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TECHNICAL ARTICLE: USING GPRS TO CONNECT SMALL, OUTLYING STATIONS

Process monitoring and control for electricity distribution grids until now has been available only at the transmission and highest level distribution substations - for lack of communications lines. Now the wireless communications technology GPRS permits low cost connectivity to even the lowest levels of the distribution grid. This provides the grid operator far deeper control over the grid, shortened reaction times in case of a failure and the efficient use of sophisticated network calculation programs. The same observation may be made for other distributed processes, like in pipeline control and monitoring. This paper shows how to use GPRS as a communications medium for power distribution and also displays a project realized this way. Please note, this paper describes fixed applications of GPRS or 3G/UMTS, where the lack of a low cost communications line is the important topic.

By Walter K. Eichelburg

BACKGROUND In the past, online process monitoring and control of electricity distribution networks was possible only at the highest levels. This means the transmission network and the upper levels of the distribution network. This was partly determined by the cost of communications lines, but also by the business model and labor cost. As a result, only the stations in the transmission grid and the highest level stations of the distribution grid got the communications lines necessary for remote monitoring and control.

But now, grid companies want to monitor and control more of their distribution level networks (medium voltage), sometimes even down to the last transformer. This not only helps with reducing maintenance cost and repair times of their networks, but also makes the operation of sophisticated network optimization and simulation tools possible. Reduction of outage times is important for power quality. Unfortunately, many of those stations that now require remote access don't have the necessary communications lines.

Small electricity distribution stations are well suited for GPRS monitoring/control

Telecom Deregulation

Before telecom deregulation, users didn't have many choices for communications lines. They could lease lines from the monopoly telecom providers at exorbitantly high cost and very limited reliability. Because in these times, most utilities had the right to lay their own communications lines so they interconnected their highest level sites, first using copper cables then using fiber, mostly embedded in the earth wires of high voltage lines. But this is costly.

After the deregulation of the telecom industry in most countries, it is easier to get communications lines at reasonable prices. It is also easier to lease lines, so it is no longer necessary to own all lines. For very small and distributed stations even a leased line at the new price may be too expensive or not be available at the location or only for very high installation costs.

Using the Internet

One modern way to reduce the line cost is to use the Internet as a carrier instead of leasing a line. The Internet now is available almost everywhere at reasonable cost. An additional advantage when connecting many stations over a leased line, fewer interfaces are necessary: one at each substation and only one at the central site. In contrast, transparent leased lines require two interfaces for each line, where each interface (last mile) costs the most.

Firewall routers build a secure tunnel through the public Internet

But it is necessary to build a secure, private tunnel for each station through the public Internet. Placing a firewall on both sides does this. Usually a small "firewall router" is sufficient. Although not absolutely necessary, data encryption and authentication usually is employed.

Virtual Private Network

The security aspects of using the Internet as a corporate network are easy to solve, so this technology is being used in a widespread manner. Even security sensitive banks use it. Because a secure, private network is being built on the public Internet, this technology is also called a Virtual Private network (VPN).

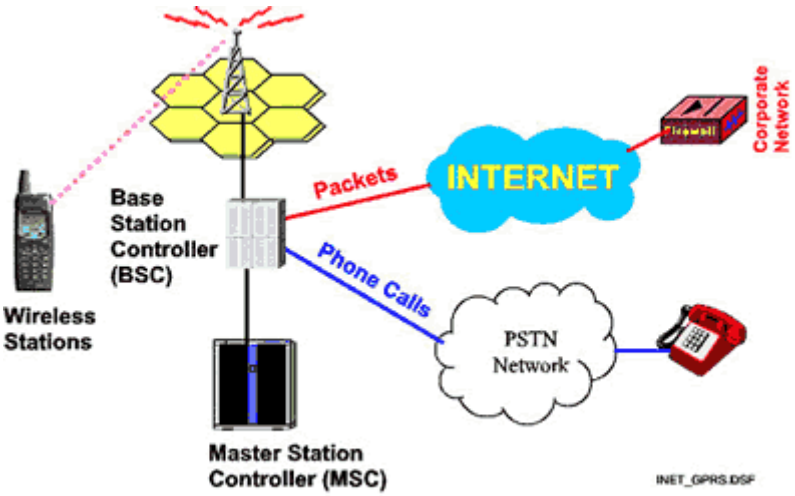
WIRELESS INTERNET

VPN technology may also be used on some wireless networks. It reduces cost even further and does not require the installation of physical lines. There are several wireless Internet/VPN technologies available on the market:
- GPRS, the Internet/packet service of GSM. Is today available almost everywhere in the world where GSM, the cellular phone network exists. Its low cost, universal availability makes it interesting for small stations where its limited bandwidth isn't a drawback. Also industrial grade GSM/GPRS modems are available
- UMTS (Universal Mobile Telecommunications Service), also called the 3rd generation (3G) follow-on of GSM/GPRS. Permits far higher bandwidth but is available only in urban areas of a few countries. No industrial grade modems are available yet.
- Wireless WAN hotspots:
They are available in some areas and buildings, so the chance of getting Internet access this way at a distribution substation is low. Also they employ Personal Computer specific login schemes not easily adapted to telecontrol applications.
So, the best choice for our application is GPRS.

The other wireless Internet networks and also wired Internet like ADSL may be used when available and suitable. The methods of provider selection, tunneling, etc. are the same. This paper will concentrate on GPRS because it is the most suitable medium for small stations.

The GPRS Network

GPRS (General Packet Radio Service), is the Internet/IP based data service of GSM (Global System for Mobile communications), the worldwide cellular phone network.



The GSM/GPRS wireless network and its "outlets"

The diagram above shows the network. Essentially, the GSM and GPRS networks are the same. They use the same infrastructure consisting of transmitter stations (one per cell) and controllers. The cell structure is because of efficient reuse of frequencies.

It is important to note, that on the network side, this network has two "outlets":
- One for phone calls leading into the Public Switched Telephone Network (PSTN)
- One for data packets leading into the Internet

So, in a "normal" GPRS environment, a mobile station always exchanges IP (v4) packets with the Internet. On the "Internet-side" only one line into the Internet is sufficient to communicate to all mobile stations. Some providers also offer a "private network" version, where the mobile stations of this "private network" are not part of the public Internet. This requires a special line to the provider.

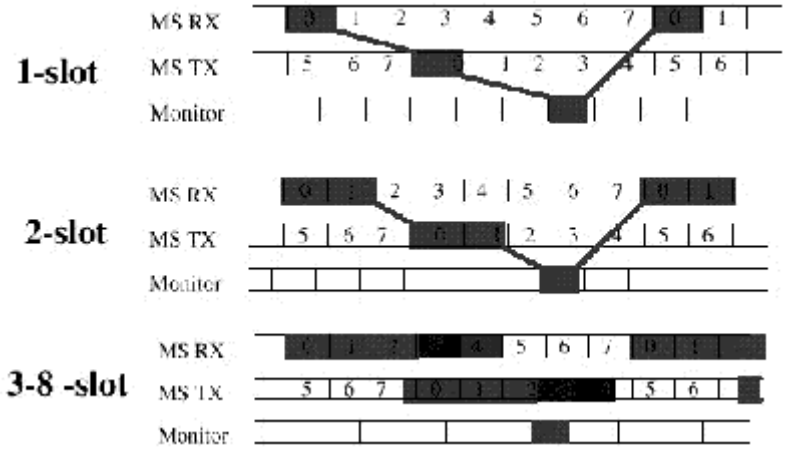
The standard way to interface a GPRS data network is by using an Internet line. In most cases the Internet line of the utility to the office network may be used. This further reduces cost.

Network Availability - Power

Many process control operators ask: what happens when there is a power failure. This is the time I need my communications network most. Depending on the GSM/GPRS provider, transmitter stations are able to work on battery from zero time to 3 days. One should select a provider with battery backup capability of at least one day. Central units (controllers) usually operate longer and have diesel generators too.

Network Availability - Network Load

Besides cost, this is the most limiting element of using GPRS for process control. GPRS has been designed as a data service for low to medium speed Internet access from personal computers, PDAs and mobile phones. Because it shares the GSM network with the mobile phones, some prioritisation is necessary. Unfortunately, with most providers, phone service gets the higher priority, although some providers offer a "real-time" version of GPRS with different priority mechanisms. The most limiting effect comes from the Time Division Multiplexed (TDM) nature of each cell. Each cell operates full duplex on three frequencies (see diagram below):
- The receiving channel (RX)
- The transmitting channel (TX)
- The monitor channel, to organize the link between mobile unit and base station controller



GSM/GPRS time slot structure

The RX and TX channels operate full duplex with 8 time-slots each handling a mobile phone unit. This is classic phone network technology. Whereas a phone only can use one slot at any one time, GPRS may give a data device one or more slots to transfer packets faster (the diagram shows 1, 2 or 5 slots). The number of slots in each direction is negotiated between the network and the mobile unit. It also depends on the network load. So at some peak times, no time slot for GPRS may be available. Connectivity comes back after a minute or so.

This is the reason not to use GPRS for important stations where continuous connectivity is a must. But compared to classic dial-up connections, GPRS offers almost continuous connectivity in both directions like a leased line. So a GPRS substation is directly able to connect to the control center without any front-end controller in between. It can send and receive spontaneous messages.

Addressing

Most GPRS providers assign private, dynamic IP addresses 10.x.x.x or similar) to mobile stations. Besides providing security, the firewall routers on both sides have the additional task to overcome this Network Address Translation (NAT) scheme in the network. As a result, each GPRS-substation gets an internal, fixed IP address of the process control system range. So besides process control, these connections may be used for any IP service, bandwidth permitting, e.g. for remote maintenance. This is an additional important advantage compared to any dial-up scheme, which is not transparent.

Cost Control

This is a very important topic with small stations. With most GPRS providers, the cost of a GPRS account depends on two factors:
- A basic monthly fee, which also includes a maximum transfer volume between 1 and 500 MB. Often, different volume packages are available.
- Each additional megabyte costs extra

So it is important to compare pricing schemes and also to evaluate the required volume per month beforehand. Although GPRS/Internet use gives the system designer a lot of freedom because no physical line is necessary, care must be taken to keep costs down. So it is necessary to look at the tariff model when selecting a GPRS provider. Otherwise, the solution might get too expensive for the intended application.

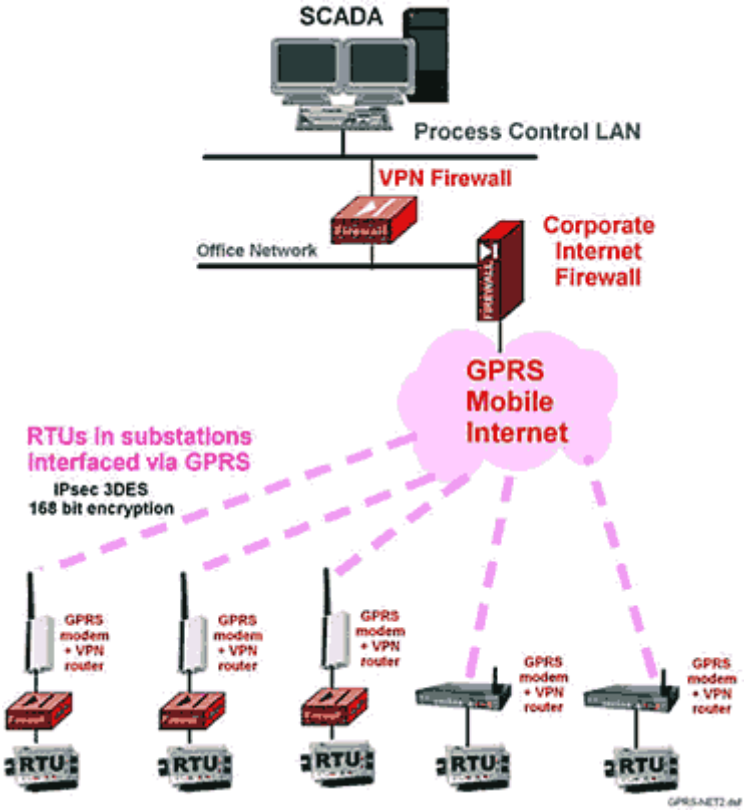
Examples: - One data packet in IEC-60870-5-104 format: 192 bytes
- One NTP packet: 172 bytes (for time synchronization)
- Connection establishment (IPsec): 4 Kbytes

So, GPRS is low cost with low data volumes but provides permanent connectivity capable of sending spontaneous messages at any given time. It also handles cyclic messages as typical for measurands, impossible to deal with dial up lines for cost reasons. But it is necessary to use cycle times, which are not very short.

In the project example below, the GPRS cost per station and per month is about EUR 27. In this project, there is one measurand per station transmitted every two minutes. Some optimizations had been necessary to keep line cost down. E.g. NTP time synchronization first created more data volume than the process itself.

A GPRS PROJECT

This GPRS project has been implemented for a German municipal utility. The author developed the overall concept and design. In the meantime it has been applied many times, The task has been to connect many small medium voltage distribution substations with no communications line. The customer owns a control center for the entire grid with network calculation programs. To make these programs more precise and efficient, measurands from previously unconnected stations where needed.



GPRS project to monitor a power grid

The Control Centre

The control center (SCADA) uses its own local area network (Process Control LAN). To not to install an extra Internet access line, the Internet access of the office network is being used, employing a firewall to the Internet. Between the office network and the process control network is a VPN-Firewall router (Cisco 2611XM), which establishes secure tunnels to each firewall router at the substations. All tunnels use the IPsec security protocol with 3DES 168-bit encryption. As one can see, there is only one Internet line necessary to connect to all GPRS substations simultaneously. And this line really "belongs" to the office network. No additional cost there, except for the VPN-firewall-router. Currently, there are 25 GPRS-substations online; the planned extension is to 145 substations. The VPN-firewall router with hardware-encryption is able to handle even more VPN-tunnels at GPRS speeds.

GPRS-Substations

Each substation uses a small RTU (SAT TM 1703 MIC) with analog inputs and an Ethernet interface. It monitors one measurand (voltage) and sends a packet to the control center whenever the value changes in a big way or else every two minutes. Remote maintenance (web configuration) and time synchronization also use the GPRS-Internet channel.

Substation equipment: RTU, router, modem

The RTU via Ethernet directly connects to a Cisco 1721 VPN/firewall router. This router is an essential element because it terminates the tunnel at the substation side. Also, in the case of a connection interruption caused by the GPRS network it

automatically reestablishes the connection - without changing any addresses at the RTU side. So, if the interruption is short, the TCP connection will not even time out. The router connects to an industrial grade GSM/ GPRS modem, although a mobile phone may also be used (not recommended). But new stations will use a single router/modem configuration. This is all the equipment needed at a substation - no physical line there. The availability of a station in this project is about 99% - sufficient for the application.

CONCLUSION

GPRS is a medium very well suited to connect small stations of any kind into a process control system. Its biggest advantage is that there is no line of any kind required to connect these stations. Although the "quality" is not the same as with a privately owned line, it is sufficient for many applications - and it is there!

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