IP-based RFID architecture and location management

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Abstract: **Designing IP-based RFID system allows low cost deployment and easy integration with IP-based services. In this paper, we propose IP-based RFID architecture and focus on location management which allows determining "where" the object is after moving. The IP-based RFID architecture includes several components that allow collecting information from RFID infrastructure and updating the current location of RFID tags. A SIP-oriented architecture is proposed for validation purpose.**

Keywords: **RFID, EPC network, location management**

1. INTRODUCTION

Radio frequency identification (RFID) has been developed since decades. RFID technology makes it possible to identify an object, to track it and to know its characteristics remotely with a label emitting radio waves, integrated or attached to the object. RFID technology enables reading of labels even without direct line of sight and can pass through thin layers of material (paint, snow, etc.).

In the short future, RFID may evolve into something that we cannot comprehend today. Every day, our understanding of the fundamentals of RFID is refined and new applications are conceived [1].

The first known implementation of RFID is believed to be the "identification, friend or foe", or IFF, system developed during the World War II.

In 1978, RFID tags were successfully implanted under the skin of dairy cows. The tags employed contained peripheral functionality in additional to standard identification. The tags could not only identify cow but could also measure and transmit their body temperature. A cow implanted with one of tags could be monitored for possible health issues, ovulation cycles, and felling patterns [2].

The United States Department of Defence (DoD) was the first major entity to throw fuel on the RFID fire. The DoD was one of the early adopters of the technology because of potential logistics rewards.

Companies around the world have field-tested and implemented RFID solution ranging from food produce monitoring to hospital workflow management. Companies like Nokia, for instance, are integrating RFID system with mobile phone either in tag mode, in reader mode or both. These phones can enable online transactions using RFID credit cards in the near future [3] [4].

We envision a future network where the very cheap components (RFID tags) are attached to all kind of objects (e.g., product, animal, or person …) or integrated into IP devices (e.g., PDAs, smart phones, or laptops ...) thus enabling a large scale use of the RFID technology[1].

The most representative RFID management system is the EPC global network developed by EPCglobal [5][6] [7]

EPCglobal is an industry-driven organization which aims at standardizing the electronic product code (EPC) and an automatic identification system in the supply chain. EPC code stored in the RFID tag allows uniquely identifying a physical object. EPCglobal defines EPCIS (EPC information system) for object identification. The EPCIS includes several components that allow accessing/exchanging information between the enterprises subscribing to the EPCglobal network.

Our work is motivated by developing IP-based RFID system thus enabling low cost and large scale deployment of the RFID technology as well as openness and ease of integration with IP-based services.

In this paper, we propose IP-based RFID architecture and focus on location management which allows determining "where" the object is after moving. When the object moves between RFID readers coverage, its location is updated. The object location is considered to be the IP address of the RFID reader that the object is attached to.

IP-based RFID architecture includes several components that allow collecting information from RFID infrastructure and updating current location of the RFID tags.

This paper is organized as follows. Section 2 presents a motivating scenario. Section 3 briefly summarizes the RFIDs technology and ECPglobal network. In section 4, we present IP-based RFID system architecture, its components and its operation. The architecture validation based on SIP (Session Initiation Protocol) [8] is also presented in this section. Section 6 concludes this paper with further work.

2. MOTIVATING SCENARIO

In this section, we present a motivating scenario that shows the benefits of RFID/IP integration and utility of location management services in daily life.

Dr. John wears a doctor card integrating an RFID tag. In the hospital, the RFID readers are installed everywhere. Dr. John moves often from this hospital to another one. When Dr.

[1] *This work is a part of the SUN (Situated and Ubiquitous Network) research project which aims at defining a global communication network including RFIDs and IP entities. It introduces a new IP-based RFID architecture to support location and mobility management. The French National Research Agency (ANR) funds this project.*

John moves under the RFID reader coverage, the RFID reader learns the tag attached on his card and the location service updates the Dr. John location. If someone wants to look for Dr. John, he/she can ask the location service to determine where Dr. John is.

Dr. John has a laptop integrating a RFID tag. Sometime, Dr. John does not remember where he lefts his laptop. As in the previous case, the location service can help him to determine easily the location of his laptop.

3. BACKGROUND AND RELATED WORKS

3.1 RFID technology

RFID is a technology that allows a RFID tag attached to object to be identified at a short distance using radio frequency. These tags contain transponders that emit messages readable by specialized RFID readers.

RFID tags fall into two general categories, active and passive, depending on their source of electrical power. Active RFID tags contain their own power source, usually an on-board battery. Passive tags obtain power from the signal of an external reader. RFID readers also come in active and passive varieties, depending on the type of tag they read.

There are multiple standards relative to RFIDs. The ISO 14443 standard introduces components dealing with the 13,56Mhz frequency that embed a CPU and consume about 10mW and the maximum working distance (from the reader) is about 10cm. The ISO 15693 standard also uses the same 13,56 MHz frequency, but enables working distances as high as one meter. The ISO 18000 standard defines parameters for air interface communications associated with the following frequencies 135 KHz, 13,56 MHz, 2.45 GHz, 5.8 GHz, 860 to 960 MHz and 433 MHz. The ISO 18000-6 standard uses the 860-960 MHz range and is the basis for the Class-1 Generation-2 UHF RFID, introduced by the EPCglobal consortium [9] [10].

Recently, the combination of the RFID tags and Wi-Fi technology allows to enlarge the coverage area of the RFID technology. *AeroScout* solutions use Wi-Fi-based Active RFID to provide complete wireless asset tracking and monitoring [12].

3.2 EPCglobal Network

The Electronic Product Code (EPC) was designed by EPCglobal in 2001 to provide an automatic identification system in the supply chain. The EPC is a unique physical identifier of a physical object stored in a RFID tag.

Figure 1 shows the EPCglobal architecture. It includes two main components: EPC information service (EPCIS) and object name service (ONS).

EPCIS allows exchanging data between enterprises subscribing to the EPCglobal Network. The EPCIS includes several components such as RFID reader, filtering/collecting middleware, EPCIS capturing application, EPC repository, and EPCIS accessing application. These components allow scanning the EPCs code of the RFID tags within the coverage of a given reader and filtering/collecting of received data based on the criteria defined by the EPC capturing application. Then, the data are stored at the EPC repository to be used by others companies. The EPCIS accessing application carried out overall business decision.

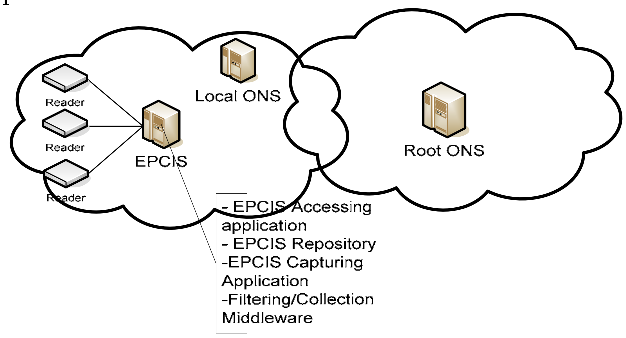

Figure 1 - The EPCglobal Network Architecture

The ONS provides a simple lookup service, which takes an EPC as an input and produces a contact address of the EPCIS as the output. The ONS can be hierarchically implemented similar to the DNS in the Internet. In the EPC architecture, the ONS hierarchy includes two kinds of ONS: root and local ONS.

The object location management implements two main functions: location registration and tracking request.

a. Location Registration Procedure

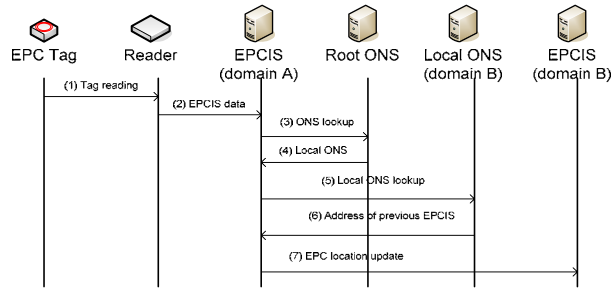

Figure 2 - The EPC location registration procedure

In Figure 2, the following steps are performed for location registration in the EPCglobal network.

Two EPCIS domains are considered: domain A and domain B.

When a tag or tags enter the interrogating field of a reader, for example, in domain A, they are identified by the reader.

The information read is then forwarded to the EPCIS of domain A. The middleware of the EPCIS performs the filtering and collecting function.

The EPCIS of domain A finds the corresponding EPCIS of domain B that maintains information about the tag, by consulting the root ONS.

However, if the root ONS is unable to resolve the EPC number, it delegates further lookup procedures to the local ONS which resides in the domain B. The local ONS replies with the EPCIS's address (B). Finally, the EPCIS of domain A updates the current location of the object by sending a location registration message to the EPCIS of domain B.

b. Location Tracking Procedure

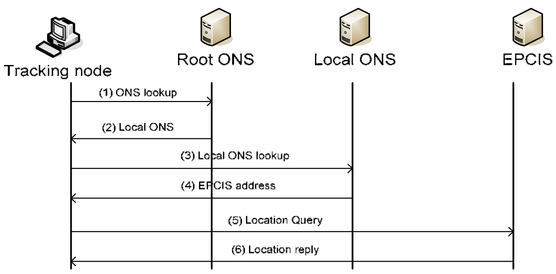

Figure 3 - The EPC location tracking procedure

Figure 3 illustrates a location procedure in EPC network. We assume that a tracking node (TN) (e.g. a computer) wants to obtain the location of an object identified by an EPC number. For this purpose, the tracking node consults the root ONS and local ONS. The same procedures as illustrated in the location registration procedure are executed.

After finding the corresponding EPCIS, the TN sends a location query to it. On receiving this query, the corresponding EPCIS replies with the current location of the object. Note that this step (object localization) is carried out by a specific application which is not provided or specified by EPC global network.

4. IP-BASED RFID ARCHITECTURE AND LOCATION MANAGEMENT

With the motivation to develop IP-based RFID system to allow low cost and large scale deployment of the RFID technology as well as openness and ease of integration with IP-based services, we conceive IP-based RFID architecture. In particular, to localize the current location of the RFID tags which are attached to all kind of objects, IP-based RFID architecture makes it possible to track the current location of the RFID tags. Each RFID reader is assumed to have an IP address. A tracking node (e.g. computer) can learn the current location of tags by associating the RFID number with the IP address of reader which the tag resides.

4.1 System Architecture

The system architecture is depicted in Figure 4. It includes the following components: the RFID readers, a location database, RFID Agent (RA), a location server (LS), and a name server (NS).

-*RFID Readers:* are installed to read information from RFID tags.

- *Location database:* is a database maintaining the current tag's location, in particular, the mapping between the RFID number and the IP address of the reader the object is attached to.

- *RFID Agent (RA):* is a component that fulfils the functions of the middleware of the RFID system such as RFID collecting/filtering. The filtering function is similar to the filtering/collecting middleware in EPC. In addition, RA is responsible for location registration procedure. RA is a logical entity which can be integrated within the RFID reader if sufficient (hardware and software) resources are provided by the reader or can exists independently.

- *Location Server (LS):* is a server that accepts register and tracking requests. When receiving register requests, LS stores the information it receives into the location database. This database is used to manage the RFID tags' current location. Each RFID has its own home location at its home domain. When the RFID tag moves to a visited domain, it should make a location registration procedure to the current location and inform its home location to update the current location. When receiving the tracking requests, LS looks up the location database and replies the current location of RFID tags.

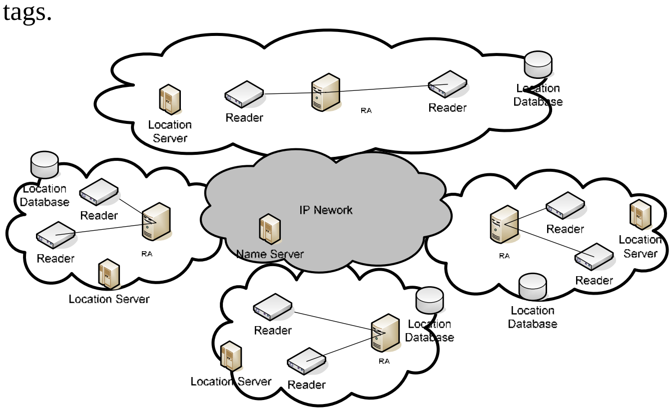

Figure 4 - IP-based RFID architecture supporting location management

- *Name server (NS):* is a database to maintain the mapping between the RFIDs tags and the address of the location servers. The NS provides lookup service similar to DNS or ONS. For example, the NS takes an RFID tag as an input and returns the IP address of the home location server as the output.

Due to performance and practical reasons, the NS may be deployed in a distributed and hierarchy manner. If a local name server is not able to resolve a registration query for example, it can delegate the request to other higher up NSs recursively.

To implement the location registration procedure, and tracking request, we define two messages: REGISTER_MES and TRACKING_MES messages.

The REGISTER_MES message is sent by the *RA* to register or update the current location of an RFID tag. The RA sends this message to update the current location of the tag to the home LS. It performs also the location registration to the Location Server at the current domain.

The REGISTER_MES contains two fields: the RFID tag and the IP address identifying the RFID reader which the tag is attached to (e.g RFID: 1A2B3C4D <-> IP: 137.194.204.249).

When the home LS receives a TRACKING_MES message, it looks up the location database and replies with the current location of RFID tag. The response message contains two fields: the RFID tag and the current IP address of the reader.

4.2 System Architecture Operation

a. Location Registration Procedure

Figure 5 shows the location registration procedure. For illustration, it is assumed that the RFID tag is attached to Dr. John card and its home Location is *hospital A*. The doctor moves to a new location e.g. *hospital B*.

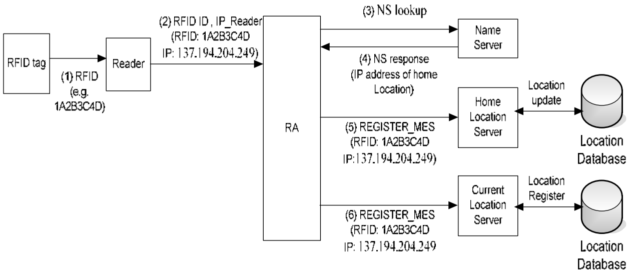

Figure 5 – The object location registration procedure

- *Step 1:* The reader scans the doctor card and learns its RFID tag (e.g. RFID number is 1A2B3C4D).
- *Step 2:* The reader forwards the RFID tag and related information (e.g. its own IP address and time-stamp for filtering purpose) to RA. When receiving the RFID information, RA performs the filtering process to check the redundancy tags using the time-stamps and select the interesting tag (e.g. RFID tag attached to the doctor card).
- *Step 3:* After the filtering process, RA consults the NS to obtain the address of the home LS corresponding to the RFID tag. The NS lookup procedure is similar to DNS lookup procedure.
- *Step 4:* NS finds out the address of home Location and sends back to RA containing IP address of the home LS.
- *Step 5:* RA performs a location registration by sending REGISTER_MES message to the home LS. This message contains the current location information including two fields: the RFID tag's number and IP address of reader (e.g RFID: 1A2B3C4D <-> IP : 137.194.204.249).
- *Step 6:* RA also registers the RFID tag at the current LS by sending REGISTER_MES message. This message contains also the current location information: the RFID tag's number and IP address of reader (e.g RFID: 1234567 <-> IP: 137.194.204.249).

b. Location Tracking Procedure

Figure 6 illustrates the location tracking procedure. We assume that a tracking node at hospital C wants to determine the location of Dr. John when he moves from hospital A to hospital B.

- *Step 1:* The tracking node consults the NS to find the home LS address of Dr. John
- *Step 2:* The name server finds out the corresponding home LS address and returns it to the tracking node.
- *Step 3:* When receiving the home Location address, the tracking node sends a TRACKING_MES message to home LS of the tag (e.g. hopitalA.net).
- *Step 4:* After receiving TRACKING_MES message, the home LS looks up the location database and replies a response message which contains the current IP address of the reader (e.g. RFID: 1A2B3C4D <-> IP: 137.194.204.249).

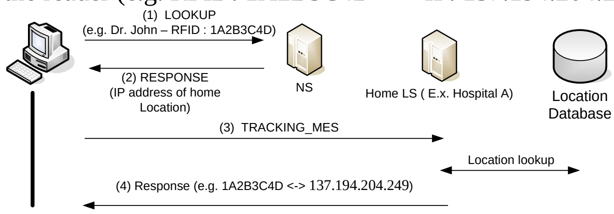

Figure 6 - The object location tracking procedure

4.3 A SIP-based RFID location management system

In this section, we propose an implementation of IP-based RFID architecture based on SIP protocol for proof of concept purpose.

The typical SIP architecture consists of SIP servers and user agents. SIP server implementations may contain a number of server functionality, or may operate as a different kind of server such as proxy, redirect, and registrar server.

The proxy severs are used to relay received SIP messages to other SIP server or user agents. A registrar is a server that accepts REGISTER requests and stores the information it receives into the location service. The redirect server receives a request and sends back a reply containing a list of the current location.

The user agent is software entities that initiate SIP transactions.

In SIP, the user agent registers its location at the registrar before establishing a session. The location registration procedure is also a core operation to manage the RFID tags. The RA should integrate a SIP User Agent to initiate Registration requests.

To initiate the tracking request procedure, the tracking node has also to integrate the SIP User Agent.

The LS has the same functions as Registrar in SIP to support the location registration. It plays also the role of a redirect server in case of tracking requests. Indeed, the LS has to send back to the tracking node the location information using a redirection class response (3xx) [11]. Moreover, the LS can integrate the proxy server functionality to forward the INVITE message to the LS for the tracking request purpose.

The NS provides name resolution services for location/tracking of RFID tags. The NS have to maintain the mapping between RFIDs and SIP URIs.

a. Location Registration example

In this example, we use the same scenario of section IV.1 to carry out the location registration. The illustrative example is depicted in figure 7.

The reader scans the RFID tag, learns the RFID number and forwards the RFID number and its IP address (e.g.

137.194.204.249) to RA. When receiving the RFID information, RA carries out the filtering process and consults the NS to obtain the address of the home LS. NS forms the URI address corresponding to the RFID tag. This URI address contains the name of the tag (e.g. *doctor_1*) and the address of the home LS (e.g. *doctor_1@hopital_A.net*).

After determining the URI address, NS sends this address back to the RA.

RA performs a location registration by sending SIP REGISTER message. This message contains the current location of the tag (e.g. *doctor_1*@137.194.204.249) in the Contact field. The Registrar places this information into the location database.

If the registration is successful, the Registrar replies with a 200 OK message back to the RA.

The RA performs also a location registration by sending SIP REGISTER message to Registrar in hospital B domain. Similarly, the message contains the current location of the tag (e.g. *doctor_1*@137.194.204.249) in the Contact field.

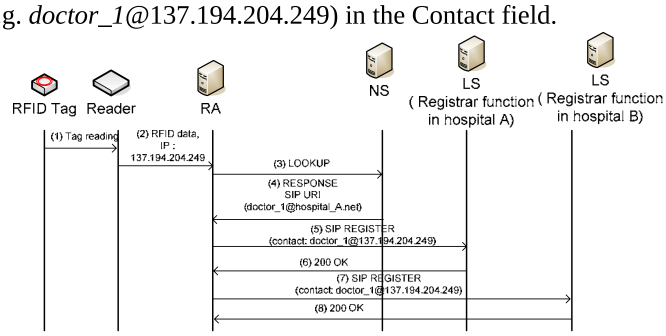

Figure 7 - The SIP-base location registration procedure

b. Tracking procedure example

In this example, a tracking node being at hospital C wants to localize the Dr. John. At this moment, Dr. John working at hospital A has moved to hospital B.

As illustrated in Figure 8, the tracking node consults the NS to find the home LS of Dr. John.

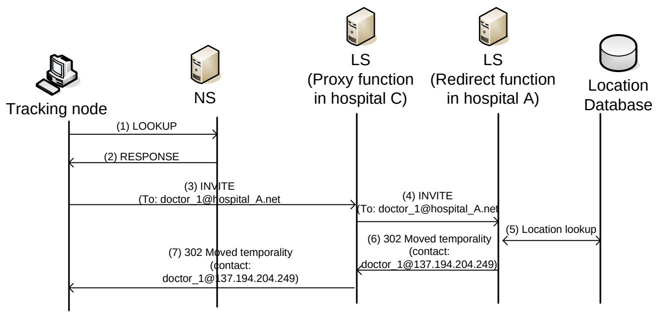

Figure 8 - The SIP-base location tracking procedure

The NS server finds out the corresponding URI address and returns response message to the tracking node.

After receiving the URI address, the tracking node sends an INVITE message to queries the LS to find the current location of Dr. John. The LS proxy sever functionality at the hospital C domain forwards this message to the LS. The LS looks up the location database and finds out that Dr. John has moved to another location (e.g hospital B), the LS (using the redirect function) notifies a *302 Moved Temporarily* message. This message contains the current location of Dr. John in the contact field (e.g. *doctor_1*@137.194.204.249).

5. CONCLUSION

In this paper, we have proposed IP-based RFID architecture that allows low cost and large scale deployment, as well as easy integration with IP-based services.

Particularly, a location management support is provided. The RA is introduced to handle the location registration messages and tags filtering. The LS provides the location service to update the current location of the RFID tags. The NS is used to provide global name service between RFID tags and the address of the LS.

A SIP-based architecture has been proposed for validation purpose.

This work is a part of our overall framework which aims at defining a global communication network using RFIDs to support the location and mobility management.

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