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DEVELOPING A WIRELESS SENSOR NETWORD WITH RFID CAPABILITIES

empirical study

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Abstract

The concept underlying the pervasive communications systems is Internet of Objects, defined as a global network of smart objects, resulting in "attachment" of communication functions, data acquisition, data processing objects we interact with daily. Internet of Objects will be based on 4th generation of Internet systems. In such systems, each intelligent networked device must offer its users a number of services, which constitute a development of the current model of Web services. Such services will result from aggregation of micro services offered by each pervasive device connected to the Internet. Aggregating these micro services requires that each node in the network has the opportunity to present / expose its capabilities (so-called "advertising") in a standard way for client applications to be integrated into complex services. Therefore there appears the need to introduce a coding scheme to identity the nodes in the network, enabling the identification of their capabilities. An alternative to implementing such a system of encoding / identifying characteristics of network nodes is active RFID technology. The aim of this chapter is to develop a method to ensure the convergence of wireless sensor networks with active RFID systems within a pervasive hybrid network based on the IEEE 802.15.4 standard, which satisfies the Internet of Objects network.

1. CLASSIFICATION OF METHODS OF INTEGRATING WIRELESS SENSOR NETWORKS WITH RFID SYSTEMS

In terms of applications that can be developed, hybrid networks WSNRFID potential is considerable. The integration of these two technologies must take into account the specificities and constraints of the developed application, and according to them there are several possibilities for integration. At concept level we defined four categories of alternatives for integrating WSN networks with RFID technology (illustrated in Figure 1).

The integration method that we propose in this chapter falls into the second category of solution integration, and involves extending the capabilities of WSN MICAz nodes, so that they reach to encompass the functionality of RFID tags and readers, respectively.

2. ANALYSIS OF WSN - RFID INTEGRATED METHODS FROM THE USED TECHNOLOGIES PERSPECTIVE

In terms of wireless technology used, there are 3 main directions of development in the field of active RFID systems (discussed in Chapter 1), namely

- Active RFID systems based on IEEE 802.15.4 standard in the bands 868 MHz, 900 MHz and 2.4 GHz
- Active RFID systems based on the IEEE 802.11 standard in the 2.4 GHz band
- Active RFID systems based on ISO 18007 (DASH7) in 433 MHz band

Since most of the current WSN networks use IEEE 802.15.4 radio stack, active RFID systems based on this standard can be easily integrated with such networks as WSN. That is why we opted for developing such integration methods.

3. DEVELOPMENT OF A METHOD FOR INTEGRATING WSN-RFID IN A HYBRID PERVASIVE NETWORK

The purpose of this subchapter is to present the principles of the WSN - RFID integration method that we defined and implemented in this paper. WSN - RFID hybrid network architecture, communication protocol and logic operation for each category of node wireless network are presented.

From the architectural point of view the proposed network has a tree topology (Figure 2). The network consists of three classes of components, as follows:

- **Tag type nodes** – are active RFID nodes (battery-powered), capable of transmitting, in addition to identification data to RFID (RFID code associated), ambient data taken from sensors connected to such nodes. Tags regularly transmit such data to the reader parent from their coverage range. Communication tag reader is based on the IEEE 802.15.4 standard.

- **Reader nodes** (interrogator) - periodically receives data from the tags within their coverage range, to which they respond with receipt confirmations (acknowledgment - ACK). Once received the data from the tags, they are directed to the coordinator node of the network. Reader nodes, together with a coordinator node, form a network based on IEEE 802.15.4 standard / ZigBee.
- **Coordinator node** – its role is to initialize and create the IEEE 802.15.4 network (formed together with the interrogators nodes) and to achieve WSN server network interface with the monitor and control server of the network, which is connected via USB interface.

3.1. The working principle of hybrid pervasive network

The proposed WSN-RFID hybrid network operates on the principle "tag talks first" (TTF - Tag Talks First). In other words, each tag node regularly transmits (to the parent reader it belongs) a pack containing besides identification data (RFID code), data from sensors it is equipped with. The readers that successfully receive this data (Atmega 128L Serial Flash Memory Log ID 802.15.4 Transceiver Connector Antenna 51 Pins) send an acknowledgment to the tag. Confirmation transmission mechanism is needed to resolve problems that arise in environments where the number of tags / reader is very high. In such cases problems occur due to concurrent access to the transmission medium. Reader directs data to the coordinator node, determining the next step of routing. Coordinator node confirms data from the reader, then directs them to the server of monitor and network control via USB interface.

The principle of TTF communication was elected to the detriment of the principle of ITF communication (Interrogator Talks First) to reduce energy consumption at the tag. Thus tag can operate in hibernation mode for a predetermined period of time and can "wake up" periodically to acquire sensor data and transmit it to the RFID reader along with associated code. There is also the possibility that the tag nodes is not attached permanently to the readers' network, which give them greater flexibility in terms of choosing various networks available at a time and migration between different networks.

3.2. Tags interaction with the query network

Tag nodes within the hybrid network are equivalents to RFD devices (Reduced Function

Devices) within an IEEE 802.15.4 classic network, not having data routing capabilities. Thus they can only operate on the edge of pervasive networks. In designing their functioning mode it was aimed to minimize energy consumption by maximizing periods of hibernation and reduce transmission to a minimum.

4. IMPLEMENTING A HYBRID NETWORK USING A WSN DEVELOPMENT PLATFORM WITH REAL-TIME OPERATING SYSTEM

As noted above, for demonstrating the capabilities of the method of integrating WSN networks with active RFID systems proposed in Section 4, it was implemented a network functional core, based on MICAz platform. The main functional characteristics of MICAz wireless nodes (having the architecture illustrated in Figure 3) are the following:

• ATmega 128L, 8-bit, 7.7 MHz clock, 128 kB Flash memory, SRAM 4KB memory Microcontroller

• Transceiver RF Chipcon CC2420, frequency band 2400 MHz, the maximum transfer rate: 250 kbps

• Sensors for temperature, humidity, pressure, light and accelerometer for 2 axis at software level, the implemented hybrid WSN-RFID nodes use in real-time the TinyOS operating system.

It was chosen TinyOS as it is the standard solution for real-time operating systems for wireless sensor networks. TinyOS open source solution is most often used in practice in WSN deployments, being recognized for its performance in the academic community. For each category node (tag, reader and coordinator) it has been developed one application TinyOS. These applications represent implementations of network operating principles set out in section 3. The applications were written out in NesC, an extension of the C programming language dedicated TinyOS operating system. Next there will be presented the structure of TinyOS applications that have been developed for node tag, reader and coordinator node respectively.

4.1. The application for tag node

The diagram in Figure 4 shows the composition of the application tag, highlighting application components (represented as nodes of the graph) and the interfaces between them (shown by arcs of the graph). For each triplet of the form (Component A, X interface, component B), the direction of the arch indicates the interface that uses component X (in this case the component A) and the component that provides the interface X (in this case the component B). Each interface consists of orders and / or events. A component A using an interface X provided by component B , calls orders provided by the component B and implements the callback functions for handling events generated by interface X. In other words, the communication from A to B is accomplished by calling some commands, and from B to a by means of events.

For tag application, the used components are as follows:

• **Main** - the first component that is executed for any TinyOS application. Through StdControl interface it initializes RfidTagM component (the main component to the tag). StdControl interface is the main control interface of TinyOS components.

• **RfidTagM -** is virtually TinyOS’s main component (in the terminology of TinyOS is called "mode”) from the perspective of the developer, here being implemented the logic of the developed application.

• **XMeshBinaryRouter** - is the component that implements the network layer of the stack XMesh , providing interfacing with the mechanism routing (interface RouteControl) , referral data (code RFID + data from the sensor Sensirion) in a multipurpose manner (interface MhopSend) and operating under ELP regime (Extended Low Power) to reduce energy consumption of CC2420 transceiver .

• **XPLPowerManagementM** - is the component that provides energy management services for microcontroller Atmega128 at the application level

• **Timer** - Is a component that provides timing services needed for determining the precise duration of each cycle of the program. Specifically, in this case it used a timer which at every 30 seconds “wakes up” the node from hibernation phase to acquire sensor data and send it to the reader.

• **SensirionHumidity** - component that provides the interfacing of the application with the temperature and Sensirion SHT11 humidity sensor with which the sensor board MTS400 is equipped.

4.2. The application for the reader node

The TinyOS application structure for reader node is illustrated in the diagram in Figure 5. As can be seen, from the perspective of application, node reader is used to initialize and start XMeshBinaryRouter component (through StdControl interface), interface that implements the entire routing logic in a multipurpose manner.

4.3. The application for the coordinator node

Similar to the reader application, the application for the coordinator node (structure shown in

Figure 6) relies heavily on services provided by the XMeshBinaryRouter component which offers, besides classic services of data routing, services of data targeting, received via the radio interface, to the serial port of the coordinator node.

5. CONCLUSION

The aim of this chapter was to design, develop, implement and test a method for securing the convergence of wireless networks of pervasive devices (such WSAN) with active RFID technology. The method that was defined and implemented aims to capitalize on the untapped potential of both technologies by creating a hybrid network consisting of nodes that can “promote “capabilities to applications that use them. Thus each node of a pervasive network provides a micro service which can be aggregated at middleware level to create a comprehensive service.

The proposed method was chosen after a thorough analysis of the main potential solutions for integrating the two technologies mentioned above. It has opted for a highly versatile and flexible method for extending the functionality of a "classic" WSN network by introducing a RIFD mechanism for encoding. Thus a sensor node is converted to a WSN – RFID node, including either the functionality of RFID tag or RFID reader functionality. The integration consisted in designing and developing a network architecture that includes such hybrid nodes. It was also designed a communication protocol that defines the principles of interaction between the various categories of nodes in the network. For implementation it was chosen the MICAz development platform, a platform that has become somewhat standard in the academic world in terms of research in WSN domain. In terms of software there were developed applications that use services of abstracting the details of the hardware, offered by the TinyOS real-time operating system.

Reading recommendations

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Annexes

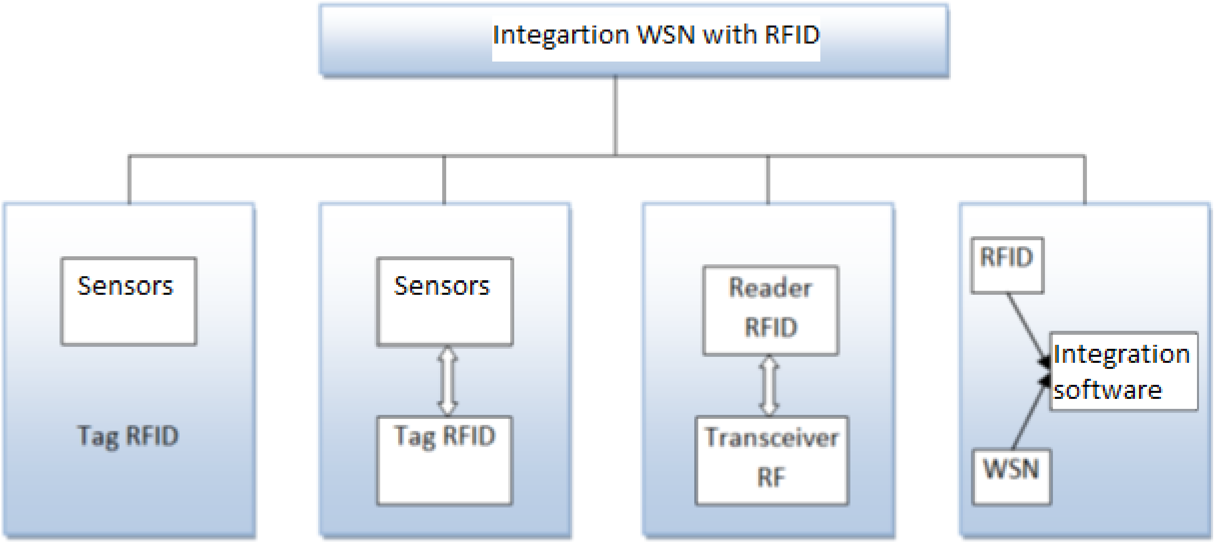

Figure 1: Classification of WSN-RFID integration methods

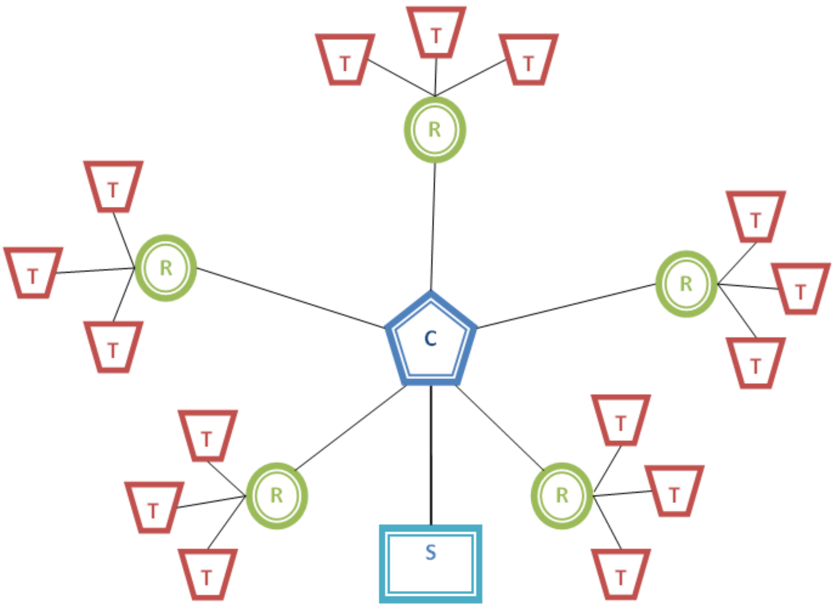

Figure 2: The network architecture of hybrid wireless sensor nodes with RFID functionality (T -Tag, R- Reader C- Coordinator, S -Server Monitoring and Control)

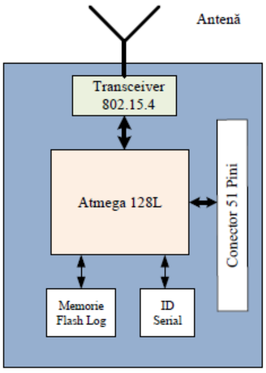

Figure 3 Architecture of MICAz node

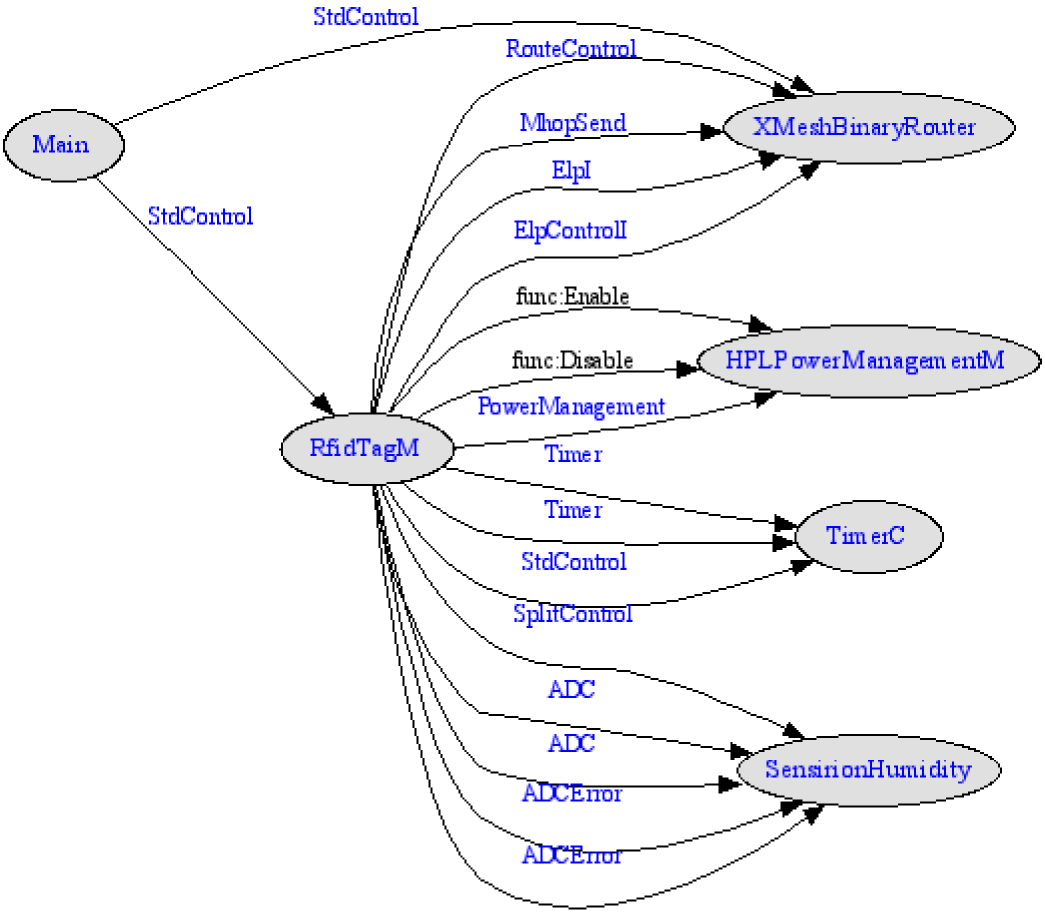

Figure 4: The structure of TinyOS application for tag node

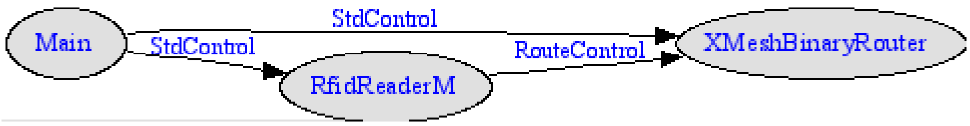

Figure 5: The structure of TinyOS application for Reader node

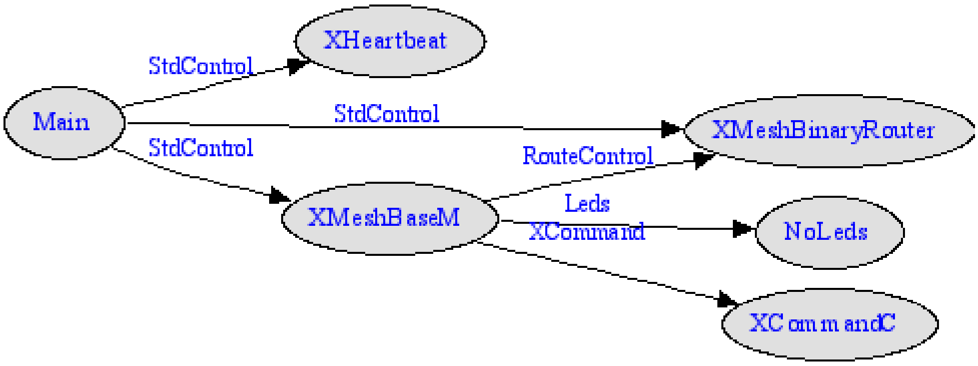

Figure 6: The structure of the application for Coordinator node