Tracking, Safety of the Small Pirogue and Monitoring of Ocean Natural Resource in West Africa Coast

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Abstract. The uses of Telecoms and IT technology change the daily life of million Africans. Our researches focus on tracking, monitoring and safety of the small traditional pirogue used by fisherman, alongside with allowing better ocean resources management. Using mobile technology for data transfer network and low-cost embedded device; we propose a solution model for developing the efficiency of the sea activities, optimizing the distribution of natural resource, and increasing security.

Keywords: Safety, low-cost sea, pirogue, tracking, mobile technologies, monitoring.

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1 Introduction

In sub-Saharan region, people used more than two devices to stay online. Fisheries contribution in food safety is important because most of the local African meals are made with fish. In fact, fish consumption per capita is 26 kg, far above the global average, which is 16.8 kg [1]. This is the reason why we propose a solution that will increase the productivity of fishery and make better food distribution among populations.

The system relies on a wide network composed of an offshore sub network of dual communication channel (SATCOM/GSM) equipped navy boats and pirogue with embedded GPS/3G/4G device and a sub network of servers and 3G/4G ground stations, on both sides.

The easiness of its implementation and the low-cost on-board device for pirogue make the efficiency of this solution. It will be beneficial for: populations by giving a better access to the resources, security, and rising market for fishermen; and governments by monitoring pirogue activities, preventing them from straying in other territorial waters, also reach food supply safety. The system can offer the following:

- Pirogue location;
- Current information about the pirogue catch;
- Distressed pirogue location;
- Border alerts;
- Distance and direction of different quays;
- Weather forecast;
- Current prices per fish species per quay basis;
- Current unloaded tonnage per fish species per quay basis.

The solutions proposed in previous work require specific devices. Each solution is dedicated to specific tasks. Nowadays the multifunctional solutions are more efficient for the African consumers.

The paper consists of the following sections:

- Overview of existing solutions
- System architecture;
- Functioning procedure;
- Application graphical user interface;
- Solution impact;
- Optimization of the main parameters.

2 Overview of the existing solutions

Several solutions of information systems for fishery were developed around the world. The main systems are:

- Vessel Monitoring System (VMS) enabling ships to send and receive information via satellite. Some developed countries require VMS devices in fishing vessels [3];
- Global Maritime Distress and Safety System (GMDSS) which is a set of systems based on an international agreement of equipment and procedures for safety and search and rescue (S&R) of ships and aircrafts. It may include high frequency or satellite communication devices [4];
- Long Range Identification and Tracking (LRIT) that allows administrations to track and identify vessels. It, generally, relies on shipborne satellite communications equipment [5];
- Automatic Identification System (AIS) allows identifying and locating by electronic data exchange among ships, base stations, and satellites. It is used for many applications such as fishing control, navigation, S&R and so on [6].

In our previous works [2] a system comparison was proposed as mentioned in the following table.

Table 1. Systems Comparison [2]

System	Fishing regulation	Automatic identification	Safety	Affordability
VMS	+ +	+	-	+
GMDSS	-	-	+	++
LRIT	-	+	-	+
AIS	+	+ +	+	-
Local solution	+	+ +	+	+++

These systems are international, reliable and provide global coverage. But the required equipment and technology make them unaffordable low-income fishermen with traditional pirogues.

In developing countries, some models were implemented, based on GSM/GPRS technology and integrated GPS/GLONASS Smartphones [7], [8]. The main goal of these was to allow fishermen and vendors get up to date information about the price of sea products in the markets. Also, some of them try to solve some security issues offering automated SOS alerts, first aid knowledge, border alerts to prevent fishermen from crossing national waters. The systems are generally accessible via mobile applications. The falling cost of smartphones made these solutions very attractive, but they are limited by the GSM coastal coverage, which are usually some kilometers.

The study of all existing solutions shows their inadequacy for West African countries extent. The brand-new solution allows coverage of large areas in high sea and profits to all parties (governments, low-income populations, fishermen, Telecommunications operators).

3 System architecture

3.1 M2M architecture

During the last decade, the telecommunication industry has been revolutionized by the growth of machine to machine (M2M) applications. Their major assets of are possibility of data sharing and access among various applications, security and privacy management, and suitability for Internet Protocol (IP) Networks. Reasons why standardization of M2M communications have been attempted by many organizations. The following figure is the M2M architecture according to the European Telecommunications Standards Institute (ETSI) [9], [10], [11], [12], [13].

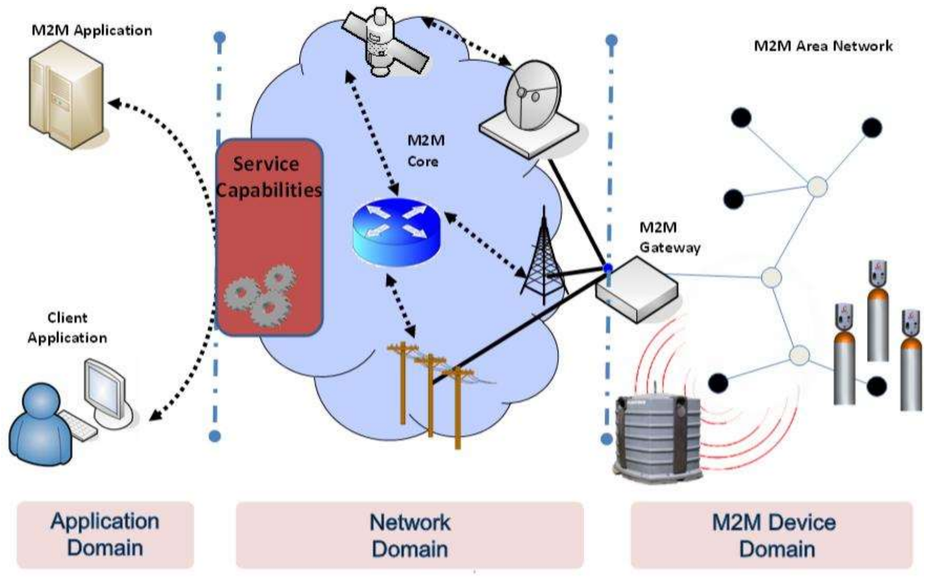

Fig. 1. ETSI M2M architecture [9]

3.2 Transport solution

It is important to note that, in Senegal, the activity zone exclusively reserved to traditional fishermen is from 0 to 7 nautical miles (13 km) [14].

Costal base stations range will only be about 13-16 nautical miles (24-30 km). Below that distance, information flows directly through the 3G networks to the core server. But to reach pirogues out of that range, the information path will change. Navy patrolling boats will act like base stations by generating a 3G signal with high power antennas and communicating with the core server via satellite.

3.3 Global architecture

The following scheme shows the architecture of the system.

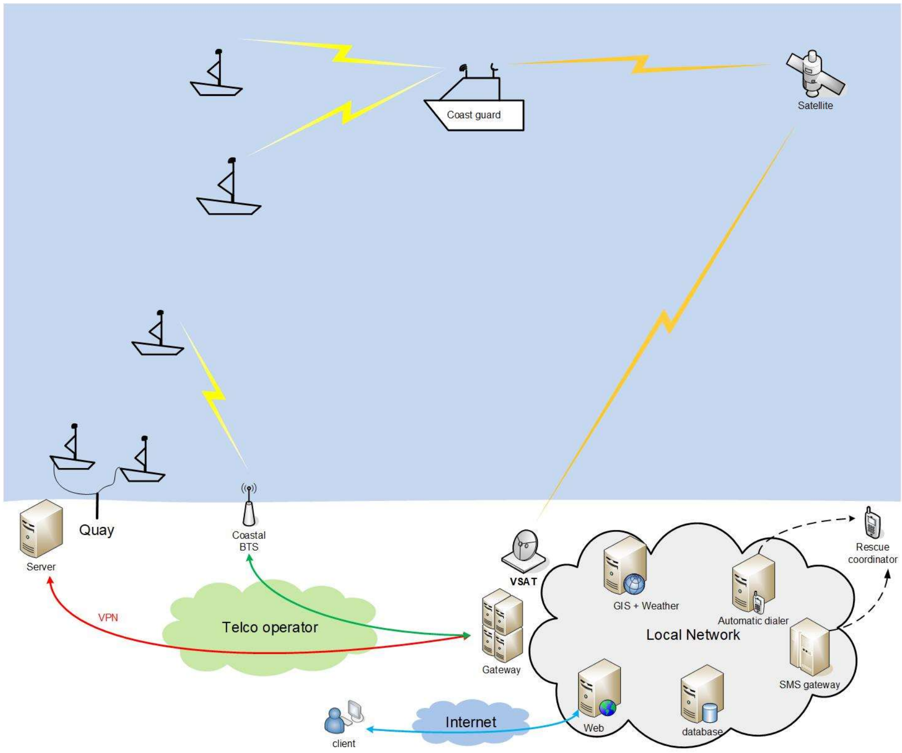

Fig. 2. System architecture

Our solution allows using the local telecoms infrastructure as transport network. It is fast to deploy and the costs are very low compared to satellite solutions. The satellite links are necessary to update information from the guard coast that relay signal generated by pirogue located in several kilometer from the coast.

The solution architecture presented in the fig. 2 is composed from nine main items presented below.

1. Pirogue onboard device

- Microcontroller gets the position from the GPS module, sends, and receives information from/to the core server via the GSM interface, displays information on the LCD screen;
- GSM module (with SIM card inside) enables TCP connections/SMS with the gateway;
- GPS module gives the position of the pirogue;
- LCD screen shows useful information;

- Keyboard enables navigation and input;
- High autonomy battery permits long period of use.

2. Coast guards relay boats

- BTS provides and manage radio interface for pirogue devices;
- Server manages the base stations and communication with the shore server;
- SATCOM system interacts with the satellite link;
- The use of this kind of boats can be very useful for safety of fisherman and the security by identifying devices embedded in different pirogues.

3. Coastal base stations

- Dedicated to sea coverage, offer 3G-radio interface to the pirogues within reach of their signals.

4. Quay managers and servers

- Manager collects and updates the local server;
- Server, periodically and automatically, updates information (pricing, unloaded catches, and others) with gateway.

5. Gateway (GW)

- Interface area and core networks (with SATCOM and operator connection);
- Manage security access protocol;
- Collect and route information from/to onboard devices and quay servers;
- Collect and route information from/to other core network servers.

6. Geo Information System (GIS) and weather server (GIS&W)

- Stores and retrieves geospatial and weather forecast information.

7. Database system (DBS)

- Stores and retrieves information about users, devices, quays, pricing, catches, and national fishery statistics.

8. Automatic dialer and SMS gateway

- Allow the system to contact and inform rescue coordinator and people in charge of rescuing.

9. Web server

- Provides Web application for map and data visualization.

3.4 Functioning procedure

The system manages automatic updates with M2M devices through a secure IP channel. Information exchange format is eXtensible Markup Language (XML) [17].

3.5 Authentication and authorization procedure

The gateway (GW) manages addressing, security and privacy for core network access. It runs a Dynamic Host Control Protocol (DHCP) server that provides internal IP address to the onboard devices. The other entities have fixed internal IP address. Onboard devices are identified by their pirogue registration number as it was issued with their fishing-license. A quay server is identified by its Medium Access Control (MAC) address. In addition, a password is needed for all entities to be connected.

The following example shows authentication and authorization requests and response:

XML code 1 Authentication and Authorization requests and response

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!-- authentication and authorization request example -->
<auth_request>
  <origin>
    <id>
      SEN-NL9032 <!-- every pirogue or boat has its
unique registration number -->
    </id>
  </origin>
  <id>
    SEN-NL9032 <!-- every pirogue or boat has its unique
registration number -->
  </id>
  <mac /> <!-- only quays' servers are identified by mac
address -->
  <pwd>
    KLA983N1K2L3 <!-- password of fisherman -->
  </pwd>
  <alert>
    no <!-- yes means the pirogue is in distressed situa-
tion -->
  </alert>
</auth_request>
```

The following example shows authentication and authorization response:

XML code 2 Authentication and Authorization response

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!-- authentication and authorization response example --
>
<auth_response>
  <origin>
    GW01 <!-- sender is the first gateway -->
  </origin>
  <code>
    200 <!-- code 200 means success -->
  </code>
</auth_response>
```

3.6 Updating information

The Onboard devices send their coordinates, on a regular basis, to the system. This information is sent to the GIS&W server. Here is the geo information update call flow and an XML message example:

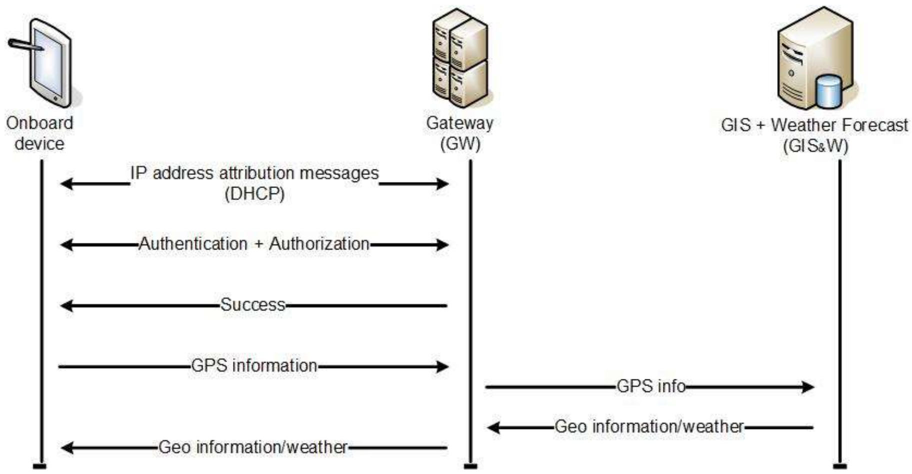

Fig. 3. Normal geoinformation update

The following example shows pirogue's geoinformation update XML code:

XML code 3 Geoinformation update

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!—geographic information update example -->
```

```
<update_localisation>
  <origine>
    <mac> <!—mac address of embedded device -->
      AF:BE:CD:AD:EE:FF
    </mac>
    <pass>
      SKE893E2ED
    </pass>
  </origine>
  <GPS>
    <long>
      14,9837 W <!-- in decimal -->
    </long>
    <lat>
      17,0938 N
    </lat>
    <hour>
      2019-06-18T15:05:10.0Z
    </heure>
    <speed>
      80 <!-- kilometer/hour -->
    </speed>
    <altitude>
      30 <!-- meter -->
    </altitude>
  </GPS>
</update_localisation>
```

The GIS&W response contains some geo information (for instance neighbors' positions) and weather forecast. The onboard device will display this information. Note that it has a preloaded map. Thus, the GIS do not have to send a map to each pirogue's device.

The following example shows the geoinformation and weather update message:

XML code 4 Geoinformation and Weather update

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!—geoinfo and weather message example -->
<geoinfo_weather>
  <origin>
    GISW <!-- geoinfo system and weather server -->
  </origin>
  <neighbor> <!-- location of a neighbor -->
    <GPS>
```

```
      <long>
        149837 W
      </long>
      <lat>
        170938 N
      </lat>
    </GPS>
    <alert>
      no
    </alert>
  </neighbor>
  <weather_forecast>
    <wind>
      NE-SW-15 <!-- wind direction north-east to south-
west 15km per hour-->
    </wind>
    <temp>
      25-30 <!-- morning and noon temperature-->
    </temp>
    <sky>
      cloudy
    </sky>
    <storm>
      1300 <!-- possible storm at 13:00 -->
    </storm>
  </weather_forecast>
</geoinfo_weather>
```


As soon as quay manager update fish pricing and stocks on its local server, data are automatically sent to the system and broadcasted to other quays' servers. The following figure shows how the update is made.

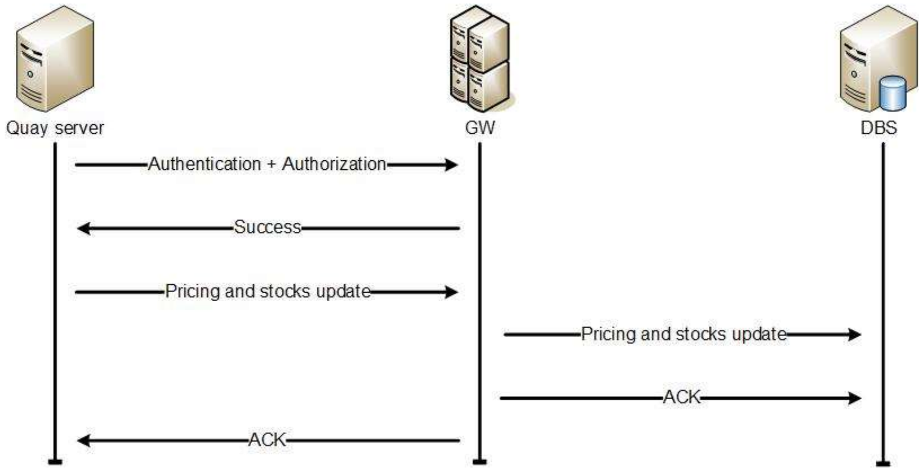

Fig. 4. Information update: pricing and stocks

To meet network security requirements, information exchange between quays' servers and the gateway is made through a Virtual Private Network (VPN) tunnel. To avoid bandwidth and system resources waste, this kind of information will not be automatically broadcasted to all the pirogues. Fishermen will request it themselves.

The following example shows the pricing and stocks update XML code:

XML code 5 Pricing and Stocks update

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!— pricing and stocks update example -->
<pricing_stocks_up>
  <origin>
    QS02 <!-- quay server number 02, each quay has a
unique id -->
  </origin>
  <fish> <!-- information about a specific fish, each one
has an id -->
    <id>
      12
    </id>
    <stock>
      20 <!-- in kg -->
    </stock>
    <price>
      1200 <!-- xof per kg -->
    </price>
    </demand>
```

```
      high <!-- this species is highly demanded by the
market -->
    </demand>
  </fish>
</pricing_stocks_up>
```

3.7 Requesting information

The following figure represents the pricing and stocks request processing.

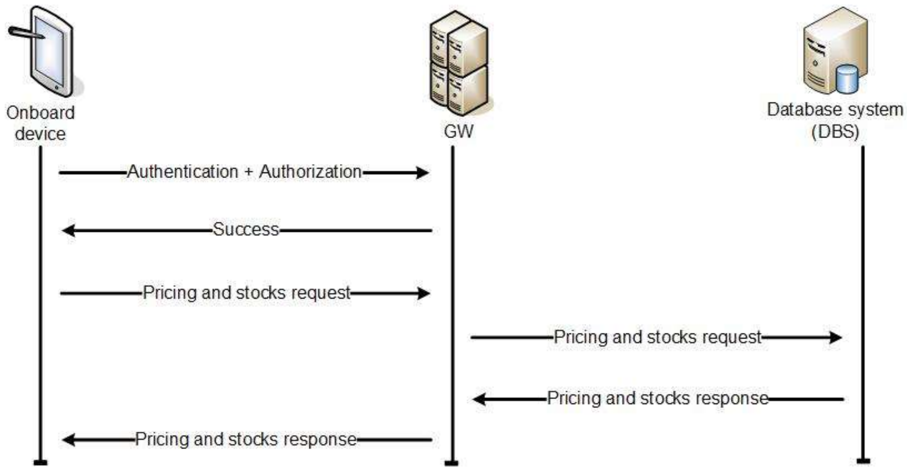

Fig. 5. Request for information: pricing and stocks

When a fisherman wants to know about fish prices and stocks, his device will send a request to the DBS through the GW. The message can be vague or specify the quay, city (area) and fish species.

The following XML code illustrates the pricing and stocks request:

XML code 6 Pricing and Stocks request

```
<! DOCTYPE auth_request SYSTEM "auth-request.dtd" >
<?xml version="1.0" encoding="UTF-8"?>
<!— pricing and stocks request example -->
<pricing_stocks_req>
  <origin>
    <id>
      SEN-NL9032
    </id>
  </origin>
  <fish>
    <id>
```

```
      12
    </id>
  </fish>
  <quay>
    <id>
      03
    </id>
  </fish>
</pricing_stocks_req>
```


3.8 Alerting system

When a pirogue triggers its alert, a message with its coordinates and an alert flag “on” is sent to the system. This position appears with a red dot on the monitoring Web page and the rescue coordinator will be contacted by the automatic dialer and SMS gateway. Information exchange is represented by the scheme below.

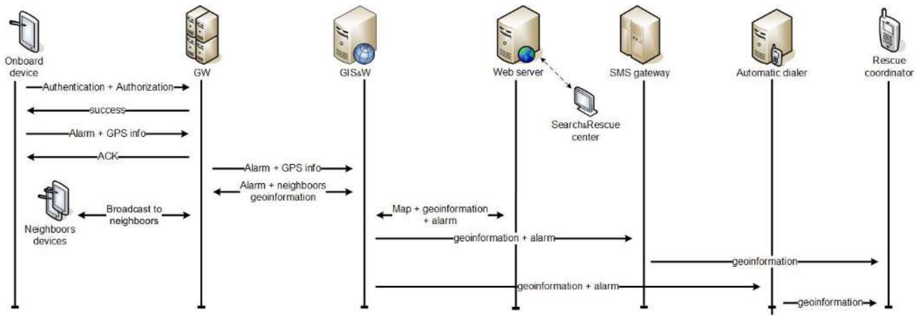

Fig. 6. Alarm from distressed pirogue

3.9 Web service and systems interconnection

Fishermen, dealers, government services and partners can access to information through a web server. Combined to the DBS and the GIS and Weather, it retrieves overall data about the national fishery. Here is the processing for Web service usage:

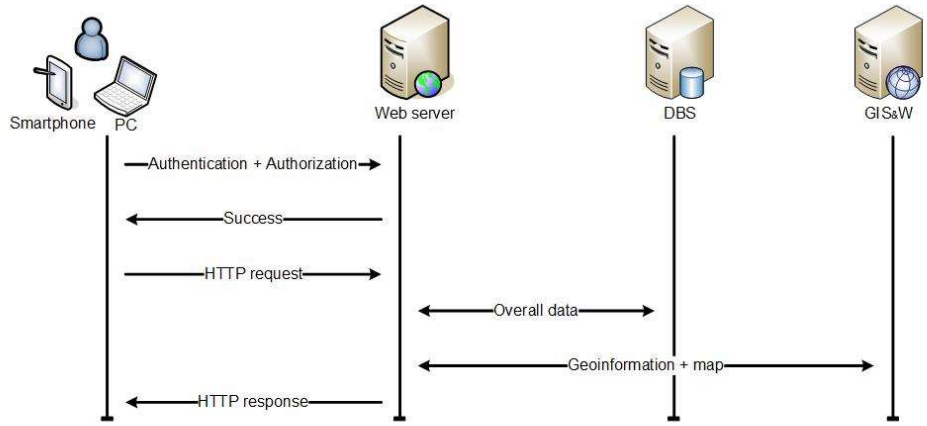

Fig. 7. Web service

The DBS is installed in a cloud. Thus, all the information is accessible and synchronized with others international systems' data such as AIS, GMDSS or LRIT.

4 Application Graphical User Interface

Because most of the traditional fishermen are illiterate, the pirogue application should be very easy to use and available in local language. The following figure gives an outline of home, information request, pricing, and stocks pages of the onboard device application GUI.

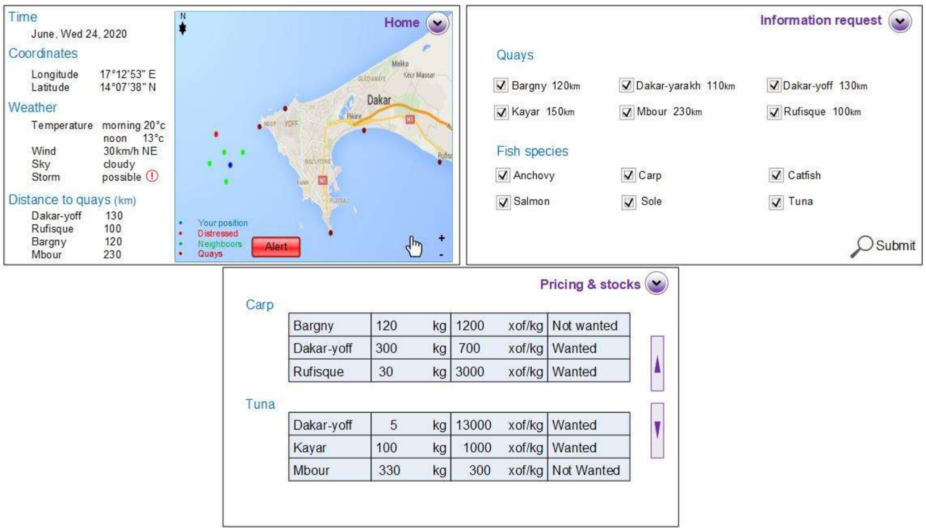

Fig. 8. Onboard device application GUI outline

Some prototypes of the solution are already realized and operate with several traditional pirogues.

5 Solution impact

The solution impacts are various:

- Low cost device compared to solutions deployed in modern vessel.
- Local government will own an independent IT solution.
- Development of local expertise in IT field.
- Development of new value-added services based on location, market, and transport.
- Digitalization of the traditional pirogues.

Also, the solution will allow fishermen to work in a more secure environment by quickening the search and rescue procedure and helping them avoid water boundaries illegal crossing.

6 Optimization of the main parameters

Further in this section, the analytic solutions to the following two tasks of defining and optimizing the M2M processing characteristics are given:

- Choosing an optimal value for scanning period τ;
- Evaluating an optimal number N of machine connected to the main server.

Let us consider as optimal such duration of period τ when a minimum of total time expenditures from machine to machine interrogation procedure per time unit, averaged on an infinite time interval, is reached. These total expenditures can be divided in two parts: time expenditures on machine interrogation depending on interrogating rate, and the time expenditures caused by delay in request detection [15].

It is evident that the more is a scanning period τ, the less are time expenditures on interrogation per time unit:

$$S_1 = \lim_{t\to\infty} \frac{S_1(t)}{t} = \lim_{t\to\infty} T_0 \frac{\left]n+\frac{\Delta t}{t}\right[}{n\tau+} = \frac{T_0}{\tau} \tag{1}$$

Where brackets] [mean an integer part of a number within them: n =1,2,…. ; 0≤Δt≤ τ.

Where $T_0 = N \times t_0$ mean number of connected machines multiplied by the period time needed by data request to travel from machine to machine.

Delay expenditures in request detection tend to increase with the growth of period τ and proportional with a coefficient χ. Here, a coefficient of proportionality χ has a sense of a fine per time unit of delay in request detection.

$$S_2 = \lim_{t \to \infty} \frac{S_2(t)}{t} = \chi\left(\frac{\tau}{2} + T_0 + \frac{\lambda\tau}{2\mu}\right) \quad (2)$$

Where λ represent the total intensity of request arrivals in the input interfaces of the main server (carried out with period τ).

The function S_1 (τ) decreases monotonously with t growth, and function S_2 (τ) increases monotonously; thus, function S_1 (τ)+ S_2 (τ) has the only minimum, which is the solution to the equation:

$$\frac{\chi}{2}\left(1 + \frac{\lambda}{\mu}\right) - \frac{T_0}{\tau^2} = 0 \quad (3)$$

Then, an optimal value of an interrogation interval is

$$\tau_{opt} = \sqrt{\frac{2T_0}{\chi\left(1+\frac{\lambda}{\mu}\right)}} \quad (4)$$

As a practical example of using the result (equation 4), consider the task of choosing an optimal signal request-scanning period from M2M system.

Let the number of pirogues N=5000 The average time to reach a machine port embedded from one pirogue to another is less then 1ms, so T_0=5000*0.001=5s. The total intensity of request arrivals is λ=250 request/s, and μ=750 request/s. The delay detection of requests χ (coefficient of proportionality) is equal 1 request/s.

Using equation (4), we can calculate the optimal value of an interrogation period.

$$\tau_{opt} = \sqrt{\frac{2\times 5}{1\times\left(1+\frac{250}{750}\right)}} = 2.74\, s \quad (5)$$

Thus, an optimization task for defining the number of pirogues N and the value of scanning period τ is proposed to be solved by using two independent procedures, as follows:

- Finding, with the fixed value τ, a minimal value of N which meet the quality of services defined in ITU-T Recommendation [12];
- Finding, with the fixed value N, an optimal value of τ using equation (4). The value N is included in equation (4) through $T_0 = N \times t_0$.

Where $t_0 = 1/\mu$, that is,

$$\tau_{opt} = \sqrt{\frac{2\times N}{\chi(\lambda+\mu)}} \quad (6)$$

In general, a simultaneous optimization by both N and τ is needed.

These parameters can be proposed for the M2M standardization (ITU, ETSI and IETF) in case when it is necessary to find an optimum between the value of scanning period τ and the optimal number N of connected machine.

Conclusion

The use of machine to machine technology, programming tools and low-cost device has allowed to create an IT solution for location and monitoring of natural resources. The parameters of the solution have been optimized to ensure the work of thousands of devices.

Global warming being people's major concern nowadays, everybody is working out ways to keep environment safe from the aggression of greenhouse gases. In so doing we will be able to restructure the ozone layer that has too much suffer from man's action.

In the future we propose the use of photovoltaic solution for the power supply of the embedded M2M devices, which is a green solution.

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