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Geodesic Embedded System for Real-Time Tracking and Communication Offline

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Abstract. Nowadays, hybrid (air and land) systems are applied for solving syndemic problems, which have caused millions of deaths by COVID-19. In support to military and medical communications with tracking in real-time, public, or private security of objects and people, we propose a multiplatform Geodesic Embedded System for Real-Time Tracking and communication offline. The Middleware was built with Encrypted Global Navigation Satellite System (GNSS) and DB async replication. It was built under a client-server architecture of multi-Tiers and logical multilayers, was developed with Nodejs-Express-Angular with Object Relational Mapping and Data Transfer Object with PostgreSQL. Generally, tracking systems with GNSS technology are slow without a base architecture and adequate development tools and require an internet connection in some of their stages. The proposed system was tested with other applications; it used Geoserver and Dockers in two different environments. The results showed its functionality in different situations applied in problems of aeronautic and terrestrial tracking, guaranteeing a projection of personalized geodetic maps, and OpenStreetMap used in an agile way, efficient, and secure communication in real-time. The proposed architecture allows native development, integration of new modules, and cross-platform implementation in an easy way, and a cellular transceiver with 94.6% of efficiency. The proposed architecture, permit to use the application in different platforms with the same configuration.

Keywords: Cellular transceiver**,** DB async replication, Communication encrypted.

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1 Introduction

Currently, public safety has used the hybrid aerial and terrestrial communication systems due they are deployed fast and large coverage [1,2]. Today syndemic problems in the medical area need to track objects (germicidal robots, ambulances, medicine, and so on) to reduce infections and comply with health procedures during the transfer of a patient by aircraft or terrestrial, to provide medical assistance in real-time without an internet connection and maintain communication between organizations, centralized and remote.

This allows coordinating different activities in safe way avoiding the information intrusion [3,4,5,6]. Merrill Singer (1990) defines the syndemic as a set of epidemics with implications at the biological and social levels. COVID-19 creates a health, educational economic crisis and so on, originating a syndemic.

The aim of this paper is to propose an architecture with 3-Tiers and logical n-layers to ensures that multiplatform Geodesic Embedded System be a functional, scalable, reliability system and high performance for long time and can track a vehicles fleet, aircraft, objects, and so on in Real-Time. This will ensure communication offline to give technical support and to take decisions during the execution of its operations by means of secure data link communication (GNSS), and DB async replication. Telecommunications and cryptography have been an integral part of information security, avoiding the intrusion and reception of unwanted or malicious messages [7,8,9]. The tools used of this paper were Nodejs-Express-Angular with Object Relational Mapping (TypeORM) and Data Transfer Object (DTO) with PostgreSQL for the DB async replication.

This project can be used by hospitals, air force, Police Security Systems, or whatever company public or private that need the objects or person’s geolocation.

The rest of the paper is structured as follows. Section 2 refers to the state-of-art. Section 3 is devoted to we show the proposed solution architecture. Section 4 is oriented to presenting the results to show the performance of the proposal. In short, section 5 describes some brief conclusions about this work.

2 Related Work

In recent years, portable tracking systems, geographic information (GIS), or commercial graphical interfaces [10,11] have been developed to facilitate the collection, visualization of data on a map [12,13] and the patterns analysis [14] of objects or people for decision-making. Geographical information [15] is used through digital cartography, and from physical sensors such as: Global Navigation Satellite System (GNSS). GPS, digital mapping, and geodetics enable geographic data processing and are essential for ground and aerial remote sensing applications. GPS is a space-based radio-navigation system of the United States of America that provides reliable, free, and uninterrupted positioning, navigation, and chronometry services to civil users around the world. It is supported by absolute precision and reliability [16,3,17,18,11,16].

Recently, some researchers have developed telemetric systems with Global System for Mobile Communications (GSM) controlled remotely in an encrypted way through SMS and applications Web. This has become a standardized infrastructure for remote monitoring [7,8,9,19].

Related lightweight cryptographic hash functions of the United States National Security Agency and published by the National Institute of Standards and Technology (NIST) provide security on devices with limited resources. Hash algorithms are among the most widespread cryptographic primitives and are currently used in multiple cryptographic schemes and security protocols. Other papers are focused on DB asynchronous replication [20].

Boriani et al., used the SHA-256 and SHA-512 algorithms with the round pipe technique and obtained a higher yield per cut of 57% and 17%, respectively in comparison to other implementations. S. L. a. K. Shin [21], used SHA-512, which is based on a 32-bit data path. The result is an efficient implementation that can use in IoT security applications. Also, Rote and Selvakumar [22], the authors implemented the SHA-252 hash function in different FPGA families to compare the performance metrics such as area, memory, latency, and clock frequency. This allows a selection of the most suitable FPGA for an application and the implementation of SHA-256 and SHA-512 algorithms.

A decade ago, the N-Tier architecture of physical distribution and n-layers of logical distribution with reusable modules and components emerged in software engineering. Telemetry is a technology that allows the remote measurement of physical quantities and the sending of the information to the operator. This information relates to the data necessary to maintain control of all computer equipment. The operator would be aware of any irregularity or problem that may arise, responding quickly to any mishap, reducing the probability of information loss or damage to hardware.

Currently, communication can be established from a control center with any portable module to send or receive information and give instructions to operate remotely. Furthermore, the design and creation of complex systems with maximum scalability, reliability, high performance, and integration are required for different applications [23]. On the other hand, the outbreak of the SARS-CoV-2 pandemic has disrupted health, social and economic systems worldwide, giving rise to urgent needs for technical solutions, thus emerging various robotic platforms with an intelligent and autonomous control system. Furthermore, the germicidal SARS-CoV-2 robots usually use commercial software and hardware [24,25].

2.1 Our contribution

The proposal ensures to build a Geolocation and communication System (GCS) with its subsystems and modules. This architecture has 3-Tiers and logical n-layers, it ensures that the application has the characteristics of a functional, scalable, reliability system and high performance for long time. The geodesic web system uses an encrypted algorithm SHA-256. Furthermore, this architecture allows that web system be installed any device (desktop or mobile) regardless of the S.O. (Windows, Linux, Android) used. To proof the architecture, we built an embedded system (Data Link), it uses technology GNSS and a cellular module with the best reception to track a fleet of objects in real-time and to ensure a bidirectional communication. In the middleware we used a personalize encrypted algorithm, in this paper is identified as Encrypted Data Link Package (EDLP). Furthermore, the Data Link System has a subsystem async replication with Bucardo and PostgreSQL to recovery lost data.

3 Proposal Architecture

The embedded Geolocation and Communication System is depicted in Fig. 1. The main modules are Fleet Control Station (FCS), Operator Data Link (ODL), and Data Link (DL).

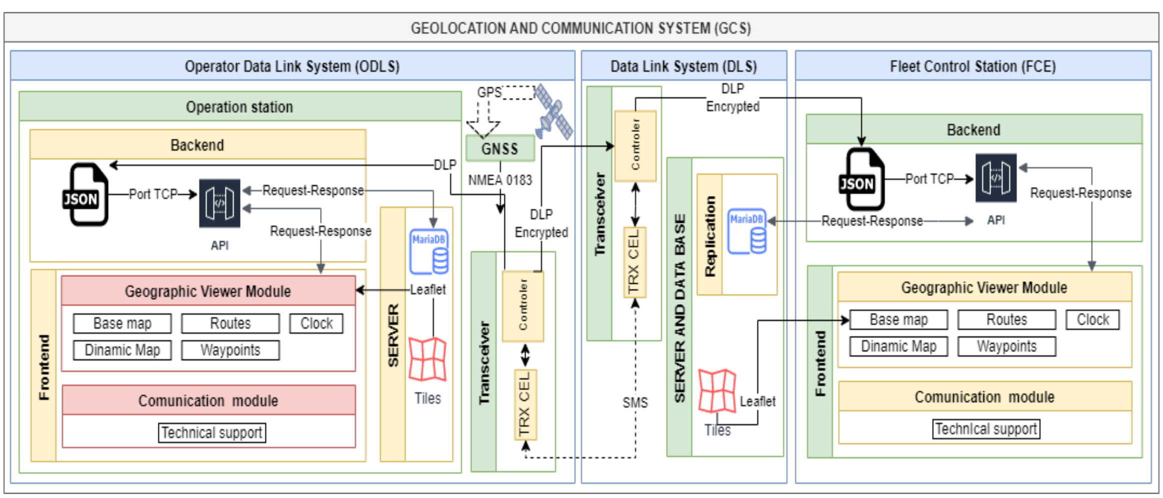

Fig. 1 Geodesic Embedded System Architecture and Encrypted DLS.

3.1 Data link system

The Data Transceiver *(***DT).** is a Middleware with technology GNSS Encrypted, built on Arduino ATmega328P with I2C (LCD), TTL (SIM, GPS) and SPI (SD) communication protocol at 9600bps, all modules connected independent, data transmission module with GSM / GPRS / GPS technology and antenna (SIM800L and SIM808L, respectively), with GPS weft (UTC, coordinates, and satellites number) with AT commands. The transmission and reception pins (TX3, RX3) are used in a crossway of both circuits and a cellular protocol SIM card, both selected by high sensitivity level (-108dBm, 23dBm), see Fig. 2(a).

Fig. 2(b) shows the DT operation. - it sends and receive Encrypted Data Link Package (EDLP), georeferenced positions and establish secure communication between DT-Transmitter and Receiver (DT-T, DT-R). Furthermore, has personalized cryptogram and use 256 bits with standard NMEA-0183, this is acquired through the configuration of the GNSS to emit GPS weft, to validate and send data to the interface controller and *data linking*.- this processes the geodata, transforms it into an EDLP and validates the weft that will be sent by the *interface controller*.- configures the web server, send the user geodata and SMS message. Finally, sent to the log controller to connect and record in the DB future communications and I/O history.

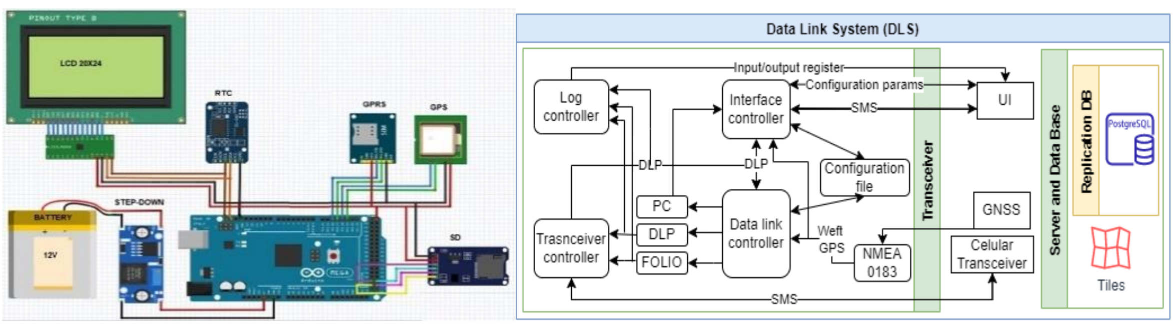

Fig. 2 (a) Independent modules connection diagram, (b) Embedded System Architecture

To ensure that the Weft-SMS be safety and allow a bidirectional communication we use EDLP, the security system was built personalized way and has the follow structure, see Table 1:

Table 1 Encrypted DLP Attribute (Weft-SMS)

Attribute	Label	Chars	Format	Communication Link Package
ID	Sender	2	99	[T-'message']. Example: T- Hello everybody
	Addressee	2	99	"X-" + key. Example: + [X-1]: all very well
	UTC	12	AAMMDD hhmmss	+ [X-2]: Process started + [X-3]: …
Object-Geoposition (G-User)	Latitude	8	+ggddddd	"N" + Event: + [N-0]:
	Longitude	9	-gggddddd	Operating + [N-1]:
	Elevation	5	99999	Reject + [N-2-'id_Operation']:
	Speed	3	999	Authorized + [N-3]:
	Azimuth	3	999	Started + [N-4]: Finished
				+ [N-5]: Canceled
CLP	kind of message	2	X-	"S" + Request. Example: + [S-0]: Request of status
	Message sent	76	Hello everybody	+ [S-1-'Folio of Operation']: Request authorization to start

Each attribute requires a given number of digits. *ID:* (0-99) first block with user identifier Sender-Addressee, 100 user's max. *UTC:* date (*01-04-2021*) and time (*14:05:01*). LATITUDE: North/South & 7 digits (0-90º), tenths of a degree (0.00001-0.99999)/0.1 (*20.1234° North*) arcseconds=3m. LONGITUDE: East/West & 8 digits (0-180º), tenths of a degree / 0.00001 degrees approximately 1m (*90.12345° West*). ALTITUDE: Maximum 99999 ft=*7,000*. SPEED: Maximum 999 knots=*185*. AZIMUTH: Range 1-360° (*45°* with respect to geographic north). *CLP:* identifies operation geodata, the type of data message sent a) personalized. - Maximum 76 chars, b) predefined. - they use a key, and they will be hosted in the DB local.

Table 2 shows Weft-SMS structure, operation trace, open, unencrypted, or predefined messages. The latter is technical content and just sends a key, and the criteria of the cryptogram "ID / Robot-Position / CLP" were used for the security of the data output. The SMS sends 140 characters, and the proposal sends EDLP of 45 and 76 chars for predefined or free text messages. Example: EDLP-SMS = "1001201201130001 + 2012345-090123450700013045T-Hello everybody".

Server and Data Tier. We Host the maps in tiles format. Furthermore, builds and manages DB with a persistence engine using PostgreSQL through Object-Relational mapping (TypeORM) and Data Transfer Object (DTO). Furthermore, has a DB replication system in case of disconnection during operation.

3.2 Operator and Fleet Control Station

Was built with three tiers, and each has *N* logical layers, see Fig. 3:

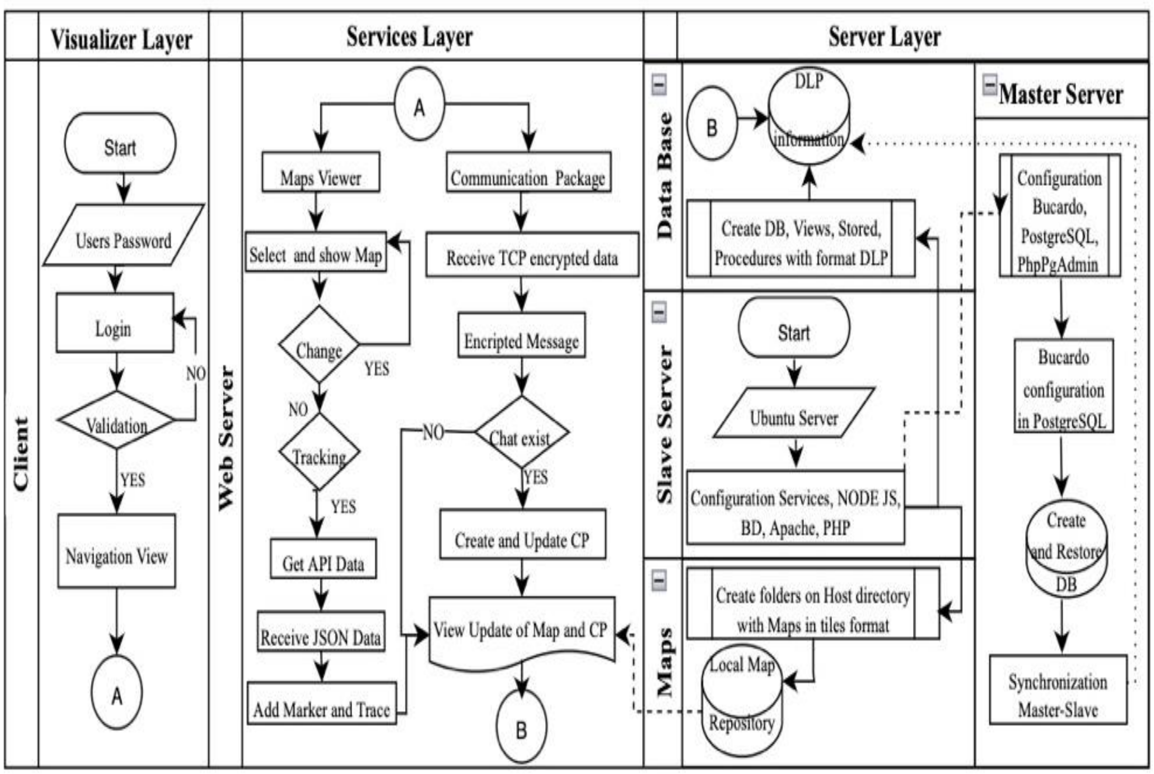

Fig. 3 Architecture Client-Server multi-Tier and multi-Layer of the CGS

Server Tier. Configured with Apache Tomcat to host and manage geomaps in Tiles format at different scales and zoom levels. If they are not in the tiles format, they are preprocessed with Maptiler. To build a CGS with the proposed architecture, we need n logical layers to develop API and services, we required: Nodejs-Express-Angular (Backend and Frontend), Leaflet plugin to interact with raster and vector maps with EPSG coordinate systems: 4326 and TERMUX: a terminal emulator for Android.

Client Tier. This is an application multiplatform; it can authenticate the operator, track objects, and has an interface that allows communication between the controller and operator. It displays objects relevant information (Weft-SMS) and we to track its routes. It manages operations and DLP through a communication interface to provide technical support and make decisions. This tier works thus: a) Viewer Interface. - Load static layer (base map) and dynamic layer (base map with markers and routes in real time), its function is to track different objects using a personalized maps variety or OpenStreetMap. b) Communication interface. - it communicates with data tier or server Tier, it has a service to consult user data, manages EDLP-Json of free or predefined text and sends it to the DT. c) Encryption. - the crypto.js library is used in DLP-Json to continue maintaining the data received security from the DT-R or DT-T (EDLP-SMS) to the viewer.

Data Tier. It guarantees high scalability and manages the DB in an easy way, providing a reliable migration system. Has an async replication system controlled by PgadminIII, Bucardo and PostGIS to replicate slave server geodata when work without connection in the master server through extraction, transformation and loading of data with a PostgreSQL Data Base Manager System (DBMS).

4 Experimental Results

We test the EDLS to send / receive geodata and personalized or predefined messages (SMS Weft) to give technical support in real time using GNSS technology (Fig. *2*). Furthermore, we validate the CGS architecture and their modules (Fig. 1) with other applications.

4.1 Datasets

We used the proposed DT with module SIM808L and commercial DT (Garmin Glo) to test the EDLS. the Mexican Air Force pre-processed the maps Enhanced Compression Wavelet (ECW), the required Disk Space is 457.1 MB, 25.23 MB, 172.3 MB, 1.52 GB, and so on. These were pre-processed with maptiler to unzip and obtaining the geomaps in Tiles (16.87, 244.82, 11.37, 67.07 GB, and so on) with zoom of 10.

4.2 Data Transceiver Experiments

Now, we show how is structured the transceiver, how works, and we will see its behavior. The DT has a SIM808L module, this had less data loss, better performance, and communication than SIM900 and commercial devices such as Garmin Glo, see Fig. 5(b). The function principal of the DT is to send geodata only, or to generate encrypted DLP-SMS message (Table 2) of different waypoints and routes, see Fig. 5(a).

```
0100210518153125 +1974983 -0990148307380000314
0100210518153315 +1974983 -0990148207381000314 -T -hello
0100210518153415 +1974982 -0990148207383000314 -T -Operation start
0100210518153819 +1976058 -0989797608657099093 -T -Route start
0100210518154650 +1977832 -0988317409057042131 -T -Heading to Santamaria Ajoloapan
0100210518154750 +1977493 -0988273608811001113 -T -Heading to San Cristóbal
0100210518155158 +1980363 -0988247508687098065 -T -Heading to Santa Maria México
0100210518155209 +1980559 -0988201708637092071 -T -First stop
0100210518155817 +1980644 -0988017408363081013 -T -Second stop
0100210518160251 +1980798 -0987976808392079014 -T -in path
0100210518160626 +1981431 -0987962008199000027 -T -Fourth stop
0100210518161242 +1977898 -0987327508214033267
0100210518163142 +1982360 -0989015808655112257 -T -Fifth stop
0100210518163242 +1981381 -0989308108612109246 -T -Heading to San Pablo
```

Latitude	Longitude	Altitude	Speed	TrackTrue	Time UTC	Satellite
19.533.902	-99.202.227	7253	0.22	102.2	181312.9	5
19.533.908	-99.202.226	7253	0.25	102.2	181313.9	5
19.533.994	-99.202.263	7281	2.49	0.8	181320.0	6
19.534.049	-99.202.315	7308	3.34	270.8	181327.0	7
19.534.144	-99.202.500	7378	0.03	282.3	181338.0	8
19.534.168	-99.202.533	7394	0.58	282.3	181352.1	11
19.535.872	-99.201.157	7421	22.29	94.4	181545.3	12
19.535.276	-99.191.453	7421	8.25	97.2	181734.0	13
19.535.270	-99.191.411	7421	8.45	97.9	181735.1	13
19.535.265	-99.191.368	7420	10.14	97.6	181736.1	13
19.517.191	-99.143.325	7377	24.61	198.3	182749.0	15
19.516.088	-99.143.443	7370	1.98	155	182806.2	15

Fig. 4 (a) EDLP-SMS obtained from DT, (b) data obtained from Garmin Glo

To value the DT and EDLS, we did six proofs and we to read geodata at different places of the México state and city, the time to send the NMEA weft with or without text message was one minute. Fig. 5(a) shows the SMS sent and lost during the proofs. Table 2 shows the average results, achieved an efficiency of 94.68%, and Fig. 5(b) shows the received messages of the different proofs.

Table 2 Efficiency of the DT

Weft/Proof	1	2	3	4	5	6	Average
Sent	53	87	153	255	879	1432	879
Lost	4	6	10	12	45	75	45

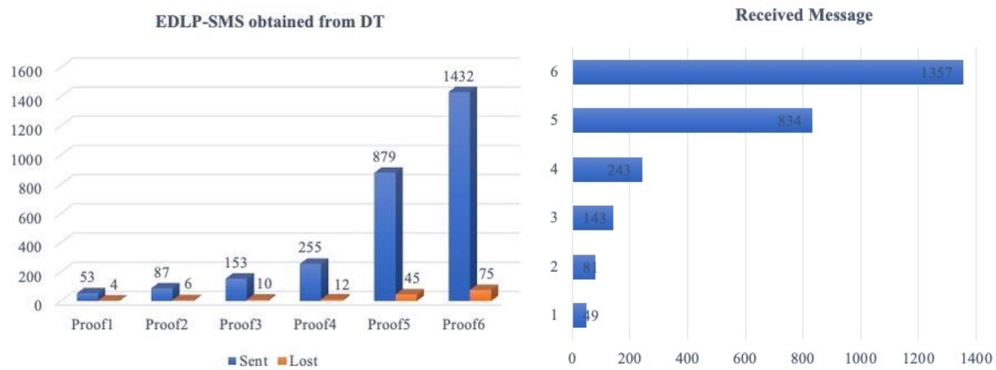

Fig. 5 (a) Sent and lost messages results. (b) Received Messages

4.3 CGS Experiments

Fig. 6 show the PINA Application works only on Windows 8.1, Tomcat 9, Java, Nodejs, MySQL, GDAL and GeoServer 2.0.8 as a Web Maps Service (WMS). Unfortunately, only works in windows, the exchange of base layers is very slow, and it crashes when interchanging the dynamic layers and when does several processes at a time.

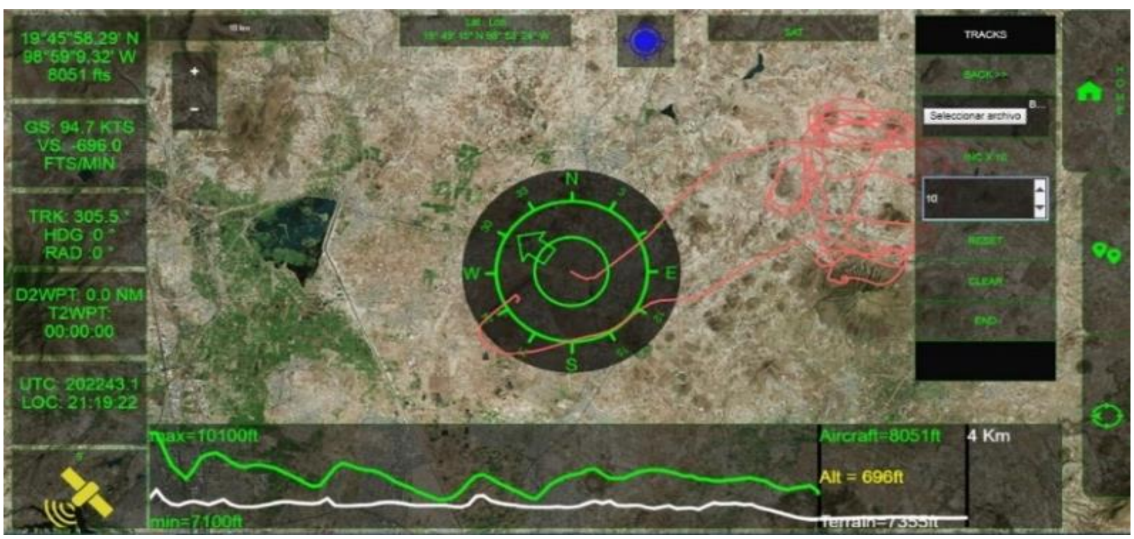

Fig. 6 PINA application

To proof the application behavior on Linux we used Geoserver with dockers as WMS to load maps ECW, unfortunately require configurations different.

The CGS visualizes geodetic data offline and is configured on a microcomputer, PC, server or mobile (multiplatform) and only requires enough space to host the base maps in tiles to speed up the work of the cartographic server. The dynamic maps are successfully graphed, it supports several routes at the same time, uses custom markers, and can use the chat, all operates in real-time without internet.

The architecture is validated by installing the application on a HUAWEI Android 8.0 Tablet, 32GB, 256GB; We only require TERMUX and APT package manager for an easy configuration and installation. In addition, functionality tests were carried out with waypoints and tracking obtained from an aircraft, achieving its tracking and communication from the control tower in real-time without internet (Fig. 7). Furthermore, germicidal robot of the COVID-19 was tested used OpenStreetMap, see Fig. 7 (b). The embedded system allows tracking the operations carried out and provides technical support to the operator.

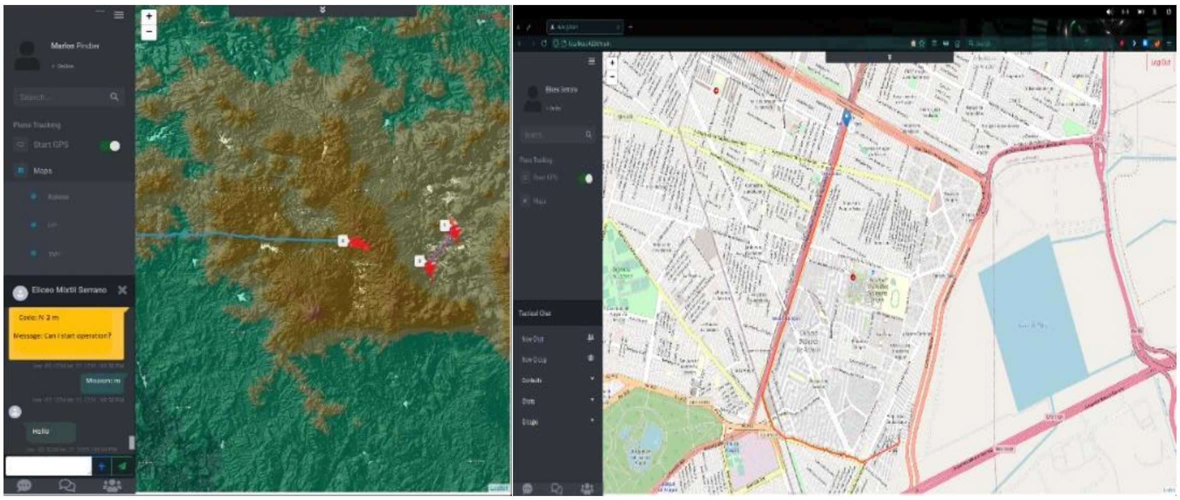

Fig. 7 (a) Tracking of the three aircrafts, and (b) germicidal Robot.

The configuration structure and replication asynchronous master-slave with PostgreSQL, allowed to copy and store 100% of the geodata by triggers of all fleets.

5 Conclusions and Directions for Further Research

This paper achievement the goal and we were using tools opensource. We use a client-server architecture with 3-tiers and N-layer. We use this architecture to build an application multiplatform allows that web system be installed any device (desktop or mobile) regardless of the S.O. (Windows, Linux, Android). It solves medical and tactical communication problems (air and land) and tracking of robot's, aircraft, and transport fleets, and so on in real time without internet connection. it can authenticate the operator, track objects, and has an interface that allows communication between the controller and operator. It displays objects relevant information (Weft-SMS) and we to track its routes. It manages operations and DLP through a communication interface to provide technical support and make decisions.

The embedded system achieved an efficiency of 94.68%. Due to the system has GNSS technology, and a cellular module SIM808L with the best reception to track a fleet of objects in real-time and to ensure a bidirectional communication. To achieve that, we did six proofs and we to read geodata at different places of the México state and city, the time to send the NMEA weft with or without text message was one minute Furthermore, it has a personalized cryptogram de 256 bits with standard NMEA-0183. it ensures that be scalable and consistency due the innovative tools of high-performance, and easy maintenance. The EDLS achieve to secure, control, encrypt, and guaranteed the predefined or open text EDLP-SMS and permit to send / receive a single packet avoiding the loss or intrusion of this. Also, it maintains security at the client level by using the Hash-512 algorithm.

When the application lost signal, this save geodata in local DB, when the device arrives to control tower, we are using an Async Data replication that guarantees high scalability and manages the DB in an easy way, providing a reliable migration system, improving the availability and accessibility of data.

The CGS was integrate and proof in military aircraft and had good performance. In attention to COVID-19 syndemic to social level, we prevent the spread of the coronavirus, by mean of integration of the CGS to germicidal robot to track its operation when it to work in hospitals, education institutions, industry, and so on.

As Further Research it is intended to use the app modules in other projects in any aspect independently, this is possible due to the paradigm of the tools used. On the DT side, it is intended to build a hybrid transceiver (GPS, Radiofrequency, and Iridium) that guarantees communication in all moments.

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