), which can group several sensor nodes.

III. Conclusions

We outlined the EMMON system architecture aiming at enabling large-scale, dense and real-time WSN applications. It is a fully integrated and innovative system, where communication protocol stack, middleware and command and control mechanisms are combined to maintain as much as flexibility as possible, while meeting specific applications' requirements. This architecture is supported by a complete planning, dimensioning, simulation and analysis toolset and has been validated through extensive simulation and experimental evaluation. Future work will address improvements to fault–tolerance and data aggregation.

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