The E-Care@Home Infrastructure for IoT-Enabled Healthcare

Nicolas Tsiftes[1(✉)], Simon Duquennoy[1], Thiemo Voigt[1], Mobyen Uddin Ahmed[2], Uwe Köckemann[3], and Amy Loutfi[3]

[1] SICS Swedish ICT, Kista, Sweden
nvt@sics.se
[2] Mälardalen University, Västerås, Sweden
[3] Örebro University, Örebro, Sweden

Abstract. The E-Care@Home Project aims at providing a comprehensive IoT-based healthcare system, including state-of-the-art communication protocols and high-level analysis of data from various types of sensors. With this poster, we present its novel technical infrastructure, consisting of low-power IPv6 networking, sensors for health monitoring, and resource-efficient software, that is used to gather data from elderly patients and their surrounding environment.

1 Introduction

In order to cope with our aging society, a current vision in the area of ICT-supported independent living of the elderly involves populating the smart home with connected electronic devices ("things", such as sensors and actuators) and linking them to the Internet. The mission of the E-care@home project is to create such an Internet-of-Things (IoT) infrastructure with the ambition to provide automated information gathering and processing on top of which e-services for the elderly residing in their homes can be built [2].

While the things need to communicate, wiring them is, however, unfeasible, inflexible and costly. Recently, low-power wireless communication has made tremendous progress. Today, we can network at least tens of stationary, battery-driven sensors and actuators wirelessly with a lifetime of several years using low-power IP-based communication stacks [6] on top of the IEEE 802.15.4 standard. In a smart home for elderly such communication means can be used to provide a reliable infrastructure consisting of stationary nodes. Stationary nodes are, however, not enough as monitoring the health condition of elderly people also requires on-body sensors such as physical activity and weight monitoring, blood pressure, blood glucose, heart rate, and oxygen saturation. Most of these sensors do not come with support for IEEE 802.15.4, but use Bluetooth—in particular Bluetooth Low Energy (BLE). This leads to a hybrid communication architecture where stationary nodes communicate with each other using communication protocols on top of the IEEE 802.15.4 standards while on-body sensors use BLE. For communication between on-body and stationary nodes, some stationary nodes are also equipped with BLE radios.

M.U. Ahmed et al. (Eds.): HealthyIoT 2016, LNICST 187, pp. 138–140, 2016.
DOI: 10.1007/978-3-319-51234-1_22

Our healthcare application requires that in some situations, messages from sensor nodes must be delivered timely and with very high reliability. In the following we explain more about our architecture, which caters to these application requirements, and provide some initial evaluation results.

2 Architecture

The E-Care@Home software architecture, illustrated in Fig. 1, comprises different components that are built to execute in Contiki, an open-source operating system for the IoT [1]. To be able to meet specific application goals regarding metrics such as packet delivery rate, energy consumption, latency, and node lifetime, we employ TSCH (Time Slotted Channel Hopping MAC), one of the MAC protocols of the IEEE802.15.4-2015 standard [3]. At the routing layer, we use RPL [8], the routing protocol for low-power IPv6 networks standardized by the IETF ROLL working group.

Table 1 shows some results from our previous work [5], which reveals that even without centralized scheduling, TSCH achieves end-to-end delivery ratios of over 99.99 %. Hence, we improve reliability by two orders of magnitude compared to asynchronous low-power MAC protocols, while achieving a similar latency-energy balance. Furthermore, we can provide bounds on energy consumption. One of the challenges in our project is to extend the performance bounds to end-to-end latency and also include the on-body sensors that use BLE.

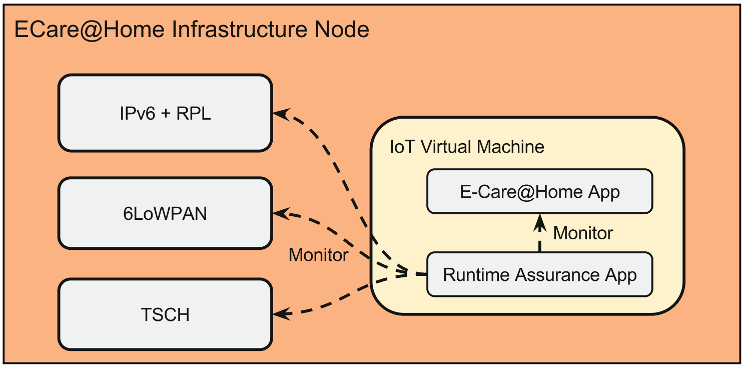

Fig. 1. The software architecture of static infrastructure nodes comprises a low-power IPv6 stack, built on top of TSCH. The application software runs in a virtualized environment that provides safe execution.

Another key component of the architecture is a virtual machine, which executes bytecode in a safe manner so that application software cannot exceed their assigned privileges. Inside the virtual machine, the sensing application executes and communicates sensor samples and system status to a base station using

Table 1. Performance of Contiki's 6TiSCH implementation on a 98-node testbed. RPL + TSCH data collection at a 1-minute packet interval [7].

	Delivery ratio	Latency	Radio duty cycle
Always-on	99.910%	126 ms	100.0%
6TiSCH Minimal (3-slot slotframe)	99.870%	349 ms	3.1%
6TiSCH with Orchestra Scheduler	99.996%	514 ms	1.6%

CoAP and UDP over IPv6. Depending on the type of sensor, the communication can occur at regular intervals or in response to events. Some health parameters, such as blood glucose and weight, are measured sparsely; whereas others, such as electrocardiography and respiratory rate, are measured continuously at specific time periods [4].

The base station, which collects all incoming messages from the infrastructure nodes and the on-body nodes, contains a sensor database, which stores all sensor samples in a structured manner, and which can be used to extract data for context-aware data processing and reasoning. Another application residing in the virtual machine is the runtime assurance application, which continuously monitors the main parts of the system, and ensures that the performance stays within the guaranteed bounds.

Acknowledgment. This work and the authors are supported by the distributed environment E-care@Home, which is funded by the Swedish Knowledge Foundation 2015-2019.

References

1. The Contiki Operating System. http://www.contiki-os.org/
2. The E-Care@Home Project. http://www.ecareathome.se/
3. IEEE Standard for Local and metropolitan area networks–Part 15.4. IEEE Std 802.15.4 (2015)
4. Ahmed, M.U., Björkman, M., Causevic, A., Fotouhi, H., Lindén, M.: An overview of the internet of things for health monitoring systems. In: 2nd EAI International Conference on IoT Technologies for HealthCare (HealthyIoT) (2015)
5. Duquennoy, S., Al Nahas, B., Landsiedel, O., Watteyne, T.: Orchestra: robust mesh networks through autonomously scheduled TSCH. In: Proceedings of the International Conference on Embedded Networked Sensor Systems (ACM SenSys), Seoul, South Korea (2015)
6. Hui, J., Culler, D.: IP is dead, long live IP for wireless sensor networks. In: Proceedings of the International Conference on Embedded Networked Sensor Systems (ACM SenSys), Raleigh, North Carolina, USA, November 2008
7. Watteyne, T., Handziski, V., Vilajosana, X., Duquennoy, S., Hahm, O., Baccelli, E., Wolisz, A.: Industrial wireless IP-based cyber physical systems. In: Proceedings of the IEEE, Special Issue on Cyber-Physical Systems (2016)
8. Winter, T., Thubert, P., (eds.) et al.: RFC 6550: RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks, March 2012