Short Term Scientific Mission (STSM) Scientific Report for COST Action IC1404 MPM4CPS

November 22, 2018

1. Initial purpose of the visit

Internet access, e.g. with IEEE 802.11 protocol, is one of the common methods of communication for Cyber-Physical Systems (CPS). One of the embedded devices providing an easy way to use Internet access for communication is NodeMCU. On the other hand, there are recent low power communication mechanisms, e.g. IEEE 802.15.4 protocol, which are used in Wireless Sensor Networks (WSN). These networks can be expanded without adding extra sink nodes to collect data from different resources, such as sensors. Benefiting from a multi-hop network, additional source nodes can send data via relay nodes with low transmission power to the sink node. Use of both Internet protocols and low power communication can bring the advantage of both. In this STSM, a use case called Fire Detection system is applied. This system will have both communication approaches as well as computation and control properties (3C) as a CPS. This CPS has also a log management system which handles the human interaction and feedback. This study focuses on the development processes of the use case, considering the hardware, software and networking aspects of the system. In the scope of this STSM the prototype of the case study is implemented and a detailed report of its architecture and development process is presented.

2. Description of the work carried out during the STSM

A fully-functional demonstration of the use case is implemented as a CPS using IoT and WSN. This CPS includes:

- WSN based Sensors

- IoT based Actuators and Sensors

- Cloud based Log manager

- HCI using push notifications

The CPS is developed for a fire-detection system in a library. The architectural view of the system is depicted in Figure 1.
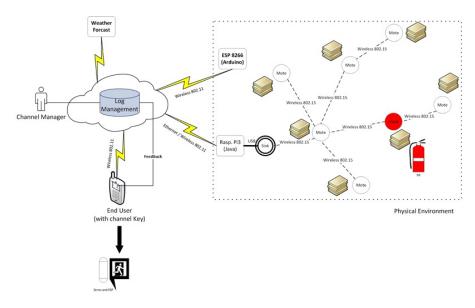

Figure 1: The architecture of fire detection system.

To establish a WSN, the system is developed using IRIS motes to measure the temperature. These motes have the low power IEEE 802.15.4 compliant. Although WSNs are battery powered, they have energy efficient microprocessors and low energy transmission protocols leading to a feature of long life battery.

In the scope of this study, the nodes are considered to be placed on the bookshelves of a library, and the ESP8266 (as a NodeMCU) is positioned at the center of the building to measure the ambient temperature. In our study, Contiki operating system is selected to implement the nodes with features of IPv6 addressing and low power packet transmission for energy saving purposes. Furthermore, Contiki operating system supports lightweight stack-less proto-threads which reduces memory consumption and supports multi-threading. The

sink node, which collects all data from the source nodes, is connected to the gateway using Universal Serial Bus.

Another part of the system is a RaspberryPI 3 and a Java application running on it to implement the gateway. The Java application is developed to read the serial port, send the data to the Log Manager, gather forecast information from a website using an API and send notifications to Smart Phones. Moreover, the Java program has a GUI which displays a blue, orange or red screen depending on the local temperature (around,a little bit higher, or higher than average building temperature).

The local temperature is the temperature that is collected by a source node locally and the building temperature is the temperature which is measured by an ESP8266. To this end, an ESP8266 module with a Wi-Fi transceiver using IEEE 802.11 protocol is used and located in the common place of the building.

The ESP8266 consumes an electrical current 7 times greater than a IRIS mote. To reduce this consumption and to gain more efficiency, ESP8266 can be operated in deep sleep mode. Unlike IEEE 802.15.4 protocol, IEEE 802.11 protocol does not require additional gateway to send data to the Cloud. The ESP8266 can send the data directly to the Cloud using GET or POST methods.

The last but not least part of the system is a Cloud based information processing system called Log Manager which is implemented to handle the data. It keeps forecast information, source nodes temperature values, and ESP8266's room temperature. If any temperature rising occurs, it sends a callback to another ESP8266 which controls the door lock, to unlock the door. It can also send notifications to the mobile phones (to notify the end users/visitors).

3. Description of the main results obtained

A WSN can be implemented using a single hop or multi-hop connections. The selection of this connection is important for the performance of the system. Typically, a source node can transmit a packet as far as 150 meters in open area without any obstacles to reduce transmission distance. Inside an area such as a library, there are many obstacles such as visitors, shelves, books which are mostly wooden objects which affects transmission power and distance. During our experiments, the transmission distance is reduced to nearly 30 meters.

An expanded library area requires a network to be able to cover all area, and a single-hop network cannot maintain coverage for such a place. There is a need for several sink nodes for different rooms and a computer for each sink to read incoming data. This would rise the system cost unnecessarily. In the single-hop network with several sink nodes, there would be problem of synchronization between sink nodes. Moreover, in case one of the sink nodes has powered off for any reason, the whole network at that area would be down. The multi-hop connection is a promising solution for increasing throughput and providing coverage for a large physical area without these challenges. Therefore, in this use case, a multi-hop network is used instead of a single-hop network.

During this study, the technical challenges were generally about integrating multiple components and satisfying their stability. WSN nodes and ESP8266

modules require a common component which acts as a bridge to compare the measured results. Moreover, ESP8266 power consumption is far more than IRIS, and to overcome this problem and avoid increasing the system's energy consumption, deep-sleep feature of the ESP8266 is used.

As a conclusion, the system has many components and modules which are interacting each other to build the CPS. These components and modules are handled mostly by application software (such as the gateway, log manager, and HCI) or embedded software (such as ContikiOS program and Arduino program). This brings structural complexity to the system design and implementation. Also, the technological variety for the tools to implement the system brings even more complexity to the development of the CPS.

For reducing the complexity of the system development, considering the multi-paradigm characteristic of the system, a higher level of abstraction can be a useful technique to avoid the details in different phases of developing the system. To this end, further studies can be established to model each of the main components in the system and use them for the system development. Also, platform independent modeling techniques and model transformation mechanism can be used to protect the developers from the technological variety.

4. Future collaboration with the host institution (if applicable)

The collaboration will continue to complete the work and publish the developed use case.

5. Foreseen publications/articles and other contributions

In this STSM, the detailed process of developing a use case of IoT and WSN aware CPS including analysis, design, modeling, and implementation were realised. The detailed report is going to be published as a book chapter in the scope of WG4.