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Methods of Collecting Field Data: Gulf South Pipeline's Conversion from Microwave and VSAT networks to a Frame Relay Network

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Abstract
Upgrading the communications network to monitor and control the Gulf South Pipeline natural gas system was based mostly on the monetary savings seen by ending the microwave tower lease contract. Initially there was some thought to making the communication system a complete satellite network, since part of the system already used Very Small Aperture Terminal (VSAT) units. But after discussion with the Information Technology (IT) group, we decided to expand on the existing sixteen frame relay circuits from the home office to various field locations. The new network is now more reliable, has better failover redundancy, gives the company high speed data links to all field locations, and is more cost effective.

Introduction
In the 1970's and 1980's when the company was named United Gas Pipeline, a network of microwave towers were constructed along the pipeline to transmit the Supervisor Control and Data Acquisition (SCADA) information and telephone communications between the field offices. In the 1990's, when Koch Industries purchased the pipeline, the microwave tower system was sold off to a PCS communications company to be used for the growing cellular phone business. Koch Gateway Pipeline made an agreement to lease back the space on the towers for the microwave dishes and various field radio antennas. Part of the tower system in Mississippi was abandoned completely and replaced with thirteen VSAT links. Koch Industries had used VSAT communications on other pipelines and chose it as the primary communications method for these locations.
The microwave network was made up of 72 towers throughout Texas, Louisiana, Mississippi, and Alabama. At forty-eight locations along the pipeline and microwave system, data concentrators were stationed to gather field data from approximately 370 field Remote Terminal Units (RTU's) and compressor station Programmable Logic Controllers (PLC's). At the start of the migration project the data concentrators were Arcom Control Systems, APEx units. They were used strictly for polling the RTU's and passing the data to a Host Communications Processor (HCP), which was in turned polled by the host SCADA system. The microwave system had no automatic backup system in the case of a communications failure. When communications were lost at one of the APEx locations, a communications technician would be dispatched to troubleshoot the problem. In some cases field measurement technicians and compressor station operators were called to manually monitor the stations and call in data readings to Gas Control. In a few cases a temporary dial

backup connection was made to replace a microwave station when equipment failures could not be repaired quickly.

In October 2000 the pipeline SCADA system was moved from Wichita, Kansas to Houston, Texas when Koch Industries entered into a joint venture agreement with Entergy Corporation of New Orleans.

The communication costs in 2000 for leasing the tower space and paying for the VSAT network was approximately $113,000 per month. The contract on the towers was due for renewal or cancellation in February 2003, with the VSAT contract due for renewal in September 2004. Plans were drawn up for replacing the microwave system with either a complete VSAT network, a combination VSAT and frame relay network, or an all frame relay network. After reviewing the budgetary numbers and advantages and disadvantages of the various systems, it was decided to create an all frame relay system with dial backup.

Communication (SCADA) System Specifics

The host SCADA system controlling the pipeline stayed in place. The SCADA system consists of three HP Alpha servers running the Telvent, OpenVector SCADA system on a VMS platform. Each of the three SCADA nodes is constantly updated with live data so that any one of the three could assume the role of the primary in case of a failure. The primary SCADA server polls each field location at intervals of approximately once per minute through a Host Communications Processor (HCP) running Arcom Control Systems, HCPNT software. There are actually two HCP units in Houston running in a cluster format with a shared fiber-linked hard drive. The host SCADA system and HCP are connected on the network in Houston through the SCADA core router, a Cisco 5500 Catalyst. The HCP in turn polls the 49 data concentrators, now Arcom Control Systems, Directors, over frame relay networks ranging in bandwidth from 56K bits/sec to a full T1 or 1.544M bits/sec. At the field locations there are Cisco 1721 routers to make the network connection to the Directors. The Directors then poll each of the RTU's over various communication methods. At some locations we have MDS spread spectrum master radios polling as many as 18 remotes. At other locations have all leased circuits out from the Director. At other locations we have combinations of radio, leased circuits, and yard cabling to the end RTU's. The communication method used to reach each RTU varies depending on the most practical and cost effective option.

The most widely used brand of RTU on the Gulf South Pipeline system is Bristol Babcock. We have both model 3330 and 3305 units. Approximately 18% of the RTU's are Thermo Electron Corp RTU's, such as Superflo II's, Automate's, and AutoPilot's. The protocols used for polling the RTU's are almost entirely binary Modbus, with the exception of a handful of units that communicate using Modbus ASCII. There are 22 compressor stations that transfer data across the network to the SCADA system. Most of these stations are controlled by Allen-Bradley PLC's which communicate using binary Modbus to the host SCADA system. There are a couple of Siemens/TI PLC's and one Entronics PLC in the system. There are also 22 locations that are dialed up directly from the SCADA system on intervals between fifteen minutes to two hours.

The IP network begins with a Cisco 5500 Catalyst SCADA core router and a 7500 Series network router in Houston. We use 2900 Series Cisco switches, model 501, 506, 515 and 525 Series Cicso Firewalls, and AS5396 Access Servers in the system. At the Houston office all of the network routers, switches, and access servers are Cisco brand. At the field data concentrator end we use Cisco 1721 routers to connect the Directors to the network. There are some LinkSys hubs and switches used at a few field locations, to connect users and end devises to the network. At some field locations the network had to be extended from the demarcation location to another building on the facility over yard cabling. This task was accomplished by using Patton Electronics, model 2158 LAN extenders. These devices allow us to extend the network over twisted pair cable much further than CAT 5 network cable will reach.

New Features and Capabilities

As the new frame relay circuits were installed we began using new tools for monitoring and troubleshooting the communications system and equipment. The new tools include network monitoring software, network traffic monitoring web pages, web interfaces for remotely connecting to power switches and UPS units, and the ability to PING, Telnet, and FTP to the data concentrators.

A network management piece of software called SNMPc by Castle Rock is used to monitor communications on the system. This software PING's network manageable devices with IP addresses and e-mails and pages the SCADA engineers and network support people when communications are lost. There are over 120 devices currently setup for monitoring on the Gulf South system. Every 180 seconds all of the monitored network devices are PING'ed for a response.

Network traffic web pages were developed for each frame relay location using a Multi Router Traffic Grapher program. See Figure 1 below. These displays show the traffic of the frame relay links updating in five minute average intervals over the past day. There are also weekly, monthly, and yearly graphs for each location. The graphs show traffic leaving the Houston office in blue plot and a trend of traffic sent from the field in a green plot. These graphs show when there is heavy usage of the network and how much bandwidth is being used.

At each of the 49 data concentrator locations we have installed APC brand remote master power switches. These switches are network manageable devices that allow up to eight, 110 volt AC items to be plugged in and remotely power cycled. The master power switches have web page interfaces which are used to show the items plugged into each outlet, the status of the outlet, and other features. The power switches keep a log of every event that occurs on the switch, such as when someone logs in and when an outlet was reset. The switches have often been used to reboot Directors and modems when there has been a communication problem.

Much of the SCADA system communications navigation screens were revised with the frame relay network because new features such as PING, Telnet, and web interfaces could now be triggered directly from the screens. See Figure 2 below. From the SCADA displays we can view all data concentrator locations and tell whether any one of the 370 field RTU's is not communicating. The communications overview display shows status colors for each of the Director sites. A green color in the location name means all of the sites are communicating properly. A yellow color on the name means there is at least one site that is communicating below an 80% good reply level. A red color on the location name means one or more sites are below a 50% good reply level. A black color on the location name means the site has stopped communicating.

There are five communication signals generated in each RTU and polled by the host SCADA system to monitor the health of the RTU. The five signals are a discrete "Alive/Dead" status, and four analog signals for the percentage of good polls, the total number of polls, the number of no reply errors, and the number of CRC errors. If the RTU fails to answer after three retries, it is set to a "Dead" state until the next poll cycle. The poll cycle from the Director to an RTU is typically 60 seconds.

These tools are used to quickly tell if the frame relay link is down or to troubleshoot problems within the Director.

Each of the Director locations has a dial backup phone connection. Communication port #1 on each Director is reserved and configured for connection to a dial backup modem. There are two Cisco Access Servers, one located in Houston and one in Goodrich, Texas. Both Access Servers are programmed with the dial backup phone numbers to all of the Director locations. When a frame relay circuit fails, the HCP automatically selects the secondary IP path. The secondary path is configured in the Cisco Access Server to dial the appropriate phone number and connect to the field Director. The Access Server has one of 46 phone lines from two PRI circuits to use for the dial backup connection. When the frame circuit begins responding normally, the HCP automatically fails the circuit back to the primary path and drops the modem connection.

Each of the frame relay locations also has a backup Primary Virtual Circuit, PVC used as a backup in the case of a network failure from Houston. If the network in Houston fails, the traffic is automatically sent to the network in Goodrich and the PVC circuits take over communication to all field locations.

Cost Savings and Benefits

When the project was first begun it looked as if we would save a little over $1,000,000 per year on SCADA communications. Since that time the scope of the project changed. Originally, the cost of leasing tower space for all of the microwave dishes was $106,000 per month. After removing the microwave dishes, there were still 45 towers where leases needed to remain for local data radio circuits. The tower lease however was reduced to $22,405 per month. The original upgrade was intended to install 56K frame circuits at all of the unmanned locations and most of the smaller manned locations. The estimated monthly Sprint frame relay cost for all of the sites was expected to be $18,889. As more field users became aware of the high-speed data circuits being installed, the field area business leaders decided to increase the bandwidth at many locations and thus the monthly costs for many frame circuits increased. The current cost for 51 frame relay sites is approximately $45,000 per month.

Although the overall frame circuit costs have increased, the company is still saving money compared to the old systems. Each of the field offices has a high speed network connection for E-mail, data file sharing, and Internet access. This has made it easier computer upgrades and for other applications like Maximo, maintenance management software, to be used throughout the company.

Before the frame relay circuits were installed, the monthly cost of the field dial-up connections was approximately $8,500. It was estimated this cost would drop by 75% when the project was finished and that only users would only use dial up connections when they were away from the field offices. There have also been significant reductions in man-hours spent troubleshooting communication outages and after-hours callouts. The communication technicians who used to spend a great deal of time maintaining microwave and satellite systems can now work on other field communication and learning new skills.

Reliability, Troubleshooting, and Problems

The frame relay circuits overall have worked much better than the microwave and satellite systems. The callouts from Gas Control to the SCADA support group and the field communication technicians have decreased from on average three to four callouts per week to one per month. There are fewer pieces of equipment to maintain and fewer spare parts for the field technicians to carry in their vehicles for troubleshooting.

The backup modem connection to each of the data concentrator locations keeps the data flowing to Gas Control when primary frame circuit fails. In the past we had seen outages on the microwave system which would cause half of the network to be lost. Now, when we have a communication outage it is only at one data concentrator location on the pipeline.

The dial backup circuits have worked well most of the time, but there have been a few cases where both the primary and backup have failed. One such case of double failure occurs when both circuits are in the "final mile" of trench or overhead line and the cable is cut. In these cases field personnel are called to monitor the remote locations until communications can be re-established.

During Hurricane Ivan, in September 2004, we lost communications to two data concentrators (Mobile, AL and Pensacola, FL). Both sites were near the eye of the storm. Most of the problems during the hurricane involved power outages more than equipment damage. As soon as the power was restored to the local telephone offices and at our field offices, the frame relay circuits began to work again. When a frame relay outage occurs, we simply call Sprint, (our service provider) and if they have not already issued a trouble ticket for the outage, we can issue one ourselves on the Sprint-In-Touch website. Sprint logs the troubleshooting from Atlanta and contacts the local telephone companies to test and repair the circuit. Sprint usually follows up with a status update by phone every hour to two hours, and we can follow the troubleshooting documentation on the Sprint-In-Touch website.

The SCADA data takes up a very small amount of the bandwidth of the frame circuits. There were times early on when some frame circuits would be overloaded with network traffic such as when large downloads were pulled from the field. In these cases the SCADA data would become sluggish or fail to update. We monitor the network traffic to make sure the SCADA data is not interrupted, and we have increased the size of the frame circuits in the areas where bottlenecks have occurred.

Conclusion

Replacing the microwave and satellite networks with the frame relay network has improved the communications for the Gulf South Pipeline system. We have reduced our communications costs, improved the reliability of the system, and given high speed data connections from the home office to all manned field locations. There are areas where we see improvements can be made, such as programming the routers in the field to make the dial backup call to the Access Server in Houston instead of having the HCP make the decision. Another area for improvement could be to replace the Arcom Directors with Cisco Terminal Servers. We have had some problems with the Directors locking up or stopping polling on individual ports intermittently. A third area for improvement is with some of the Cisco network devices. Some of the devices in our system are older and nearing their end of life, so there may be some replacements there in the near future. Overall, we feel the conversion to a frame relay network has improved our system for growth and change in the future.

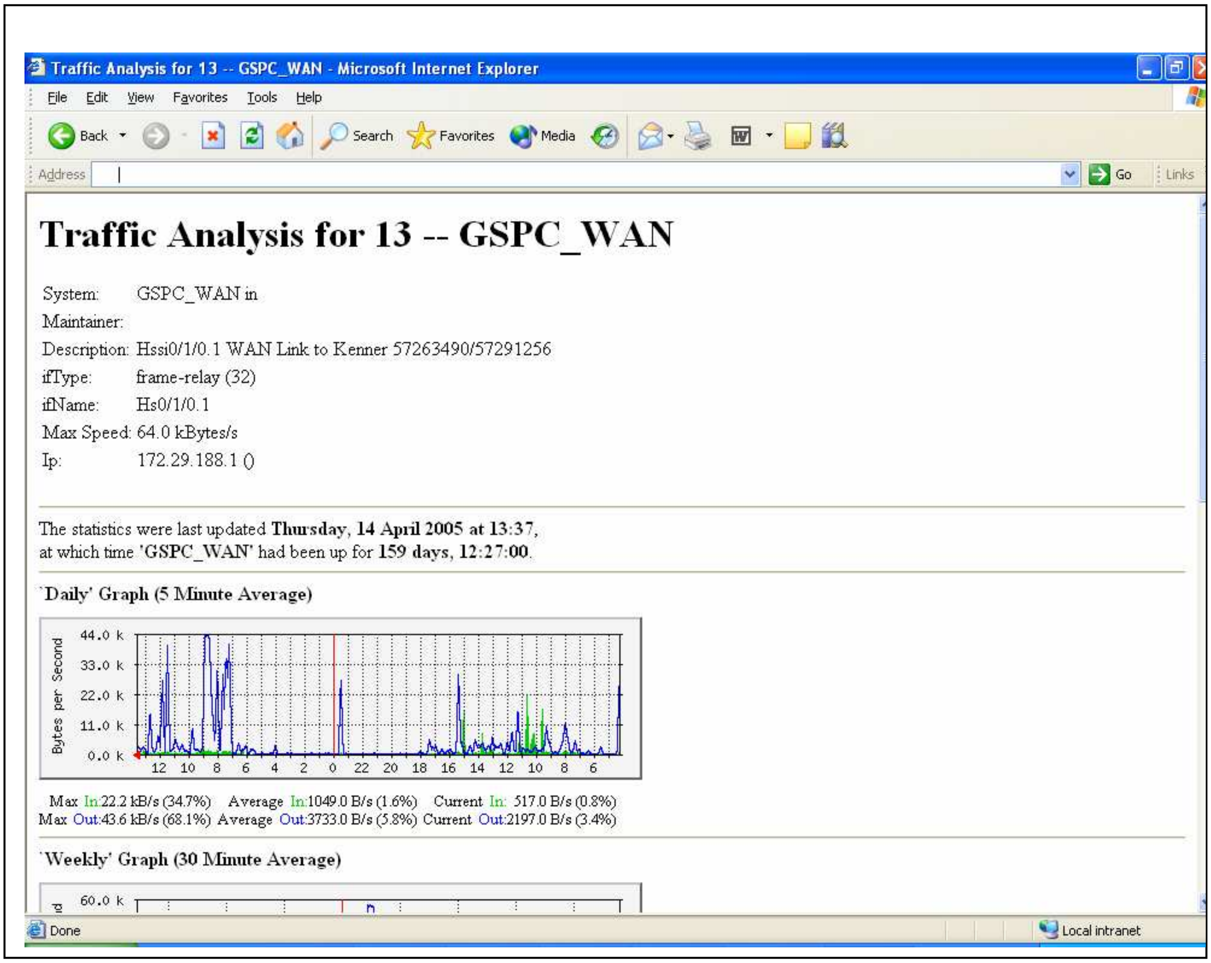

Figure 1 – Multi Router Traffic Grapher display

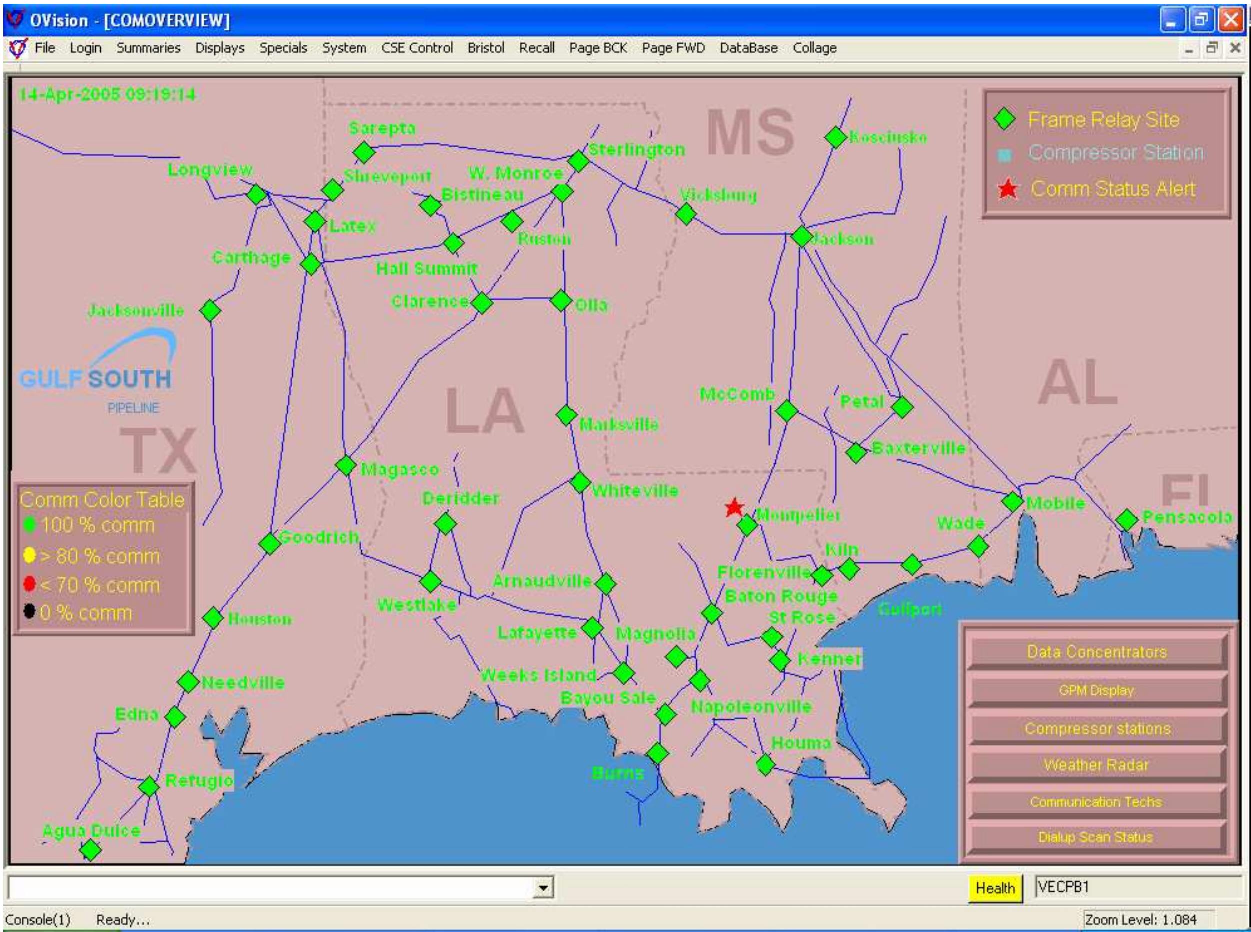

Figure 2 – Ovision Communications Overview display