Deterministic or Probabilistic – which is best?

Why would you even care?

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RFID systems rely on arbitration mechanisms, more commonly known as anti-collision protocols, to identify and collect data from individual tags out of a population presented to a reader. That's quite a mouthful! Advocates of *tree-walking* protocols claim that these are fully *deterministic* and therefore inherently more reliable whereas *Aloha* protocols are *probabilistic*. On the other hand advocates of Aloha protocols claim that the *world* is *probabilistic* and therefore a well designed probabilistic system will deliver a system which is as least as good as a deterministic system but with increased versatility and utility. What is the truth?

Before going on to examine the relative merits of the two approaches let me illustrate tree-walking and Aloha crowd management. A collection of tags trying to communicate with a reader is akin to a public meeting with a chairman. Each person has some information (data) that they wish to convey to the meeting. If everyone were to talk at once then no-one would hear anyone else and all you would have is noise. In the case of tags all these simultaneous transmissions would clash or collide. The function of the chairman (reader) is to arbitrate the meeting and give everyone (tags) an opportunity to convey their information (data). In a well ordered meeting, the chairman would give everyone a chance to speak. There are two methods he could employ. Either he could poll each person to find out if they wished to speak or he could ask each person wishing to speak to raise their hands and then recognise each one in turn so that each had a chance. Once a person has started speaking it is considered polite for everyone else to remain quiet. If someone does attempt to interrupt the chairman will act to silence him.

The first method of arbitration is similar to tree-walking while the second is the basis of the Aloha schemes.

Let us now consider each in more detail.

Tree Walking (Binary Search) Protocols

Tree Walking is an advanced polling method which uses the unique characteristics (identity) of each individual (tag) to singulate or individually identify them. If we again use the example of the public meeting the chairman will follow this procedure.

- The Chairman calls for speakers – Everyone responds at one time and their responses clash.
- The Chairman refines the selection argument by calling for a subgroup, for example only women - If there is more than one, they will all respond (clash) again making it impossible to hear any of them.
- The Chairman further refines the group by calling for another sub-group, for example only women with blue eyes.
- This process continues until only one woman having a unique characteristic is selected and is able to speak without interruption.

- After each person has spoken, the chairman then backs up and repeats the process with another group again going through the selection process until everyone in the room has been isolated and has had their chance to speak.

Imagine now that one or more people join the meeting late after the chairman has started the selection process and their characteristics have already been called. They will need to wait until the chairman gets around to starting from the beginning again. This is akin to the problem of late arriving tags in a dynamic or moving tag population.

Aloha (persistent) Protocols

The use of Aloha protocols does require a knowledge or recognition of individual characteristics in order to properly arbitrate a population. This is known as anonymous arbitration. Let us again refer to the public meeting.

- The Chairman calls for anyone wishing to speak to speak out, but he further asks that each person randomly select a number from one to ten and then wait that number of seconds before speaking. The effect is that everyone responds but in a random manner.

- The Chairman then recognises an individual and tells everyone else to remain quiet while the recognised individual has his chance to speak.

- When that individual has finished speaking, the chair acknowledges him (tells him to be silent) and then again calls for a speaker, everyone again responds in a random manner.

- The process continues until all speakers have had an opportunity to speak and have been acknowledged.

This method of arbitration is called persistent because each individual will persist in calling to speak until they have been given a chance and acknowledged by the Chairman. You will notice that though each individual remained anonymous when being selected to speak, each person was distinguishable by the time slot which they chose in which to speak. If two people called at the same time, the Chairman would ignore both and have them call again. If too many people call at once and the Chairman was unable to select a single individual, he simply tells everyone to pick a number from a larger range, eg. between 1 and 30. As the number of people waiting to speak decreases so the range of time in which to call can be decreased.

Again consider the situation where one or more people enter the meeting late. They do not need to wait to join the arbitration but are able to do so immediately.

RFID protocols can be either *Probabilistic* or *Deterministic*.

A *Probabilistic* protocol is one in which the operation and nature of the protocol does not absolutely guarantee that every tag in the population present will be singulated and read but a good protocol will maximize the probability of every tag being read. *Probabilistic* protocols operate by distributing Tag to reader messages in time slots to ensure that each tag gets an opportunity to send its Identity to the reader. The more uniformly that tag to reader messages are distributed, the better the chance that an individual message will be heard by the reader. Failure by the reader to correctly receive each message on the first attempt is not fatal. In heavily loaded systems it may take a few attempts. Whilst this may at first glance appear to be an inherently unreliable way of operating, every tag will continue to send its message until it has either passed out of the reader field or has been successfully read and acknowledged. It is worth noting that Wireless LAN systems such as 802.11 are in fact *Probabalistic*.

A *Deterministic* protocol will always be able to singulate and read every tag in a population present, provided that each of the tags has a unique identity number and that they all remain in

the reader's field for the duration of the arbitration process. *Deterministic* protocols operate by having the reader prompt a tag population for responses from any tags matching the response selection criteria. Such systems do not always require the tags to send any data to the reader as the reader can derive the tag ID by successively building up the tag ID one (or more) bits at a time.

A system is either *Deterministic* or *Probabilistic.* To be deterministic a system must not show any probabilistic behaviour. Several real-world considerations can result in protocols that are claimed to be *Deterministic* being *Probabilistic* in operation. The most obvious being in the case of a tag passing through a reader field and not being read because it enters and leaves the field before the reader gets to read it (the problem of late arrivers). Another example is the case where a population present is stationary in the reader field (for example a pallet load of goods) and one or more tags is in an RF null and not seen by the reader. It is evident that these tags in nulls will not be identified or read by any protocol, deterministic or not.

It would therefore be true to say that in the real world of RFID there is no such thing as a truly deterministic system, but rather that all systems are probabilistic to some degree or other.

Privacy Issues

A major concern of Consumer Privacy groups is the potential use of RFID tags to identify consumers or associate goods purchased to the purchaser. If tags are killed or destroyed at the point of sale so as to no longer be readable, RFID tagging will lose considerable value or attraction in supply chain management. RFID tags have considerable value after goods are sold. For example manufacturer batch codes can be used for traceability and consumer safety, sold date written to a tag may be used to verify warranty information and finally, re-cycling information may be stored in the tag. Many of the concerns of Privacy groups may be satisfied by making tags *anonymous*.

It will still be necessary to arbitrate tags and collect their data after they have been rendered anonymous. Aloha type protocols are ideally suited to this because they arbitrate and collect data from anonymous tags.

Another benefit major benefit of anonymous arbitration is to protect tag identity from eavesdropping. In the case of tree-walking protocols, the tag EPC or unique identity is transmitted by the reader as part of the arbitration process therefore tag identities can be collected by eavesdropping equipment listening to the strong reader transmissions. Aloha systems rely on the tags transmitting their identity back to the reader. Readers will propagate signals over distances of several kilometres, whereas tag backscatter transmissions will propagate over only 10's of metres or less.

What the user wants

To Summarise, in the RFID world there is no such thing as a truly deterministic system. No matter how deterministic the protocol, the real world environment will ensure that the system behaves probabilistically. Probabilistic protocols can have deterministic elements that make them more robust and versatile. The goal should be to maximise RFID system performance and reliability in the real operating environment. The system should meet the needs of the user. Don't be blinded by theory, clever figures and computer simulations. Make allowances for the laws of physics, which are the same in London, Los Angeles, Moscow, Sydney and Tokyo. No-one has yet re-written them.