CELLULAR BROADBAND TELEMETRY OPTIONS FOR THE 21st CENTURY

Looking at broadband cellular from a telemetry perspective

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ABSTRACT

With the recent broadband upgrades to various cellular infrastructures and the myriad new emerging wireless broadband standards and services offered by carriers, it is often difficult to navigate this sea of technology. In deciding the best choice for broadband telemetry applications, one must look not only at the technology, but also at the economics, market timing, bandwidths, legacy issues, future expandability and coverage, security, protocols, and the requirements of the specific application. This paper reviews the technology roadmap of cellular providers keeping these issues in perspective as they apply to TCP/IP data for images, audio, video, and other broadband telemetry data using CDMA 1xRTT, EV-DO, and EV-DO Rev A systems as well as GSM GPRS/EDGE, UMTS/W-CDMA, HSDPA, and HSUPA networks. Lastly, issues seen by system integrators when using cellular channels for telemetry applications are examined, and a case is presented for overcoming many of these issues through the use of cellular routers.

KEY WORDS

WAAV, 3G Wireless, Mobile Broadband, Wi-Fi Cellular Router, EV-DO, EDGE, UMTS, W-CDMA, HSDPA, HSUPA, WiFi, GPS, Vehicle Internet.

INTRODUCTION

For remote telemetry applications, there are many methods of getting broadband TCP/IP data to be transmitted back to multiple users from a mobile location. Cellular systems are one of the most widely-available and cost-effective delivery systems for telemetry data, and with national coverage and new high-speed capabilities being added by carriers, they will continue to be a dominant player well into the 21st century for broadband telemetry applications. The author describes the evolution of cellular data services and highlights the latest new services coming out today for use in future applications. Implementation issues due to the nature of TCP/IP data over cellular networks are always present, but the author presents a case for using a commercial cellular router to solve many of these constraints.

BODY

Before looking at the specifics of broadband technologies, the user needs to decide the specifics for his or her telemetry application. These include the application's bandwidth usage, the latency, where and how it will be used, and the cost target. As technology continues to evolve, so does the meaning of the term "broadband". Only a few years ago, a 14.4 kbps modem was considered "broadband". It is the opinion of this author that "broadband" today should be defined as 728 kbps download speeds and 256 kbps upload speeds at a minimum; these are approximately equivalent to DSL speeds. Telemetry applications, however, are normally more concerned with the upload data speeds from the remote application to the Internet, and this paper places more emphasis on such capabilities. For certain applications, the latency of the transmitted data is a critical issue; these include applications with real-time 2-way interaction such as VoIP (Voice over Internet Protocol), video conferencing, or push-to-talk services. Standard remote video normally does not require an extremely low latency, since the application is only sending 1-way video data. Furthermore, cellular systems provide the only feasible solution today for applications that require low costs and mobility while transmitting.

The amount of bandwidth being sent through any telemetry application may depend on the amount of local processing available. In video applications, for instance, if a local processor can definitively know there is nothing of interest in a video stream then it may not be necessary to send it. This may be true of systems that monitor traffic: instead of transmitting the entire video feed, a local processor can determine the speed of the vehicles and then just transmit the average vehicle speed every given period of time. Or perhaps the system can determine each vehicle's license plate and just send that information back. Since there are many situations where local processing may help in reducing the channel bandwidth, these alternatives should be explored first. Sometimes, local processing cannot help decrease the amount of information to be sent so full broadband data transfer is necessary. While many types of technologies were investigated for these applications, due to paper length requirements, the author here will only review the latest cellular technologies.

Cellular Networks:

Today's cellular data services are exploding with new options for mobile broadband. In the United States, there are two main types of cellular systems – CDMA (Code-Division Multiple Access) and GSM (Global System for Mobile communication). Each of these systems has a separate evolution to broadband data services.

CDMA Systems:

Code-Division Multiple Access provides multiplexing among users by multiplying each user's data-stream with a unique code that is orthogonal to all the other codes. In this way, each data-stream is spread over a broader bandwidth (spread spectrum) but can still be individually recovered at the receiving end. Qualcomm pioneered the use of this type of multiplexing scheme and used it in a formalized physical interface for a digital cellular phone system, called "cdmaOne" (also known as "IS-95"). They then followed this original standard with a newer standard called "cdma2000", also known as "IS-2000" or "IMT-2000", that doubled the throughput while keeping backwards compatibility. This system is in use today by several U.S. cellular carriers including Sprint PCS and Verizon among others. Note that the term "CDMA

Systems" refers to these physical standards (cdmaOne and cdma2000), even though competing standards such as GSM today also use forms of CDMA such as W-CDMA (Wideband CDMA) for multiple user access and data services.

The data services available over cdma2000 have progressively increased in bandwidth. The term 1xRTT stands for "1 times Radio Transmission Technology", and is so designated because it uses one full channel pair (each 1.25 MHz wide) for data. It provides true packet data over a circuit-switched technology. While the system originally was planning on using more channels for wider bandwidths (3xRTT, etc.), in practice most carriers do not yet support it. The 1xRTT raw bi-directional data rate for cdma2000 release 0 is 153.6 kbps (144 kbps net). According to the CDG (CDMA Development Group), cdma2000 release 1 supports 307.2 kbps data rates [6].

After 1xRTT, Qualcomm introduced a network overlay called EV-DO (originally for EVolution for Data Only, later remarketed as EVolution for Data Optimized) for the cdma2000 system to again increase capacity and allow for enhanced data services. It is a third-generation (3G) wireless technology for broadband mobile data services. 1xEV-DO Revision 0 (also known as Release 0, and ratified as IS-856) of EV-DO allows for 2.4576 Mbps peak download data rates, but the uplink today is still only at the 1xRTT rate of 153 kbps.

At the time of this writing (May 2006), an upgrade to the cellular infrastructure is occurring and a new revision of EV-DO is being deployed to further increase the data rates. This new revision of EV-DO is called "Revision A"; it keeps the same 1.25 MHz channels in the physical layer, but it allows for peak data transmissions of 3.1 Mbps download and 1.8 Mbps upload [6]. It has added QoS features (Quality of Service) that allow it to monitor channel quality. It also has better multicast capabilities on the downlink side, and therefore is more effective at transmitting video data to users. One major benefit, though, is improved latency; this is especially important when using VoIP and Push-to-Chat technologies that require immediate response. The latency of EV-DO Rev A is approximately 70-95ms total end-to-end, plus any additional latency in traveling over the Internet. 1xEV-DO Rev A maintains fully backwards compatibility with 1xEV-DO Rev 0 and 1xRTT. If modems do not find a local cellular tower with Rev A capabilities then they will drop back to Rev 0 or to 1xRTT data rates.

According to the CDG, a new cdma2000 Revision B standard using a 64-QAM modulation scheme is being finalized now and will come to market in 2008. It will push the downlink rate of a single 1.25 MHz channel to 4.9 Mbps. Multiple 1.25MHz channels can be aggregated together for higher throughputs, theoretically reaching download rates of 73.5 Mbps and uplink rates of 27 Mbps; typical usage of 5 MHz of spectrum will have a download data rates 14.7 Mbps [6].

Note that the data rates mentioned for each of these systems (1xRTT, EV-DO Rev 0, EV-DO Rev A) are all peak data rates. Standard data rates are much less and depend on many factors, including the system noise and the distance from the nearest cellular tower. Average or actual data rates vary widely since this depends on the signal strength and system loading among other issues, and the author includes them here for reference only. Standard 1xRTT average throughputs are on the order of 60-100 kbps. EV-DO Release 0 is around 300-700 kbps, although with some easy optimization described below it can reach 400-800 kbps. EV-DO Rev A signals were not available for testing at the time of this writing.

GSM/UMTS

The GSM system initially offered circuit switching only; each channel provided a fixed data rate of 14.4 kbps when connected. GPRS (General Packet Radio Service) was introduced to allow the first packet switching on GSM networks and enabled devices to be always connected, even when not sending data, without requiring a complete channel to do so. GPRS data rates use multiple channels for a maximum throughput 115.2 kbps (140.8 kbps theoretical maximum), although the actual throughput is around 40-50 kbps. The next evolution for GSM networks, called EDGE (Enhanced Data for GSM Evolution), allows 384 kbps by sending three bits per symbol instead of one, yielding a three-fold increase in data rates (to a theoretical maximum of 473.6 kbps); the typical throughput is about 100-130 kbps. This is sometimes called EGPRS, only to stress the fact that the new physical layer is used with packet-switched data not circuit-switched data. For this paper, the author will use the term EDGE to refer to this higher-speed packet-switched data rate.

The next upgrade for GSM operators after EDGE (or in parallel with it) is W-CDMA. While some claim UMTS (Universal Mobile Telecommunications System) and W-CDMA to be interchangeable terms [9], UMTS is the 3G successor to GSM that uses W-CDMA as the underlying physical standard. Note that Japan's FOMA system, not compatible with UMTS, also uses a W-CDMA physical interface. Even though W-CDMA uses 5 MHz channels that are code-division multiple access, UMTS is an evolution of the GSM system and is not compatible with the CDMA system mentioned above. The UMTS/W-CDMA capabilities are in addition to any GSM/GPRS/EDGE capabilities of a system, and they normally run on different frequencies in parallel to the GSM/GPRS/EDGE system, although hand-offs are seamless between the two. W-CDMA user data rates are also 384 kbps.

In Europe, the GSM/EDGE physical interface uses 900 and 1800MHz. W-CDMA in Europe uses a 1900 MHz uplink and 2100 MHz downlink. These systems are made so users can roam seamlessly between them, with all back-end operations taken care of by the carriers. In America, GSM/EDGE is on 850 MHz and 1900 MHz. Cingular uses both of these frequencies, and T-Mobile just started using the 850 MHz frequency in addition to their standard 1900MHz. W-CDMA was rolled out by Cingular using the same 1900MHz spectrum, and they are using it for both the uplink and downlink since the 2100MHz frequency was not available at the time.

Just as EV-DO is an additional overlay to the cdma2000 system, HSDPA (High-Speed Downlink Packet Access) is an overlay to the W-CDMA physical interface of UMTS. HSDPA increases download data rates to 3.6 Mbps (with average rates expected to approach 2 Mbps), with current user hardware of 1.8 Mbps having average data download rates around 400-700 kbps. Equipment is just being released now for the 3.6 Mbps download rate, but theoretically the download speed with HSDPA can be increased to 14.4 Mbps depending on the type of modulation scheme used. While HSDPA does vastly increase the download rates, it does not increase the upload rate. Remote telemetry users should keep this in mind.

The next step on the UMTS roadmap after HSDPA is HSUPA (High-Speed Uplink Packet Access). Also known as EUL (Enhanced UpLink), this again increases system capacity and improves the uplink data rate by further reducing the latency and minimizing the time between retransmission requests. Depending on the exact scheme and transmission time interval, maximum upload data rates of 5.76 Mbps are possible. Nortel has already made a phone call in February 2006 based on this technology with an upload data rate of 1.46 Mbps, which is four times the current uplink rate. Equipment will not be available to carriers until 2007, with a rollout sometime thereafter [5].

Issues with TCP/IP telemetry data over cellular and benefits of a cellular router

Now that the reader fully understands most of the available cellular data rates available for telemetry applications, it is first necessary to decide which cellular network to use. This will also determine the use of CDMA (EV-DO) or GSM/UMTS (EDGE/HSDPA/HSUPA). The coverage maps from the three major carriers in the United States – Sprint, Cingular, and Verizon are available at:

http://www.sprint.com/business/products/products/evdoEnterZip.jsp
http://www.cingular.com/support/maps.do
http://www.verizonwireless.com/b2c/mobileoptions/broadband/coveragearea.jsp

At the time of writing this paper (Mid-2006), Sprint had EV-DO in 221 cities covering 152 million people. Sprint currently has aggressive expansion plans and intends to finish upgrading their entire network by 2007. Verizon had EV-DO in 181 cities covering 150 million people. While Verizon's coverage for EV-DO may not be as broad as Sprint's, they do have large areas covered by 1xRTT. While Cingular offers great data rates with HSDPA, at the time of this paper the service was only available in 18 cities and was not included in their coverage maps. However, Cingular does have great coverage with EDGE and is continuing to upgrade their network with more HSDPA coverage areas as well. When choosing a carrier, one should also consider the frequencies that are used; normally lower frequencies can penetrate buildings better than higher frequencies [4]. For CDMA Verizon uses both 800 MHz and 1900 MHz frequencies, but most of their EV-DO is on the 1900 MHz frequencies. Sprint PCS uses 1900MHz as well. GSM/GPRS/EDGE in the United States is on either 850MHz or 1900MHz, and UMTS/HSDPA is only on 1900MHz. It is highly desirable to get real hardware and test out the actual speeds that are seen in different areas during different times of the day. The lowest data rates should be used for determining the actual system performance for remote data uploads unless the data will only be sent during off-peak times. Sometimes some areas are highly populated and the over-crowded cell towers limit the amount of bandwidth going to the end customers. The carriers normally do not expect this to happen and plan cell towers accordingly, but in some cases (such as conferences with many users or places where many people congregate) it may still happen. There are methods described below which help in this situation (such as using an external signal booster to push the signal to the next cell tower), and carriers are constantly adding new bandwidth to combat these types of issues. However, it is always best to obtain a device and try it out first to determine actual bandwidth in any given area.

There are a few methods of increasing the average data rates from cellular systems. First, an external antenna is almost always required – especially in a mobile environment. This will increase coverage area and connection speed by providing better signal strength. The best mobile antennas should be used; for mobile applications, these include permanent mount NMO antennas that extend above the vehicle. If this is not possible then an external magnetic-mount or internal glass-mount antenna can be used. Note that a fully-integrated cellular router with the cellular modem integrated inside is preferred, since other modems (like the Sierra Wireless Aircard) do not have robust antenna connectors and can easily break in use, especially in mobile environments. In a non-mobile environment, it is best to place the antenna outside where it has the best reception or a direct line-of-sight with the cellular base station. If this is not possible, then the antenna should be positioned on the glass of a window in the building. Due to the cable loss, very long or extended antenna cables can do more harm than good; so if a cellular router is used at a fixed location such as in a building, then the antenna and router together should be placed at the best location for cellular reception (even outside in a NEMA enclosure), and an Ethernet cable (or Wi-Fi) can extend it to the area where the application is located some distance away. Power-over-ethernet (PoE) can be used to power the router through the Ethernet cable; this makes it very easy to extend the distance between the router and the application. This works well for signals in the basement of a building that may not have other means of broadband access. Other methods of increasing the average data rates from cellular systems include using external signal boosters. These will help more in rural areas where coverage may be weak and cell towers may not always be close by, and they will help in building penetration and in reducing any "deadzones" in coverage. Signal boosters can range in price from $200 to $350, though, so for many cost-conscious applications, external antennas are always considered a must-have, and signal boosters can be added only if necessary.

One issue that often arises with cellular networks is how each carrier treats TCP/IP traffic and ports. Since wireless packet networks are vulnerable to the same types of security attacks as wired networks, some carriers have resorted to various methods of dealing with these security issues and viruses. In some cases, certain services are not available to users of wireless networks that are normally available over wired networks. For instance, some carriers may block high port numbers (over 1024) or may not transmit data coming from commonly-used ports like port 80 for HTTP servers, port 25 for SMTP, etc. While this may not adversely impact standard mobile users surfing the web, it can be an issue for telemetry applications that normally use such port numbers, and the user should check with the carrier's policies before attempting to use these ports. An additional advantage of a cellular router here is its capability of rerouting port numbers explicitly for such circumstances, allowing the telemetry application to work without modifying it for the rules of each carrier. Furthermore, if using limited-data telemetry plans on a cellular network, then any such attacks or attempts at getting into the remote application may constitute billable traffic. This can be eliminated by going through approved partners with the carrier that will only transmit data to the remote device when coming from a certain known IP address. All traffic to the remote device can then come from this one access point. Even in systems with unlimited data (such as most broadband cellular data plans today), this is still good practice not only for reducing traffic and bandwidth usage, but also for reducing hacking attempts. Instead of only relying on the carrier's protection, a cellular router can further act as a secondary firewall system against intruders as well, allowing incoming traffic only from a given IP address. It also maintains logs of any hacking activity and authorized logins.

Some applications may transfer sensitive data, and in these cases it is best to apply some level of encryption to the data being transferred through the Internet. If Wi-Fi is being used, most have built-in WEP and WPA security protocols that should be used. While it is extremely difficult to tap into the air interface of a CDMA system, it is still essential to encrypt private data being sent over a cellular network since the data also will normally travel through the public Internet to reach its destination. The U.S. government requires "Type 3 encryption" on all sensitive but unclassified data to meet FIPS-compliance (Federal Information Processing Standard), and requires more encryption for classified data. Since this typically requires increased CPU performance of the router, reduces bandwidth throughput, and increases latency, encryption algorithms for normal civilian use depend on the application. Proprietary methods of encryption require the computer (or a server) on the receiving side to run the same algorithm to decrypt the data. Standard security protocols for normal civilian use, like VPN (Virtual Private Networks) or secure shell access (ssh), can set up a secure tunnel through which all the data can be transferred from the router to the receiving machine.

Sometimes, it is not security but maximum throughput that is required. In such cases, bandwidth can be maximized by compressing any data being sent or received. Normally, audio files such as MP3 are already fully compressed. Video files are likewise compressed, although the compression rates vary greatly from one vendor to another, depending on the exact compression algorithm used. Standard text files, email, web traffic, or other such data is not compressed at all; in this case, running an extra compression algorithm will reduce bandwidth and allow more data to be transmitted simultaneously. Compression for these types of files requires software on both sides of the cellular link. With video files, this is normally accomplished directly from the remote telemetry application, and compatible software at the receiving end with the same video codecs is used.

Quality-of-Service (QoS) is also an important part of any TCP/IP packetized data implementation that has mixed types of data. For streaming live real-time information at the same time as having non-live data (such as file transfers or web browsing), then the non-live data can adversely affect the transmission of the live data. These QoS issues are easily heard when using VoIP phones while uploading a large file; the voice signal is lost or greatly degraded during the transmission of the file. A more desirable solution would have the file transfer take an extra second or two without degrading the voice quality of the VoIP phone. Routers that have QoS built-in know the type of information that is being routed and can reduce such effects. VoIP data, gaming data (that requires immediate throughput), or any other real-time data is given a higher priority of using the available bandwidth. This issue not only affects people with mixed data-types (realtime and non-realtime), but it also affects those using a TCP/IP connection that is shared with others or one that uses a high percentage of the available bandwidth. By prioritizing the information in a time-sensitive manner, the router can decide which data to transmit immediately and which data can be transmitted a few milliseconds or seconds later. Not all routers are QoS-capable yet, and having a capable router at the cellular end may have no effect if other routers in the data transmission path (often near the receiving end) don't have the capabilities. While all of the latest 3G systems above have provisions for QoS, it is not a guarantee that the carriers will provide QoS outside their system. In these cases, programs can be written that correctly prioritize data for efficient bandwidth usage; these programs can run on the telemetry hardware (or in the cellular router) and on the computer at the receiving end (or on a server on the backbone of the Internet) to provide "pseudo-QOS" functionality.

In some cases multiple devices or sensors in a given area will be linked together to one central location that then aggregates the information and transmits it to the user over the Internet. In addition to standard 10Base-T/100Base-T LAN capabilities, many cellular routers today can provide a Wi-Fi hotspot to which multiple devices can connect. Some routers even provide Bluetooth, ZigBee, or UWB capabilities for surrounding devices as well. Most other types of devices (such as non-standard RFID readers, etc.) require a custom solution that can then connect to the cellular router through a single LAN connection. On the receiving side, multiple people may need to view the remote data simultaneously. Creating a connection for each person to connect directly to the device or cellular router will cause a loss of bandwidth through the cellular connection. Since most carriers today do not support multicast capabilities on the uplink, the data should be fed from the remote location to a server on the Internet. Not only is this more secure, as described above, but it will maintain better bandwidth and give multicasting abilities from the server rather than from the remote telemetry application itself.

If the remote application is installed in countries outside the United States or roams from country to country, then the situation can be even more complex. Just as different carriers in the U.S. block different ports, each carrier outside the U.S. deals with security issues differently. Worldwide roaming is almost possible since most countries use a type of GSM/UMTS system. However, the frequency spectrum in other countries is different from that in America, so a multi-band modem or cellular router with such a modem must be used. Some nations' GSM cellular systems may not have been outfitted with broadband capabilities. The user must also be aware of the data-plan roaming capabilities and charges when moving from country to country. Many CDMA-based systems do not roam to other countries, even if they have a similar CDMA-based system due to backend billing issues. These issues were clearly specified in the GSM specifications, though, so most GSM-based products can roam. Roaming charges can range to more than $0.02 per KB, though, which can add up quickly. Also note that roaming on data plans in other countries varies vastly by country and region, and the user should check with the carrier to make sure this capability exists.

Sometimes users need to access the remote telemetry application to download its data, log in for maintenance, issue tele-commands, etc. In these cases, the telemetry application needs to tell user the IP address the carrier has assigned to it. Furthermore, if the application is mobile then its IP address may need to be updated each time it changes cell towers. A cellular router takes care of this automatically and updates a dynamic DNS address so the user always has access to the router, which can then route the user to the telemetry application.

Higher-end cellular routers built for mobile applications will also include GPS options. Instead of having the user's application include GPS data, the location information can be sent automatically from the cellular router. This also helps when the user wants to activate a certain application based on position. As the router moves into the desired physical position where data will be captured, it can automatically notify the application to begin sending data. The GPS option can also aid in remote tracking of multiple units in the field, so the user can remotely see where each unit is located and can request data only from units in a given location.

Cellular routers with multiple modems

After evaluating all of the above cellular capabilities, some users will find that the upload data rate is currently still not enough, especially for applications like multiple streams of video. While this should no longer be the case with the release of EV-DO Rev A hardware in September 2006 or with the full rollout of HSUPA, at the time of this writing it still poses a major issue for certain applications. There are a few cellular routers on the market that allow the user to overcome this issue by aggregating the bandwidth of multiple cellular modems. These modems then perform load balancing over these multiple connections so any outgoing TCP/IP traffic will be divided between the connections. Note that standard load balancing between two modems, the aggregate bandwidth will not be twice as fast for connections coming into the box unless special software is running on the server-side that knows there are multiple paths back to the router. Normal connections into the box will still use a single connection at a time, although some connections may come into one modem while other connections will come into another. The uplink transmitted data, though, will be balanced between the connections and provide close to double the speed. Having multiple modems is more expensive, since multiple accounts are required, but it will provide much greater bandwidth when other options are not available. This works great for situations with multiple video streams as well as for situations when multiple people or applications will be using the same router.

In addition to bandwidth issues, there are other reasons for using multiple modems in a single cellular router. Different types of modems can be used; for instance, one can be on a CDMA/EV-DO network and another on a GSM/UMTS/HSDPA network This provides multiple paths to access the remote application's data and guarantee access from one carrier even when another carrier does not have a cell tower nearby. This extends the footprint of where the application can be deployed, providing improved coverage as well as increased bandwidth. Emergency services, government vehicles, and similar types of mobile telemetry applications often require this type of redundant network connection, since it will still provide data access even in the event of one carrier being unavailable.

Load balancing between connections does not necessarily need to come strictly from multiple cellular connections. A router can also load balance between a cellular connection and a hard-wired connection. The hard-wired connection can come from any type of fixed internet provider (DSL, cable modem, satellite, etc), or it can be a separate mobile IP connection such as a mobile satellite connection, WiMAX connection, or even Wi-Fi. This can aggregate all the available bandwidth for a given application.

Some setups may require a cellular backup connection instead of a "load balancing" connection; a cellular connection may be used as a backup and is only turned on when the router senses the land-line connection is down. This provides an always-on solution that allows seemless connectivity while the landline connection is being repaired. People on these plans normally only pay for the traffic since the connection is only used when the primary connection is unavailable. This also works over two different types of mobile Internet connections; for instance a router can be set to switch over to a satellite connection if there is no cellular tower nearby. This allows for a less-expensive and faster cellular connection when one is available, but the application can still function properly by switching over to a slower or more expensive satellite connection when cellular is not available. This is useful for boats or for vehicle applications that travel into very rural areas that still require a connection even when remote. If the bandwidth of the alternate method is much slower than the cellular network, the application should be set to automatically decrease its required bandwidth as well.

CONCLUSION

While there are definitely some drawbacks to cellular broadband technology today, it is constantly continuing to improve. With new releases and rollouts of faster broadband services from carriers, these services can be used effectively for broadband telemetry data. Furthermore, cellular routers help overcome many of the issues that telemetry system integrators face when using TCP/IP protocols on mobile cellular networks. Multiple cellular connections can be aggregated into one router, and as bandwidths of competing technologies continue to improve, these solutions will also be incorporated into the routers of the future. For now, the cellular technologies described here enable users to understand the bandwidth limits of the cellular networks and the issues they will face in deploying their telemetry application.

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