Radio Communication Model For Mobile Positioning Devices

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Abstract— **Location systems for remote objects (vehicle, person, commodity, etc.), such as RTLS (Real Time Location System) in general and AVL (Automatic Vehicle Location) particularly for vehicles, are increasingly used today by several enterprises. Indeed, this facilitates the management of personal, products, increases productivity, and so on. These systems use positioning devices such as GPS and communication devices to send remote location data. The first constraint of GPS is that it does not provide a precise position at any time. The extensions of GPS such as WAAS systems and A-GPS, that improve the precision, have also other constraints (availability and cost). The second constraint comes when sending remote location data. Often, the communication devices used for this purpose are GSM modules that send data on the GSM network. The use of GSM network is expensive to send data periodically. To overcome these drawbacks (improve precision), we propose a network and software model to create a reliable location system by coupling the radio devices at low integration cost with GPS devices, and allowing different mobile objects to cooperate.**

I. Introduction

Location systems are becoming increasingly sought today to ensure the location of distant objects [1], to facilitate the management of personal, and their products, increase the productivity, etc. these systems are known as AVL (for vehicle location) and generally the RTLS (for real-time location of several objects). These systems can be divided into two approaches: i) positioning approach by satellites, such as GPS, and ii) positioning approach by WSN (Wireless Sensor Networks) that use networks of wireless sensors. This second approach is divided into two categories: Coarse-grained and Fine-Grained. Coarse-grained is based on Radio frequency Identification (RFID) and used to cover an area of hundred meters in diameter. The precision in this case is lesser as much as the readers coverage is larger [2]. However, Fine-grained uses Radio signal strength (RSS) that operates on radar system. the number of antennas used is proportional to the area to cover [3]. For approaches (GPS and WSN), triangulation using three antennas or at least three satellites, provides a point of geographical position. The method is called APIT (Approximate Point In Triangle) [4].

Unlike WSN, GPS does not require complex and costly ground infrastructure to find its position. It is based on an existing satellite network open to the public, to triangulate its position [5].

A GPS device cannot transmit remote data, since it can only read signals from GPS satellites to interpret. Some GPS devices use a GSM-GPRS embedded module to send the location data. Sending data via the GSM network is reliable given the wide coverage of the global network. Because it is a private network, data sent are charged. The accuracy of GPS positioning can be improved by a correction signal from WAAS satellites reaching WAAS (Wide Augmentation Area System) [6]. This signal is not always received and still rely on the sensitivity of the GPS antenna and weather. A-GPS is a costly alternative, in case of non availability of WAAS data correction. It allows to contact ground stations that provides data corrections similar to WAAS via a GSM-GPRS. However, the use of communication via GPRS is expensive.

The following sub-sections summarize the problem and describe possible usage scenarios:

A. System Features

The proposed system must meet the following points: i) How can we improve the positions identified by the GPS at a lower cost, ii) How to centralize data from multiple traceable mobiles objects to create a overview of the system and facilitate its management?

B. Scenarios of Use

- A person with Alzheimer's may get out of a security perimeter. The tracking localisation system reports this dangerous movement by giving the position of the person using the coordinates X, Y, Z.

- A car equipped with this localization system will periodically send its position and speed to our system.

- To increase the precision of measurement devices (GPS) (portable or vehicle) in the two previous cases, the system is able to broadcast data correction (A-GPS) to these devices, via a long range radio communication.

C. The HCS (Hybrid Communication System)

We propose a model network (topology and application logic) and its implementation. In this model we use radio (wireless) devices to freely transmit and receive position coordinates and correction data via a long range radio antenna. Indeed, it is firstly a communication model that provides location data relayed from one device to the others till it reaches our main server. Secondly, our model introduces a new way of using correction data which can be used for accuracy improvement and loading it on the remote location devices. Therefore, this model is providing a cooperating communication system which extends the basic routines of a standard communication system to allow collaboration between all nodes of the mobile system. HCS will be detailed in section 3.

Section 2 contains a short description of technologies and systems used in this research. Section 3 brings the elements of our solution for an optimal system in terms of cost and location accuracy and availability. Section 4 shows an overview of program implementation. Conclusion and future research will be given at the end of this article.

II. BACKGROUND

This section describes briefly GPS, WAAS, AGPS, and communication radio systems that are used in this paper.

A. Global Positionning System (GPS)

Through a constellation with between 24 and 32 satellites, GPS can provide information to GPS receivers on their position, speed and time of acquisition of such information [5]. GPS satellites synchronize sending their signals to receivers on the ground, and the distance is calculated based on the moment of the signal arrival. A signal from a remote satellite takes more time to arrive than the signal of closer satellite to the GPS receiver. To localize, a GPS receiver requires three satellites (2D position) and four satellites for a 3D position (this includes the depth). The position accuracy also depends on the receiver; the majority of location systems has an accuracy of 10 meters which varies depending on the design quality (chipset, antenna type, protocol, etc.). Other receivers use DGPS signals (Differential GPS). These signals include data for correcting the position to achieve accuracy levels of less than 5 m.

The stand-alone GPS cannot achieve optimum accuracy (less than 5m) if weather conditions weaken the signal, or obstacles in urban obstruct the view of satellites and cause multiple reflections of waves [14]. In these cases, GPS needs assistance through WAAS or A-GPS.

A.1 WAAS

As with DGPS, WAAS is a differential technique and consists of three geostationary satellites and 25 ground stations (WRS: Wide area Reference Stations). It has the ability to bring precision to three meters or less, in horizontal and vertical [6] [8]. The stations collect data on the constellation of GPS satellites and send this information to two master stations (WMS Wide area Master Station, located on the west and east sides). These stations calculate the clock corrections for GPS satellites and the integrity of collected information to the geostationary satellites. However, GPS compatible with WAAS can make the needed corrections. If the accurate information on data integrity is below the threshold tolerated, DGPS is disabled so that the signal is processed only with GPS signal having a greater precision error margin [15].

A.2 Assisted GPS (A-GPS)

Unlike GPS, which requires a receiver and an antenna, the A-GPS works in conjunction with a server hosted by A-GPS operator [7]. The mobile terminal, equipped with a miniaturized GPS receiver, sends a request to the server through the IP network. The latter, which knows in real time positioning satellites, and serves as dispatcher tells the terminal to monitor the GPS signals. With this method, the mobile terminal A-GPS receiver can, unlike traditional GPS receivers, detect signals of very low amplitude [9]. The A-GPS servers can provide correction data that can bring accuracy on some GPS to a few tens of centimetres [10] [FAA, 2010]. Often A-GPS data is sent via the cellular network.

B. Radio Communication

The radio transmission was initially implemented to provide point to point communication over long distances (microwave, satellite connections geostationary) between the fixed networks.

As we are in mobility-oriented environment (e.g. cellular phones), buildings obstruct the view of the antennas by radio equipments that are at ground level in an urban environment.

In an urban environment, communication via radio waves is carried by radio signals that are reflected to all buildings along several directions (multipath). The most used waves belong to the UHF frequency band (300MHz-3GHz) to provide mobile communications in urban areas such as wave allows multi-path, crossing barriers with a tolerable loss of signal, depending on the material (loss: 4dB Wood, Concrete 10dB).

To allow a communication radio, we need modems and radio antennas to increase signal gain. There are several types of antennas. Those we are interested in are the omnidirectional antennas (transmitting in all directions) of type: whip antennas (allows a gain of 2 dBi) and the collinear antennas (allows a higher gain 10 dBi-4).

III. Hybrid communication system (HCS)

A. Model Description

The RFID or wave radio location systems, cannot compete with the accuracy of GPS. Our HCS uses GPS to identify object location without going through the GSM network to provide location data. The system may use GPS modules that enable to read the correction data (e.g. RINEX). The correction data will be downloaded via a server connected to a correcting land station through an internet connection. An antenna will be used via a radio modem connected to our server and be able to broadcast the correction data over a dozen kilometres (the chosen modem can achieve a transmission radius of 50 km in open field). The geo-localized objects are classified into two categories: the portable devises (cell phones, portable GPS and other portable devices including a small GPS) and the larger objects (such as vehicles, the old merchandise, etc).

The case of large located objects does not make a problem of coverable radius to transmit location coordinates and receive correction data from our server.

The smallest detectable objects are often located far from the antenna of our server. To overcome this problem, we propose a model to allow portable devices to relay messages to our radio antenna. This later is connected to the server via the largest objects that have greater range and in the vicinity of our short-range devices.

In fact, our hybrid communication system provides location data relayed from one source device throughout the other relay devices till it reaches our main server. Second, our model introduced a new way of using correction data which can be used for accuracy improvement and to load it on the remote location devices. Therefore, HCS is providing a cooperating communication system which extends the basic routines of a standard communication system (radio system) to allow collaboration between all nodes of the mobile system. Each device integrates our OSGI based software which chooses the optimal communication canal in order to avoid the costly GSM/GPRS system as much as possible by using free radio communication.

When a device with a low radio coverage is in need of sending its data to our main server, it broadcasts a signal, on a radio canal said number 1, saying “I am in need of a relay to send my data” over the relaying nodes of our devices network. This signal is sent for example each 10 seconds. This period of time allows us to avoid radio network saturation and jamming the other devices radio signal. When a relaying node (a device capable of sending radio signals farther than small radio devices limited in their transmission radius) is in the neighbourhood of a requesting device, it gets its ID included in the relay requesting signal. The first device signal that reaches the relay node is the first to be processed. Then the relay node sends an acknowledgment signal to the device accepted to be served, by including its own ID in the ACK signal. When the small device receives the ACK signal on the radio channel number 2 with the ID of the relay node, it sends a radio signal containing all its positioning data on this second radio channel that should be received by the relay node. When the relay node gets all the positions, it stores them to its memory in order to send them as soon as it gets a direct radio connection to our main server.

To summarize, the solution consists of three modules: GPS, radio and GSM/GPRS for handheld devices. The first handheld devices to send the details via the radio module to our server. If direct connection is not possible, these devices ask the long range radio modules nearby to relay information to the server. When the second method fails, the GSM / GPRS module is requested to send location data to the server. Vehicles can also work together if they are out of range of our server radio antenna. In the opposite way, the server broadcasts the data to correct positions without using long range antenna which is capable of covering a large urban area.

B. System netwoork Topology

Figure 1 illustrates the network topology of our system.

This topology is described by the following steps:

i) The GPS satellite sends the signal to three components 2, 3 and 4, which calculate respectively their positions by analyzing the GPS signal.

ii) Set of portable devices that can communicate in radio mode A1 to send their positions to our server 6. In case where the radio fails, the system switches to GSM-GPRS data items A2 that sends data via the Internet (B2) to our server 6.

iii) The vehicles are equipped with larger Radio Modems with a broader, enabling them to relay location data of Group 2 in B1. Cars can also be equipped with GSM/GPRS module and further to use as portable devices for two (2).

iv) A-GPS station (4) which calculates the positioning error of GPS in its area. These data are downloaded from our server via an Internet connection D. The GPS correction data is broadcasted in F over a wide area throughout a long-range modem at 5. This allows our mobile network equipments (2) and (3) to use the correction positioning data in (4) to adjust their positions.

v) Radio Modem Long Range up to 50 km. It receives location data from our server with a serial connection (USB, RS232, etc..) via E, transforms the data into radio packets and broadcasts to our remote location equipment in 2 and 3 via radio waves F.

vi) Our server collects location data via B1 and B2, formats data and stores them on a database. It can also allow regularly to consult the A-GPS server 4 to download data for correcting the position and spread via the radio modem in 5. It also provides an access interface to an application (GoogleMap), which will display the location data on a terminals (computers, PDAs, etc.) in 7 through an Internet connection G.

vii) A set of users who have access rights to our server 6.

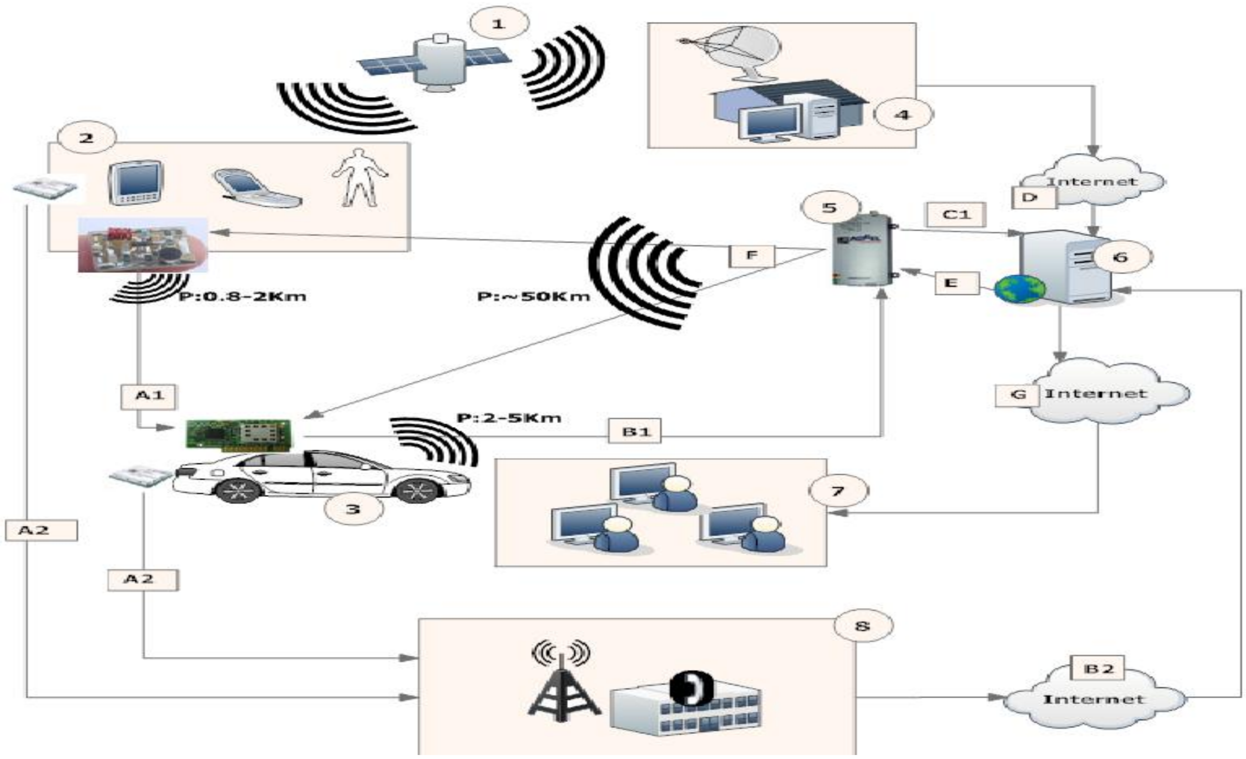

Fig. 1. Network Topology of our system to communicate Radio and GPRS

C. Communication system process

We use an extended communication system considering each remote mobile device as a node of our mobile network. This extended communication system allows relaying radio devices with low radio coverage to reach its final destination. It looks like an ad-hoc communication network. However, we use a specific routing algorithm which allows the following:

3) sending the positioning data to the server when it is out of its range. In this case the data are saved in an internal ROM till the device recovers its lost direct connection with our data server.
4) If the source emitter (low-range radio) or even the intermediate relay (medium to long-range radio) are not able to transmit their awaiting data to our server,

6) the following :

1) Relay the positioning data of the devices with low radio coverage to the long range available radio. device in proximity as vehicles which are able to reach our radio server antenna directly.
2) Lets the long range radio equipment to wait before

our algorithm allows the system to change its communication mode to work with the costly GSM/GPRS in order to transmit the positioning data before it becomes obsolete.

5) To avoid signal jams in the case of simultaneous transmissions our system acts in 2 steps (a, and b) as

a- The mobile radio equipments awaiting to transmit their data to a relay are sending a specific short signal on the first radio channel including its own unique ID every few seconds and waits for an answer from the available and ready relaying equipment in their range.

b- The radio devices (long-range radio) of our network that acts as relays, stands in a listening mode till they receive the first low range radio devices request signal as those in step (a).

The standard ad-hoc mode needs an overstocking wireless network cards compared to our small radio modules that allows making more portable and lighter devices. Our communication algorithm chooses the optimal communication mode available for transmitting data. Our approach gives, to each mobile radio equipment, the opportunity to transmit its positioning data freely using free radio communication channels.

D. *Cost study*

To illustrate the efficiency of our model (using a hybrid solution of the standard GPRS and a common communication radio system) compared to the classical communication solution systems (using standard GPRS communication system), we have made a cost study on both of them. In fact, the use of the radio communications is free instead of the costly GPRS.

The use of the GPRS needs a monthly communication plan, a hardware and a server. The cost of this solution is getting higher with the communication plan. The overall cost of this solution on a period of 5 years for 100 units is 416 000 $.

Combining the free radio communication with a smaller GPRS plan in the case that the radio communication falls to transmit data will lead us to a great gain on the overall cost. We need 3 types of devices, Small radio mobiles with short transmission range, medium radio mobiles like the ones we can put in vehicles with medium to long transmission range, and a long range modem with its antenna on the server side to receive the radio data packets. If we consider 100 units during 5 years, this solution costs approximately 122 275 $.

Comparing the two solutions, we conclude that we make a gain of 293 725 $ on our solution compared to the classical GPRS solution because of saving on the costly GPRS communication plan. In other words 2.4 times less than the GPRS exclusively.

IV. IMPLEMENTATION

This section briefly describes in pseudo code the implementation of the communication program (Figure 2). Subsequently, we illustrate the communication with the GPS on a COM port. Finally, some screenshots are given.

A. *Pseudo Code of Communication Program*

This section specify a set of functions used to establish the communication between mobile devices in HCS.

Function send_serv(msg, Id)
Start function
If connexion_serveur_radio.open(port)==true **do**
/* We have the parameters as location message to be transmitted, a random verification key generated by RAND and the Id_serv which is the ID of our server for a shipment sent (Id_serv) */
Send_radio(message_localisation, cle_aleat, Id_serv)
/* connexion_serveur_radio with "port" which is our local radio port parameter is a function that opens a connection via the radio port. if the connection is established, it returns true, otherwise returns false.*/

Timer1=5000; // put the variable to 5 seconds

/* Check_Ack function that turns timer1 awaiting acquittal. the server when it receives our message, pay our random key, and ack cle_aleat are compared, if they are equal, then the payment is positive and we conclude that the transmission is complete. The function returns true if matching and false otherwise */

If Check_Ack(cle_aleat, ack, timer1) == true **do**
connexion_serveur_radio.close(port)
// closure of the radio connection
elseif
/* when you do not receive acknowledgment from the server to the end of timer1, there is a new invocation send_serv (msg, Id) and the current is stopped with a return. */
send_serv(msg, Id)
return
end elseif
elseif

/* if no possible connection to the server, it tries to pass the message to a relay object (vehicle radio device with long range) which will relay it to our server and exit the current function.*/
…
send_relais(message, Id)
return

End Elseif
…
End function

B. *Example of AT commands to GPRS modem of a telephone Nokia [11]*

To send a message between devices using

GPRS mode, we can use one of two modes:

i) Mode Text [12] :

```
AT+CMGW="+85291234567"
> A simple demo of SMS text messaging.
```

ii) Mode PDU [13] :

```
AT+CMGS=23 //Send message, 23 octets (excluding the two initial zeros)
>0011000B916407281553F80000AA0AE8329BFD4697D9EC37
```

C. Communication with a GPS on a port COM

To allow communication with GPS devices via with specific configuration through a serial COM port, it is necessary to specify each parameter using Java code as the following:

```
// we import the classes javax.comm that manage the communication

// we create our class to open the communications port
public class OuvrePort {

/** This is our read buffer from a specific port that we define later in this code */
protected BufferedReader is;

/** variable contains the message to send to our system */
protected PrintStream os;

/** Here, we create an ID of the port */
CommPortIdentifier PortId;
...

/* Chosing physical port COM1 */
portId=CommPortIdentifier.getPortIdentifier("COM1");
…
SerialPort port;//create a serial port

/* Open our port with the message  GPS_Appli and a timeout of 30s */
port=(SerialPort)portId.open("GPS_Appli",
TIMEOUTSECONDS);
...

/* configuration of a serial port for communication */
        try {
        port.setSerialPortParams(BAUD,
        SerialPort.DATABITS_8,
        SerialPort.STOPBITS_1,
        SerialPort.PARITY_NONE);
        } catch(UnsupportedCommOperationException e)
      {}

/* to communicate with the device, we use our variables (is and os): */

        os = port.getOutputStream();
        is = port.getInputStream();

/* we send our command by writing on the port via println */
 os.println(msg);

/* to retrieve the message from the device we must read through our port variable (is) */
is.readLine();
…
```

D. Positions stored in database via GoogleMap

The following PHP code creates the points representing the geo-localisation places retrieved from our database which has previously saved the positioning data of different mobile devices. This points are displayed on a browser using the GoogleMap API.

```
<?php

// we create a link to connect to the database
$link = mysql_connect("ServerAddr", "myLogin", "myPass");
…

// pointInPolygon is an imported function that tests if a point is included in an area as a polygon, the polygon can be a road or area of any number of sides. This function is available on many internet sites and does not need to be rewritten.

include_once("pointInPolygon.php");

/* if the point belongs to a zone and that the velocity of the point exceeds the speed limit of the area, it generates AJAX code using GoogleMap API, and puts the point in red via in the map with the function createMarkerR() */

  if(($inclus==1) and ($row1['vitesse']>$row2['limite'])) {
 echo "var point = new GLatLng(" . $coord['x'] . "," . $coord['y'] . ");\n";
 echo "var marker = createMarkerR(point, 'vitesse:" . addslashes($row1['vitesse']) ." <br> Source:". addslashes($row1['precision']) . " <br> date:". addslashes($row1['dat']) ."<br> <cite><em>Copyright A.Goundafi</em></cite>');\n";
…

 // if the point belongs to a zone and that speed does not exceed the speed limit zone, we generate AJAX code that puts a green position  point with the function createMarkerV as we did for the red point in the previous function (...)
…
```

Etc..

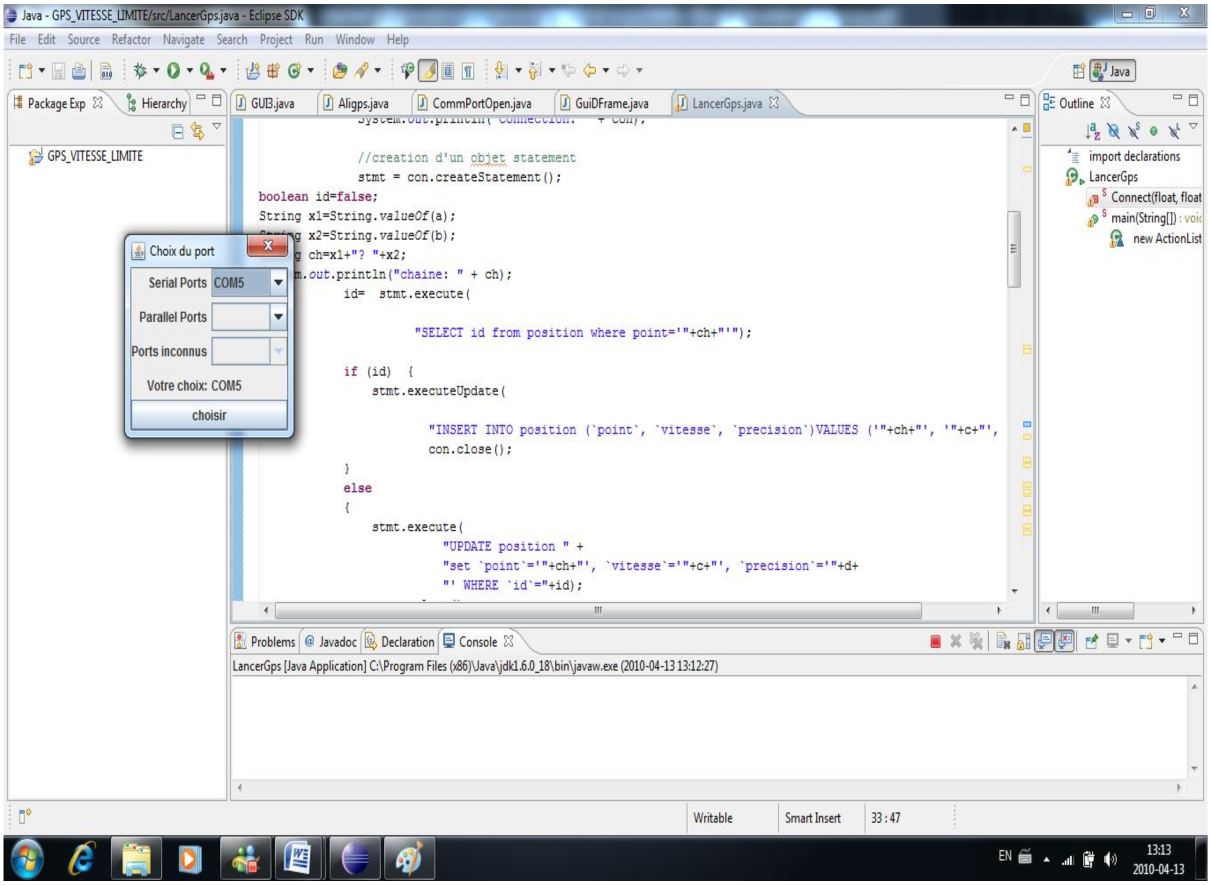

Fig. 3. Running the programme to read the positions on the GPS

After logging on COM5, our application communicates with the GPS using Trimble TAIP protocol. The information is being read and sent directly to the server via the Internet in this case.

Web Page generated via Google Map :

On the server side, we have a database that contains the positions received from our GPS, a table in our database named field, contains the area (road) as a polygon that is associated with a speed limit. In this case, we have put this part of the street " Rue Rabelais" in a polygon format:

(48.396275? -71.089984,48.395657? -71.085987, 48.395714? -71.085832,48.396157? -71.085674,48.396161? -71.085505,48.395664? -71.085684,48.395523? -71.085969,48.396143? -71.090032,48.396275? -71.089984)

Then, we have limited the speed to 45km / h. The gray points are points that belong to any area in our database and therefore are outside the road. The green point is a point which is located in the rue Rabelais, whose speed is less than the speed limit. The red dots belong to the road but they exceed the speed limit.

V. Conclusion

By comparing the different approaches to localization, we argue that the *fine-grained* methods can provide very good accuracy. The problem with these methods is that they rely on physical infrastructure rather expensive because it will install multiple sensors to cover a large area. The GPS satellite network offers the opportunity to provide the location without additional hardware with a reasonable accuracy in the range 5-10 meters which can be enhanced with WAAS or A-GPS.

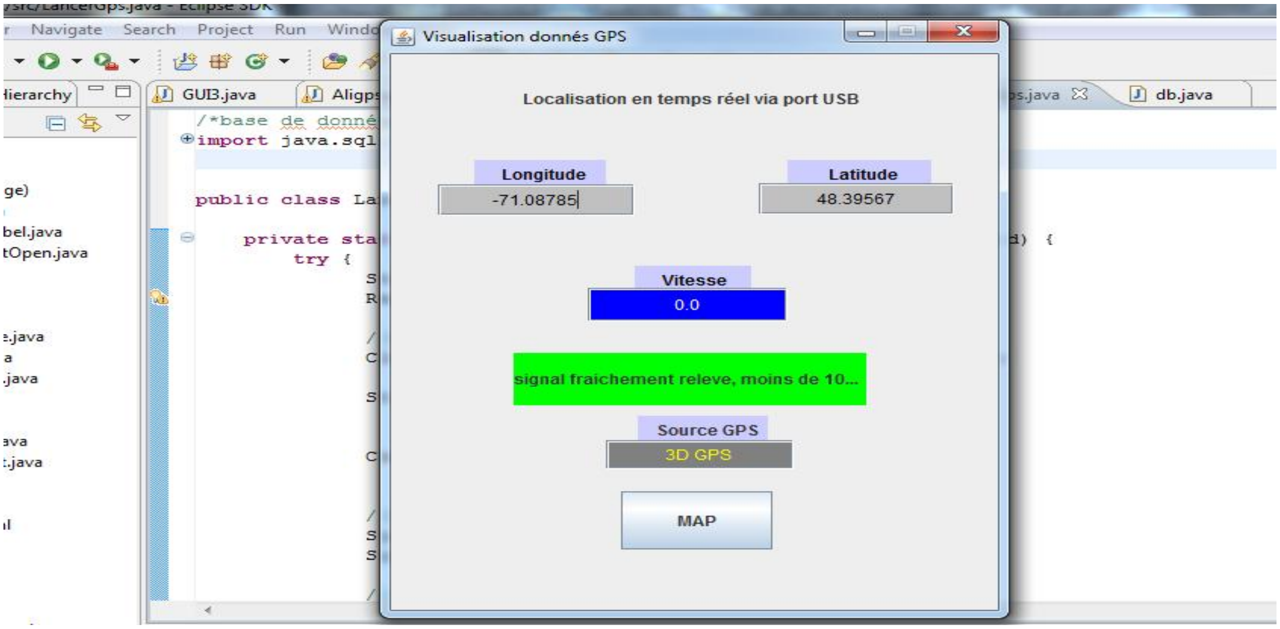

Fig. 3. Locating mobile objects in real time via a USB port

To strengthen the system, we have added communication via cellular networks where the radio communication fails.To summarize, our system offers the following advantages: i) Free exchange of data via radio waves. ii) Global vision of different types of objects detectable with better resource management and better coordination of field teams, iii) Moving Objects cooperative. The short-range devices may require long-range devices to relay their messages to the server, and iv) Facilitate the process of detection and rapid response (in cases of speeding in cars, medical emergency related to mental or physical health such as heart or for people with Alzheimer's, etc.).

For future research, we suggest i) the use of an encryption algorithm for secure radio data. The algorithm must be light enough not to take a fairly limited bandwidth with the radio systems. ii) Add a device WiMax for long range wireless communication. A large amount of data will be transmitted much faster than Wi-Max connectivity classical radio. Wi-Max is natively secured via encryption keys using WEP, WPA and WPA2.

REFERENCES

[1] Muhammad Ali Assad, *A Real-time Laboratory Testbed For Evaluating Localization Performance of Wifi Technologies*. Faculty of Worcester Polytechnic Institute, Electrical and Computer Engineering, 2007.

[2] P. Wilson, D. Prashanth, and H. Aghajan. *Utlizing RFID signaling scheme for localization of stationary objects and speed estimation of mobile objects*. In IEEE International Conference on RFID, 2007.

[3] U. Bischoff, M. Strohbach, M. Hazas, and G. Kortuem. *Constraint-based distance estimation in ad-hoc wireless sensor networks*. In EWSN, 2006.

[4] T. He, C. Huang, B. M. Bium, J. A. Stankovic, and T. Abdelzaher. *Range-free localization schemes for large scale sensor networks*. In ACM MobiCom'03, 2003.

[5] [GPS, 2010] : Global Positioning System, http://www.gps.gov/, 2010.

[6] [WAAS, 2010] : Federal Aviation: Administration , www.faa.gov, 2010

[7] [SAGEM, 2010] : A-GPS : The world's first Assited GPS SIM card, www.sagem-orga.com, 2010.

[8] [CDGPS, 2010] : The real-time Canada wide DGPS service, http://www.cdgps.com/e/desc.htm, 2010.

[9] [A-GPS, 2010] : Assisted GPS, A-GPS: an overview, information or turorial about the basics of Assisted GPS (Global Positioning System) or A-GPS used to provide location based services used for cellular technology and cellular networks, http://www.radio-electronics.com/info/cellulartelecomms/location_services/assisted_gps.php , 2010

[10] [GPSBase, 2010] : GPS Base station for post-treatment, www.gsf.qc.ca, 2010.

[11] [Nokia, 2010] :Activexpert : NOKIA GSM AT command set, http://www.activexperts.com/activcomport/at/nokia/, 2010.

[12] [DevHome, 2010]:Developpers home: How to send SMS message from a computer, http://www.developershome.com/sms/howToSendSMSFromPC.asp, 2010

[13] [GSMPDU, 2010]:GSM Favorite: Introduction to SMS PDU mode, http://www.gsmfavorites.com/documents/sms/pdutext/, 2010

[14] [Trimble, 2009] : GPS tutorial, www.trimble.com, 2010.

[15] [FAA, 2010]:GNSS library, www.faa.gov, 2010.