GENSO: A Global Ground Station Network

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This paper will discuss the Global Educational Network for Satellite Operators (GENSO) project, a software package for groundstation computers which aims to drastically increase a satellites availability to control operators. This project will achieve this goal by connecting many different groundstations together via the internet, so a person in North America can use a groundstation in Europe to communicate with a satellite. This International project is sponsored by ISEB and largely managed and funded by ESA.

There are numerous benefits to the Amateur Radio community, including motivating an entirely new generation of amateur satellite operators, more control options for AMSAT satellites, and a clearer snapshot of satellite health. Frequency usage and coordination will be discussed and the opportunities for individual amateurs to become part of the network will be explained.

While these first versions of the GENSO software package will support digital modes on VHF, UHF, and S-band, there are no restrictions on satellite frequencies and/or modes that can be passed over the network. Satellite builders would only need to distribute software drivers to groundstations. Future versions of this program will include streaming audio, orbital element calculation, and live internet chat.

1 Introduction

More and more universities and private companies are building pico-satellites these days. While there are some simple “beep beep” type satellites in orbit now, a majority of them are performing real science work. The working definition of pico-satellite used in this paper is anything less than 100 kg, but author is most familiar with the CubeSat class of satellites, which are in the 1 to 3 kg range.

With slow data rates and very low power output from these pico-satellites, one could say that the biggest problem for satellite operators is the amount of data that can be downlinked. This problem can be remedied several ways, the main way being increasing the data rate. However, on these pico-satellites (especially CubeSats), this cannot be easily done. CubeSats are power-limited satellites, and increasing the data rate would drastically increase the amount of system complexity and power needed, or would require the use of very large groundstation antennas.

So if little can be done on the spacecraft side, is there any other part of the equation we can change? There is, and it involves the other end of the radio link, the groundstation. If multiple groundstations could be used to receive data from a spacecraft, data throughput could be increased dramatically. This is exactly what the GENSO project intends to do; use the internet to link multiple groundstations around the world for increased data throughput. As a direct result of this distributed network topology, spacecraft operators will have increased access to their spacecraft in case anything unexpectedly goes wrong.

This idea for a global groundstation network really started at the first Ground Station Network conference in Tokyo, Japan, in July 2006. The Japanese universities, with the help of the Japanese student group UNISEC, have a fully functional groundstation network they call Ground Station Network (GSN), and the conference was designed as a working session for their network.

While half of the conference was in Japanese and dedicated to their GSN, there was section for other groups to present. Kyle Leveque from Cal Poly State University presented on his masters thesis [1] about a Central Server Architecture for a Global Ground Station Network, Neil Melville from the European Space Agency (ESA) presented on SatNet [2], his vision for an international groundstation network, and others presented on various networking ideas. By the end of the conference it was clear that there were enough interested parties for a global version of GSN to be developed. Soon after the conference, Neil Melville started to get the ball rolling within the Education Department at the European Space Research and Technology Centre (ESTEC). A mini-conference was held in Noordwijk, The Netherlands, in September 2006 to prepare a preliminary report and management plan for the International Space Education Board (ISEB) at the International Astronautical Congress (IAC) in Valencia, Spain, in the beginning of October 2006.

At the IAC, the ISEB accepted Neil Melville's SatNet proposal, and GENSO was born. Workshops were held at ESTEC in The Netherlands in February 2007, and at Cal Poly San Luis Obispo in July 2007.

GENSO is primarily a software project. The project is broken down into 10 work packages, with different universities doing different work packages. It is a truly international project, with students at University of Tokyo, Vienna University of Technology, Cal Poly State University, Jean Monnet University, and Aalborg University, working on the project, just to name a few. Non-profit organizations are also involved, including AMSAT-UK and UNISEC.

2 GENSO Goals

There are several main goals of the GENSO network. The first is increasing the amount of data that can be downlinked from a particular satellite by increasing the available pass times. This goal can be achieved by complete automation of existing groundstations to allow unattended operation, and by building new groundstations in desirable locations around the world. Another main goal of the project is the continuing education of students in the radio amateur realm and the satellite construction realm.

One advantage of the GENSO network is that satellite operators can control their satellite from around the world, if a situation should arise that requires immediate attention, or if their local groundstations is out of commission for some reason. The GENSO network should be scalable to thousands of stations. This makes the network architecture somewhat more difficult than when only a few stations are connected together.

Other, less important, objectives include remote uplink through trusted third-party groundstations, downlink error correction via packet comparison, and creation of a standard for groundstation software.

3 Amateur Radio Involvement

While the cynical among us claim that GENSO is only out to steal amateur frequencies, in fact there are many ways the GENSO and pico-satellite communities interact symbiotically with the amateur satellite community. Many pico-satellite programs do use frequencies in the amateur satellite service, but in return the amateur satellite community gets a steady source of new satellite builders and operators and more excitement about amateur satellites.

The biggest benefit to the amateur radio community is a steady source of new licensed amateurs. Over 80 percent of the students at the Cal Poly CubeSat program are licensed amateurs, and one of the first steps that new lab personnel take is get their ham license. That way they can operate the groundstation and learn about satellite orbits, frequencies, modes, and how to track a satellite.

While it is true that most of the universities developing software for the GENSO network are not here in the States, there will be many GENSO nodes here. While in the beginning, we expect most GENSO nodes will be attached to developers universities and universities with pico-satellite programs, once the project becomes fully functional it will be open to everyone.

After the testing phase when the network is made fully available, we really mean it is open to all amateurs and receive only stations operated by non-amateurs. Anybody with a receiver and antennas will be welcome to join and receive satellite data. The network will then forward the data to the relevant Mission Control Client much in the same way that was done with AO-40. Some amateur stations will also be able to uplink commands and specific telemetry requests. The software package is open-source and can be installed on Windows, Mac, or Linux, allowing the software to be installed on a wide variety of computers and operating systems.

The GENSO network will make the role of the IARU frequency coordinators more difficult. With the limited amount of spectrum being available, at least on the VHF and UHF bands, they are presently able to reuse frequencies depending on the location of the single mission control groundstation. They will do their best to rise to this challenge but it should be remembered that it is never possible to provide a unique and exclusive frequency for each satellite.

4 Network Architecture

The GENSO network has three distinct components, and these are discussed below. They are the Central Server, which simply authenticates nodes on the network and distributes spacecraft and groundstation lists. The groundstation Server (GSS) is located at the groundstation and controls the connected antennas and radio. The Mission Control Client (MCC) is used by satellite operators and can schedule passes and collect data from individual groundstation Servers.

4.1 Central Server

There are several different central server architectures that could be used. They range from a strong centralized system to systems with no central authority at all. There are both advantages and disadvantages to both topologies.

At one end of the spectrum is a highly centralized system, such as the University of Texas at Austin's OneStop network [3]. In this case, the central server does pretty much everything, including scheduling pass times, archiving data for future use, interpreting downloaded data, making it available in an organized fashion, calculating satellite passes, etc. While this topology is the easiest to build, it has several major disadvantages that make it unsuitable for GENSO. The biggest disadvantage is scalability. The central server can only accept so many connections from other computers. Once that magical number is reached, the network takes a big performance hit. GENSO is designed to be scalable to "an arbitrarily large number of participating groundstations and missions." [4] In the far future, this might mean hundreds of spacecraft and thousands of groundstations. Clearly one central server cannot deal with the amount of data that thousands of groundstations will provide to it.

The other extreme is where there is a very simple (or no) central server at all, such as the GSN in Japan [5]. After using a central server for network registration, GSN works entirely peer-to-peer. The advantages include limited dependency on a central server somewhere that may go down due to network issues or maintenance. However, the central server has a very limited knowledge of what is happening within the network, who is talking to who, etc.

A good hybrid of these two architectures has a somewhat stronger central server than the Japanese network. Therefore, in GENSO, we decided upon a central server that would perform network authentication and encryption, distribute satellite lists, monitor groundstation and satellite operator status and "quality", and compile network statistics [6]. We feel that these tasks are not processor intensive, and access to the central server is only limited by the bandwidth available.

Within the GENSO project, we call this central server "AUS" for AUthentication Server. Currently it consists of several very powerful servers located at Vienna University of Technology. After the alpha testing phase, two more servers will be installed, one in California and one in Japan. Each server will be able to handle all of the nodes on the network, so three servers are necessary only in case of network failure and to keep network latency low.

4.2 GSS

The groundstation Server (GSS) is the piece of software that moves the rotors and tunes the radio, so it must be located at the amateur radio station. The hardware interface for this project will use the Hamlib, which is a large software library for Computer Aided Tuning of amateur radio equipment. An abstraction layer will be provided above Hamlib for individual hams to write their own drivers for custom and/or older radios, or if the Hamlib drivers are insufficient for some reason. The Japanese GMS drivers will also interact with this abstraction layer [7].

When a GSS wants to get onto the network, it contacts the Authentication Server. From the authentication server it gets a Participating Spacecraft List (PSL). The PSL is a list of spacecraft on the network now, their status, and the frequencies, modes, and Keplerian elements. Also included on the PSL is the encryption keys of the spacecrafts MCCs so a GSS can to contact a MCC directly to transfer downlinked data.

Future versions of the GSS software will include several additional features. An Internet Relay Chat client will be incorporated, so when future cluster launches occur the groundstation operator can stay up-to-date on the current status of the launch and satellites. Incorporation of a streaming audio client, such as Skype, will allow audio to pass to the MCC to allow adjustment of frequencies and confirmation of satellite health immediately after launch. With multiple groundstations listening to the same satellite, approximate Keplerian elements can be determined using the different acquisition-of-signal times for the different groundstation.

If an individual amateur radio operator would like to use their own amateur station as they have in the past, there is an option within GENSO to disconnect from the network. The individual amateur can then use the radio and rotor control portions of GENSO for full station automation. This feature is useful when an amateur just wants to use a satellite such as AO-50 for voice communications at a particular time, but also wants the station accessible to others when sleeping or at work.

4.3 MCC

The Mission Control Client (MCC) is the application where the satellite operator can control the network's handling of a satellite. The MCC can tell the GSSs what mode the satellite is in, what frequencies, etc. It also has a prediction section where the satellite operator can predict which groundstations their spacecraft will pass over, and contact the appropriate GSS for booking passes.

Each spacecraft will have one MCC, and it can reside on any computer hooked up to the internet. It doesn't need to be physically located anywhere, like the GSS computer. Included in the MCC is an optional graphical user interface, but there is also a built-in "wall plug" interface where individuals can make their own graphical user interface that just plugs in to the MCC [7].

When a MCC registers on the network with the Authentication Servers, it gets a groundstation Server List (GSSL), which includes all of the groundstations on the network, their location, what frequencies are available, and other groundstation parameters. Upon registration, the MCC becomes responsible for pushing updates to the authentication server about what modes the satellite is in, keeping the Keplerian elements updated, etc.

5 Standard Groundstation

In order to simplify the start up of the GENSO network, a "standard" groundstation hardware specification has been developed by AMSAT-UK. It includes common rotors and radios that are commercially available now. It is intended to provide a high performance and very robust and reliable station capable of successfully operating in extreme environments. One or two of these "standard" groundstations will be built by ESA for testing purposes and as their contribution to the network.

It should be made very clear that this "standard" groundstation is not in any way trying to restrict or encourage what hardware will be supported by the network. All different types of amateur radio stations will be supported by the GENSO network. One only needs to write software drivers if their radio or rotor does not already have drivers written for it. This "standard" groundstation configuration is only meant to ease the development of radio and rotor drivers during the testing phases. With Hamlib's drivers for 152 amateur radios from all various vendors, the finished GENSO network will accept a wide variety of rotors and radios.

Due to the open-source nature of the project and extensible architecture, it will be extremely easy to write drivers and add them to the project. For example, if a new radio becomes available that needs new drivers for the network, a software-inclined person could write a driver and add it to the software repository. Once the driver is added, any person using that radio could download that driver and use it.

6 Conclusion

The GENSO project will allow much more data to be downlinked from pico-satellites, encourage a new generation of students to become radio amateurs, and allow remote uplink of commands. It will accomplish this goal by connecting hundreds of amateur groundstations together using the internet. This international software project will begin limited testing in the end of 2007, with a finished product available for download by the end of 2008.

7 Bibliography

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