RFID Reliability

Matti Hiltunen
AT&T Labs - Research

Research Report
51st Meeting of the IFIP 10.4 WG
Acknowledgement

Joint work with
- Rittwik Jana (AT&T)
- Ahmad Rahmati (Rice University, AT&T summer intern)
- Lin Zhong (Rice University)
RFID Overview

RFID = Radio Frequency Identification

RFID tags/ids can be read over a distance of several meters.

Active tags: battery powered, more complex processing (encryption, authentication), longer range.

Passive tag: no battery; powered by the signal from the RFID reader.

Numerous proposed applications: supply-chain management, US passports, boarding passes, luggage tags, euro bank notes, ...

Security and privacy issues have gained a lot of attention, reliability challenges not so much.
Reliability challenges

False negatives the main problem.

Read reliability affected by:
- distance between reader and tags, number of tags,
- distance between tags, speed, tag orientation, ..
- materials (metals, liquids): grounding, blocking, reflection
Impact of distance to antenna

![Graph showing the impact of distance to antenna on the read tags (out of 20). The graph illustrates a decrease in read tags as the distance increases.]
Evaluation scenario


Speed ~ 1 m/s. Minimum distance to antenna 1 m.
Impact of distance between tags

Care must be taken when multiple tagged objects are on the same pallet/shopping cart/bag/etc.

If multiple tags are used per object, they need to be located carefully.
Impact of orientation

- Inter-tag distance
- Movement direction
- Antenna
Impact of orientation

[Graphs showing the impact of inter-tag distance on tags read out of 10.]
Read reliability for tags on objects

Moving pallet with 12 wireless routers in original packaging, stacked 2 high in 2 rows. One antenna.

<table>
<thead>
<tr>
<th>Tag location</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>87%</td>
</tr>
<tr>
<td>Side (closer)</td>
<td>83%</td>
</tr>
<tr>
<td>Side (farther)</td>
<td>63%</td>
</tr>
<tr>
<td>Top</td>
<td>29%</td>
</tr>
<tr>
<td>Average</td>
<td>63%</td>
</tr>
</tbody>
</table>

Location makes a big difference due to blocking (metal or liquid).
Read reliability for tags on humans

One tag/person, located away from skin (hanging from belt). One antenna. Multiple subjects pass antenna at the same time. Speed 1 m/s.

<table>
<thead>
<tr>
<th>Tag location</th>
<th>One subject</th>
<th>Two subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Close</td>
<td>Farther</td>
</tr>
<tr>
<td>Front / Back</td>
<td>75%</td>
<td>90%</td>
</tr>
<tr>
<td>Side (closer)</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Side (farther)</td>
<td>10%</td>
<td>30%</td>
</tr>
<tr>
<td>Average</td>
<td>63%</td>
<td>75%</td>
</tr>
</tbody>
</table>
How to improve reliability?

Redundancy: multiple readers per portal, multiple antennas per reader, multiple tags per object.

Results:
1. Multiple readers/portal => reduced reliability!
2. Multiple antennas/reader => ok, but not quite as good as expected.
3. Multiple tags/object => ok, when tags separated far enough.
Object tracking with redundancy

Same experiment with 12 routers.
Human Tracking with Redundancy

![Bar chart showing reliability of human tracking with different combinations of antennas and tags.](Image)

- **1 antenna, 1 tag**
- **2 antennas, 1 tag**
- **1 antenna, 2 tags**
- **2 antennas, 2 tags**
- **1 antenna, 4 tags**
- **2 antennas, 4 tags**

Reliability:
- **Measured**
- **Calculated**

1 subject
Human Tracking with Redundancy

![Bar chart showing reliability for different antenna and tag configurations for 2 subjects.](chart.png)
Lessons learned

Do not assume unobtrusive RFID tag detection will be 100% reliable in any system.

Reliability can be increased through engineering and redundancy techniques.

- Redundant tags are effective when placed carefully.
- Redundant antennas help with blocking.
- Redundant readers (in the same location) may decrease reliability (depending if dense-reader mode is implemented by the reader).