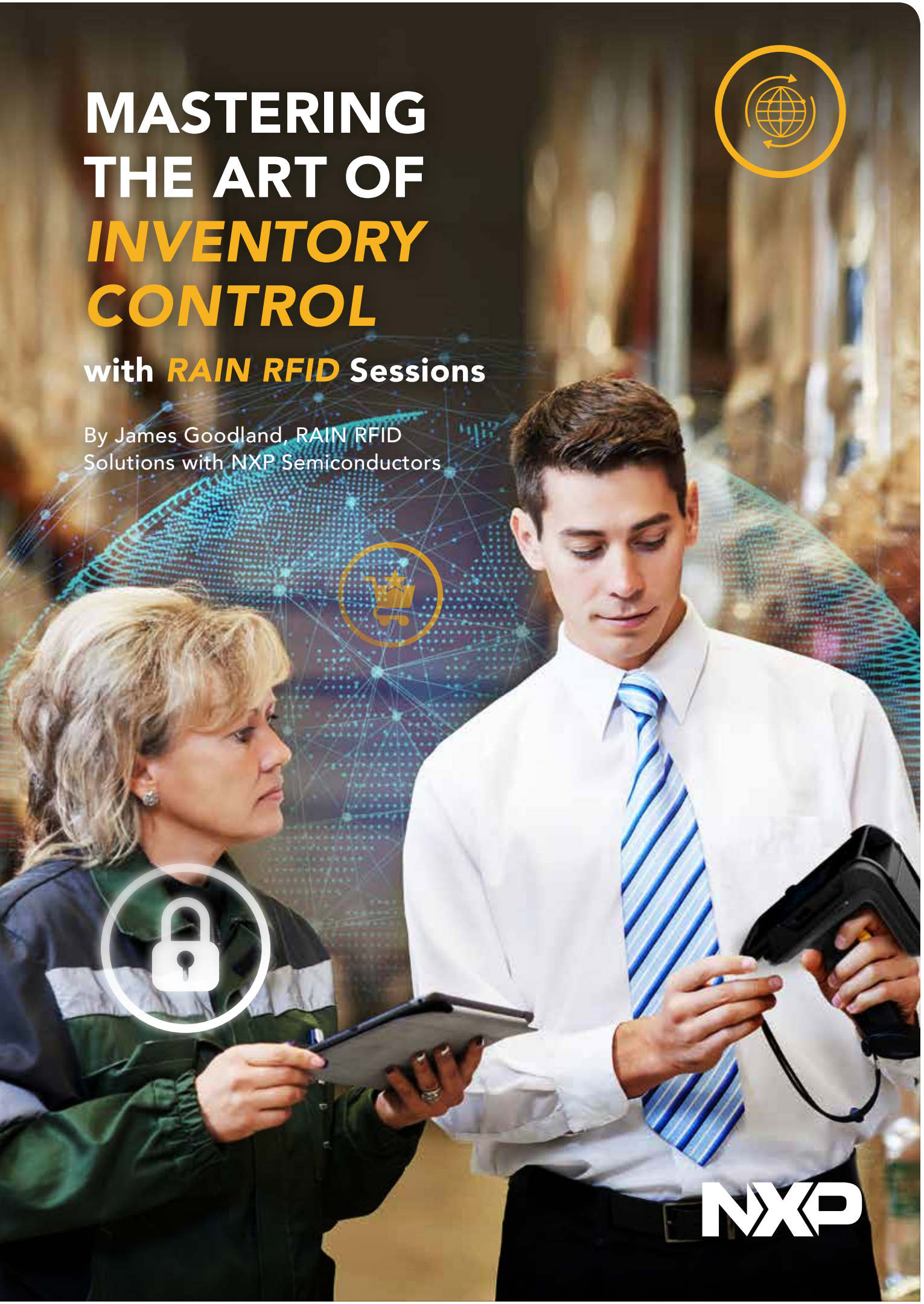
MASTERING
THE ART OF
INVENTORY
CONTROL
with RAIN RFID Sessions
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A special mechanism in the ***RAIN RFID*** standard, called a session, ***increases accuracy*** when reading large numbers of tags and lets multiple readers operate in the same area without interference or miscounts. This paper looks at the ***four session types*** defined for RAIN RFID, and discusses their considerations for use in the field.

When it comes to inventory control, the passive ***UHF technology*** known as ***RAIN RFID*** makes it easier to know exactly what's where and when to replenish. Whether it's stocking shelves in a retail outlet, monitoring medications in a healthcare facility, keeping track of tools on the factory floor, or receiving goods at a warehouse, ***RAIN RFID*** offers a unique combination of speed, accuracy, and standardization. The tags are inexpensive to produce, can be read in large batches – up to 1,000 tags per second – and are defined by international standards that simplify deployment on a global basis. In fact, adoption of ***RAIN RFID*** is so widespread that it is now one of the fastest growing segments of the ***RFID*** market overall.

But there's a catch, because not all RAIN RFID tags are created equal. Some are more sensitive to RF signals, and therefore more responsive and easier to read, than others. There are several reasons for this, ranging from inherent chip sensitivity, and the suitability of the antenna design for its intended use, to the level of quality in the tag's manufacture. The operating environment can have an effect, too, depending on the orientation of the tag to the reader's antenna or the material next to or surrounding the tag. Think stacks of folded denim or piles of heavy tires; in general, the denser the material, the more the signal from the RAIN RFID reader changes as it passes through, and the harder it is for a given tag to harvest the power it needs to be read.

The variation in tag sensitivity means that there are times, especially when large numbers of tags need to be read at once, when inventory counts are likely to be less precise. That's because the tags in the grouping that are more sensitive to RF signals can consume the available power coming from the reader and respond continuously, while those that are less sensitive to RF signals or further away from the reader are unable to power up and report. So how do you ensure that stronger, more responsive tags don't overshadow weaker ones, and skew inventory counts? By telling each tag to be quiet after it's been read.

USING SESSIONS TO CONTROL CROWDS

A special "session" mechanism in EPC Gen2, the standard used to define RAIN RFID, can push a tag into a dormant state once it has responded with its EPC number, so the ***tag stops drawing power and stops responding.*** That way, others in the group can have their turn.

Using sessions to trigger a short period of dormancy after the EPC number has been read gives weaker, less sensitive tags a chance to speak and be heard, so the entire batch of tags can be read and inventoried more accurately. Using RAIN RFID sessions also lets multiple readers operate in the same area without interfering with one another or interrupting counts.

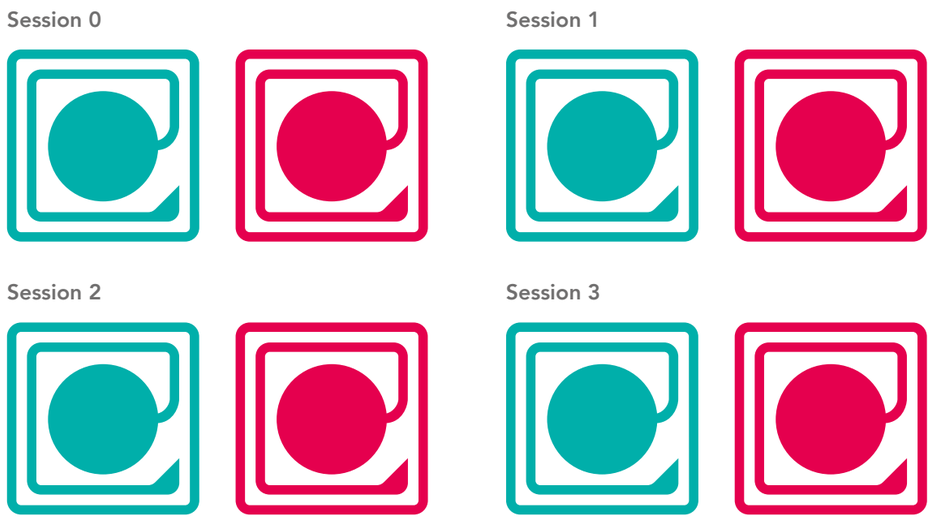
The Gen2 standard defines four sessions for RAIN RFID. The reader specifies which session it's using each time it takes inventory. Designers can use these sessions to optimize read performance based on the expected operating environment and how tags are going to be read.

Before we look at the details of each session type, though, it's important to explain two other Gen2 concepts, the flag state and target search mode.

THE A AND B FLAG STATES

The Gen2 standard specifies two flag states for each session, A and B. In the active A state, the tag is awake and readable. In the B state the tag is usually dormant and will not respond to the reader. As shown in Figure 1, each of the four sessions is associated with an A and B flag state.

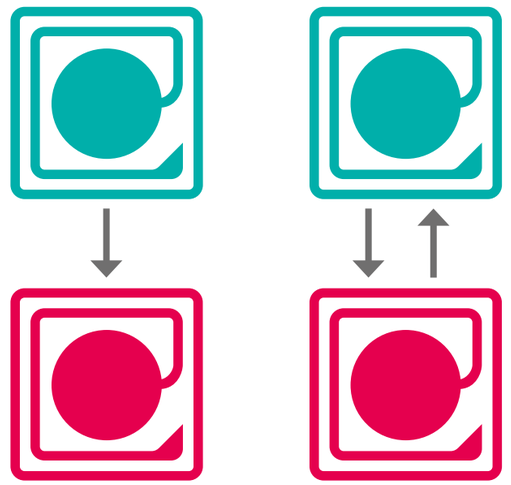
Figure 1. Each session is associated with A and B flag



SINGLE AND DUAL TARGET SEARCH MODES

There are two search modes in the Gen2 standard, Single Target and Dual Target.

Figure 2. Single and Dual Target Search Modesstates



In Single Target mode, the reader only searches for and reads tags in the active A state. When the reader finds a tag in the A state, it reads the tag then places it in the dormant B state. The approach is essentially "read once then move on," and is a good option for high-population, dynamic environments, because it reduces the number of reads per tag and makes it more likely that every tag in a population is read at least once.

In Dual Target mode, the reader searches for tags in either the A or the B state. When the reader finds a tag in the A state, it reads the tag and moves it to the B state. When it finds a tag in the B state, it switches the state to A, reads the tag, and then switches it back to B. The result is continuous reading of all tags for as long as power is present. This is useful with static configurations, when it's important to know if a tag is no longer present.

THE FOUR SESSION TYPES

Having defined tag states and search modes, we can turn our attention to sessions.

As mentioned above, there are four types of sessions available with RAIN RFID. The sessions are independent of one another and their effects can persist across different inventory rounds. That way, multiple readers can take inventory at the same time, without interfering with one another and without interrupting an in-process count. The tag switches between sessions depending on which reader is sending the RF field. Table 1 defines the four session types.

Table 1. Gen2 Session Types

Session Type	What Happens
0	Tags reset to the A state upon power up.
1	Once read, tags move to the B state and remain there for between 0.5 and 5 seconds before returning to the A state.
2 and 3	Tags persist in the B state for at least 2 seconds to a maximum time that is tag specific.

Here's a closer look at each.

Session 0 (s0)

The tag always powers up in the A state. Following an inventory round, the tag moves into B state and remains there until a new inventory round begins. To create a state of continuous reading,

Session 0 can be used in combination Dual Target search mode. In this case, once all tags have been read and placed in their B state, the reader will then target all tags in the B state, flip them back to the A state, and read them once more before returning them to the B state. This cycle will continue for as long as the tags are powered. As shown in Figure 3, reading continues for as long as power is supplied. The only break is when the reader stops transmitting. Because there are no breaks in the read cycle while power is applied, we can refer to this as "continuous fast reading."

Figure 3. Continuous fast reading: Session 0 and Dual Target search mode

Session 0 is a good choice for smaller populations where the tags need to be identified multiple times. This can, however, lead to large volumes of data and can reduce the number of unique tags recorded.

Session 1 (s1)

The tag powers up in the A state and, once it has reported its EPC number, enters B state. The tag remains in this state for between 0.5 and 5 seconds, according to the specification. Once the "rest" period is over, the tag reverts to the A state and is available for future Session 1 inventory rounds. Using Session 1 in combination with Single Target search mode, the same tag is read repeatedly with an approximate time between reads of 0.5 to 5 seconds. The amount of time in the B state, known as persistence, is usually on the shorter end of the time range and will expire regardless of whether the chip is receiving power or not. Figure 4 illustrates the behaviour of Session 1 with Single Target search mode. Tags are read continually for as long as power is applied, but because there is a built-in delay between tag reads, we could refer to this as "continuous slow reading."

Figure 4. Continuous slow reading: Session 1 and Single Target search mode

Session 1 is well suited for use with larger tag populations where the tag needs to be read repeatedly but with a delay between reads. This makes it a good choice for smart cabinets and, potentially, retail stock inventory.

Sessions 2 and 3 (s2, s3)

These two sessions operate in the same way but are independent of one another. Once the tag has taken part in the inventory round and reported its EPC number, the state changes from A to B. The tag stays in the "rest" state, unavailable to a reader using Single Target search mode, for a period of at least 2 seconds after leaving the RF powered field. That is, the tag remains in the B state for as long as the RF field is present and then, once the RF field is removed, enters a period of persistence, which lasts for at least 2 seconds, before returning to the A state. If, at any point during the persistence time-out, the tag detects an RF field from any reader (regardless of which session is being used), the process begins again.

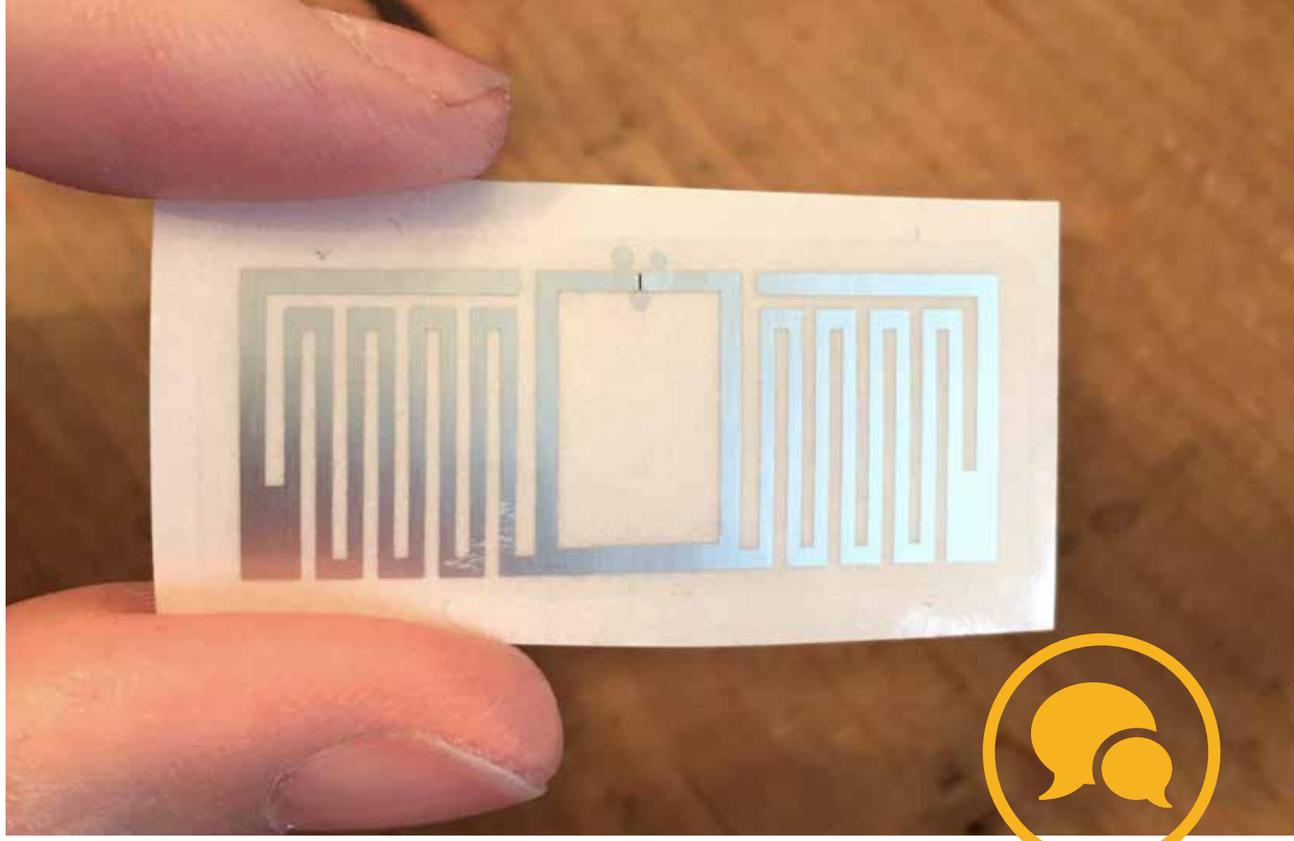
Figure 5 shows how this works.

Figure 5. Read once: Session 2 or 3 with Single Target search mode

Sessions 2 and 3 support "read once" functionality, which is great for large populations where the tags don't need to be read again immediately after leaving the antenna energy. But care must be taken to ensure tags aren't gaining energy erroneously, because erroneous charging can prevent future reads from taking place (more about this later).

It's also important to note that the persistence time-out – that is, the amount of time the tag spends in the dormant B state during Session 2 or 3 – has a minimum length of 2 seconds, but the maximum length can vary. The Gen2 standard gives manufacturers a certain amount of flexibility in how they define the persistence period, and differences in manufacturing processes can produce different persistence times, too. For example, tags using NXP's UCODE 8 family of RAIN RFID ICs have a persistence period of approximately 11 seconds, but tags from other manufacturers may have stay asleep for a longer or shorter period.

As one might imagine, this can have a significant impact on the application. For example, if the tags in Session 2 have an extended persistence period, and remain asleep the next time they need to be read, the inventory count will be missing some items.



Having to wait for the persistence period to be done before doing the next read can add delays, and can cause backups at building exits or transition doors within a building. For these reasons, it's useful to understand the approximate persistence time of the tags involved when designing a solution, especially when dealing with mixed-tag populations.

As a review, Table 2 lists the persistence times for each Gen2 session.

Table 2. Gen2 Session Persistence: Length of Sleep Time

	Session 0	Session 1	Session 2	Session 3
Tag energized	Forever	0.5 to 5 seconds	Forever	Forever
Tag not energized	None	0.5 to 5 seconds	At least 2 seconds	At least 2 seconds

PUTTING IT ALL TOGETHER: TWO REAL-WORLD EXAMPLES

The ability to mix and match sessions and search modes gives solution designers more ways to support today's complex use cases. There are, however, a few combinations that, depending on the setup, can lead to unwanted consequences. For example, designers can unintentionally create dead zones, where tags get stuck in a cycle of unreadability, or can trigger data overload, where tags are read so frequently that the information becomes difficult to manage. A look at two examples – a retail store and a smart supply cabinet – can help designers avoid trouble.

Retail Outlet

Many retailers now use handheld RAIN RFID terminals for front-of-house inventory and fixed portals or overhead systems for monitoring the passage of items in and out of storage, through doorways, or, in the case of clothing, in and out of dressing rooms. Different sessions are typically used for different RFID equipment. Session 2, for example, might be used for handheld terminals and Session 3 for gate readers. Sessions 2 and 3 are good options in these cases, because they let multiple devices read the same tags at roughly the same time, to generate independent inventories, and because their "read once" behaviour lets quieter, less sensitive tags have a chance to reply, for a more accurate tally.

But, as mentioned earlier, mixing Sessions 2 and 3 can be tricky, especially if the environment includes "always on" readers. In many operating environments, fixed RFID infrastructure is often set as always on, meaning that, within the bounds of local regulations, the reader is always transmitting a signal. This presence of a constant RF field can extend the persistence timeout indefinitely and cause the "erroneous energy" situation mentioned above. If tags have taken part in an inventory round in Sessions 2 or 3, they will not be available for reading if they are still receiving power from the reader (regardless of the sessions used) or within the session 2/3 time out. There needs to be a break in the RF field, of at least 2 seconds, before a tag can end its persistence period, return to its A state, and participate in another inventory session. Note that two seconds is the minimum, there is often a much longer delay than this.

For example, consider the clothing store shown in the images. There is an "always on" reader mounted on the transition door that connects the back of the store to the front. The "always on" reader identified tagged items, using Session 2, as they pass from the back of house onto the sales floor. Items on the sales floor are then merchandized and inventoried with a handheld reader using Session 3. If there is a clothing rail located too near the door-mounted "always on" reader, the tags on that rail may stay sleep indefinitely following being read for the first time with the handheld. This happens because even though the handheld reader is trying to talk to tags using Session 3, the 'receiving power flag' is still checked and so both the Session 2 and 3 flags will not return to their 'A' state and cannot therefore be inventoried for a second time. Ultimately, this can lead to an inventory inaccuracy that is hard to detect within the solution.

Clothing store

Items Read by "Always On" Fixed Reader

Tagged items move through transition door.

Items recorded by the fixed reader in session 2

Session 2 flag goes to B state.

Tags close to the transition door still have power. They cannot be read in Session 2 again until power is removed and Session 2 persistence times out (2+ seconds).

First Time Items are Read by Handheld Reader

Items recorded by handheld reader in session 3.

Session 3 flag goes to B state.

Tags have not yet been inventoried in session 3, so there is no conflict.

Once inventory is complete, the handheld is put away until the next inventory is taken.

Next Time Items are Ready by Handheld Reader

Later, the handheld is used again for inventory, using Session 3.

Some Session 3 flags are still in the B state, because they are receiving power from the “always on” reader using Session 2.

Only tags that have been out of any RFID reader power for more than 2 seconds will be in the A state and can be inventoried

Smart Supply Cabinet

To keep track of high-value assets, such as medications, expensive components, or materials used on a factory floor, items can be stored in a “smart” supply cabinet equipped with RAIN RFID equipment that accounts for cabinet contents. For example, an automotive plant might place RFID-enabled tools in a smart supply cabinet. When tools are in their designated positions, the cabinet’s onboard reader will identify the tool as present. In this case, continuous reading, in Session 0 or Session 1, is called for. The key is to decide how fast the read rate needs to be. With Session 0 and Dual Target search mode, the reader will read tags continuously. Absence can then be detected by the control software. Note, however, that the speed with which RAIN RFID operates can be a drawback in this situation. The reader can read up to 1,000 tags per second, and can generate so much data that the system becomes overwhelmed.

A better option is likely to be Session 1 with Single Target search mode. With this combination, the reader will read the tag and then place the tag in a sleep state that lasts for between 0.5 and 5 seconds. Even this small amount of latency can make the data volume more manageable, while meeting the application requirements.

CONCLUSION

The sessions and search modes associated with ***RAIN RFID*** make it easier for solution designers to specify which tags will be involved in an inventory count, when they will be queried by the reader, and how they will respond to the reader. Sessions also make it possible to have more than one reader doing inventory at a time.

Today's RAIN RFID applications often include a complex mix of portal gateways, overhead systems, and handheld reader. Having an understanding of how sessions and search modes interact lets designers ensure that all the hardware and software components involved in these environments work together effectively with the shared pool of tagged items.

To learn more about RAIN RFID and how it can enhance inventory control, visit ***www.nxp.com.***