An IoT-Aware Architecture for Smart Healthcare System

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Abstract

- Smart hospital system (SHS) relies on complementary technologies specifically RFID, WSN, and smart mobile, interoperating with each other through a Constrained Application Protocol (CoAP)/IPv6 over low-power wireless personal area network (6LoWPAN)/representational state transfer (REST) network infrastructure. The SHS is able to collect, in real time, both environmental conditions and patients’ physiological parameters via an ultra-low-power hybrid sensing network (HSN) composed of 6LoWPAN nodes integrating UHF RFID functionalities. Sensed data are delivered to a control center where an advanced monitoring application (MA) makes them easily accessible by both local and remote users via a REST web service.
Introduction

• Current procedures for patient monitoring, care, management, and supervision are often manually executed by nursing staff.

• Need of delivering quality care to patients while reducing the healthcare costs and deal with the nursing staff shortage problem.

• IoT technologies are spurring the smart systems to support and improve healthcare

• Technologies enabling the implementation of smart healthcare systems:
  • radio frequency identification (RFID)
  • wireless sensor network (WSN)
  • smart mobile

Proposed SHS

• Guarantee innovative services for the automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes.

• Able to collect, in real time, both environmental conditions and patients’ physiological parameters via an ultra-low-power hybrid sensing network (HSN)

• Composed of 6LoWPAN nodes integrating UHF RFID Class-1 Generation-2 functionalities.
  • During normal operations, therefore (no WSN based transmission)
  • Timely and reliably manage emergency situations (WSN-based transmission is activated)
Related Work

- UHF RFID technology are mainly focused on tracking patients in hospitals and nursing institutes.
  - Ex. NIGHT-Care, for monitoring the state of disabled and elderly people during the night.
  - UHF RFID technology is limited to patient/devices monitoring and tracking in quite small environments because RFID tags can operate under the reader coverage region.

- WSN technology are used to implement solutions to meet the specific requirements of pervasive healthcare applications.
  - WSN allows the patients to be monitored in a more efficient manner at the cost of complex algorithms required for their accurate tracking.

- Combining UHF RFID and WSN technologies could bring considerable benefits

System Architecture Overview

[Diagram of system architecture overview]
6LRR Device

Hardware:

- Planned scenario relies on two distinct levels of integration between IEEE 802.15.4-based WSN and RFID devices.
  - reader-level
  - tag-level

- Proposed integration strategy makes the information exchanged between the tag and the reader via the Gen2 air interface directly accessible by 6LowPAN devices.

- allowing standardized EPCglobal data to be relayed over the IEEE 802.15.4-based 6LowPAN network.

6LRR Device

Software Integration:

- Interfacing between XM1000 mote and Discovery Gate UHF RFID Reader have been implemented in Contiki OS.

- Organized in several layers and highly memory efficient.

- Full IP network stack, with standard IP protocols such as UDP, TCP, and HTTP

- Supports IETF protocols for low-power IPv6 networking
  - 6LowPAN adaptation layer
  - RPL IPv6 multihop routing protocol
  - CoAP RESTful application-layer protocol
HT Device

• 3 main parts:
  • a dual-interface RFID Gen2 tag
  • a 6LowPAN node
  • a multi-sensor board

• Contiki OS has been chosen to develop the MCU firmware of the 6LoWPAN node.

• Implementing required software components for MB851 MCU to communicate with both sensors and RFID chip.

Architectural Details
Hybrid Sensing Network

- REST Request/Response paradigm piggybacked on CoAP messages has been exploited in the HSN design.

- 3 different resources can be identified:
  - ambient sensor
  - health sensor
  - RFID-related resources

- Each resource can be individually accessed from anywhere in the Internet by using CoAP methods

IoT Smart Gateway

- Two-Way Proxy:
  - enables transparent communication with CoAP devices
  - receive, process, and reply to requests
  - embeds a resource directory

- Management Application and Control DB:
  - standalone Java application
  - allows network operators to control hospital environmental conditions
  - responsible for monitoring the patients’ health status and alerting doctors in case of critical situations

- Secure Access Manager and User DB:
  - ensures privacy and data protection
User Interfaces

- **Operator Interface:**
  - allows network operators to register to the SHS
  - set rules and alarm notifications
  - configure new nodes identified using the RD server

- **Medical Interface:**
  - allows medical staff to register to the SHS
  - configure the HT nodes assigned to new hospitalized patients
  - visualize and change the historical patient data
  - allows doctors to directly access to the health sensor data of each patient wearing an HT node
  - doctors can interact remotely with the system using the Medical App

Proof of Concept
Functional Validation

- Main actors of the system are:
  - HT node, in charge of monitoring the patient’s health status and detecting potential patient’s falls
  - 6LRR node, in charge of reading and delivering to the IoT Smart Gateway data retrieved from the user memory of the Monza X-8K RFID chip equipping the HT node.
- Demonstrate the efficiency of SHS, the 6LRR and the HT nodes maintain a list of active subscriptions, while, in the MA, an event handler is installed at run-time and associated to receive notification messages.
- The functional validation has been conducted considering 2 cases (patients’ monitoring and emergency)

Architecture Comparison

- Few attempts to combine UHF RFID and WSN technologies in the healthcare application scenario.
- Proposed SHS is able to track and monitor medical devices and hospitalized patients, and also to provide medical staff with advanced features and services.
- Reducing power consumption by allowing HT nodes to maintain their IEEE 802.15.4 transceiver in deep sleep mode.
- Services provided by SHS: patient tracking, staff tracking, remote patient monitoring, and alert notification (table IV)
Conclusion

- SHS architecture for automatic monitoring and tracking of patients, personnel, and biomedical devices within hospitals and nursing institutes has been proposed.

- Complex network infrastructure relying on a CoAP, 6LoWPAN, and REST paradigms has been implemented.

- Proposed system perform identification and tracking of patients, nursing staff, and biomedical devices within hospitals and nursing institutes, and provide power-effective remote patient monitoring and immediate handling of emergencies.