Integration of the INPE Ground Station into the SATNet Network for Supporting Small Satellites Programs in Brazil

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Integration of the INPE Ground Station into the SATNet Network for Supporting Small Satellites Programs in Brazil

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The researchers of the Ground Station at the National Institute for Space Research[1] (INPE) in Brazil have started working, together with the main developers of the SATNet network, in the integration of their ground segment into that very same network. This paper presents the description of that integration process together with the results obtained and with a description of the current and upcoming small satellite projects in Brazil and in Latin America. The SATNet network aims at incorporating the capabilities of all the already deployed university Ground Stations into a single, coherent and usable resource. The approach used for this network is based on heterogeneity, allowing the integration of very different ground stations into a single ground system.

Introduction

Within the scope of the approach selected for the development of the SATNet network, each ground station is considered to contribute with its own communication capabilities, incorporating a set of new channels (modulations, bitrates, bandwidths, polarizations... etc.) from a different location -

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thus, extending the coverage of the ground system. The operational availability of each ground station will be defined by the owners, depending on issues such as their degree of autonomy, their maintenance schedule and reliability, etc.

Satellite operators are expected to access this network with their own clients, registering in the network their satellites and their associated communications requirements. These will be used by the network to compute the compatibility with the ground stations registered. Combining the compatibility and the availability, spacecraft operators will only be allowed to schedule the utilization of remote ground stations during the passes of compatible satellites over ground stations that are available.

In order to accommodate all this complex diversity, the network is composed of a central server that orchestrates the functioning of the system. Remote ground stations are only required to install a simple client that allows sharing its resources with remote spacecraft operators. Therefore, the key for the success of this approach relies on the capacity of integrating this ground station client into very diverse ground stations. The second release of the software already includes a generic client that eases the integration process of these ground stations through a process of adaptation to the specific hardware.

The Importance of Ground Station Networks

The concept of a ground station network enables the description of management support tools for ground operations system. It has allowed several universities to develop ground stations networks aiming at optimizing the use of resources, eg GSN-WG [2].

Using multiple stations connected in a network improves monitoring pico-satellites and enables tracking to have a high degree of accuracy. They are creating federations of ground stations distributed around the world to improve the tracking of satellites.

Station networks improve data delivery time to the owners of the satellites, also the access time increasing the amount of data transmitted. Creating various ground station network as evidenced, for example SNIP, SSDL, GSN-WG, GSML, GENSO, SATNet, SatNOGS, etc.

The evaluation of some variables used to verify the ground stations efficiency of the most popular networks in the world is shown in the table 1. In this case Mercury [3], MC3 [4] and SATNet from USA, GSN [2] from Japan, GENSO [5] from the European Union, SatNOGS [6] from Greece were analyzed. The variables analyzed were the paradigm, the type of information that can be accessed remotely, the network type, security programming, source code download site and the license that was used for development. This study does not assess what is the best, only shows information about the networks in question.

	Mercury	GSN	MC3	GENSO	SATNet	SatNOGS
Paradigm	Client server	Client server	Legacy GCA	Hybrid P2P	Distributed network	Centralized
Remote GS	Data	Data	Data	Audio/Data	Data	Data
Federation	Yes	-	Yes	-	Yes	Yes
Scheduling	-	-	Central	Distributed	Hybrid	Central
Security	Central	-	Central	Central	Distributed	Central
Sources	Source forge (2003)	-	-	Unshared	Github	Github
License	GPLv2	-	-	-	Apache v2	GNU Affero GPL
Country	USA	Japan	USA	ESA	Spain/USA /Brazil	Greece

Table 1. Comparison of key ground station networks, adapted from [7]

What is SATNet?

SATNet is a ground station network with an expanding number of nodes around of world aiming to keep a much longer control and tracking of small satellites. With an increasing number of networked earth stations around the world it will be easier to increment time in contact with the satellite signal.

SATNet basic architecture is composed of several blocks and concepts which can be seen in Figures 1 and 2 in this text: (1) Network Paradigm: distributed servers; (2) N-System: main network node; (3) G-Client: ground station client; (4) M-Client: mission operation client; (5) Services provided by the central N-System and; (6) Clients: remote access library.

Each central node creates an isolated sub-network. Approach similar to IP routers. Users decide to interconnect nodes for scaling sub-networks. Nodes interconnection: scalability, redundancy, and privacy.

The SATNet network is intended to provide a flexible cloud-computing based solution. This solution will utilize its main cloud facilities for enabling CubeSat ground stations, this repository contains the source code for a generic client of the SATNet network. This is the open source for a Ground Station with a TNC to demodulate/modulate the frames which are being received/sent from/to the satellite.

The SATNet Architecture

The elements of the network concept are shown briefly in Figure 1 and defined as follows:

- A set of software clients for spacecraft operators to command remotely the satellites. From now on, they will be defined as Mission Operations Clients or M-Clients for short.
- A set of software clients for providing direct access to the services of the ground station facilities. From now on, Ground Station Clients or G-Clients for short.
- A cloud system for the coordination of the communications in between these two types of clients. From now on, Network Communications System or N-System. It is important to note that the N-System is not a single server but a cloud-computing-based system. This way and depending on further implementation decisions, this cloud system may evolve into a network of interconnected servers that will provide the service required.

The N-System implements the following interfaces for permitting an automatic communication among software entities, without the need of direct human interaction:

- **G-Client Interface (G-Client-IF),** that permits the ground station clients to connect to the network services.
- **M-Client Interface (M-Client-IF),** that permits the mission operations clients to connect to the network services.
- **Direct Client Interface (Direct-IF),** that permits the mission operations clients to connect directly to the ground station clients.

The current implementation of the SATNet network provides only the M-Client-IF and the G-Client-IF interfaces, being the Direct-IF left for future releases. This decision was made so that it is possible to incorporate the

feedback from the community once the initial deployment is made and, therefore, the definition of this remote client-to-client interface can be tailored to specific operational requirements from CubeSat developers.
This approach, although it allows the utilization of fully-automated ground stations, it also considers the possibility of human intervention during the operation of the CubeSats. This is a basic requirement to be met by the software since the IARU has a requirement that forces the presence of a human operator at the remote Ground Stations if a radio amateur band is used [8]. Therefore, the mix approach of the SATNet network that both allows the addition of fully-automated ground stations and the operation of the same by a human operator, is necessary in order to allow very different ground segments to be used within the same network.

The diagram shown in Figure 1 provides a graphical definition of the elements of the network and how they are interconnected with the given interfaces. In this diagram, it can be seen that the SATNet network allows heterogeneous clients to be incorporated into the network and this expands its final capabilities without requiring users to change the hardware that they have already installed at their ground stations.

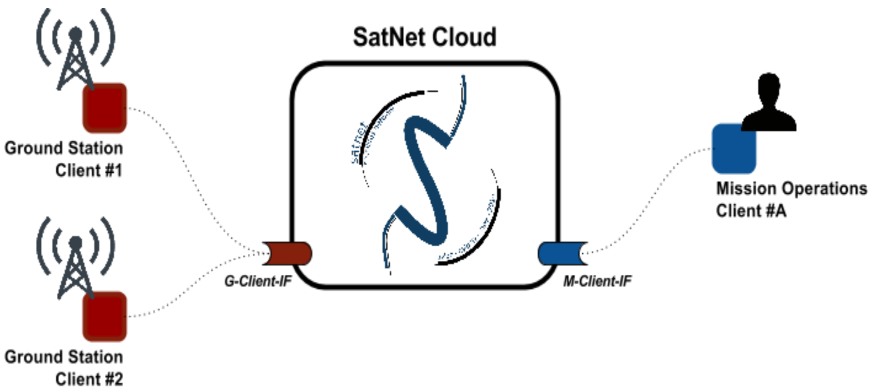

Figure 1. SATNet basic network concept

SATNet Deployment and its INPE Integration

At this moment, some testing activities are taking place for the integration of the INPE ground station into the SATNet network. This will increase the capacities of the network itself by providing additional coverage for remote CubeSat operations in the southern hemisphere. The envisaged scenario is shown in Figure 2, where the current SATNet deployed network server is located at CalPoly where it is already providing operational services. In the near future, two more servers are planned to be deployed, namely: one at Vigo in Spain and the one prospectively located at INPE so that it will provide coverage for the southern hemisphere.

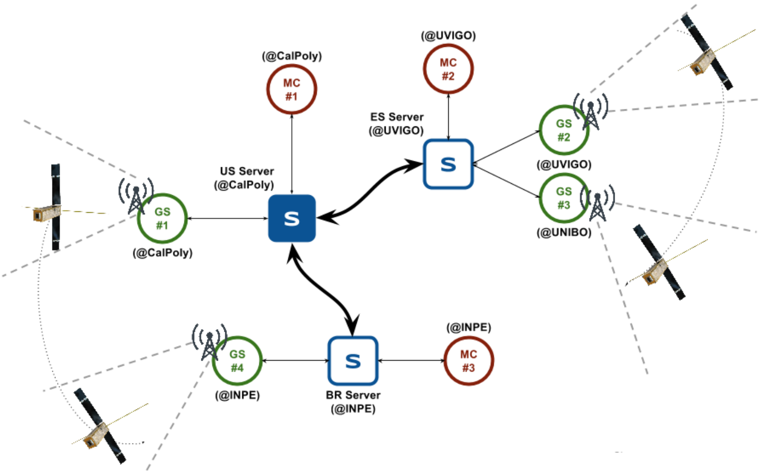

Figure 2. Current deployment of INPE participating node to the SATNet Network

The integration process follows a list of steps which are shown in Figure 3 and basically defines some keys parameters for the new integrating ground station node to the main SATNet network [10]: (1) Set new ground station location, (2) Define new ground station metadata, (3) Define channel information for the new ground station and, (4) Configure network services for additional client node.

The Satellite Control and Tracking Center, CRC in the Portuguese acronym, is composed of integrated facilities, systems and persons mainly engaged in operation in orbit of satellites developed by INPE or in collaboration with foreign institutions together. The CRC is also able to support its own space missions and third parties space partners.

The CRC is distributed into a set of facilities, namely: (1) the Satellite Control Center (SCC) in Sao Jose dos Campos (SP), (2) the ground station of Cuiabá (MT), (3) the ground station of Alcântara (MA) and, (4) the communication network of data and voice connecting these three sites. In addition, the ground station located at the Aeronautics Institute of Technology [9] (ITA) was recently acquired and it is dedicated to the control and tracking of small satellites: NanoSatC-BR1, BR2-NanoSatC, ITASat-1, and UbatubaSat among others. The CRC operates 24 hours every day in a 7-by-7 basis throughout the year.

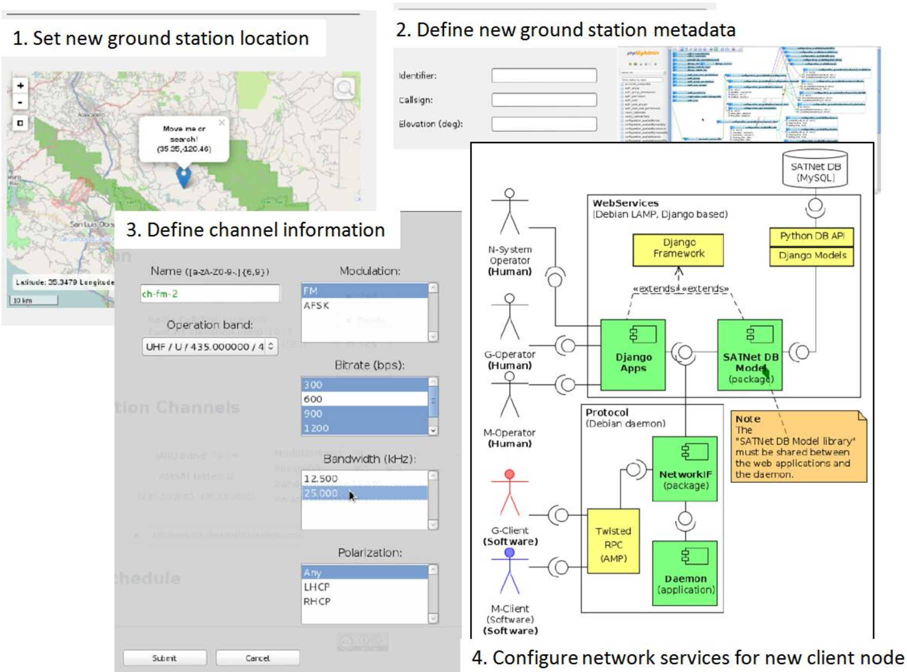

Figure 3. Simplified steps for integrating new participating nodes to the SATNet Network, adapted from [10]

In order to deliver the excellence of its current and future operational activities with a minimum of human resources involved, CRC maintains an ongoing process of research and development in the technological upgrade of the satellite control systems and automation of its operations.

Conclusions

This work presented the first steps for the integration of an INPE ground station located at ITA-Brazil into the SATNet network aiming at supporting small satellites programs. The SATNet network is concretely providing the first network for sharing ground stations in between the members of the community of CubeSat and small satellites developers.

Brazil undergoes various space activities in Latin America through the INPE. The country joins now the SATNet network looking for a greater autonomy and flexibility in tracking and control of its small satellites.

The integration of the INPE ground station to SATNet network still in development and are doing the respective test runs, this will allow satellites as NanoSatC-BR1, NanoSatC-BR2, ITASat-1, UbatubaSat be controlled any longer as the network of ground stations SATNet be used. In the near future, two more servers are planned to be deployed, one in Vigo – Spain and another prospectively at INPE.

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