11TH ICCRTS

Coalition Command and Control in the Networked Era

COMMAND AND CONTROL INFORMATION SYSTEMS FOR LITTLE UNITS: *SIMACOP*, A RESEARCH SYSTEM TO TEST NEW CONCEPTS

Topics: C2 Experimentation, C2 Concepts and Organizations, C2 Architecture

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Abstract

Generally, current military command and control information systems aim is to elaborate the Common Operational Picture (COP) focused on the higher hierarchical levels, from battalion level and upwards.

However, in majority of present conflicts, including peacekeeping missions, many operations are carried by small units like platoons and downwards.

It would be extremely useful a command and control tool which:

- Allows obtaining the COP at platoon and squad level, virtually locating friend, neutral and enemy units over an operations theatre cartographic database with the suitable scalability at each level.
- Facilitates command and control decisions from one or from many tactical command and control locations, forward or rear.
- Allows shared awareness based self-synchronization among platoons.
- Acquires individualized data from troop units, particularly video flows and position.

In this paper, a practical research in this field is described based on the development of SIMACOP ©. SIMACOP © is an experimental C4ISR multimedia system, developed at the Technical University of Valencia, Spain.

SIMACOP © is a useful tool designed and implemented for researching on the most advanced concepts in the current C2IS development: agility, information power in the mission border (Power to the Edge), self-synchronization and coalition interoperability.

1. Introduction: Motivation of SIMACOP

SIMACOP is an experimental C4ISR multimedia system, developed by the Real Time Distributed Systems Lab at Communications Department at the Technical University of Valencia(UPV).

Generally, the aim of army command and control information systems is to elaborate the Common Operational Picture (COP) at a high hierarchical level, i.e, from battalion level and upwards.

However, in most of present conflicts, including peacekeeping missions, most operations are carried by small units: platoons, squads and even fire teams. It must be highlighted, in the scope of asymmetric conflicts, urban guerrilla or counter-terrorist operations.

In such a kind of operations, from the command and control point of view, it is fundamental to acquire a global vision of the situation (*Situational Awareness*, SA) by means of sharing each unit situation perception. Starting from the perception sharing among units (*Shared Awareness*), collaboration among them and a better effectiveness in reaching the mission goal are obtained.

Nowadays, this situation sharing is reached through units' direct vision (friends, neutrals or enemies) and vocal communications using the tactical radio combat network. In general, obtained SA is quite poor, all the more since in stress situations related to street-fight or counter-terrorist actions, characterized by a short and accelerated execution tempo.

It will be extremely useful a command and control tool which:

- Allows obtaining the COP at platoon and squad level, virtually locating friend, neutral and enemy units over an operations theatre cartographic database with the suitable scalability at each level.
- Facilitates command and control decisions to platoon and squad level, from one or from many tactical command and control locations, forward or rear.
- Allows s*elf synchronization among* platoons*, shared awareness based.*

- Acquires individualized data from troop units, which therefore will act as sensors and actors simultaneously.

To develop all these objectives, we will start from two hypotheses:

- Availability of a combat network capable of delivering digital data with the appropriated bandwidth.
- Automated information acquisition for COP generation. This process must be performed transparently to the troop units, that is, without their intervention in the information elaboration process and without interfering in their tasks.

In these scenarios, the person in charge, so as to obtain the enriched situation awareness, needs many times to “see through his own eyes” the operation scene, to make the proper tactical decisions. This requires the inclusion and fusion of multimedia flows, gathered from different sensors, particularly video flows.

Therefore, to obtain the adequate SA, it is required: 1) knowledge the exact location of units and individual elements at the operations theatre, by means of a GPS device carried by every individual element. 2) Multimedia information gathering, mainly video, from every individual element to “see through his own eyes”. Therefore, every individual element must carry a video or infrared camera. 3) Moreover, and taking into account the high value of the elements involved, it would be helpful to be able to collect from them biomedical information such as EEG or body temperature, at least. This kind of information would be obtained through biometric sensors allocated on each individual element. 4) Fusion and transmission of gathered data to the C2IS application through the combat network.

Small units tactical operations feature present strong similarities with emergency management operations as, for instance, can be forest fires: it is required the coordination of small units, being most of the times very useful the unit's real-time self-synchronization ability. Obviously, the enemy nature varies (terrorist or urban guerrilla members to forest fire fronts...) and the way to locate their positions and react to their behaviour patterns also changes. Nevertheless, it seems appropriated to think about the duality of the proposed system, both in the military and civil emergency management domains.

Finally, it is important to emphasize the need of compatibility between a system such as SIMACOP with higher level units command and control systems as SIMACET (Command and Control Information System of Spanish Army). To guarantee this compatibility it is required the usage of the same data model (Command and Control Information Exchange Data Model, C2IEDM), aspect that is being considered in the SIMACOP development.

2. Functional description

SIMACOP is a small unit's C4ISR multimedia system based in COTS technologies, with multimedia streaming and fusion capabilities, including video streaming.

The system consists of various C2 nodes connected among them and to individual nodes with sensor/actuator functionality, by means of a wide capacity (tenths of Mbps) wireless data network, based in IEEE 802.11 WiFi standard in the current functional prototype. It is planned the migration to IEEE 802.16 WiMax.

The functional approach of the system can be summarized in the following points:

- Each individual member (squad leader and troop units) carries a SBC (Single Board Computer) which fuses data sensored from different sensors (video or infrared camera, GPS, biosensors, enemy and neutral units location identifiers) and generates a unique information stream per individual element.

- Each individual unit SBC is connected to the others by means of an ad-hoc wireless network, so that the squad leader receives, fuses and forwards each troop unit streams (and its own stream) to the C2 first level. In case of squad leader equipment failure, the network self-configures electing another node as link point with the platoon C2 node.

- First level C2 application generates the COP at platoon level since it receives data flows from squads that constitute the platoon. The connection of this platoon command and control post with different squads is done by means of a wireless data network. The C2 application is executed on a militarised laptop with wireless connection.

- C2 node can receive and fuse streams from other non-human sensor sources such as managed aerial vehicles (helicopter flying over operations theater) or non managed (UAV) or fixed sensors distributed in the operations field (cameras with streaming capacity, presence sensors, etc).

- The squad commander is equipped with a tablet PC where the squad soldiers GPS position is shown on an operation theatre GIS. The unique information represented in the tablet PC for the squad commander will be the squad soldier GPS position and their operational status. More information on his squad an of course form the rest of squads will not be useful in combat stress situation for the squad commander. The rest of the squads participating in the action will be managed in the command post at section level. The information shown in the tablet PC will be updated and sent automatically from the corresponding C2 node without any action from the squad commander.

- A platoon/squad level C2 node can operate in the following three ways:

    1. Isolated from the others when, due to dimension of the mission, no more C2 levels are required. A unique COP at platoon/squad level is generated.
    2. In an autosynchronized manner with other C2 nodes involved in the mission. In order to achieve this mode of operation, full wireless connectivity among involved platoon level C2 nodes is required. The COP is generated by the different C2 nodes.
    3. Under the hierarchy of a higher level C2 post that coordinates several platoon/squad level C2 nodes. Full wireless network connectivity among platoon/squad level involved C2 nodes and higher level command and control post (from now on named as " platoons level") is required. The COP is generated by the different platoon level C2 nodes and the higher level node.

- The commanders orders are transmitted by voice using the radio combat network..

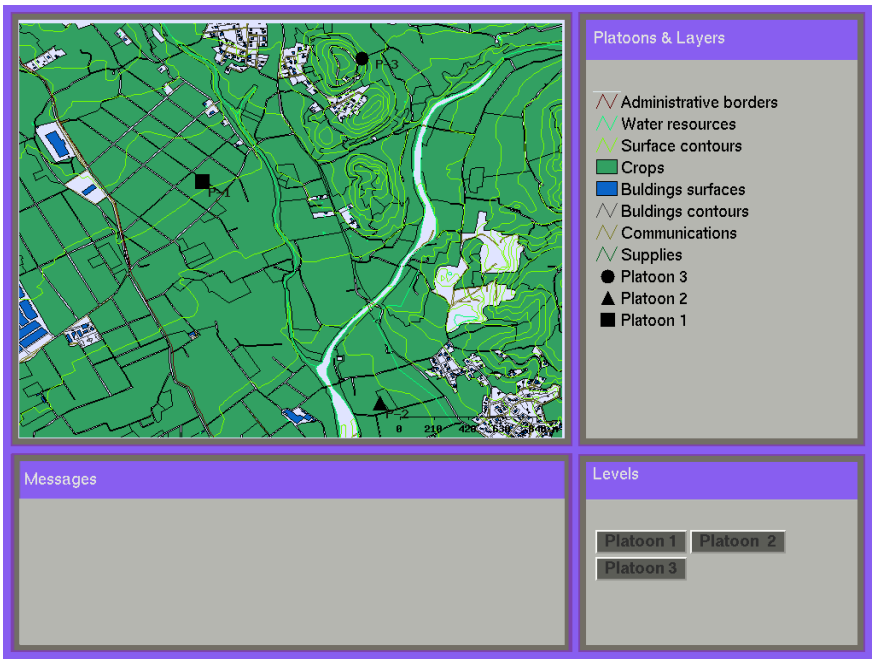
- Number of C2 nodes, its operation, number of platoons and squads as well as the squad components is easily configurable with very simple dialog boxes, granting global system huge usage flexibility for each tactical scenario.

- The connection with other higher-level command and control nodes (for instance SIMACET) can be done throughout the tactical network (RBA in the Spanish Army).

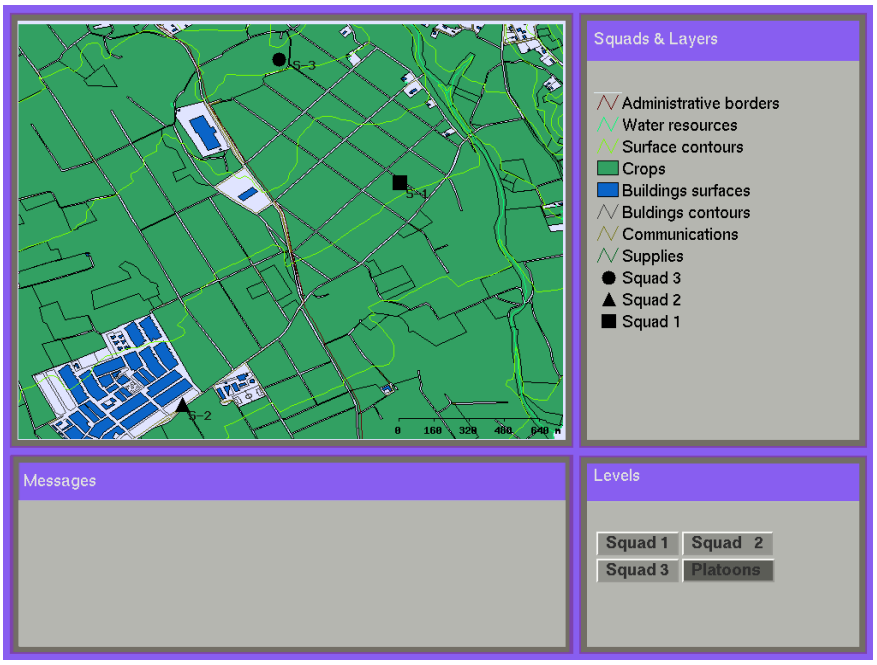
Four screenshots of the current prototype application are included below to get a more graphic view of the ideas explained.

These screens are live captures of the prototype at its current development stage and include: vectorized cartography, higher and lower level access buttons, live video stream from the selected individual element as well as vital signals of the element. The elements/levels at platoon, squad and troop units (SL stands for squad leader and TU for troop unit) can be accessed by clicking on the corresponding button or by clicking over the moving icon overprinted onto the operations theatre cartography.

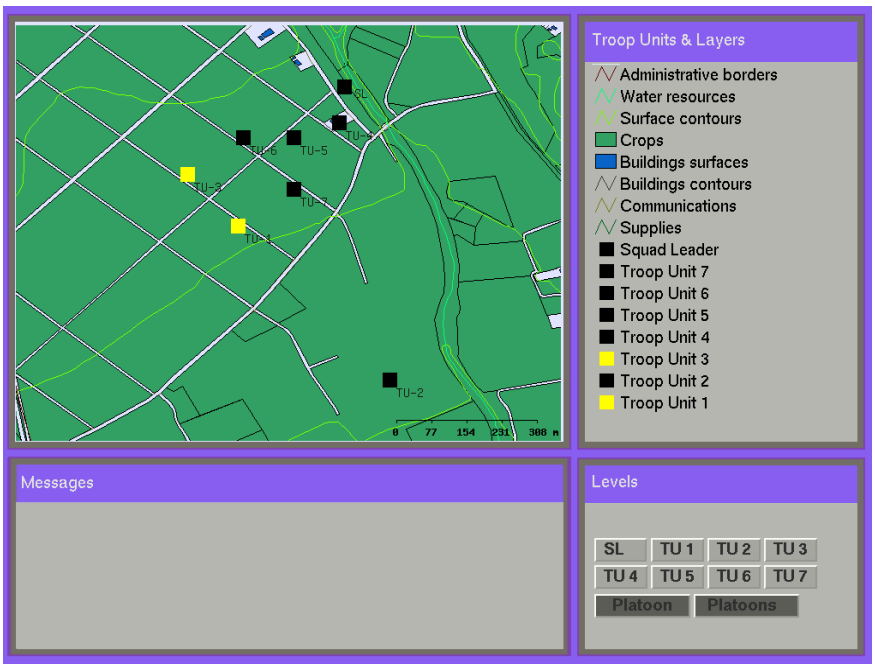
It must be remarked that, in the platoon C2 nodes auto-synchronization operating mode, the person in charge of a platoon "sees" its own platoon and also "sees" the rest of platoons, as they share the same COP.



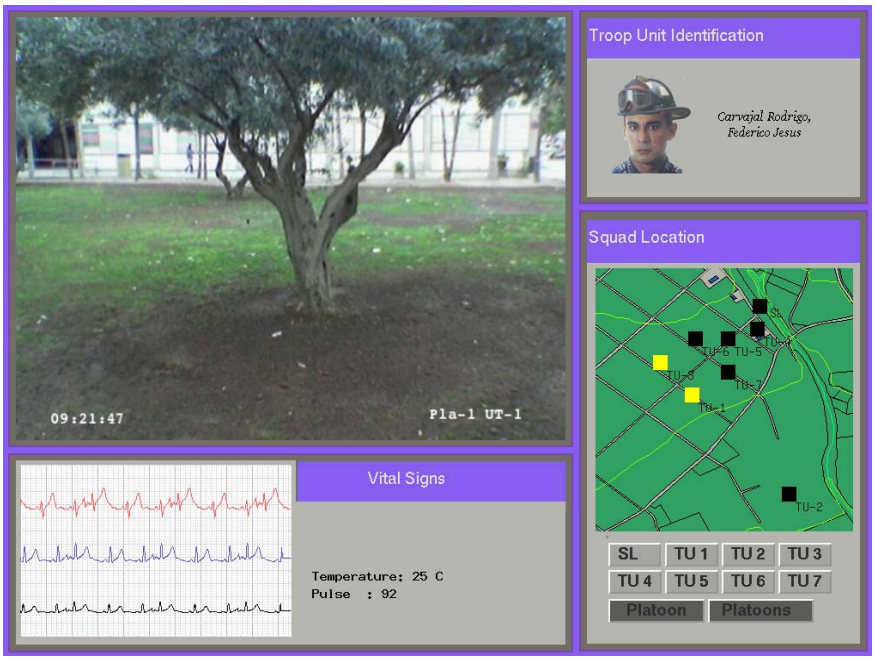
C2 node screen, platoons level



C2 node screen platoon/squad level



C2 node screen, squad/troop units level



C2 node screen, troop unit level

The prototype also includes the bio-signals monitoring functionality of each troop unit: if its bio-signals degrade the unit or element icon colour changes from black to yellow (as can be seen at the last two screens) and if the degradation/alarm increases, to red.

If it is considered suitable, for greater size operations, a higher level screen (companies level) can be defined, which would directly link with the battalion level.

3. Potential benefits

As stated before, army C4ISR systems sparsely focus below battalion level. A small-units C4ISR system (below battalion level) would cover C2 requirements at operations where, due to their nature, small but highly specialized units fast deployment is required. Furthermore, as these operations usually have a very fast operation tempo.

Possible usages of this system would be operations of urban war or counter-terrorism. Also, interposition operations in peacekeeping missions in which, due to the operation's political component, the remote command and control post requires specific and “visual” information of the situation for the decision-making process.

SIMACOP can bring support both to military and civil missions in the scope of emergency management or humanitarian missions, so compatibility in joint missions is guaranteed.

The system incorporates the most advanced concepts in the current C2IS development:

- Agility. Command and control adaptability to variety of dynamic scenarios.

- Information power in the mission border (*Power to the Edge*). In the above cited missions, it is required a powerful information system at the operations theatre, directly interacting with enemy forces.

- Self-synchronization. It is based on the shared reality perception of mission involved units and, to be efficient, requires clear starting orders, effectiveness in the low echelon commanders, complete shared information regarding the tactical scenario and mutual trust among units. SIMACOP considers all these aspects.

4. Development state

Right now, there is a completely developed a stable prototype that includes all the features described in section 2.

Next steps in development are:

- IEEE 802.16 WiMax connectivity.
- Automatic designation and localization of neutral and enemy forces.
- Simultaneous camera playback at the C2 node.
- Incorporation of security mechanisms for wireless communications.
- Incorporation of VoIP techniques for the vocal communications.

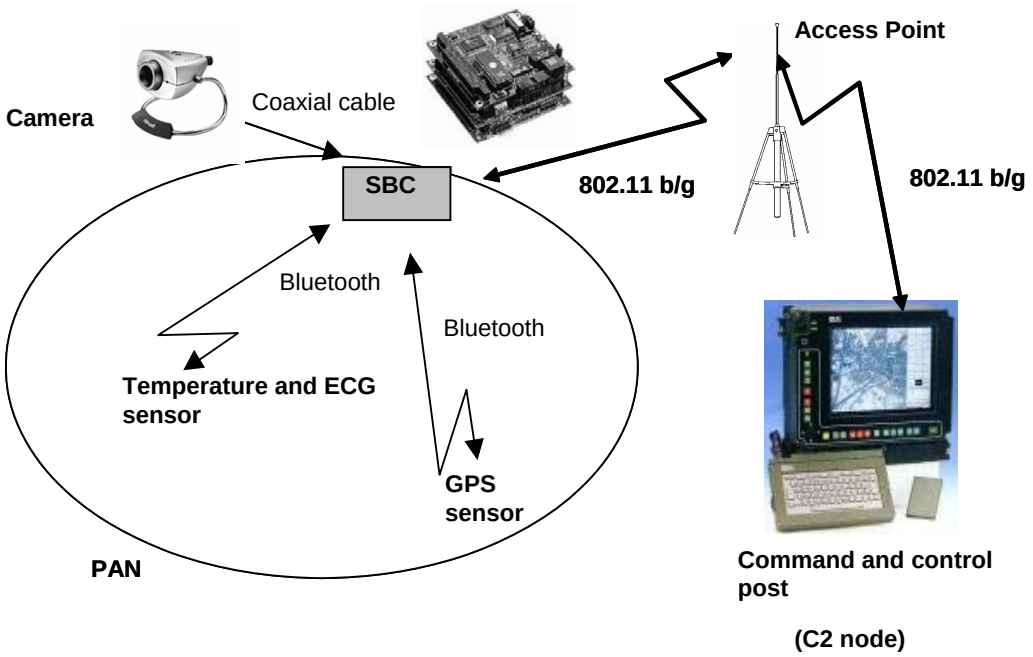
In order to develop an operative commercial product, all the electric, electronic and mechanical elements of the system must be militarized and/or ruggerized. As well, Spanish Army Geographic Service Cartography must be incorporated. Nowadays, the prototype works with the Instituto Cartográfico Valenciano cartography, which only covers the Valencia Region area. This won't constitute a problem because SIMACOP can works with any world wide vector cartography.

5. Used technology

Prototypes of a C2IS node and of the individual equipment for each troop unit, have been developed. Prototypes include the following technologies, all of them COTS:

- Video cameras and grabbing cards.
- Biosensors: electrocardiogram (ECG), pulse and temperature.
- GPS.
- SBC with linux operating system (distribution with minimal components).
- MPEG-4 codification and streaming software module.
- Data fusion module.
- Bluetooth and coaxial connectivity.
- C2 node computer with linux operating system.
- Apache web server.
- Mapserver GIS.
- IEEE 802.11 WiFi connectivity, with immediate inclusion of IEEE 802.16 WiMax.

All these technologies are summarized in the following figure.



Used COTS technologies

SBC

The election of the SBC, embedded PC that follows the PC104+ standard, as a computing and communications device was motivated by the following elements.

At one hand, it is one of the smallest form-factors at the market which is a very important aspect for our design. On the other hand, in this family there are processors which represent a compromise between computing power (mainly due to software video codification) and energy consumption.

Additionally, PC104+ is the most extended standard in SBC solutions so availability of devices and components is guaranteed. Moreover, due to the modularity of the board racking system and the number of devices simultaneously supported in a bus (PCI or ISA), we had at our disposal much flexibility to integrate different boards(communications, processors, grabbers, ...)

Finally, another fundamental aspect is that many PC104+ manufacturers provide solutions with extended range temperature and humidity features, which is an application's must.

Used SBC features:

- Fulfills the PC104+ standard
- ULV BGA Intel Celeron @400Mhz processor, 256 KB level 2 cache, 100Mhz PSB
- Intel 815E chipset
- 128 MB SDRAM
- Extended temperature range: from -40 to 80 C
- Interfaces for:
- IDE, parallel port, 4 USB, Ethernet and PCI (PC104+) and ISA(PC104) buses
- power requirements: 5V and 8W consumption

(a) (b)

a) Complete SBC with PCMCIA module, wireless card, DOM and heat-sink, with mechanized enclosure. b) Video camera mounted on helmet.

In order to supply power to the SBC, Sony-type Li-Ion video-camera batteries are used in conjunction with a Traco power stabilizer. This allows the system 2.5 hours of heavy-duty continuous operation, or with 2 more serialized batteries, 4.5 hours.

Operating System

In embedded systems, the operating system is a key point. It has been completely customized for SIMACOP, mainly at the SBC but also at the command and control post laptop. The footprint has been reduced due to storage requirements (64Mb space on embedded disk) and also to minimize unnecessary software failure points. Due to this, only strictly necessary software modules are included. Kernel is configured to support:

- ext2 file system.
- ISA, PCI and IDE.
- TCP/IP.
- PCMCIA is not at the kernel level but at the user-space level via PCMCIA-CS.
- Wireless LAN (linux wireless extensions API).
- Terminals.
- Watchdog.
- Video for linux(v4l).

- USB.
- Bluetooth stack.

The file system is completely minimized, with only the essential binaries and scripts to start the system, load the drivers for the used devices and start the applications and daemons that manage them. Moreover, most of the binaries are statically compiled and against a minimized and embedded systems specific libc. As is required in an embedded system, the system starts by itself (in 20 seconds is operative sending sensed information) without any interaction with an operator and without screen, keyboard or mouse.

In the command and control post laptop there are more storage and computing power resources but, also, device drivers load and daemons and services are minimized, in order to minimize failure points and start time. As at the SBC, the system starts by itself, without any operator intervention.

GPS

The following factors determined the election of the GPS device:

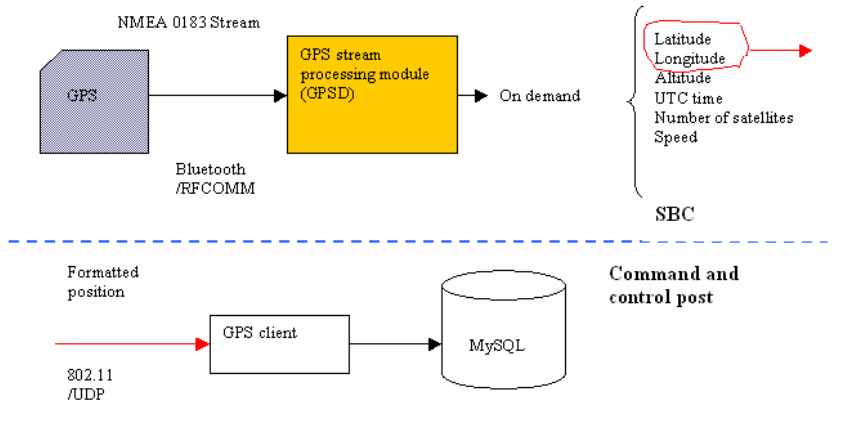
- Extended temperature range: from -10 to 70 ºC and 95% relative humidity.
- Acceptable spatial resolution (2.2 m by means of EGNOS usage)
- Standard protocols as NMEA 0183.
- Reduced weight (75g) and size 52.8 mm (w) x 85.9 mm (h) x 21.7 mm (l)
- long-term batteries (15 hours)
- Two different connection interfaces, Bluetooth and serial port.

The GPS device is carried by individual elements attached to the helmet. Another advantage of the chosen device is that an external antenna can be plugged in. The selected device fulfils the stated requirements and, additionally, uses the Sirf-II chipset, one of the most widespread and successful.

In the open source community, particularly in the linux domain, there are some all-in-one solutions, that is data gathering, visualization and user interface, which obviously did not fit in our requirements. There can be remarked solutions as GpsDrive, Roadmap, Position and GPSman.

For the present architecture, it was required a GPS daemon that continuously gathered data from the device and feed the applications. Moreover, it was required an API to interface with the daemon. In that sense, some existing solutions can be outlined: gpsd, ngpsd that recently has joined the gpsd development branch, gpsd3d and tgpsd. The most complete and used is gpsd which also has a considerable users and developers community who helped in our software adaptation process.

In Linux systems, the access to the GPS device is done by means of accessing the special file that represents it. For instance, /dev/ttyUSB0 (USB) or /dev/rfcomm0(Bluetooth's rfcomm) in which case, if the device uses standard NMEA 0183, can be read as plain ASCII. GPS daemon is in charge of stream reading, formatting and delivery through TCP or UDP. We made modifications to the daemon to adapt it to our application, eliminating unnecessary parts, increasing its latitude/longitude precision (to the extent of the device, obviously) and extending it with some extra software modules to register some system variables such as CPU usage, memory consumption, 802.11 signal strength, Bluetooth interface features, etc... All these extensions allowed us the development of a remote system monitoring daemon with very small interference with the real system, so its eventual usage as supervision tool of the troop unit's SBC by the command and control post, is short-term planned.



GPS SW operating scheme

Video Coding

The present architecture uses digital video over IP with software coding. Based on previous work carried by the research group, the Open Source Software videolan platform was chosen due to the know-how the group had about its inner operation and about application development with this solution. Additionally, videolan is possibly the best OSS solution outperforming other platforms such us Xine, Ogle or Mplayer in efficiency and versatility. Videolan has a vast user and developer communities, it is extremely complete, modular and functionality-rich. It has codecs for mpeg1, mpeg2, mpeg4, divx1/2/3, h264, theora, WMV e Indeo Video v3. It also supports UDP both in unicast and in multicast and RTP. It has plenty of modules for transcoding, graphics interfaces, http server, CORBA, ActiveX, DVB, DVD, ... Another advantage of the elected solution is the mozilla plug-in so it is easily integrable with web applications, such as ours. Obviously, the videolan software has been accommodated to our needs, eliminating unnecessary modules, recoding parts and statically linking to fit it into the SBC.

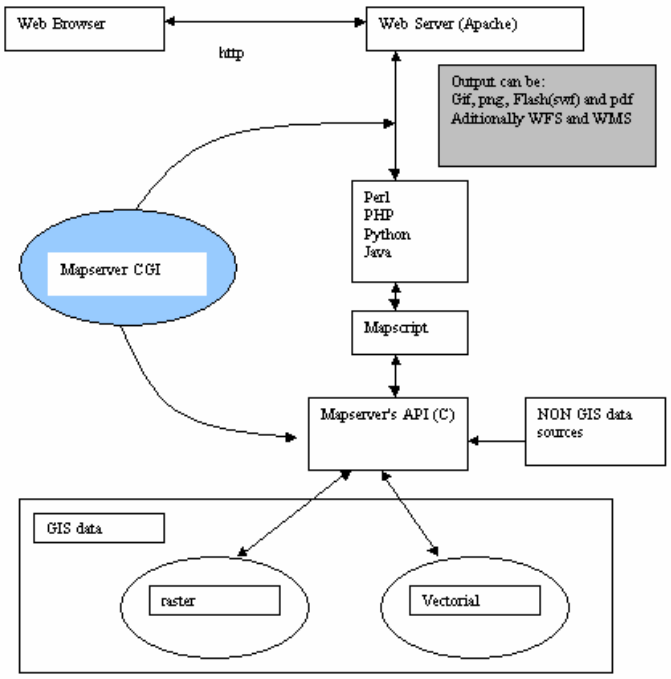
GIS

Mapserver is, by far, the most complete, versatile and used GIS tool in the OSS community. Originally developed by the University of Minnesota in cooperation with NASA and the Minnesota State Natural Resources Department, nowadays it is maintained by a huge international group of developers and users, as well as third-party enterprises that developed GIS applications based in Mapserver.

Mapserver relies on a set of well-known OSS cartographic tools such as Shapelib, Proj4.x, GDAL, OGR, on top of which a web-oriented GIS application development environment is constructed. This is due to the fact that the basic mapserver engine is a CGI that runs on Apache web servers over Linux/Unix, Mac OS and Windows platforms.

Mapserver has a considerable amount of features, adjustable at compile and run time, standing out:

- Support for many vector data file formats such as: ESRI's shapefiles, Microstation's DGN, PostGIS and many others via OGR.
- Support for many raster data file formats: TIFF/GeoTIFF, EPPL7 and many others via GDAL
- Shapefile indexing by means of quadtree techniques to archive efficiency in big map layers.
- Support for TrueType fonts.
- Support for a huge number of projections using the Proj4.x library and on-the-fly projection support.
- Support for database geospatial extensions (MySQL, PostGRES).

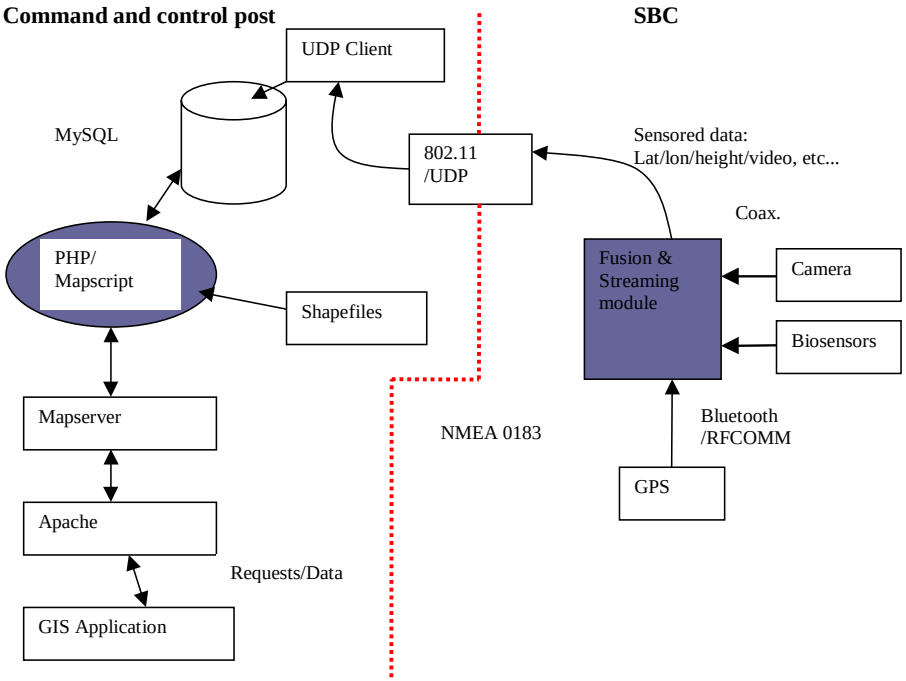


Mapserver Operation Scheme with the Mapscript wrapper

Moreover, the Open Geospatial Consortium Web Services specifications for Geospatial applications can be used, such as Web Mapping Services (WMS), Web Feature Services (WFS), Web Coverage Service (WCS), Web Map Context (WMC) and the XML subset language GML (Geographic Markup Language).

Application

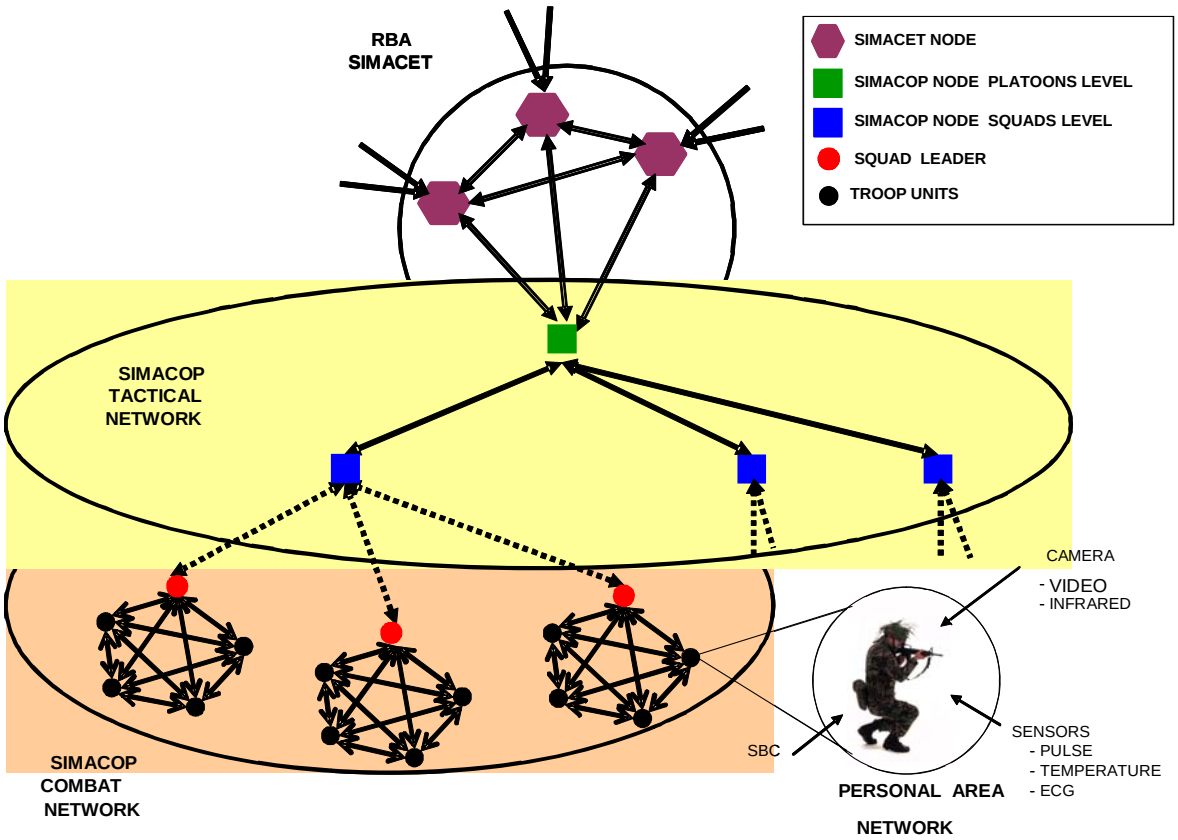
In the next figure the general scheme of the developed application is shown:



General scheme of the application

6. System's architecture

SIMACOP architecture can be seen in the following figure:



SIMACOP architecture

Components of the SIMACOP architecture are the following:

- **Personal Area Network (PAN):** interconnects each unit's sensors with its SBC. Implemented with Bluetooth and coaxial cable.

- **SIMACOP combat network.** Composed by: 1) IEEE 802.11 wireless ad-hoc network fully interconnecting squad leader and troop units; 2) IEEE 802.11 point-to-point link between squads level C2 node and each subordinated squad leader.

- **SIMACOP tactical network.** Interconnects the squad level C2 nodes among them and with the platoons level C2 node. Currently implemented with IEEE 802.11.

Some clarifications to the defined architecture:

- The connection between the platoons level SIMACOP node and SIMACET has not been thoroughly analysed.

- It is envisaged, as a prototype enhancement, the migration of SIMACOP tactical network to IEEE 802.16 WiMax and also the links between squad level C2 nodes and each squad leader. The reason of the migration is as follows:

    1. Increase the coverage area of the WIFI links (hardly 1Km) to some kilometres with WiMax (5 Kms without direct vision and up to 15 Kms with direct line of sight, but these values are approximate and depend on the particular WiMax commercial product used).

2. Increase the *indoor* penetration capacity that is almost non-existent in WIFI.

- Due to the planned flexibility for the SIMACOP configuration, the platoons level C2 node (or even a squad level C2 node if the operation's dimension is small enough) could be remotely located, far away from the theatre of operations. For instance, in a rear command post, with tactical network connectivity by means of satellite links or E1 lines, if they are available.

- Inclusion of Unattended Ground Sensors (UAG) or sensors attached to Unmanned Aerial Vehicles (UAV) is not shown in the architecture figure, but is considered. Those sensors would connect, for the sake of hierarchy homogeneity, to the most suitable squad level C2 node.

7. Field experience

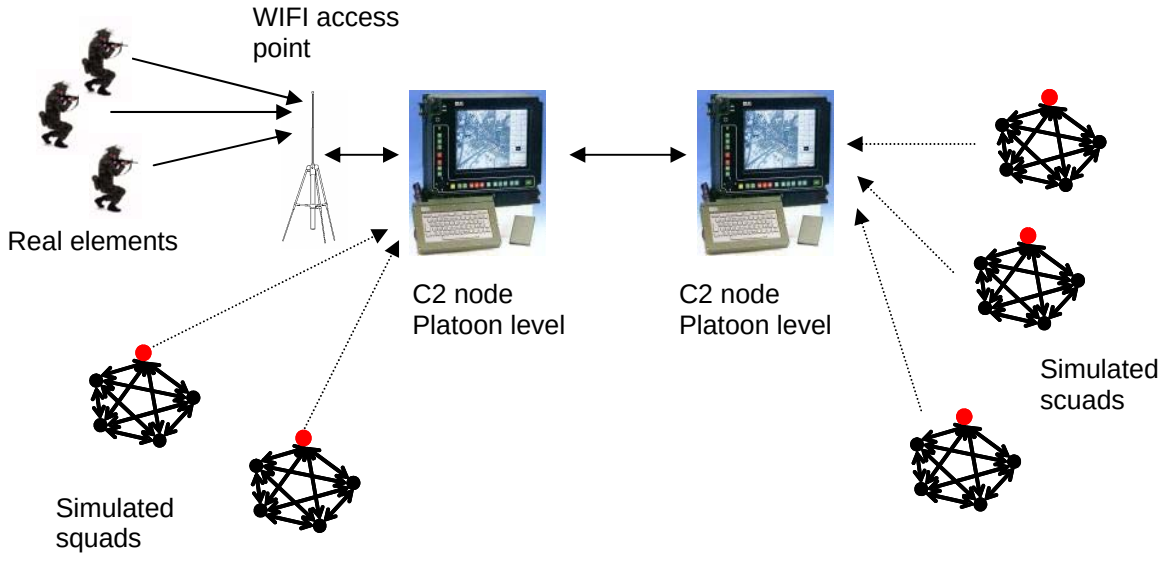
SIMACOP has been selected for the Coalition Warrior Interoperability Demonstration (CWID) 2006. The demonstration was performed in the Spanish Army Signal Brigade General Almirante base manoeuvre field last 3rd of May, 2006.

The demonstration components were the following:

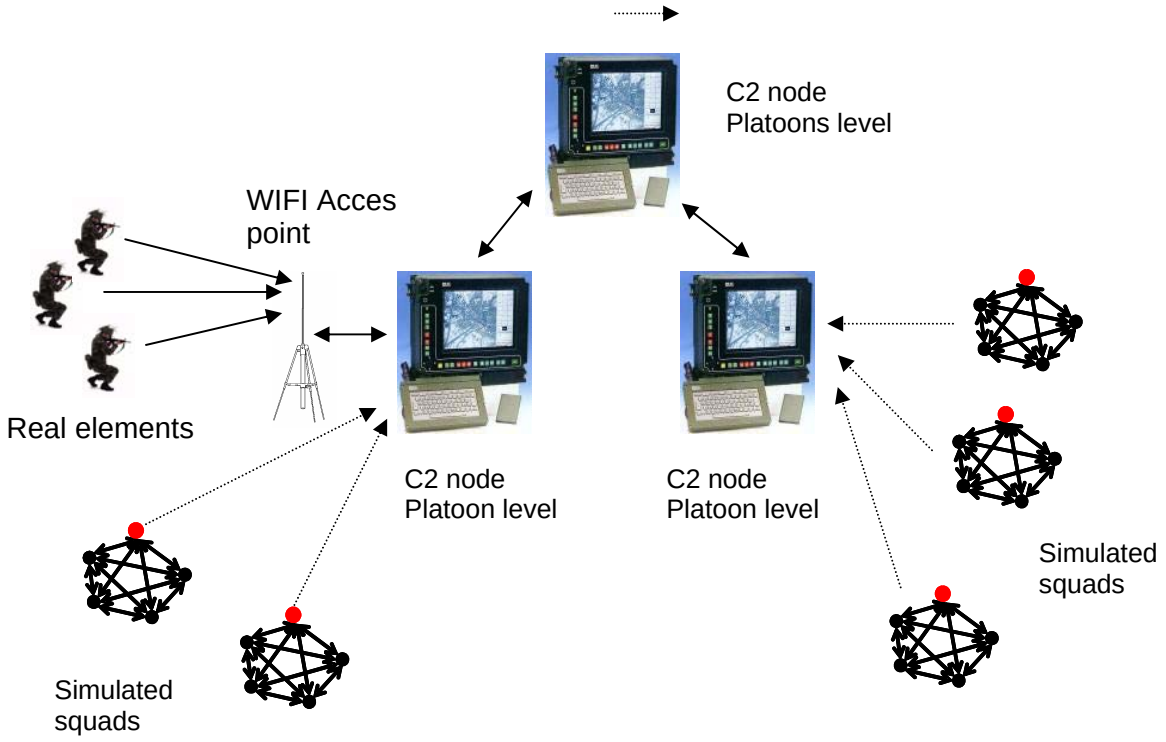
- Two section/squad C2 nodes with their own WIFI access points for connecting with its squads and a WIFI bridge for connecting with other C2 nodes.
- One platoon level node with two WIFI bridges for connecting with the lower level C2 nodes.
- C2 nodes deployment including their network equipment (laptops, access points and bridges) in two vehicles equipped with electric supply facilities.
- A military squad composed by 3 individual elements with complete equipment SBC with WIFI link, GPS device, video camera in the helmet and biometric sensors.
- The rest of the demonstration elements were simulated.

Pictures from the CWID demonstration

In the following figure the system configuration in a hierarchical and auto synchronized mode is shown.



SIMACOP: Autosinchronized working mode



SIMACOP: Hierarchical working mode

The demonstration was evaluated by Spanish army personnel from different branches: Infantry, Artillery, Cavalry and Signal Engineers.

During the demonstration following aspects were evaluated:

- The system functional feasibility
- The WIFI coverage under real operational conditions
- The lost rate in the WIFI network.
- Video quality subjective evaluation
- An overall system operability subjective probe

Some numeric results from this evaluation are (0 worst, 5 best):

Video quality at command post	4.5
Situation awareness improvement at command post	4
Decision support improvement	4.5
Application usability	4.5

The overall data gathered during the demonstration, which was performed under realistic operative conditions, is out of the scope and size of this paper. In a near future the authors expect to publish in a performance evaluation work.

8. Conclusions and future work

SIMACOP system allow to assess not only the technical aspect but rather the C2I for small units operative and doctrine aspects can be also evaluated.

Similar systems to SIMACOP only allow obtaining the COP up to squad internal level and demanding the information introduction to the units during the combat actions. Following this line advantages that SIMACOP contribute to the use doctrine of C2 systems can be summarized as follows:

Through SIMACOP the COP is obtained up to squad level, section level and also to several platoons' level.

The auto synchronization among different squads of the same section and also among platoons is facilitated by SIMACOP.

All information from units is gathered in an automatic way without interruption of their actions.

The high quality video inclusion facilitates the use of the system in intelligence actions since it allows, after an information processing in a retarded command post, the objectives and situations identification in an accurate way and in real time.

Regarding the future work, the technical improvements which allow the system to research on new command and control concepts for small units are the following:

- The use WIMAX wireless technology for giving support to the tactical network. This support could be extended to the combat network when equipment compliant with IEEE 802.16e standard was available with mobility support.

- To introduce vocal communications based on VoIP which will be directly supported on the tactical and combat networks.

- To introduce a system for enemy and neutral units automatic designation

- To introduce an automatic system for positioning own forces (Blue Force Tracking), with indoor positioning capabilities for complementing GPS information.

- To achieve international interoperability based on the Multilateral Interoperability Program (MIP) specifications. These specifications include the addition of a common data interface for the system.

    1. The common interface is the C2 Information Exchange Data Model, C2IEDM. It is a product of the analysis of a wide spectrum of allied information exchange requirements. It models the information that allied land component commanders need to exchange (both vertically and horizontally).

    2. For achieving the international interoperability the Data Exchange Mechanism (DEM) will be implemented. The Data Exchange Mechanism (DEM) is an automatic data push mechanism that co-exists with the MEM. The Message Exchange Mechanism (MEM) consists of a suite of formatted messages derived from the C2IEDM that conform to AdatP-3 Part 1, plus guidelines for their use.

    3. When a C2 application changes the state of information that it holds, and which is recognised by the DEM, this information is automatically replicated to all other co-operating systems that have agreed to exchange this information. With both exchange mechanisms the meaning and context of the information is preserved and requires no additional processing on receipt to make it useful. The MIP specifications enable interoperability at Degree 4.a 1 (DEM) and 2.h 2 (MEM) and functions at NATO Level 5 of System Interconnection

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