One-on-One with Dr. Chris Diorio

Dr. Chris Diorio, one of the chief architects of the EPCglobal™ Gen 2 specification, has, in recent months, turned his attention to the general market rollout of the new standard. As co-chair of the Hardware Action Group that developed the spec, and project co-editor of the corresponding spec (18000-6 Type C) within ISO, Dr. Diorio is uniquely positioned to discuss the issues and challenges that users will face as they begin to deploy the new technology in the field. In the interview that follows, Diorio shares candid responses to some "tough questions" about Gen 2's transition from specification to practice.

What part, if any, of existing Gen 1 systems will users be able to retain when they transition to Gen 2?

Users will be able to use existing readers that have been upgraded with Gen 2 firmware. They probably won't, however, be able to use the dense-reader capability; in most, if not all cases, support for dense-reader mode will require hardware changes. Many of the reader vendors, though, are planning hardware upgrades to support dense-reader mode, so there will be a migration path.

Users will also be able to retain a good deal of their knowledge base—what works, what doesn't work, how to apply tags, how to read tags, how to use the middleware that filters tag data. But it's important to note that Gen 2 has considerably more functionality than Gen 1, which is fairly simple in comparison. The mindset behind Gen 1 was as a replacement for barcodes. In Gen 1 systems, you can read a tag just like you read a Gen 1 tag. In Gen 2, though, you also have bidirectional communication; not only do you read a tag, but you can also turn around and lock it or kill it or write new data to it. And that increased level of tag-reader communication will require a big change in the reader and network software model.

How will Gen 1 and Gen 2 systems co-exist during what might be a lengthy and potentially bumpy transition period?

First of all, I don't necessarily see it as a very lengthy transition period. The fact is, in many respects, Gen 1 systems were used as pilots for end users to obtain practical experience with RFID; most users were waiting on the availability of Gen 2 for their full-scale deployments. And now that Gen 2 products are available, the transition will be rapid. One exception might be airports, several of which are using Class 0 and Class 0+ systems in their bag tagging operations—and they may continue to use them, even as Gen 2 matures. In a closed environment such as an airport, those protocols are apparently adequate. But for the most part, the market is moving rapidly to Gen 2; tags and readers are available now, with new vendors coming on-line quickly. Most of the readers can now read Class 1, Class 0, *and* Gen 2. Some of them can read Class 1, Class 2, Gen 2, ISO 18000-6 A, and ISO 18000-6 B. You've got readers now that can read everything. There will be a short-term performance penalty associated with multi-protocol readers, though, because if there are Class 0, Class 1, and Gen 2 tags in the same tag population, readers will have to cycle through the different protocols in order to read them all; they can't just talk to all tags at once. But that will go away once everybody adopts on Gen 2 exclusively, which may happen perhaps as early as first quarter 2006.

With talk of a "Gen 3" already appearing in some press—even before the general deployment of Gen 2—will this technology ever become stable enough to commit to?

The Gen 2 specification, and products built to it, will be applied, just as intended, to a wide range of applications and environments, including the tracking of products in the supply chain. I know of no efforts to supplant Gen2 with a Gen 3, or anything else. In fact, I've never heard of Gen 3, either in EPCglobal™ or ISO. There is an option under EPCglobal™ to produce a Class-2, Gen 2 spec, but the plan for Class-2 is to build upon the existing Gen 2 base—Class-2 Gen 2 will not replace Class-1 Gen 2. It's there to provide a path for additional tag features like temperature

sensing, additional security and encryption features, read locking, and other capabilities, but it will all be built on top of the Gen 2 foundation.

The next objective in the development plan for RFID is an item-level tagging specification, targeted for consumer products and pharmaceuticals. And that will actually be a fairly difficult task. The requirements for item-level tagging present different issues than those of pallet and carton tagging, not to mention another layer of requirements relating to privacy, security, encryption, etc. There will also be the requirement for tagging metal objects, liquid objects, bottles of shampoo, and cans of cola. It's a pretty tough set of requirements that go above and beyond those addressed by Gen 2. So at some point, an item-level tagging spec will emerge, but it will take time to develop, and may, in fact, be built upon Gen 2 also. And long before the spec is written, the requirements will have to be defined. The bottom line is Gen 2 isn't going away any time soon. As an industry, we foresee plans for massive Gen 2 deployments.

In terms of cost, will Gen 2 tags ever be able to compete with Gen 1 offerings?

Undoubtedly so; Gen 2 volumes will *greatly* exceed those of Gen 1 in the very near future. And as we all know, in this industry, volume drives costs down. With multiple vendors entering the market—and more of them coming online—competitive pressures will also drive costs down. So both large volumes and competitive pressures will conspire together to make Gen 2 products very cost-competitive. In fact, it's anticipated that Gen 2 will be the most cost-competitive segment of the RFID industry. It was designed to be so.

Specs are one thing, but how will Gen 2 play out in the real world? Will it cope any better than Gen 1 with the many external factors like noisy RF environments?

We've already seen significant benefits of Gen 2 in several recent pilot demonstrations. But to really drive the point home, we do a demo using two of our Speedway™ readers operating simultaneously in dense-reader mode. The readers are pointing directly at each other, with the two antennas about 15 feet apart, and transmitting at maximum power. The tags are right in the middle of the two antennas. As you move the tags closer to one reader, it reads all the tags, and as you move the tags closer to the other reader, *it* reads all the tags. The bottom line is, we're getting reliable reads with antennas pointing right at each other—with both readers transmitting at high power, without any time synchronization, and without using listen-before-talk. In Gen 1 systems, in a multi-reader environment, one reader has to shut off so the other one can operate; it's a time-division multiplexing scheme. Gen 2 uses a *frequency*-division multiplexing scheme, which means both readers can talk simultaneously. And even in this configuration, we've got Gen 2 operating in the worst possible mode and beating Gen 1 in throughput with not only much faster read rates, but no ghost reads or any other read errors. That's a significant advantage. That's the kind of acid test that proves Gen 2's superiority.

We've solved one major problem by developing a single, worldwide, high-performance standard. People are now solving the next set of problems, which is to introduce high-quality Gen 2 silicon and reader solutions. Impinj has already demonstrated both, and other vendors are coming out with their own solutions. But a reader and a chip do not make a complete solution. A solution comes about by a knowledge base, from people deploying systems in the field, and working through the bugs, building the right antennas, writing software into the readers, learning what works, and what doesn't work. And that's the challenge ahead for all of us going forward, for both the solution providers and the end users. As with any new technology, it's going to take some time.

With readers gaining certification while meeting only a subset of the Gen 2 spec, how robust and manageable will Gen 2 systems really be?

This question gets at a preconceived but incorrect notion about the Gen 2 spec. A Gen 2 reader must implement *all* the mandatory Gen 2 commands. It must be able to talk to *any* Gen 2 tag in the field. That Gen 2 reader need not have the flexibility to talk to tags at the full range of data rates, and it may not offer the dense-reader mode, but it is still a Gen 2-compliant reader.

Consider the analogy of a car. There are big cars, small cars, barely capable cars, cars that do everything you want. But they're all cars, they all drive on the road, and if they're sold in the US, they're capable of being driven on the freeway. It's the same with Gen 2 readers. Every reader must be capable of talking to all Gen 2 tags. Now, some readers will be faster, some readers will work better in dense-reader mode, some readers will be more robust, some will have better noise immunity. So while it's mandatory that they all be capable of talking to Gen 2 tags, there will be a range of performance differences. If you're an end user, you'd better know that you're getting what you need. If you have a small shop out in the middle or nowhere, you can get away with almost any Gen 2 reader. If you have a distribution center and plan to deploy 100 readers, you probably need the best dense-environment-capable Gen 2 reader you can find. With cars you do your homework before you buy, and probably do a test drive also; you should do the same with readers.

It seems inevitable that tag makers will field lower cost, reduced functionality tags for targeted applications that might require *some* level of Gen 2 compatibility, but not necessarily total compliance. How will this muddy the waters in the proliferation of Gen 2?

First and foremost, EPCglobal will be certifying that Gen 2 tags implement *all* parts of the Gen 2 spec. As we've just discussed, readers have to implement all the Gen 2 commands, but they don't have to implement all of the Gen 2 modes (dense-reader and maximum throughput modes). Unlike a reader, a tag *must* implement all parts of the Gen 2 spec—and that includes dense-reader mode, backscatter at the highest data rates—everything. With the exception of a couple of commands that allow some extended functionality but are not required to implement the protocol, the tag has no option—it has to do it all. And EPCglobal will be testing tags to ensure that they indeed “do it all.”

To get EPCglobal certification, tags will have to demonstrate that they meet the entire Gen 2 spec. As such, it's not possible to come out with a "reduced functionality" Gen 2 tag and receive EPCglobal certification. So end users should be looking for EPCglobal certification as a stamp of approval; they shouldn't accept anything less. And the certification plan is very rigorous; it will weed out those tags that are not truly Gen 2-compliant. That said, different tags will exhibit different performance characteristics. Just like the readers, some tags will have better noise immunity, some will have better interference rejection, some will have faster write rates, or greater range. Some will have less frequency sensitivity and will operate well in both North America and Europe. Some tags will have high frequency sensitivity and be able to operate only over a narrow frequency range. Some will implement *Access* and *Kill* passwords, others will not. Depending on the environment, many of these things may prove to be price as well as performance differentiators. But again, meeting all the mandatory aspects of the Gen 2 spec is required.

The bottom line is that users will have to be careful about choosing tags that meet their particular set of requirements. They may have to do some benchmarking, run some comparison pilots. And if they do, they'll see that two tags from two different vendors will exhibit very different read and write ranges, because they will have different levels of power consumption. It's also likely that they'll have other performance differences. For example, one may have been designed with too low a clock frequency, which will degrade the tag's ability to differentiate between data 1s and data 0s, in which case, the tag may drop commands in noisy environments. The better-designed tag may use a higher clock frequency and work better in these same environments.

The orientation sensitivity of the tag should also be taken into account. If you were to point a tag directly at the antenna, it will work great. But if the tag's azimuth angle to the reader rotates 90 degrees, or if there's a change in elevation relative to the reader, you'll want to know how those conditions will impact performance. That's a nice world where the tag is always pointed at the antenna, but that's not always the case.

So it comes down to two primary issues: EPCglobal certification and performance. All end users should buy certified tags. But beyond that, the more educated our customers are, the better off we'll be as an industry. We understand that users will demand RFID solutions that work, and the solution providers are going to have to deliver. But if end users base decisions on price alone, then getting to that working system may be greatly jeopardized. Of course, working systems have to meet cost targets, but working right is fundamental. Meeting cost targets and not working is not an option.

Gen 2 tags are essentially broadband receivers with little ability to discriminate RF sources. Is dense-reader mode performance alone sufficient to yield a reliable system in noisy environments?

Dense-reader mode works very well, and it's our belief that the dense-reader mode will be sufficient to field working systems. If we had had the option to build a narrowband tag, we would have jumped on it, but there is simply no practical way to do that. So we will always have broadband tags, and dense-reader mode is the solution we settled on for the Gen 2 spec. We believe it will work sufficiently well. We've already demonstrated its robustness—even under the worst-case RF conditions. Beyond dense-reader mode, tags can, but are not required to, implement noise filtering. Again, some tags will have it, and some not. Of those with noise filtering, some will work better than others. Dense-reader mode with high-quality noise-filtering tags should work far, far better in the field than any Gen 1 systems do today.

Given Europe's limited bandwidth, how advantageous will Gen 2's dense-reader mode be there?

Europe is a more difficult environment, because the bandwidth is very limited—2 MHz versus 26 MHz in North America. And the allocated European channels are narrower: 200 KHz versus a maximum of 500 KHz for North America. In addition, Europe's "listen before talk" is a stringent requirement—actually it is a bit too stringent, and probably should be revisited. Notwithstanding, Gen 2 is essential for European RFID deployment. For example, Gen 1 protocols have no reader transmit masks; by contrast, the Gen 2 dense-reader transmit mask is actually tighter and more difficult to meet than the European ETSI requirements. In other words, you can meet the ETSI requirements and still fail the dense-reader transmit mask. Why? Well, the analysis that went into the Gen 2 spec development showed that we needed such a tight mask. And the result is that dense-reader mode in Europe can and will work *very* well.

Will writing Gen 2 tags be any easier, faster, or more reliable than writing Gen 1 tags?

Theoretically, Gen 2 shouldn't necessarily be any faster, because the speed at which you can write is a function primarily of the memory technology, not the protocol. In practice, however, the vendors that are delivering Gen 2 tags have memory technology that is faster and more capable than that deployed in Gen 1 tags, so users will see a big difference in Gen 2 products relative to Gen 1.

I should add that there's nothing in Gen 2 that puts a hard specification on write speed (with the exception of a 20 ms tag write response window). So again, vendors should purchase tags that provide the write speed that they need. That said, the Gen 2 protocol does require some mechanisms to ensure reliable memory writing. For example, when a reader writes a tag, the tag has to reply with a confirmation that it's done; it backscatters a DONE signal that in effect says, "I have written the memory, and I have done it successfully." That was not used generally in Gen 1 systems. In the case of our Monza™ tags, we go a step further and have the memory check itself as it's being written, which makes writing even more reliable; they don't say they're DONE until they really are done.

I'll also add that writing in Gen 2 versus Gen 1 is more secure. Gen 2 has a way to mask writes, via cover coding, which offers significantly improved protection from potential snoopers—a feature that was not available in Gen 1 systems.

Shouldn't users wait until things settle down, and there's more of a proven infrastructure built around Gen 2 before jumping in? What advantage is there to getting involved at such an early stage?

The time to start is right now. We have a proven specification that is also on the fast track to ISO approval. We have multiple suppliers delivering Gen 2 product now—we've been demonstrating and sampling Gen 2 tags and readers for months now. The ramp-up is actually going to be quick. It's important to realize that it will take time for any user to understand how to deploy RFID in their environment. There will be a learning curve. You can wait until the systems are fully developed before jumping on the bandwagon, or you can get on it now and ramp-up early. But the bottom line is it's a pretty steep learning curve, and in the time it's going to take for end users to get ramped-up on that learning curve, there will be plenty of working Gen 2 systems out in the field. So the time is now. If you started today, the solution will be available before you've finished your ramp-up.