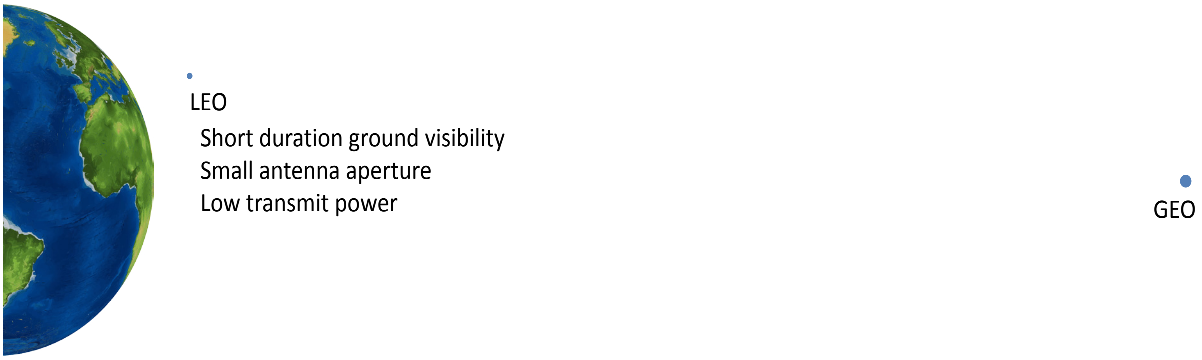
A Convergence of Technologies

SmallSats in LEO

Rapid growth in CubeSats and SmallSat in Low Earth Orbits (LEO) has brought about a shift in ground system architectures. This change is driven as much by orbit as it is by spacecraft size. Large geostationary satellites are just that, large and by making one orbit per day, essentially stationary over a single antenna location on the earth. These GEO satellites have ample onboard power to remain in continuous communication with the dedicated ground antennas that support them.



Most CubeSats and many SmallSats are in low earth orbit. This puts them at an altitude around 2,000 kilometers, and by hurtling around the earth at nearly 20,000 mph, they make a lap every 80-90 minutes, putting them in visibility of any particular spot on the earth for only 10-20 minutes. With an inclined orbit, a particular satellite may pass over any one ground antenna site only two or three times a day.

A Cubesat must carefully manage power generation and power consumption, with electrical systems on board being powered on only when needed. Unlike large spacecraft, CubeSat antennas have a small receive aperture and relatively low transmit power. Generating the RF energy to communicate data to an earth station consumes this limited resource, so most CubeSats operate on a duty-cycle where they transmit from space to ground only for limited periods, not continuously.

Cloud Computing

Just as smaller satellites in LEO are transforming space system architectures, cloud computing is transforming network and data processing. With cloud computing, a network of computer servers store and process data with software applications ‘started’ and ‘run’ when and where needed rather than hosted in a dedicated fashion. Computing and storage resources, no longer being dedicated, are more easily shared and used more efficiently.

Ground Antenna Network and Cloud Service Providers

These two transformative technologies are becoming increasingly symbiotic.

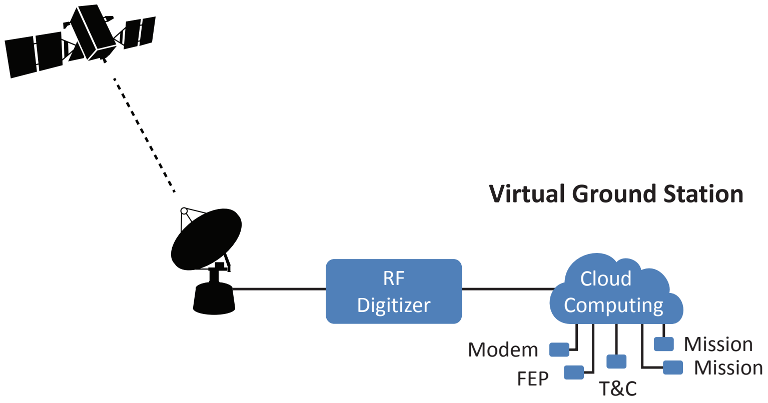
Ground antenna service providers are responding to the increasing number of LEO satellites by offering many of the same advantages as cloud computing. These providers make their antennas, modems, and other communications resources available to multiple small satellite operators. With geographic diversity, they can offer the small satellite operator contact windows (a time period to communicate with a specific satellite) at a much higher availability and at a much lower cost than dedicated systems. An antenna service provider, having the ground resources and management systems already in place, also provides rapid scalability.

Shared resources, lower cost, and rapid scalability … it seems the benefits for CubeSats and SmallSats are the same whether were talking antenna service providers or cloud computing providers. All of this leads to the Virtual Ground Station.

Virtualized Ground Stations

The data coming down from earth observing satellites in their LEO orbits is increasingly being received by network providers and then stored and processed in cloud computing systems.

A virtualized ground system can even extend cloud computing to the signal and data processing of telemetry from the spacecraft, commanding to the spacecraft, and the earth receipt of data from onboard instruments or payloads.



Satellite communications requires the ground modem to perform waveform and protocol processing that matches or mirrors the corresponding waveform and protocol processing of the spacecraft. A waveform defines how data is modulated onto an RF carrier and the protocol defines how that data can be converted from bits or symbols to represent actual information.

RF Digitization

With a virtualized ground station, the first step for the downlinks is to receive the RF signal(s) and digitize them. The RF digitization samples the radio signal within a specific bandwidth, creating a time-ordered series of digital representations of the signal (samples) and performing a digital downconversion to both tune to the frequency range of interest and to reduce the sheer number of samples to what's needed to perform the modem processing using digital signal processing. Per the Nyquist Sampling Theorem, this is typically a sample rate that is at least 2X the symbol rate. This element of the communications processing, the RF Digitization, is agnostic to the satellite-specific waveform.

Network Transport

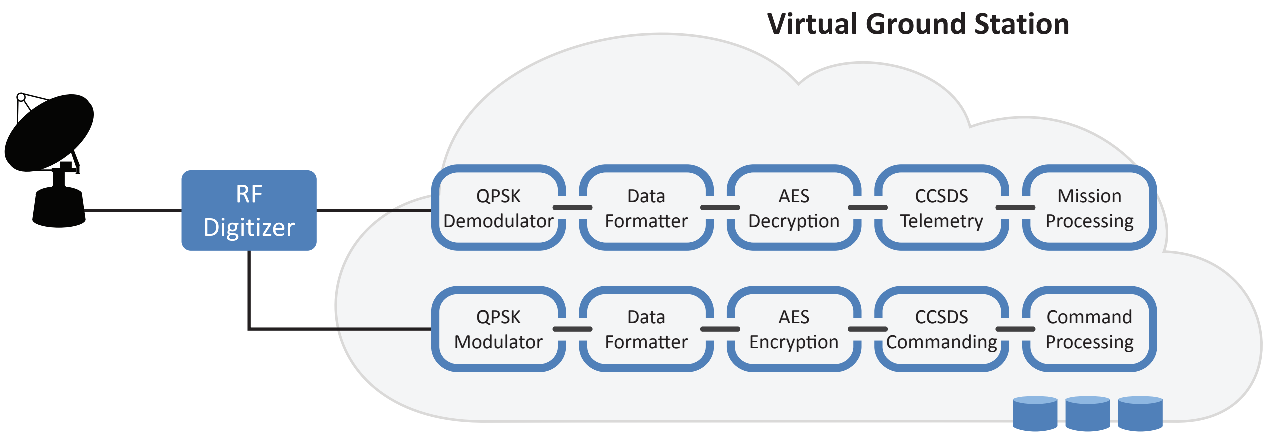
It is important to point out that RF digitization produces prodigious volumes of sample data that require reliable network transport to where they are being processed. Each sample at the ADC becomes four bytes of digital information. A 100 Mbps data stream that is QPSK modulated might require 800 MBytes per second (6.2 Gbps) of sample data to move from digitizer to software processing or from software processing to digitizer.

VITA 49 is an evolving IEEE standard that defines a packet-based protocol for transport of digitized radio signal data, and virtual ground stations are wrapping VITA-defined packets in IP packets to move the data samples over ethernet using another layer of protocol, typically UDP or TCP. Introducing the IP networks needed for a virtual ground station brings in the requirement for reliable network transport, along with minimal latency, to maintain a continuous transfer of sample data without overruns or underruns on either side of the network (RF digitizer or cloud-based servers).

Software Modems and Processors

Software modems perform the modulation and demodulation processing in software, and this software, running as an application or application(s) on cloud-based servers, enables the notion of a virtual ground station. The software modem that is specific to a particular satellite's waveform can be configured, started, and stopped in accordance with the contact schedule for that vehicle. The software modem application for that spacecraft may include additional protocol processing or other applications may support those functions. A good example is the CCSDS formatting required to implement the forward link's telecommand protocols or to perform frame synchronization and extract space packets from a return link.

Virtual ground stations may archive and store mission data for later processing or run additional cloud-based applications at the same time to process the downlinked data as it is being received. Cloud computing opens up these possibilities, where the applications specific to a satellite are run during one contact and a different set are loaded and execute when that same antenna is being used to contact a different satellite. Some customers choose to deploy the signal and front end processing as a single application, while others choose to configure a virtual string of applications.



Simple in Concept, Many Details in Practice

It all sounds straightforward to create a virtual ground station using a combination of ground network and cloud-computing service providers. There are a number of details to nail down to integrate all of the pieces in a way that has them working correctly end-to-end. Particular emphasis is on reliable network transport of digitized samples, configuration of the virtual software applications, and interfaces to the networks and other equipment that link the software to the actual on-orbit spacecraft.

These technologies are being implemented by several of our savvy customers, and AMERGINT can support you in crafting your virtual ground station.

Can we help? AMERGINT's expertise is available to assist in your systems engineering and design

Randy Culver
randy@amergint.com
719-522-2802