EMBEDDED IN THIN SLICES

The Internet of Things (Part 2)

Choosing a Wireless Carrier for Your Embedded System

COLUMNS

Bob started this article series by examining a few different ways to connect an embedded system wirelessly to the Internet. This month he covers a few options for selecting a carrier for an embedded device and covers topics such as: OTA technologies, mobile virtual network operators, data plans, and project budgeting.

By Bob Japenga (US)

Several years ago, I was somewhat startled when I saw Dan Hesse, who was then the CEO and president of Sprint, on television talking about how Sprint was positioning itself to serve the machine to machine (M2M) community in the coming years. Sprint was going to be the place to go if you were a M2M developer. As embedded systems designers, it is not very often that we are the target of prime time television advertisements. I suspect Dan was not really targeting us. There are too few of us. He was targeting investors. But the point was made. The personal phone market had saturated in the US and M2M wireless connectivity with the advent of the Internet of Things (IoT) offered an almost unlimited growth potential in the US and worldwide. And the wireless carriers are critical to making that happen.

I began this article series by discussing some of the ways our company has connected our embedded systems wirelessly to the Internet. The current buzz in our industry is the IoT. Because of our lack of experience in satellite M2M, I will not be discussing satellite options. This may be an applicable wireless technology for some of your products, but we must take things in thin slices. This month, I want to talk about one of the critical first steps in designing your embedded IoT system: choosing the wireless carrier and the wireless technology that works best for you.

TERMINOLOGY

Before we start, let's define some terms:

Carrier: Okay, so most of us know about T-Mobile, AT&T, Sprint, Verizon, and maybe even Vodafone. These are wireless carriers.

Wireless or Over-the-Air (OTA) Technology: Here we get into some marketing jargon, but OTA technologies include GSM, LTE, EDGE, and so on. They are marketed as 2G, 3G, and 4G. It does make me wonder what the Fifth-Generation OTA technology will do.

Radio Access Technology (RAT): Okay, I haven't used this term, yet but many confuse the wireless or OTA technology with RAT. Here are the most prevalent RATs: time-division multiple access (TDMA); frequency-division multiple access (FDMA); code-division multiple access (CDMA); and orthogonal frequency division multiple access (OFDMA). All of these RATs are separate ways to put multiple calls on the smallest available radio frequency spectrum. FDMA uses different frequency

bands for each call. TDMA provides different time slots to the different calls. CDMA uses statistical spread-spectrum techniques to put each call in a particular frequency. OFDMA is not easily defined in a single sentence. Suffice it to say, it assigns subsets of subcarriers to each call. Remember that the goal is to put as much data through the smallest frequency band.

GEE-WIZ

If you listen to the marketing pitch for wireless service providers, you hear them talking about 3G and 4G. Even after several years and several successful deployments of wireless systems, my head sometimes spins when all of the various wireless technologies are described. **Table 1** is my attempt at a concise table for OTA technologies.

The classification is important to us as developers because we need to choose a carrier and the OTA technology (sometimes called "air interface") that fits our product specifications including recurring costs, nonrecurring costs, life of the product, and target location. Let me see if I can tease out how this can get complicated real fast.

TARGET LOCATION

Where is your design going to be used? If it is only in the US, then you have a wide number of options. Does the product move around? If you want your target to be used anywhere in the world, then your options just reduced. You can: pick an OTA technology that is available worldwide (UMTS); design in a module that supports multiple OTA technologies; or design your system to support separate modules for each of the OTA technologies that you want to support.

Fortunately, most of the module manufacturers create pin-for-pin compatible parts which are, for the most part, software compatible. If you take this option, you must certify the two different OTA technologies. Modules that support multiple OTA technologies are much more expensive and thus increase your recurring costs. But you only certify once. Certification costs are very large and certifying two different OTA technology modules can be time consuming and expensive (non-recurring costs). Also, most modules are only certified for three years so that nonrecurring cost becomes a recurring cost before you know it.

We like to design it once, certify it and then ship it for 10 years. This time limitation on certification is a serious problem for all embedded system designers like us. We hope this will change.

PRODUCT LIFE

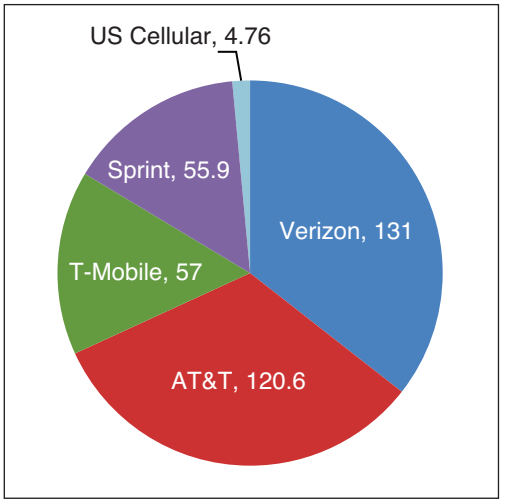
This is where the expected life of the product comes into play. M2M is very different from cell phone users who only keep their phones for one to two years. Two of our IoT devices have less than a five-year life because of their unique medical usage. For such units, choosing an OTA technology is not constrained. But one of our IoT devices has a targeted 20-year life and that dramatically complicates your decision.

Here is the problem. In 2012, AT&T announced that they were sun setting their 2G network starting January 1, 2017. When we create a design with a long life, we need to choose the technology with the highest probability of surviving for that length of time. But that is not trivial. Think of the developers of OnStar, which was based on an early cell technology. Even though the US federal government forced the carriers to extend the life of that technology to 2008, the carriers eventually shut down the system

Table 1
Bob - please write a short caption

OTA Technology	OTA spelled out	Marketing Classification	RAT	US Carriers
GSM	Global System for Mobile Communications	2G	TDMA	AT&T,T-Mobile
GSM GPRS	GSM General Packet Radio Service	2G+ (2.5G)	TDMA	AT&T,T-Mobile
GSM EDGE	Enhanced Data rate for GSM evolution	2G+ (2.75G)	TDMA	AT&T,T-Mobile
UMTS	Universal Mobile Telecommunication System	3G	W-CDMA	AT&T,T-Mobile
1xRTT	Radio Transmission Technology	3G	CDMA (CDMA2000)	Verizon, Sprint, US Cellular
EV-DO	Evolution-data optimized	3G	CDMA	Verizon, Sprint, US Cellular
LTE	Long Term Evolution	4G	OFDMA	Verizon, Sprint, US Cellular, T-Mobile
LTE-Advanced	Long Term Evolution Advanced	4G	OFDMA	AT&T

Figure 1
Millions of subscribers



used on millions of cars. If you choose a 3G OTA technology today, will it be available in 15 years? Only time will tell. I think that the M2M explosion will provide the revenue stream for the carriers to maintain these long after the phone users have stopped using 3G. But remember, I am an engineer not a financial guy.

CAN YOU HEAR ME NOW?

Once you have some idea as to the OTA technologies that are acceptable to your price point and location, how do you choose a carrier? First, in the US, you need to understand the three types of carriers that you can go with.

Cell Providers: The first type is those providers that actually build cell towers and receive and transmit RF to the M2M device. Of course, in the US, the big five are AT&T, Sprint, T-Mobile, Verizon, and U.S. Cellular. **Figure 1** shows their market shares by subscribers in the US. There are a host of very small providers with very local coverage that may work fine for one of your designs if your target is local, but we have no experience with them.

Mobile Virtual Network Operator (MVNO): We live in a day of many "virtuals." So it should not surprise you that there are scores of MVNOs. These are companies that lease wireless data services from the big five. Each is dependent upon the wireless carriers for everything. The advantage to you would only mean allowing you to negotiate with a much smaller partner for your data plan (more on this later). This is less of an issue now since the major players want your M2M business.

Hybrid Carriers: There is one carrier, Aeris, which is somewhat in a class by itself. In the US, it has its own CDMA network (3G 1xRTT and EV-DO), which is specifically designed for M2M applications. In the rest of the world, they are an MVNO leasing a GSM network (2G and 3G) from the local provider. This is a giant advantage for companies that don't want to negotiate data plans with all of the carriers worldwide. Each country can have its own separate wireless carrier. They have done the leg work for you. Of course the data plan costs will reflect this extra work, but we have found that for most small companies that we work with, the effort of negotiating a data plan with each of the GSM cell providers worldwide and obtaining the necessary certification on each network is a significant block to worldwide deployment. We have found that Aeris makes that simpler and the cost penalty is not that significant for our products.

FOLLOW THE MONEY

You don't need a Deep Throat to tell you that you need to follow the money when you consider a carrier. The carriers are getting much more competitive with their data plans for M2Ms than when we first started. Initially, we could not get companies like Sprint to even talk with us. On early M2M designs, we could not even get them to return our calls. Now, things are very different. The carriers know about our concerns. Data plans for M2M devices can be very, very cheap if your data is very, very small. All of the carriers we have worked with support data usage pooling across your fleet. Here is what that means for you. Let's say that you only utilize 600 KB of data each month and you have a 1 MB-per-month data plan. But every six months you update your software OTA. The software update takes 800 KB of data. You could update half your fleet one month and the other half the other month and stay within your 1 MB-per-month data plan.

Another area that used to be a pain has to do with device deployment and data plans. Before the carriers got on our side, we had unnecessary data plan costs when a device had to have its data plan turned on during manufacturing and then it had to sit unused in a warehouse for three months. We would pay several monthly bills even though the unit was sitting in a warehouse. Now the carriers are accommodating. Each has its own way of doing it, but most provide something that is workable with a manufacturing process that needs to test the cell operation before it ships. But you do need to find out what they offer so you can tailor your manufacturing process to their data plan.

CHIPS AND SALSA?

In choosing your carrier and OTA wireless technology, you need to factor into your cost budget the antenna and the module itself. We've found that the modules for 2G and 3G typically are significantly cheaper than those

ABOUT THE AUTHOR

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Option	Advantages	Disadvantages
Multi-carrier module	• One part to stock • Single Test procedure • Single certification	• Higher recurring costs • Slightly higher certification costs • Multiple carriers to negotiate with
Worldwide OTA technology (UMTS) module	• One part to stock • Single Test procedure • Single certification	• Higher data plan OR negotiate with many worldwide carriers • Not necessarily the best coverage in the US
Separate pin and software compatible module	• Negotiate the lowest recurring data plan cost • Can cost based on the market • Prepares you for future module changes	• Multiple SKU's • Multiple parts to stock • Multiple test procedures

Table 2
Bob - please write a short caption

for 4G and LTE. For LTE, you are required to have two antennas. That doubles your recurring cost right there. (By the way, I think that will get relaxed in the near future. For most M2M, we don't need that second antenna. It is used to increase throughput.) Your certification costs can also be significantly higher for the 4G technology parts. One quote we got was 3.5 times the cost of certifying a 1xRTT 3G solution. When you buy a module, you need to pick which carrier you want it to work on. For example, we buy Sierra Wireless modules for the AT&T network. We buy u-blox modules for the Verizon network. We also buy u-blox modules for the Aeris network.

JOIN THE REVOLUTION

Designing a device that can join the IoT revolution is not for the faint of heart. If you are new to it, there is a lot to learn in a very short period of time. And of course the sales people assume that you know all of this alphabet soup that is involved in taking the first steps in selecting an OTA technology and a carrier. As always, we have taken it in thin slices. And so can you. Next time, we will look at yet another factor in being part of the IoT revolution. Of course, only in thin slices.