RELIABLE AND LOW-COST SATELLITE NETWORKS FOR GRID AUTOMATION AND IOT APPLICATIONS

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As power grid automation, dynamic pricing and IoT applications continue to roll out, the utility is faced with conflicting challenges regarding system reach, operational cost and reliability. The utility telecom manager needs to construct reliable communication paths while controlling capital costs (CAPEX) and operational costs (OPEX). Reaching the edge of the power network is often essential for safety, regulatory or billing purposes, but not always easy with wired or microwave radio technologies. This makes satellite communications a good option for remote locations. This article will look at strategies to control costs and keep communications reliable when using VSAT (Very Small Aperture Terminal) satellite systems to communicate with those hard-to-reach locations.

This global solution has been deployed with energy and utility companies in Europe, Middle East, India, South East Asia, Australia and Latin America. A couple of networks have also been deployed in North America. FortisBC is a gas distribution utility in Vancouver, Canada, that is using the VSAT solution for pipeline SCADA and gas metering. Hoosier Energy, a G&T utility in Indiana, is using the solution for substation SCADA. Water systems operator, Scottish Water, is using the solution for management of their remotely located pipeline and treatment plant asset. ESB in Ireland is using the solution for power distribution SCADA. Scottish and Southern Energy is using the solution for SCADA of hydro power plants and offshore wind farms.

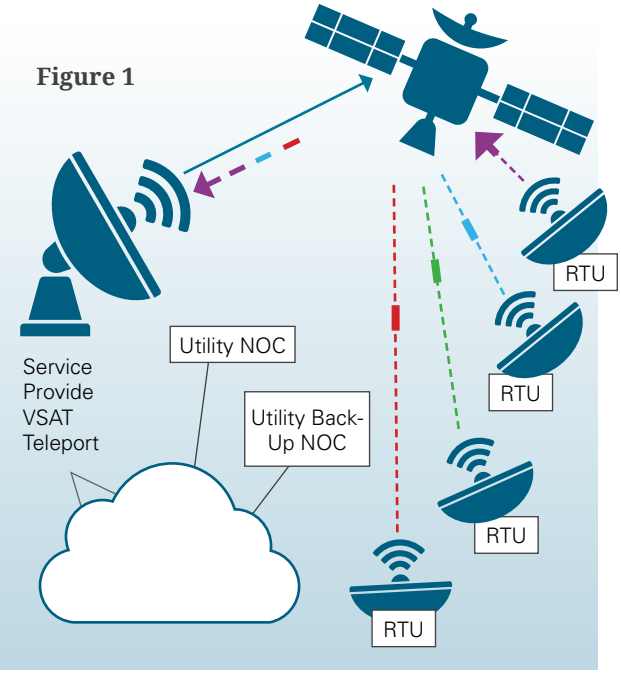
The solution is compatible with commercial satellite transponders. Satellites are spaced every two or three degrees (in geostationary orbit some 22,000 miles above equator), and cover all earths landmass except extreme polar regions. Satellite capacity is in plenty supply, so for a given area of desired coverage capacity may be sourced from two or three providers, which ensure competitive spectrum lease cost. In many countries, satellite networks are subject licensing, and in most cases a formality. In the US, FCC form 312 is used to obtain blanket authorization for new VSAT networks.

VSAT ARCHITECTURE

A Very Small Aperture Terminal (VSAT) satellite system is structured as a Hub-and-Spoke system, with the hub being larger and more expensive than the Remote Terminals (RT). With the usual “bent pipe” satellite architecture, increasing the hub antenna size permits size reduction of the RT antenna. For very large systems, such as those run by service providers, the hub antenna is very large and expensive. This antenna is located at the managed service operator’s location, sometimes called a Teleport. To reach this location with your data traffic, a connection is

required to this location. This connection is provided by a VPN or other backhaul service. It is worth noting that VPN technology may not be compliant with NERC CIP requirements.

Figure 1 shows the major elements in a typical managed service VSAT solution. In this architecture the Hub is not on the utility's property and a VPN and firewall are needed to transport the data from the Hub to the utility's Network Operations Center (NOC). This VPN and equipment results in additional transmission and queuing delays for your data traffic. This queuing delay will vary with the amount of traffic on the service provider's network. As a general rule, carriers charge for data volumes, so the utility needs to engineer their SCADA



network so that carrier induced polling timeouts do not occur. Poll timeouts result in data retransmission and more expense and in extreme cases can make a site look like it is functionally impaired.

With any shared radio architecture, we need to examine the effect multiple access techniques have on data traffic and costs. VSAT access is different in the two directions. In the outbound direction (towards the RT), the carrier is continuously transmitting, but divided in time (TDM) so that a high-rate carrier can be shared by many customers each with multiple RTs. In the inbound direction (towards the Hub) a time-based multiple access system is used with each RT being keyed on and off in a manner that reduces or eliminate collisions at the Hub receiver. The common options are TDMA, Bandwidth on Demand, Slotted Aloha or variants and mixtures of these. Regardless of the access method, each of these approaches shares an important aspect in common: the transmitted bit rate over the satellite is higher than the users' application bit rate. Why is this trait important? Because the station output power required (EIRP) is affected by the peak data rate, not the average data rate. A brief explanation is in order.

Received performance is related to the signal-to-noise ratio and is normalized for bit rate using the commonly referred to Eb/N0. Eb is measured in joules and power in joules/second (Watts) so that transmitted Energy per bit is given by:

$$E_b = {}^{TX\ Power}/_{Bit\ rate} \quad \left(\frac{J/sec}{Hz} = j\right)$$

The Eb transmitted (and hence Eb received) can be increased by any or all of:

A) increasing the transmit power

B) increasing the antenna gains (size)

C) reducing the data rate

When the shared data rate is higher than you need for your application, which is virtually always the case for a VSAT service offering, your equipment must be sized as if it was using data at the higher rate, with larger power amplifiers and/or higher antenna gains. The lowest possible EIRP is when the transmitted data rate is as close as possible to the application's needs.

Single channel per carrier (SCPC) systems can get close to the minimum EIRP condition, but lose out on the statistical multiplexing advantage of packet networks resulting in wasted satellite capacity. The preferred practical solution is to size the satellite bandwidth to fit your specific network's traffic only and share your spectrum only amongst your own remote sites. In the next section, we will introduce a simplified architecture and discuss its advantages.

AN ALTERNATIVE – THE UTILITY-LOCATED HUB

An alternative to the Managed Service VSAT architecture is a private (non-shared) VSAT network. In this approach, the Hub is located at a utility's site, usually the Network Operations Center (NOC). Hub colocation with the NOC and the SCADA front-end processor (FEP) eliminates the backhaul (VPN) link.

This private network simplification brings the following advantages to the utility:

1) Improved system security

2) Reduced operational expenses (OPEX)

3) Reduced data delays

4) Improved system reliability

This simplified network works well when the Hub antenna is modest in size, in the range of 1.8m to 2.4m. Such antennas are easy to place on rooftops and/or pedestals and require little maintenance, usually functioning for much more than a decade without repair or adjustment.

IMPROVING SYSTEM CYBER SECURITY

One of the simpler methods of increasing cyber security is to decrease the number of potential access points that need to be secured. With the Hub located at the same physical premises as the NOC the satellite interconnection to the NOC will typically be a short run of CAT-5 Ethernet cable. This approach reduces the security concern from the hub to physical building access, a security precaution that will already be very strong at a NOC.

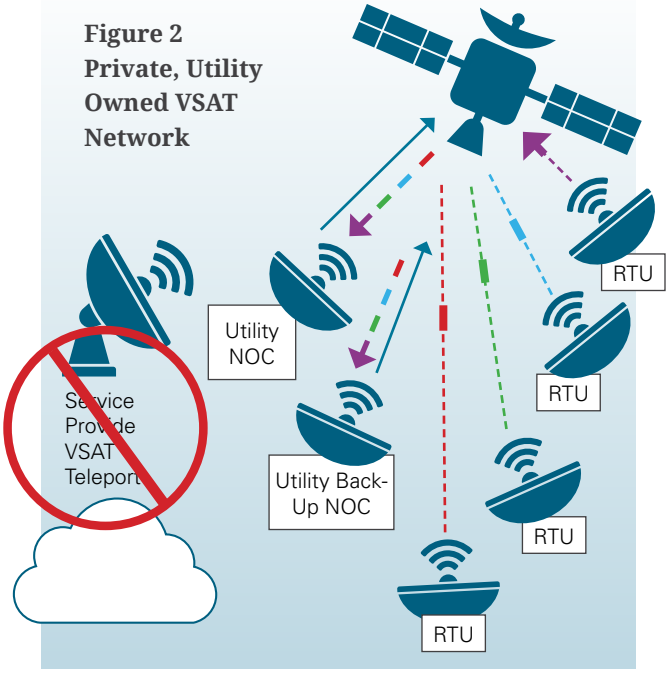


Figure 2
Private, Utility Owned VSAT Network

IMPROVING RELIABILITY

Satellite equipment, like all electronic telecommunications equipment, will occasionally fail due to stress caused by temperature, vibration and power surges, or just aging effects (such as IC electromigration), but over the useable life of the equipment the most common causes of temporary outages are due to rain and snow events.

The two best ways to combat weather related events are:

1) Redundancy

2) Strong radio links

Since SCADA communication systems are part our society's critical infrastructure we recommend the use of two Hubs so that no weather-related event causes a complete outage of the communications system.

A strong radio link is one that has a lot of excess margin so that rain and snow events do not usually cause communication failures. (Margin is the difference between the normal receive level and the minimum level required for near error-free performance).

We can increase the system margin in the following ways:

1) Increasing transmit power

2) Increasing transmit antenna size

3) Increasing receive antenna size

4) Decrease receive noise figure

5) Increasing error correction overhead

6) Changing modulation format

7) Decreasing data rate

Some of the above will seem obvious to those reading this paper, but here we see another advantage of matching your over-the-satellite data rate to your specific application needs. VSAT systems are able to increase their power during signal fades using a technique known as Uplink Power Control. This technique increases the transmit power so that the far-end receive signal remains approximately constant, subject to not exceeding the 1 dB compression point of the power amplifier. By using the minimum practical data rate, we have the maximum amount of headroom available for the up-link power control.

In summary, going slower will give us higher link availability. The slowest reasonable data rate is the data rate needed by a specific network when not sharing its RF spectrum with other users.

REDUCING OPEX

OPEX with Managed Service

If you are purchasing a managed satellite service, you may expect to see some or all of the following charges:

1) Data carriage charges

2) Connect charges

3) Teleport charges

4) Backhaul (VPN) charges

In comparison, if you are using a satellite ground station Hub located on your own site you can reduce your OPEX to one charge: a Satellite Spectrum lease.

DATA CARRIAGE CHARGES

These are usually billed according to a plan where the service provider measures your data at its Hub (Teleport) location. A ceiling is usually set for your plan in MBytes or GBytes per month for the system or by site. Above a threshold, there will be overage charges. In industrial networks data flows are usually engineered to be about 20% below the cap limits by network owners. (Consumers tend to use a much smaller percentage of the data they pay for).

One caution worth repeating: With SCADA systems network delays can cause data to be retransmitted. If you are currently using a managed service you need to be sure that queuing delays in your provider's network are not costing you money. Have a delay specification in your Service Level Agreement.

CONNECT CHARGES

This is essentially a book keeping charge to track the assets connected to the network. This charge may be associated with and/or bundled with a data amount or associated with a connection data rate.

TELEPORT CHARGES

Teleport costs are mostly an OPEX item, with a monthly bill. There are also some up-front costs. While these will vary by vendor and contract duration, the tasks that need to be completed are:

- arranging for shelf space and power
- installing routing and firewall equipment
- configuring a VPN access router
- OPEX with Utility-Located Hub

SATELLITE SPECTRUM CHARGES

If you are buying a managed service this is a charge you will not likely see as it is buried in the data charges. If you locate the hub on a utility NOC site, you can reduce your outside costs to this one charge. For a typical SCADA network, this charge will be approximately $1,000 to $3,000 per month for the entire satellite SCADA network.

SUMMARY

In this article, we have shown that there is a cost effective and secure solution to a managed service for satellite SCADA communications. By realizing a private VSAT system with a utility-located Hub and SCADA-appropriate data rates you can save thousands of dollars per month in operational expense while improving security and decreasing networking delays.

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