IntelliForest

Interim Report

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1 Introduction

Forests are a crucial part of our ecosystem; they are 'the green lungs of the Earth'. The need to protect them is indisputable and numerous people are bringing this idea into life every day. The tools and methods used develop as does the technology but one still has a feeling that much more can be done. In particular, there seems to be a lack of tool that would make use of the modern technical concepts in order to significantly facilitate the every-day work of people spending the most time in the forests.

Considering this matter, we came up with an idea of IntelliForest – a sensor-based system that helps protect, preserve and even enhance the forests. It uses a network of **Base Stations** controlling a range of endpoints, which can be various sensors, cameras or access points. Data collected from the sensors are transmitted over radio by the **Base Stations** to the **Gateway** which forwards them the central database. Collected information is administered by the **Management System**, which also serves as an interface for the users. The primary goal of IntelliForest is to provide an important working tool for the foresters, ecologists and scientists.

Additionally, some endpoints – called **Information Points** – are addressed to any person spending their time in the wild. They can be operated by tourists using a Bluetooth-enabled mobile device. The purpose of **Information Points**, in conjunction with publicly available Internet interface, is to bring forests closer to the people and in this way, help protect them.

2 Benefits of the project

In order to determine the areas in which IntelliForest will be particularly useful and to define its main functionalities, we consulted specialists from the Chair of Dendrometry at Poznan Agriculture Academy under the supervision of Tomasz Najgrakowski, Ph. D. They described in detail the management system used in the Polish National Forests, called **SILP**. Apart from dealing with the staff management and financial issues, this system focuses mainly on forestry economics – the value of trees being chopped, for instance. Mr. Najgrakowski pointed out that creating a network of sensors offers new possibilities which have not been visualized so far.

His remarks were consistent with the results of our own research on the existing systems in this area. In conclusion, the benefits of IntelliForest can be grouped into following categories:

Up to date view of the forest
Using our system, the forester is able to control the state of the forest – like measuring the forest bed humidity or watching the animal feeders online, without stepping out of the house, just browsing the Internet. This saves time and effort.

Customized measurements
The system offers three approaches to collecting data – scheduled, event-driven or on-demand – depending on different types of information that is gathered. This makes the system perfectly adjustable to individual needs.

Interaction with people – information points, feedback
The system provides endpoints that offer on-the-spot information, such as details about local plant and animal species, weather state and forecast or place description. Furthermore, it al-

lows the users to enhance the database, by gathering feedback either on the spot or over the Internet.

Taking into considerations the above benefits of IntelliForest there is a number of ways in which the system can be useful for the society. A scientist, who spends several hours a day making measurements in distant parts of forest will have them done and delivered automatically. A tourist visiting a wild forest will be able to recognize local birds by looks or voice after getting appropriate hints at the Information Point. A forester, warned by the system that a theft of wood might be happening, will send an UAV to monitor the situation.

Example use cases are included in *Appendix A.*

3 Innovation

The majority of commercially available systems designed to monitor the ecosystems are based on satellite observations. This solution, though certainly well suited to some applications, has also its constraints:

- There is a limit of measurements that can be done via satellite. In fact, most such systems are dedicated to only one functionality, i.e. monitoring the fires.
- The systems are mainly used by large organizations which can cope with their maintenance. They are not likely to be operated and managed by individuals.
- The idea of using satellite systems usually goes with the resignation of relying on any on-ground measurements.

Another type of system that is used in forestry, is the above-mentioned **SILP** system. It is commonly used by the polish foresters, who use dedicated handheld devices as its endpoints. However:

- **SILP** focuses on economical and financial matters.
- Its automation concerns the flow of information in the company and filling the documents. A forester's job remains mainly unchanged.

The innovative concept of IntelliForest is to use a wireless network of sensors and other endpoints to create a modern tool for people working in forests. This approach creates possibilities not offered by existing solutions. In particular, the unique functionalities and properties include:

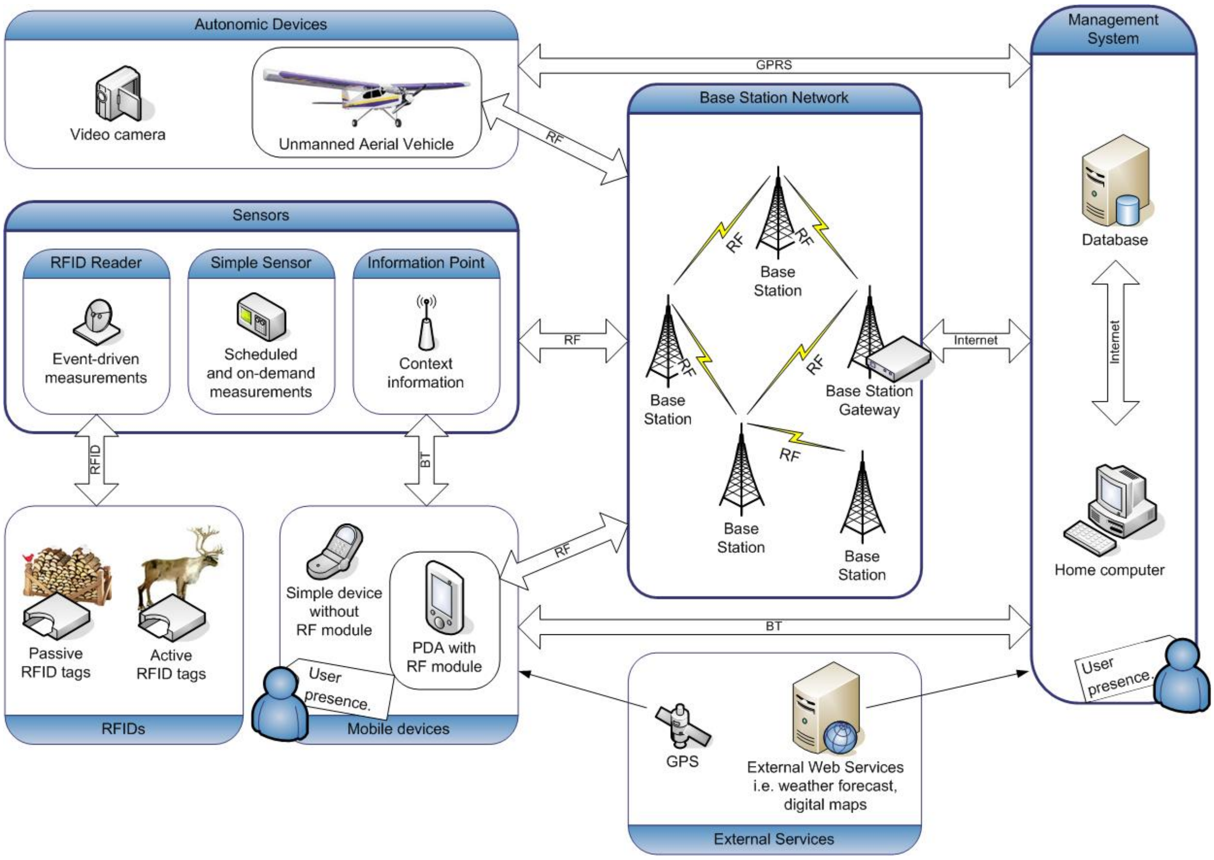
- Automatic collection of a variety of data. Thanks to IntelliForest, actions like measuring the pollution level or checking the animal traps do not have to be done manually.
- Flexibility and good scalability of system. By choosing the types of endpoints and their location, one can easily concentrate on different areas of interest. At any moment, the network can be freely rearranged. Different ways to collect the data provide additional customization options.
- Variety of applications. Information points are addressed to 'visitors' of the forest, while much of the information gathered by the system can be shared with everyone using the Internet interface. Additionally, as IntelliForest is a modular system, it can also be quite easily adapted for non-forest areas, if needed.

4 System overview

IntelliForest consists of various hardware devices and applications closely interacting with each other. The project is designed to deliver a framework for automation of measurements. The measurements have been grouped into three categories:

- **event-driven measurements –** when an event is occurs, the appropriate signal is sent over the **Base Station Network** to the **Database**,
- **scheduled measurements –** data are gathered in configurable intervals of time,
- **on-demand measurements –** data are gathered when an unscheduled request appears in the system.

4.1 Architecture

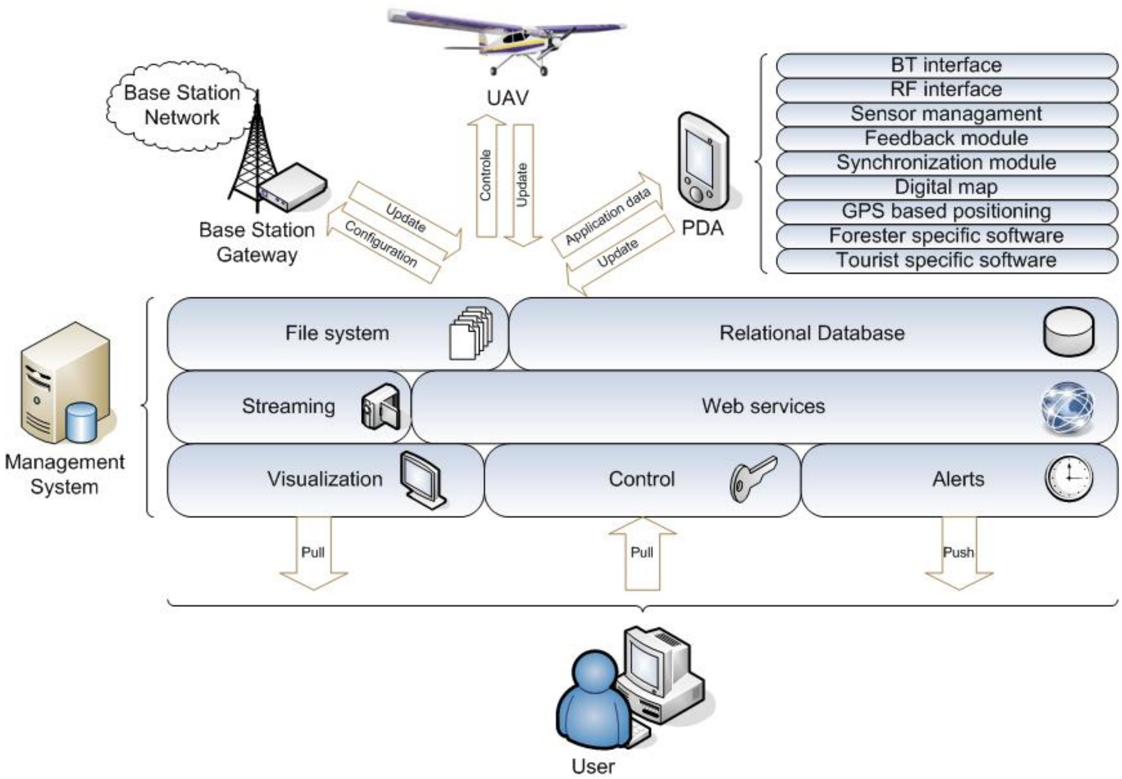


The key concepts of system architecture are modularity and independence of separate parts. The core of IntelliForest is a backbone network of **Base Stations** using radio communication (RF). Each **Base Station** controls a network of sensors, **PDAs** and autonomic devices, also using RF. Some sensors have additional functionalities of communication with **PDA** (**Information Point** via Bluetooth) or detecting **RFID tags**. The external communication between **Base Station Network** and the **Database** is provided by dedicated **BS Gateway**.

In addition, we specify the following system endpoints:

- **Simple Sensor**, which measures many different sorts of parameters, for example temperature, humidity, water pollution,
- **Information Point**, which provides context information addressed to the tourist,
- **RFID Reader**, which detects animals and objects tagged using RFID technology,
- **Camera**, which transfers video data to the **Database** using a wireless technology like GPRS Internet, or Wi-Fi with WiMAX,
- **Unmanned Aerial Vehicle**, equipped with a **Camera** and **RF module**, which is used to monitor selected areas and to collect data from faraway sensors,
- **PDA**, equipped with an RF module which enables management on the spot.

4.2 The software



The above diagram presents the functionalities provided by the **Database** and **PDA**. The emphasis on the software side is put on:

- delivering a consistent way of managing and browsing the system from the outside using **Web-Services**,
- developing various **PDA** applications listed above.

4.2.1 User / Management System communication

Communication between the **Management System** and the **User** is designed using two schemes: **Push** and **Pull**. In the first one, it is the system that initiates the communication, which is typically one-way. This is implemented in the **Alerts** module, which is responsible for managing unexpected events signalized by the system.

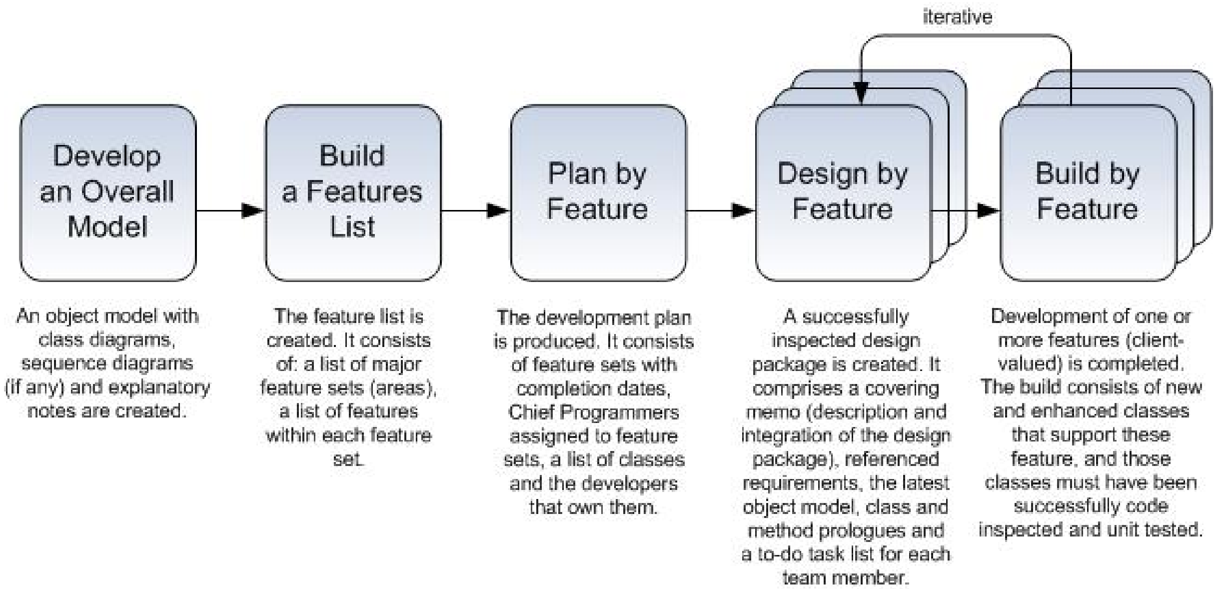
In the **Pull** scheme the **User** makes a request to the system and expects a response (this may be as simple as a confirmation). This is implemented in the **Visualization** and **Control** modules, responsible for presenting the state of the database and configuring the system, respectively.

4.2.2 Updates

Information updating the database may come from three different sources: the **BS Network**, the **UAV** and the **PDAs**. In particular, some pieces may be doubled, for example when setting a new sensor is noted by both **Base Station** and the **PDA**. The **Management System** must be able to track these updates and keep the database coherent.

5 Methodology and project lifecycle

The methodology used to create the project is **Feature-Driven Development**. It is, in short, an architecture-centric pragmatic software process, often compared to **eXtreme Programming** and other agile programming techniques. The **FDD** project lifecycle consists of five main activities:



There are a few main roles in **FDD**:

- **Chief Architect –** a person responsible for the overall architecture and cohesion of the technical side,
- **Project Manager** – a person responsible for following the schedule and accordance with the planned project lifecycle,
- **Chief Maintainer** – a person responsible for keeping all code inspected, unit tested and fully documented.

There are some aspects that distinguish **FDD** from other agile methodologies. These are: strong class ownership, detailed design before code writing, feature orientation (client-valued functionality is added in each iteration).

We have chosen **FDD** because of its strong class ownership rule. We find that collective code ownership turns out to be error prone. Strong class ownership fits this project particularly well since the system is strongly modular and the boundaries between components are well defined.

Another **FDD** aspect we find very important is the **Design by Feature** phase. Unlike traditional methodologies, only features actually implemented are designed in detail. This saves time and effort. On the other hand, unlike other agile techniques like **XP**, in **FDD** detailed design before implementation is a part of the process. That leads to better definition of the system and significantly less refactoring. Moreover, despite having strong class ownership which is important in the implementation phase, design can be done in groups, if needed. That leads to better integration of various components done by different programmers.

We have already accomplished the first three steps of the lifecycle. As the result we obtained a detailed plan of the project. We built use-case based feature list and arranged a constrained development plan (*Appendix B*). The features fall mostly in the following categories:

- features concerning **Base Stations** and sensors,
- features concerning the web interface, database and connection between the Internet and the forest network,
- features concerning mobile devices (**PDAs**, mobile phones or specialized sensors like autonomic **UAV** and **Video Cameras**).

Taking into consideration skills and preferences of the team members, we decided to assign the **FDD** roles and feature categories as follows:

- **Pawel:** Architect – Base Station, sensor features,
- **Piotr:** Maintainer – Base Station, sensor features,
- **Lukasz:** Project Manager – database, web interface features,
- **Szymon:** Maintainer – mobile device features.

6 Economical analysis

IntelliForest is a highly extensible and modular system. Its overall cost depends strictly on the types of elements it consists of, so that the designer can make a compromise between the functionality and cost. The **Base Station** costs approximately $100 and a simple sensor around $15. Detailed estimation of costs is located in *Appendix C*.

Additionally, the system requires a server (or a PC) to host the **Database** and the **Management System**. In order to fully benefit from the system the administrator and users should also have a **PDA** device.

Apart from the hardware cost, the system requires additional expenses:

- **Base Station Network** location,
- Bandwidth and energy management.

Appendix A – Sample use cases

Wood theft

1. Someone steals a log of wood.
2. A passive RFID tag located on the log after chopping the tree is detected by an RFID receiver.
3. Receiver sends a warning signal to the nearest Base Station.
4. The signal is routed by the Base Station Network to the Gateway.
5. The Gateway forwards the signal to the Management System.
6. The Management System interprets the log movement as a possible theft.
7. The Management System stores the information in the Database.
8. The Management System sends an SMS to the forester.
9. The forester sends a UAV to monitor the location of the RFID receiver.

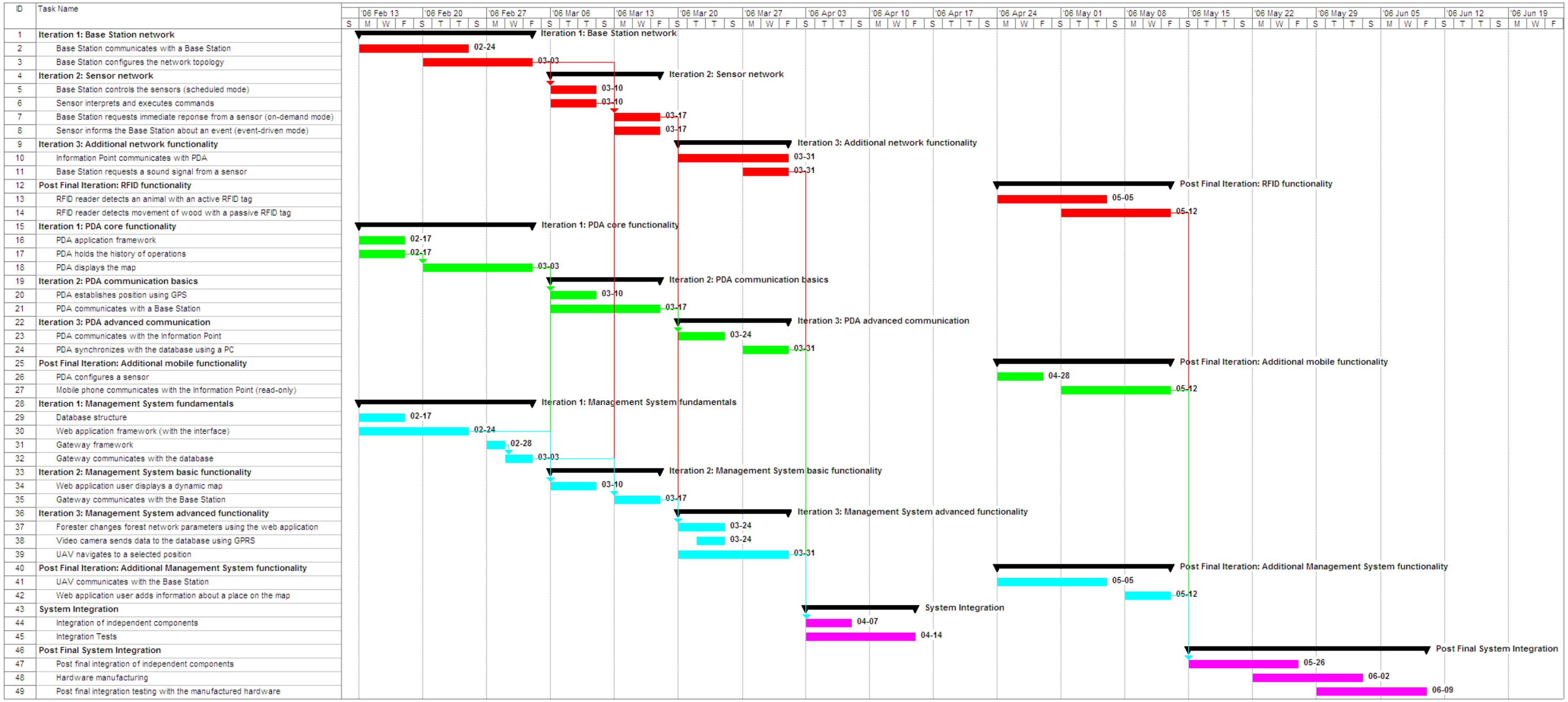
A tourist's day

1. A tourist downloads an IntelliForest Framework on his PDA from the system's web-site.
2. The tourist takes a trip to the forest.
3. On the track, the tourist approaches an Information Point.
4. The tourist downloads information about local birds species.
5. The tourist observes an unknown bird.
6. The tourist verifies the looks and the voice with the images and sounds stored in his PDA.
7. The tourist discovers that he has just seen a bird of a very rare species.
8. The tourist takes a photograph of the bird.
9. The tourist returns home.
10. The tourist uploads the photograph with his comments through the website.
11. The uploaded information is verified by the website administrator.
12. The photograph appears on the website and/or is sent to the Information Point.

A scientist makes measurements

1. A scientist logs into the Management System.
2. The scientist checks the average noon temperature over the last week.
3. The scientist is intrigued by the results.
4. The scientist requests additional measurements of forest bed humidity.
5. The system triggers the measurements and sends back the results.
6. The scientist analyses the received information.
7. The scientist orders the system to measure the humidity every day at noon and at mid-night.
8. The scientist logs out of the system.

Appendix B – The Gantt chart



Task assignment: Pawel and Piotr, Szymon, Lukasz, the whole team

Appendix C – Cost

System Component	**Cost [USD]**
Base Station	**100**
Base Station Gateway (BS, single board computer)	**400**
GPRS Video Camera	**400**
UAV (airplane with automatic pilot, RF module and various sensors)	**3000** and more (depending on model)
Passive RFID	**0.15**
Passive RFID Gateway	**3000**
Active RFID	**10**
Active RFID Reader	**200**
RF Sensor	**15** and more (depending on sensor type)
Bluetooth Information Point	**50**
PDA RF Module (connected by CompactFlash slot)	**60**