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White Paper

Cellular to Cellular Data Communications Explained

Operating legacy dial-up peer-to-peer systems over a cellular network with modem emulation

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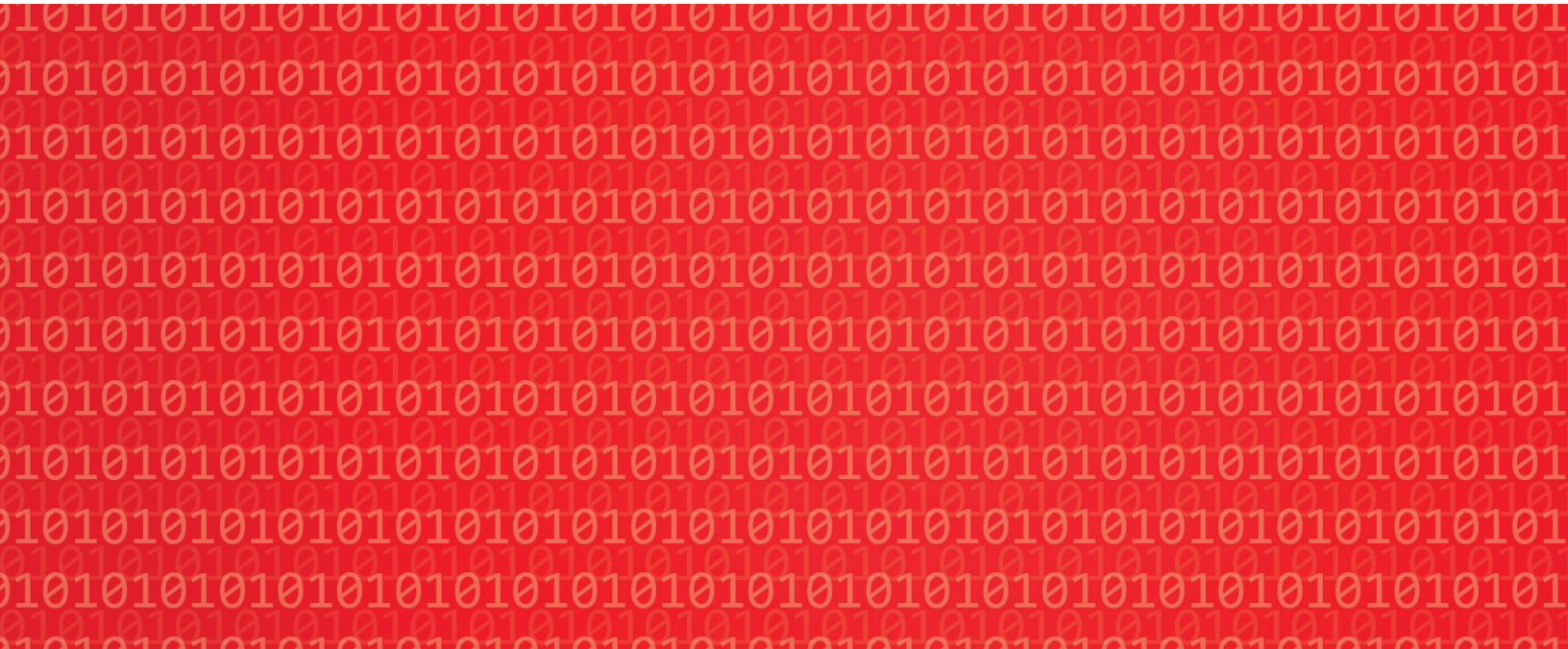
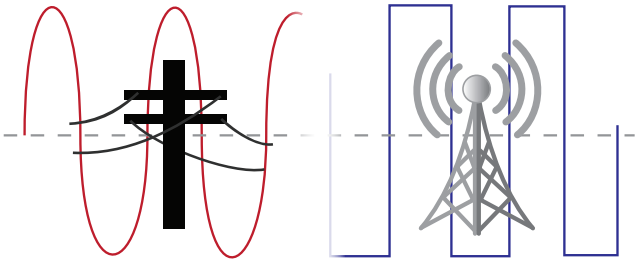


Companies are continuously assessing technology improvements and efficiencies that will lead to cost reductions and improved network stability. Systems designed decades ago using analog based solutions typically are assessed for conversion to cellular as phone line availability declines, cost of the POTS lines increases, and trends push for 21st century technologies. But the systems are intrinsically different and won't allow a simple hardware swap, making the deployment and resources required to transition a legacy analog system over to cellular extremely expensive and time consuming. A conventional upgrade path would require implementing a new IP based software solution, rolling out new hardware to every location at the same time, and training staff on the new system causing extended business disruption.

How Analog & Cellular Differ

Many assume that a cellular modem can directly replace an analog modem, but in most situations it can't and it's not clear why they don't interoperate. This white paper explains the incompatibility, and describes an exclusive USRobotics solution. We'll start by explaining the difference between the signals and connection types, the different types of networks, and why the direction of the connection matters. Then we will explain what steps you can take to replace analog connections or set up a system where cellular and dialup modems work together.



Data Signals

Analog

Telephone lines were designed to carry tonal (analog) signals. Data in the form of digital signals can't be directly sent over the telephone lines[1] so must be translated into analog. This is what dialup (analog) modems do. "Modem" is an acronym for MOdulator/DEModulator. Modems are used to modulate digital signals into analog signal to be sent over the telephone line and then demodulate the incoming analog signals to reproduce the digital data. This is classified as a point-to-point system with two modems in direct, exclusive communication with each other, as a peer-to-peer system in which either modem can initiate the connection.

Cellular

In cellular M2M communication, data in the form of digital signals is translated into cellular radio frequencies by a cellular "modem" or gateway for transmission over the cellular network. The cellular network then translates those

[1] The bandwidth of typical telephone lines is 3400Hz. Digital signals require much higher bandwidth. ADSL broadband modems, however, can receive high bandwidth modulated signals from phone lines over short distances.

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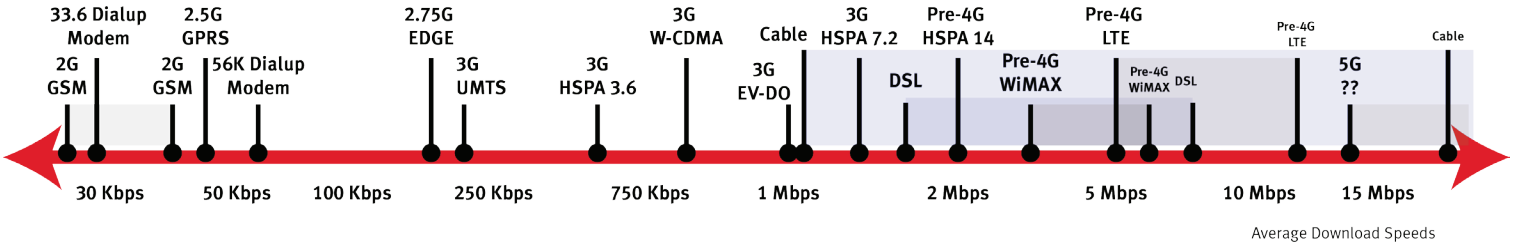
radio frequencies back into a digital data stream that is formatted into packets which can travel across the Internet. After the signals are transferred through the Internet, there must be a server to receive the signals before they are used in an application. The cellular data network, like the Internet is classified as a client/server system in which the cellular gateway acts as a client that initiates contact with one or more servers.

Connection Speeds

Many M2M applications over the last few decades have had minimal data transfer requirements - small file size and relatively quick response times. With telephone lines already in place at most locations, analog modems provided a more than adequate solution with 33.6 speeds.

As applications change and grow so too do the requirements to carry more data with better response times. 2G speeds have typically been sufficient in most cases, but as providers sunset 2G services users are forced into using 3G or 4G/LTE services that are above and beyond the needs for basic M2M applications. The range, coverage, data package costs and hardware are all different and must be taken into consideration, particularly for remote deployments where longevity means reduced maintenance.

As M2M expands out into the world of Internet of Things (IoT) the demands have increased dramatically for streaming or system failovers. These require more throughput and will rely on the newer technologies that provide a larger pipeline including 4G/LTE, 5G, WiFi, and mesh networking.



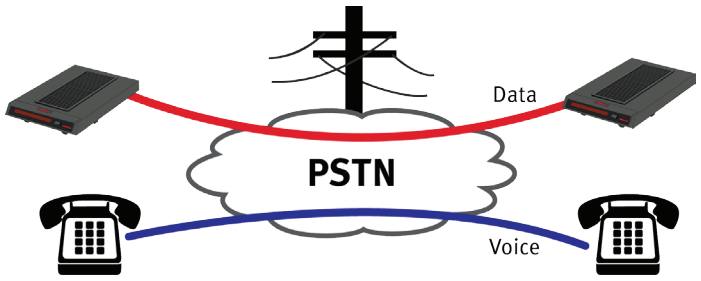
Average Download Speeds

Knowing the download and upload requirements for M2M applications helps determine what connectivity speeds that are required. Beta testing can provide estimates to make educated guesses on what service may be the best option. Faster speeds have the trade off of higher costs.

Network & Technologies

Public Switched Telephone Network (Analog Voice/Data)

The Public Switched Telephone Network (PSTN) was originally designed to carry telephone voice signals, but starting in the 1980's analog modems allowed the same network to carry computer data.



The PSTN is a type of circuit-switched network, in which exclusive connections from the originator to the answerer are created (point-to-point) for the duration of the connection, and either end is allowed to originate or answer the connection (peer-to-peer).

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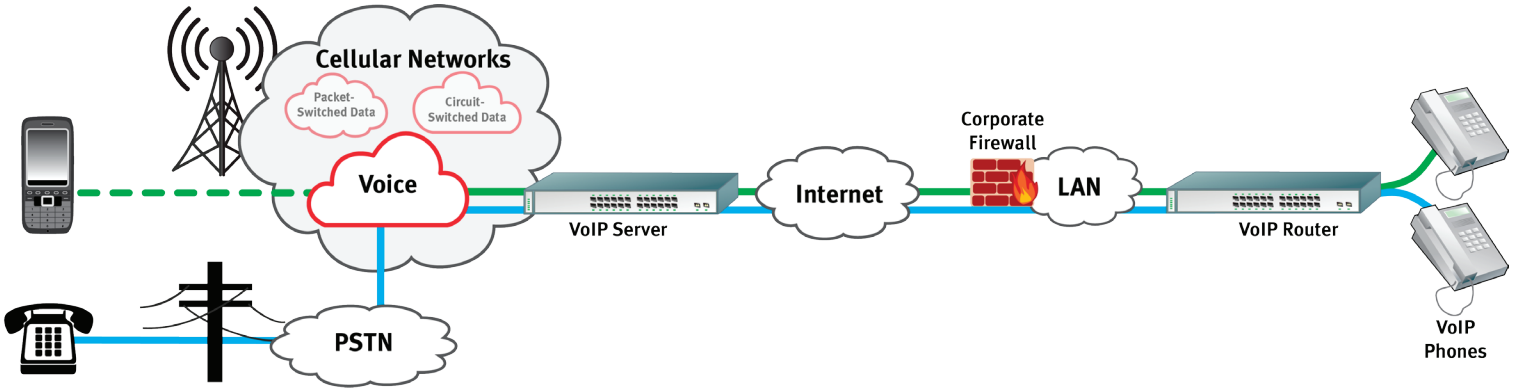
The PSTN provides in-band signaling for call setup, such as dial tone, busy tone, ringback tone, and ring signal; and accepts touch-tone signals from the originating terminal to receive the destination phone number.

The PSTN has been a mainstay of telecommunications for decades, but now it's usage is sharply down, it's costs are up, and it's availability is becoming increasingly limited. AT&T has stated a desire to retire PSTN service by 2020[2].

Internet (VoIP Voice)

The Internet was originally designed to carry computer data, but starting in the 1990's VoIP technology allowed the same network to carry voice telephony. Voice over Internet Protocol (VoIP) is a technology that allows inexpensive voice connections between phones. The connection behaves as a circuit-switched network, but is actually being carried by packet-switched networks.



A VoIP connection can made be between wired VoIP phones, between wired VoIP phones and cell phones, and between wired VoIP phones and landline phones.

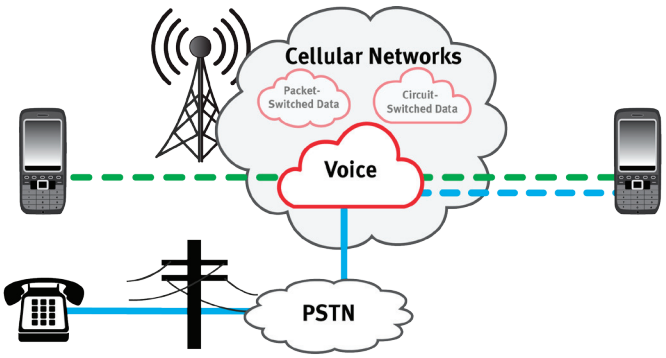
Although VoIP emulates the circuit-switched PSTN, analog modems usually cannot connect and transfer data over a VoIP connection. The VoIP data compression algorithms and the timing skew of the underlying packet network are unnoticeable to a phone connection, but prevent analog modem connections.

Cellular Voice Network

All cellular networks (GSM, UMTS, CDMA, EV-DO, etc) provide voice services that allow connections between cell phones, and between cell phones and landline phones.

The cell phones and the cellular networks emulate the PSTN by providing point-to-point connectivity, peer-to-peer operation, and call progress signaling. However, the cellular voice network is actually a packet-switched type of network.

Similarly to VoIP, the cellular voice network has data compression algorithms and timing skew that are unnoticeable to a phone connection, but prevent analog modem connections.



[2] http://www.attpublicpolicy.com/tag/ip-transition/

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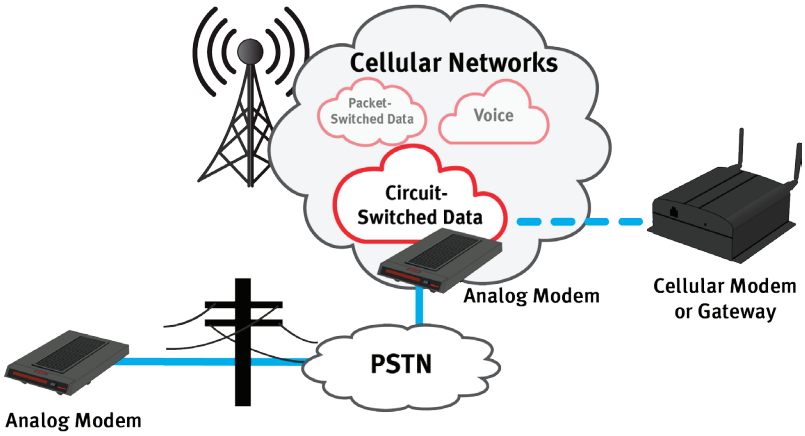
Circuit Switched Data Cellular Network

Recognizing that the cellular voice network can't carry analog modem signals, the early cellular networks offered circuit-switched data service. This service provided a low baud rate cellular data channel to the cellular network, where the data was converted into an analog modem signal and sent to the PSTN network (or conversely received from the PSTN and sent to an analog modem, then to the CSD network). The CSD service provided call progress signaling that was compatible with the PSTN. As a result, cellular modems could effectively connect and communicate with analog modems on the PSTN.



Cellular circuit-switched data service has become obsolete with the advent of cellular packet-switched data networks, and is now mostly unavailable.

Packet Switched Data Cellular Network

Mobile Originated Connection

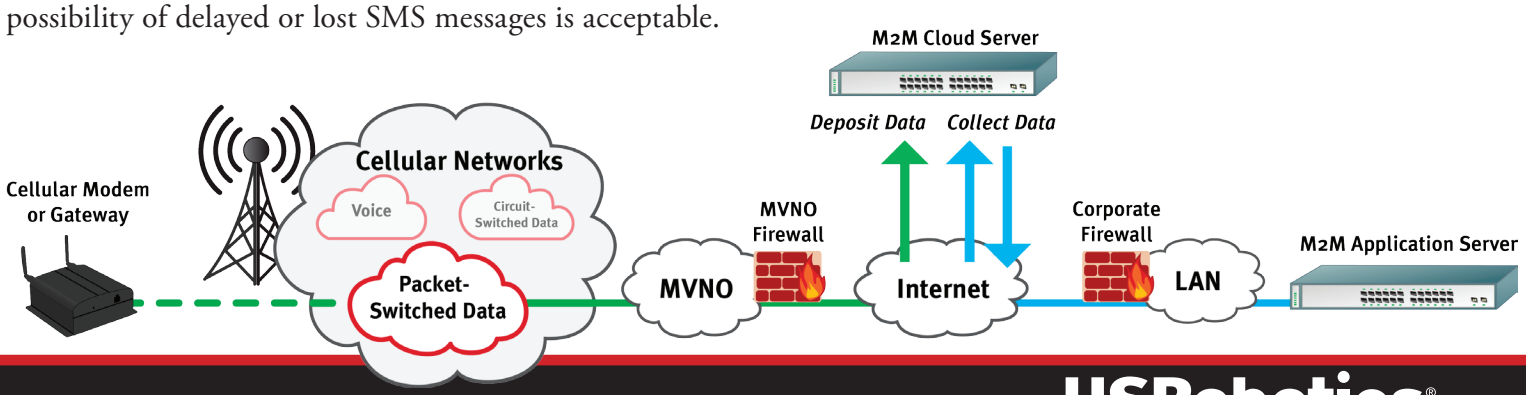
The cellular packet-switched data network is the current state of cellular data networking. With PSD, cellular gateways connect via Internet Protocol (IP) directly to IP servers. Note that no path exists from the PSD network to the PSTN, so connections to analog modems are not supported.

Instead, connections are routed directly to the Internet. A Mobile Virtual Network Operator (MVNO) may act as an intermediary, but not necessarily. In either case a firewall blocks connections into the MVNO or cellular network, preventing Mobile-Terminated (MT) connections to cellular gateways.

In typical M2M applications, the remote cellular gateways deposit data onto a publicly-routable M2M cloud server, where it can be later collected by the M2M application server at a central location.

As an alternative, the cloud server can be omitted, which would require opening a path through the firewall that protects the LAN to which the M2M application server is connected. This of course presents a security risk.

Although MT connections are prevented, it is possible to configure a system for SMS-initiated Mobile-Originated connections. This technique uses an SMS message sent to a cellular gateway (a.k.a. a shoulder-tap), which causes the gateway to connect to the M2M server. This may be an effective substitute for a MT connection, provided that the possibility of delayed or lost SMS messages is acceptable.



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Mobile Terminated or Mobile Originated Connection

Mobile-Terminated (MT) and Mobile-Originated (MO) connections are possible with any of the three methods discussed below.

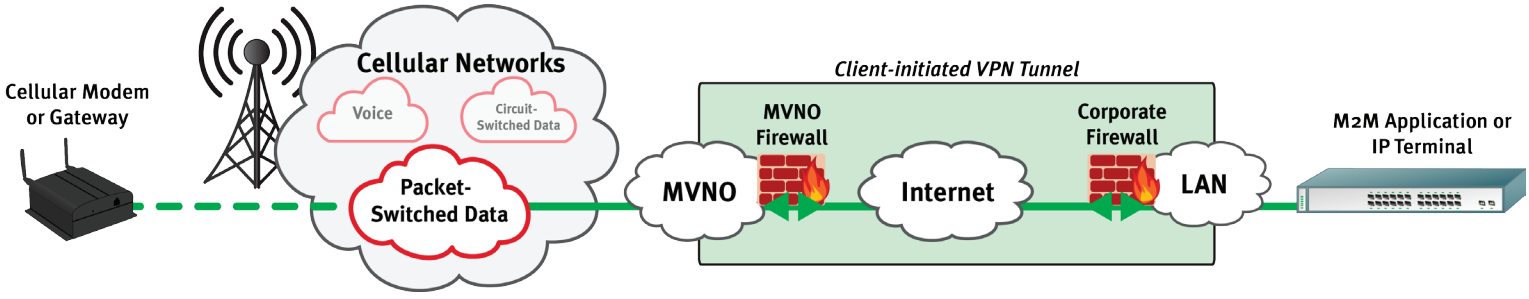
One approach to achieve MT connections to cellular gateways is to provision the gateways with public static IP addresses. However with IPv4 the number of public IP addresses is very limited, so finding a cellular service provider that can provision public static IP addresses at a reasonable cost is very unlikely. Also, public static IP addresses are vulnerable to denial-of-service attacks from the Internet, which can result in expensive cellular data charges.

Another possible approach to achieve MT connections to cellular gateways employs a Dynamic DNS service. Gateways that are provisioned with a public dynamic IP addresses can be configured to report their current IP address to a 3rd party DNS server . The DNS subscriber would assign a unique domain name to each cellular gateway, and the DNS server would translate the domain names into the last-known IP addresses. There is a cost associated with the DNS service, and the public IP addresses of the gateways are still vulnerable to denial-of-service attacks from the Internet.

A very effective and secure method to accomplish MT connections to cellular gateways is illustrated in the following diagram. Three special conditions must exist:

1. Cellular service must be provisioned from a Mobile Virtual Network Operator (MVNO). The service must include a VPN tunnel connecting the M2M application server to the MVNO private network. The MVNO will have several types of VPN service from which to choose.
2. The MVNO must also provision the cellular gateways with private static IP addresses. There may be a small monthly charge for each static IP address.
3. The cellular gateways must provide persistent connectivity with the cellular network to maintain cellular and IP connectivity, and reconnect following a network disconnect.

When these conditions are met, the M2M application server makes MT connections by simply opening IP sessions to the static IP addresses of the destination gateways. With this method, the host may be automated (an M2M application server) or may be manual (a person using a terminal emulation application).



Peer-to-peer

All of the cellular PSD architectures discussed so far allow only client/server connections, in which the remote cellular gateways connect to a central IP server. Legacy M2M systems that were designed around analog modems connecting over the PSTN expect modem-to-modem connections, which are peer-to-peer. Converting such legacy systems to cellular presents unique challenges.

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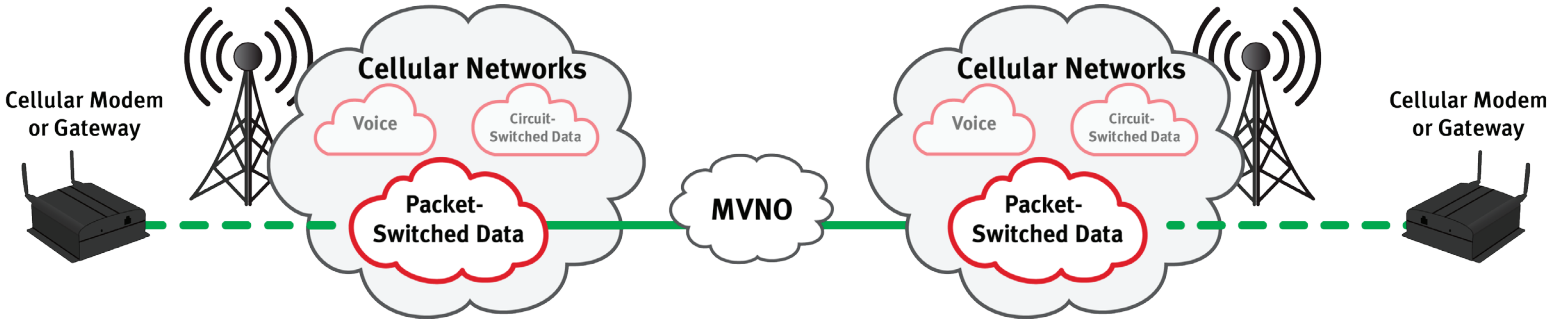
Unlike the cellular voice networks, the cellular data networks do not allow peer-to-peer connections, but only client/server connections. However, some MVNOs do offer a service that routes traffic between cellular devices, as illustrated in the following diagram. This service requires the cellular gateways to have static IP addresses.

This type of service is easy to use, and extremely secure because the data doesn't cross a firewall into the public Internet or into a LAN.



Replacing Analog

Replacing an analog modem can be done in a few different ways: emulating the phone line while continuing to use the current modem hardware, emulating the phone line and modem, or replacing the system with IP based hardware and software. Each alternative must take into consideration the type of connection needed for the application - mobile terminated, mobile originated, or peer-to-peer connections.

Emulating Phone Lines (PSTN)

The need for replacing phone lines is growing every day with the decline of land line availability. Circuit switched phone line emulation can be done over the packet switched network with an IP converter - a device with a RJ-11 port that accepts the cord from an analog modem and converts the data back to digital. The data is sent from the equipment utilizing the already installed internal or external dial-up modem, the data continues on to the IP converter for conversion, which then sends it on to a cellular gateway or directly to an IP server.

Converters have the advantage of using the hardware and software already deployed with minimal configuration changes on the remote end, though there are a few possible disadvantages: client/server connections and increased hardware to maintain and the costs associated.

- The client/server relationship may work for applications that have an IP based server accepting the data, but legacy applications often require a modem receiving a call to transfer the data properly - requiring a peer-to-peer solution.
- IP converters may not include the hardware required for cellular connections. By adding a cellular gateway there is another piece of hardware to manage for a total of up to 3 devices (modem, converter, gateway).

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Emulating Dial-up Modems

Instead of just replacing and emulating the phone line there is the option of replacing and emulating the actual modem as well as the phone line. Modem emulation can be done using software or hardware. Hardware emulation is external to the legacy hardware providing simpler installation - no software to load and no operating system restrictions; but software emulation has some additional requirements for loading and running middleware on the legacy application hardware.

- The legacy hardware must allow new software installations
- The legacy hardware must have an Ethernet port
- Requires middleware compatibility with legacy operating systems
- Requires a cellular gateway
- Only allows IP connections, not PSTN connections

Total System Overhaul

The final option is to replace the legacy application hardware and/or software at all remote sites and at the host/operations site. The remote sites' new application software must interface to a cellular gateway instead of a dial-up modem, sending an IP address instead of a phone number. The host site's new application software must receive connections from the Internet, not from a dial-up modem. For applications that require host-initiated contact, the new software at both ends must implement one of the methods of achieving mobile-terminated connections.

What if you could use the same legacy application system on the cellular network without any changes to your SOP?

USR has the Answer - *"Modemulation"*

USRobotics has developed a technology called "Modemulation" that can simplify the transition from analog peer-to-peer connections to cellular peer-to-peer connections. The USRobotics Modemulator allows a legacy peer-to-peer M2M system to be conveniently converted to cellular without upgrading or replacing application software. The Modemulator accepts and responds to the most common analog modem commands, and sends result codes to the application software that mimic a PSTN connection, which enables drop-in compatibility with the legacy application software.

Using a Modemulator at the network operations center, a Network Manager can contact a remote Modemulator over the cellular data network by entering the same dial command that is used for analog modems. The two Modemulators replace two analog modems and operate as a seamless "drop-in replacement" for analog modems and the PSTN.

The Modemulator can also route a connection over the PSTN from a local analog modem to an analog modem at a remote site that hasn't been upgraded yet. **Both cellular and analog sites can be managed conveniently using one terminal and the same familiar dial command.**

The USR3520 USRobotics Courier® Modemulator™ & 3G Cellular Gateway with dual radio.

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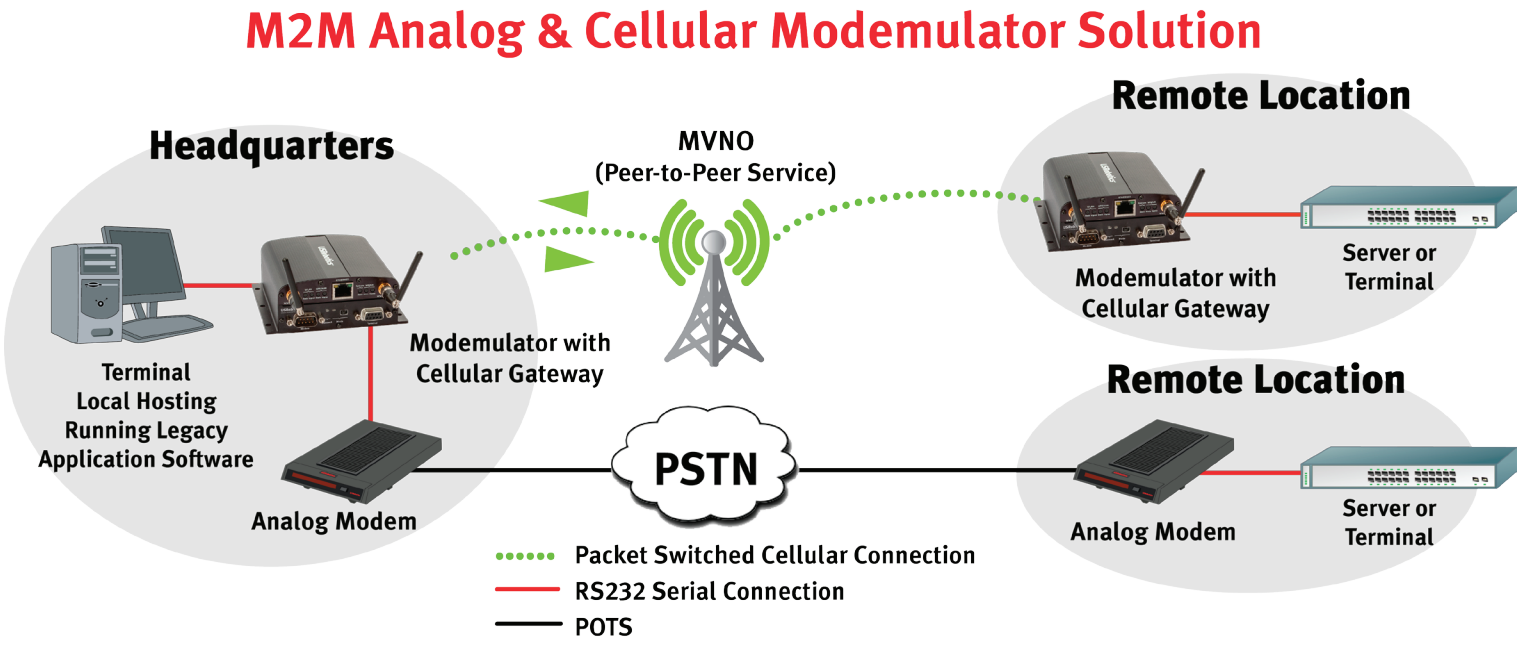
How Modemulation Works

The local Modemulator interfaces to a terminal's serial port, just as an analog modem would. The Modemulator presents to a user (or to legacy application software) a command-line interface (CLI) that mimics the AT commands and responses of analog modems, but connects to another Modemulator (or to an IP server) over a cellular data network instead of the public switched telephone network (PSTN). The remote Modemulator interfaces to the console port of the networking equipment (or port server), just as an analog modem would.

An Administrator assigns an arbitrary phone number to each remote Modemulator, and enters that phone number and the IP address and port number of each remote Modemulator into a phonebook in the local Modemulator. When a dial command (e.g. ATDT555-1234) is entered into the Modemulator from the terminal, it searches its phonebook for an associated IP address. If an entry is found, it will connect to the remote Modemulator, allowing the Operator to manage the remote networking equipment.

The connection is made to a GSM or CDMA 3G cellular data network, and the data routing is provided by a Mobile Virtual Network Operator (MVNO). A special service from the MVNO allows routing from one cellular device to another within their network, without crossing a firewall or traversing the public Internet. Such private data routing is extremely secure because 1) cellular data networks do not allow direct device-to-device communication, 2) the subscriber's private sub-net is isolated from other devices on the MVNO network, and 3) routing from the public Internet is blocked by the MVNO firewall.

If an entry is not found in its phonebook, the Modemulator realizes that the phone number is addressing an analog site and automatically routes the dial command to an attached analog modem.



Modemulators allow connections over either cellular or analog connections providing a "Mixed Network" solution and the ability to replace hardware on an ad hoc basis.

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Why Use the USR Modemulator & Cellular Gateway?

In the process of converting a legacy dial-up M2M system to cellular, the transitional period can be very disruptive. Once the host site has been upgraded to cellular, connectivity with any non-upgraded remote sites will be interrupted until they too are upgraded to cellular.

With other analog-to-IP converter solutions, keeping the host site's dial-up connectivity operational along with the new cellular connectivity may be cumbersome or impossible.

The USRobotics Modemulator, however, offers an exclusive automatic switch-over feature. With a dial-up serial modem connected to Modemulator and to the PSTN, the Modemulator can automatically detect and allow incoming or outgoing connections with sites that are still using dial-up. This allows the legacy host software to transparently connect with either cellular or dial-up remote sites.

After the transition of all remote sites to cellular is complete, the PSTN service at the host site can be discontinued. Or, maintain the PSTN service for a system that has a permanent mixture of cellular and dial-up remote sites.

Save time and money with this easy conversion of an analog based legacy M2M systems to a more modern M2M system connecting over ubiquitous cellular data networks, without upgrading legacy application software that expects an analog modem, or without installing new middleware onto the application computers.

Benefits of Modemulation

- Operators use the same terminal for cellular dialing as for analog dialing
- Operators use the same command syntax for cellular dialing as for analog dialing
- Operators can be unaware whether the phone number being entered is for an analog or cellular connection

Benefits of Cellular Remote Network Management

- Manage sites where a landline is not available
- Relieve sites of responsibility for maintaining a landline (prevent nuisance disconnections)
- Generate additional revenue by including connectivity with management services
- Reduce overall costs - pool data over large groups of modems
- A private cellular network is inherently secure
- No physical connection to network removes lightning exposure

Analog & Cellular *Together*

Contact USRobotics for more information about applications that may require mobile terminated connections including remote management, point of sale, utilities, HVAC, SCADA.

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