ID-Clicker: A Battery-Free In-Class Response System Using RFID Tags

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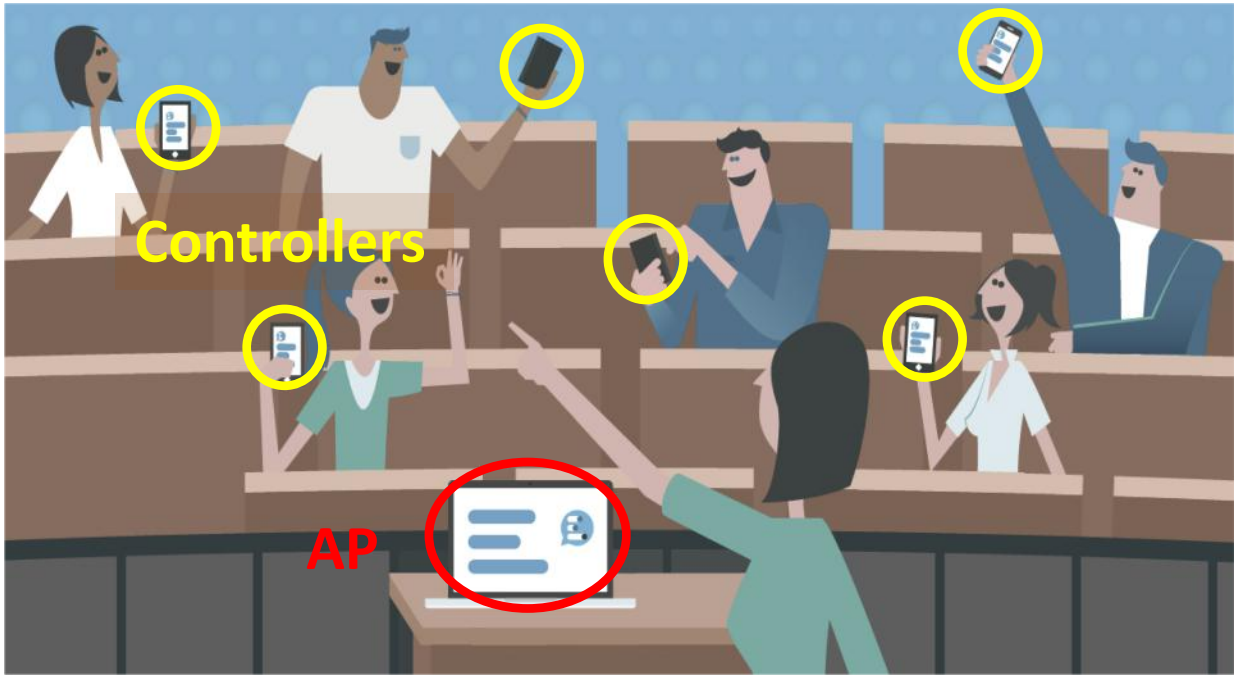
Ju Wang, Omid Abari and Srinivasan Keshav

In-class Response System

How do they work?

- Students hold remote controllers.
- Wireless Access Points (APs) collect responses.



Existing systems

- **Specialized remote controllers:**

Existing systems

- **Specialized remote controllers:**


- **Cellphone and web based:**

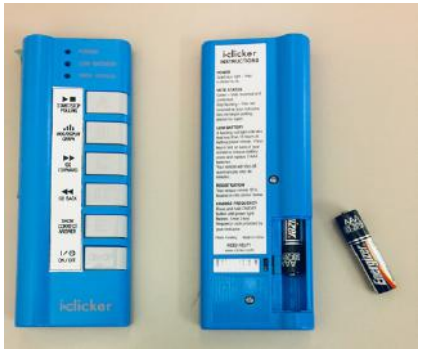

Limitation of existing systems

- **Specialized remote controllers:**

➢ Expensive

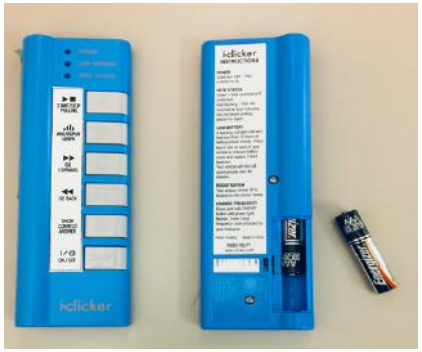
➢ require batteries

➢ can’t detect cheating



Limitation of existing systems

- **Specialized remote controllers:**
  - Expensive
  - require batteries
  - can't detect cheating



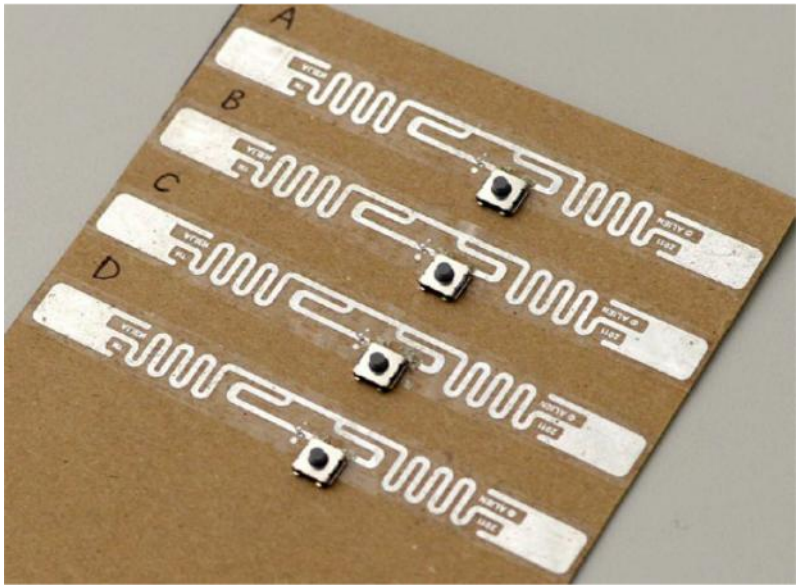
- **Cellphone and web based:**
  - more distractions, lower scores.
  - more cheating through Internet.

What can we do?

Idea: use RFID tags

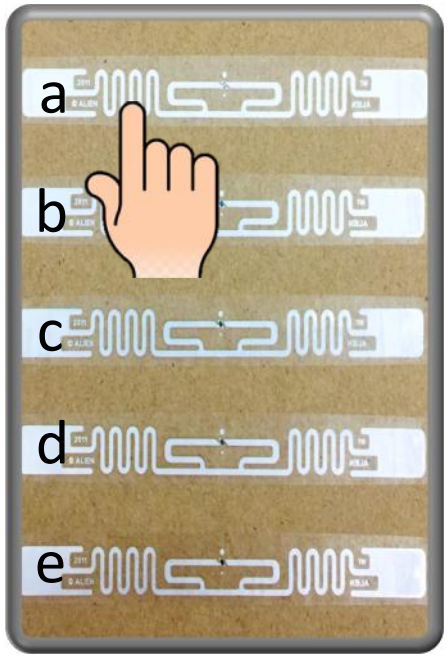
ID-Clicker

- The first RFID-based in-class response system.
- It enables low cost and battery free remotes.
- It can also detect cheating.



Challenge 1: detect a response

- **RFID touch sensing**

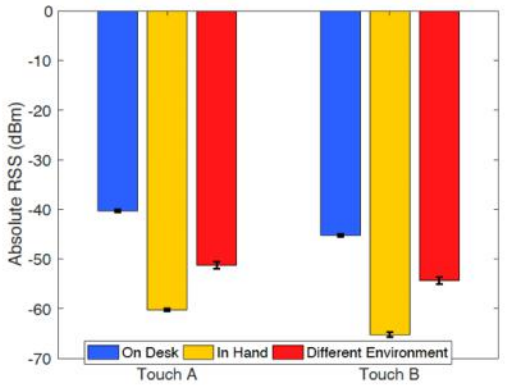


[H. Jin MobiSys'18,
S. Pradhan MobiCom'18,
H. Li CHI'16,
H. Li CHI'15, etc.]

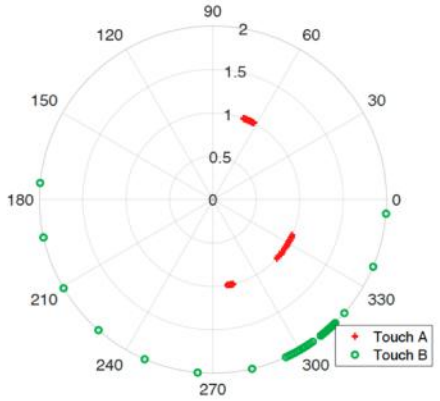
It does not work ☹

Limitation of existing RFID-based UI

- Using RSS/phase, not robust

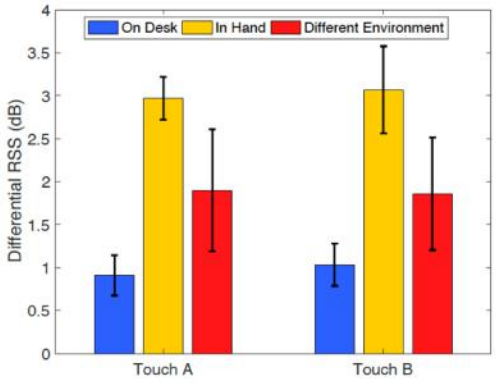


(a) Absolute RSS readings.

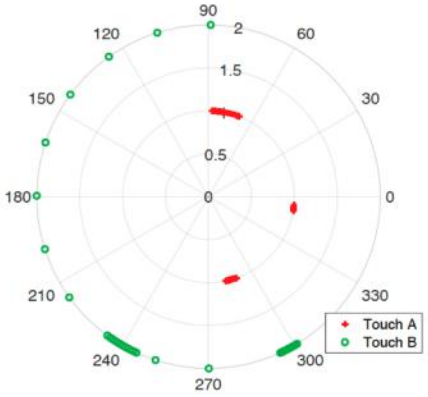


(b) Absolute phase readings.

- Using Differential RSS/phase, not robust

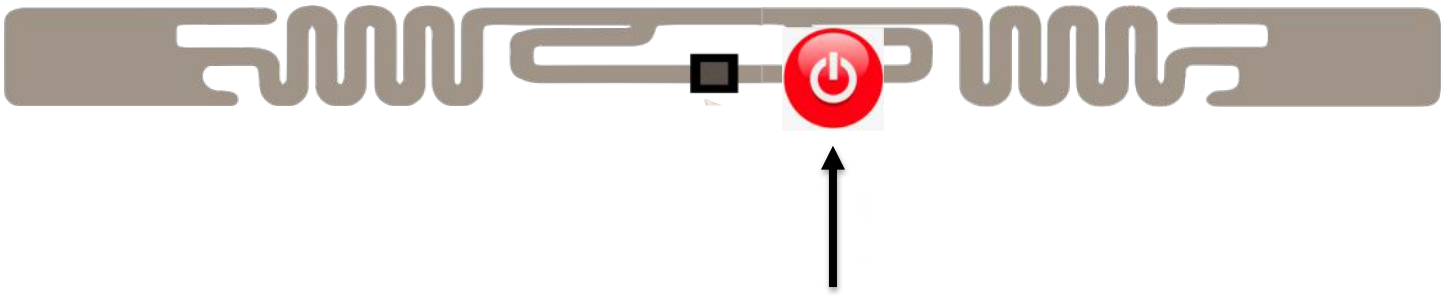


(a) Differential RSS readings.



(b) Differential phase readings.

Our solution: use digital feature



A switch controls the on/off.

ID-Clicker’s pad design

Step 1: Selecting the Tag Type

ID-Clicker's pad design

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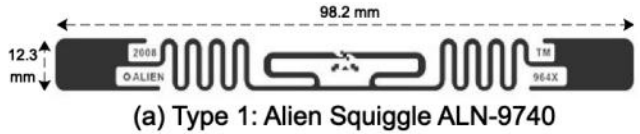
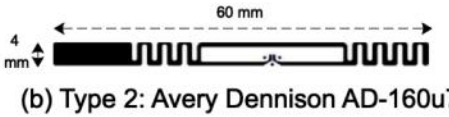
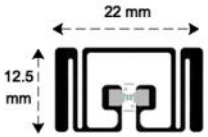


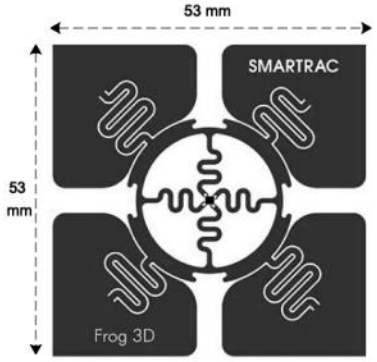
(a) Type 1: Alien Squiggle ALN-9740



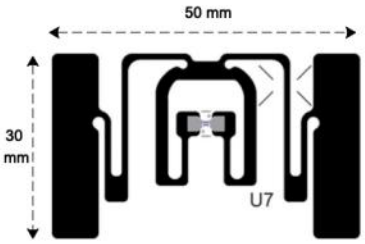
(b) Type 2: Avery Dennison AD-160u7



(e) Type 5: Avery Dennison AD-172u7



(c) Type 3: SMARTRAC Frog 3D



(d) Type 4: Avery Dennison AD-383u7

ID-Clicker's pad design

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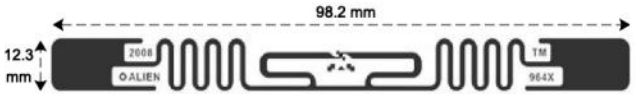

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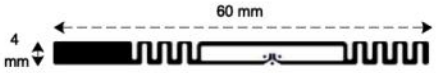
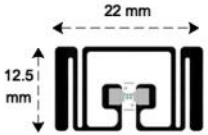


(b) Type 2: Avery Dennison AD-160u7



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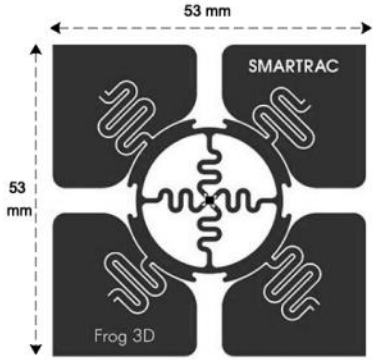

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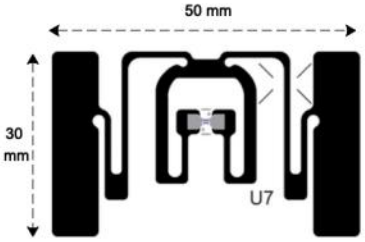

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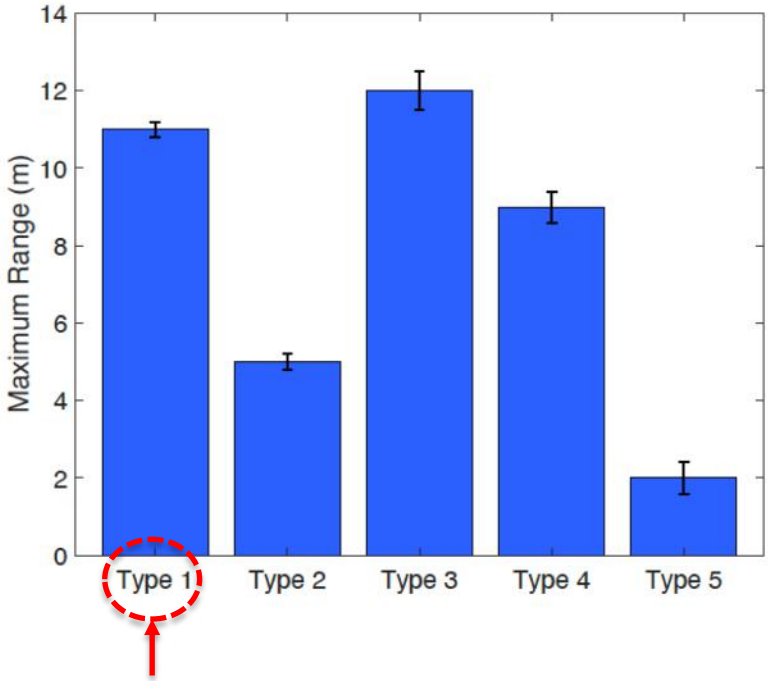

Long and stable reading range.

ID-Clicker’s pad design

Step 2: Modifying RFID Tags

ID-Clicker’s pad design

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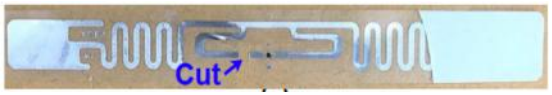
- remove the plastic cover

ID-Clicker's pad design

Step 2: Modifying RFID Tags

- remove the plastic cover

- cut away a small part of its antenna



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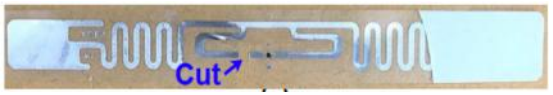

- replace the cut-off part with a switch

ID-Clicker's pad design

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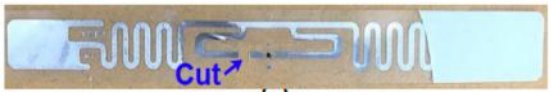
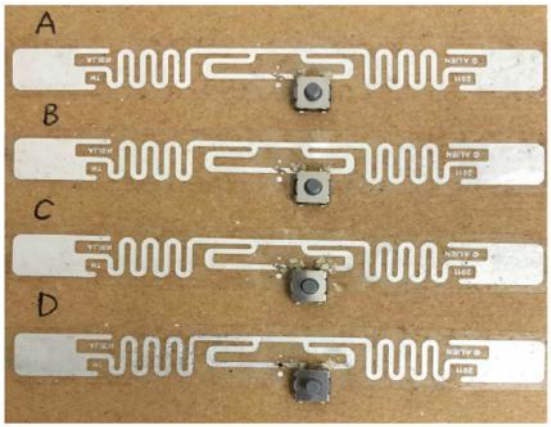


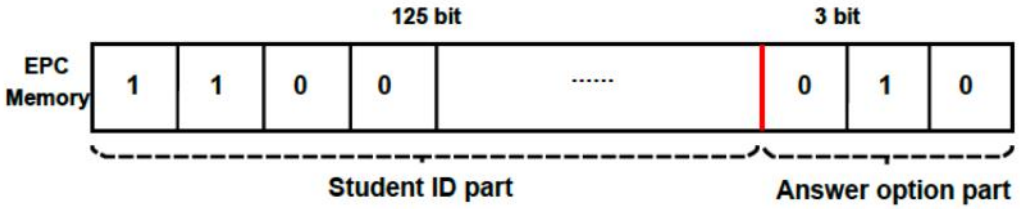
- replace the cut-off part with a switch

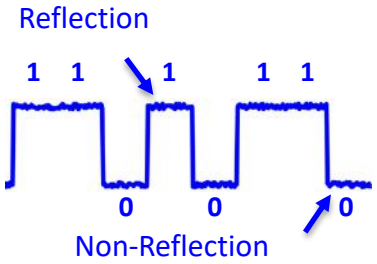
- put four modified RFID tags together



ID-Clicker's pad design

Step 3: Encoding a student's ID





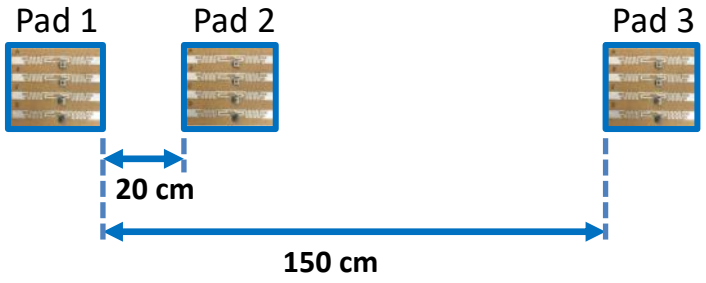
Alien Squiggle ALN-9740 tag: 128 bits of EPC memory.

- 3 bits for the answer part: up to 8 answer options.
- 125 bits for the student's ID.

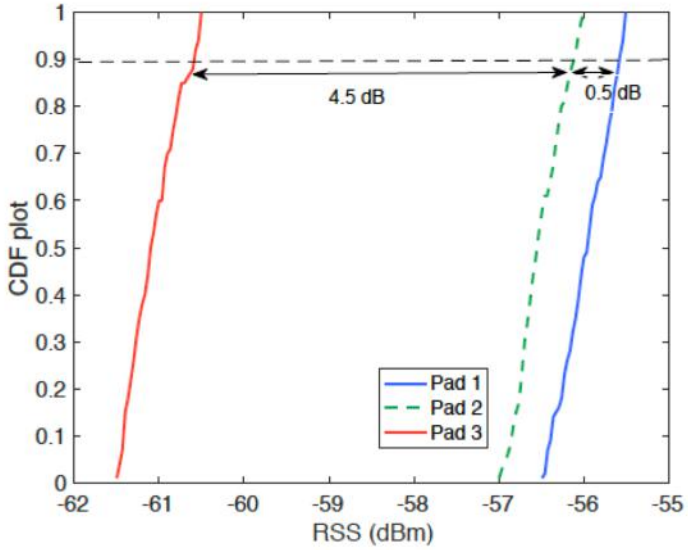
Challenge 2: cheater detection

Key insights:

1. RSS measurements of cheating pads have similar values.



Deployment of three pads.



CDF plot for RSS measurements of three pads.

Cheater detection

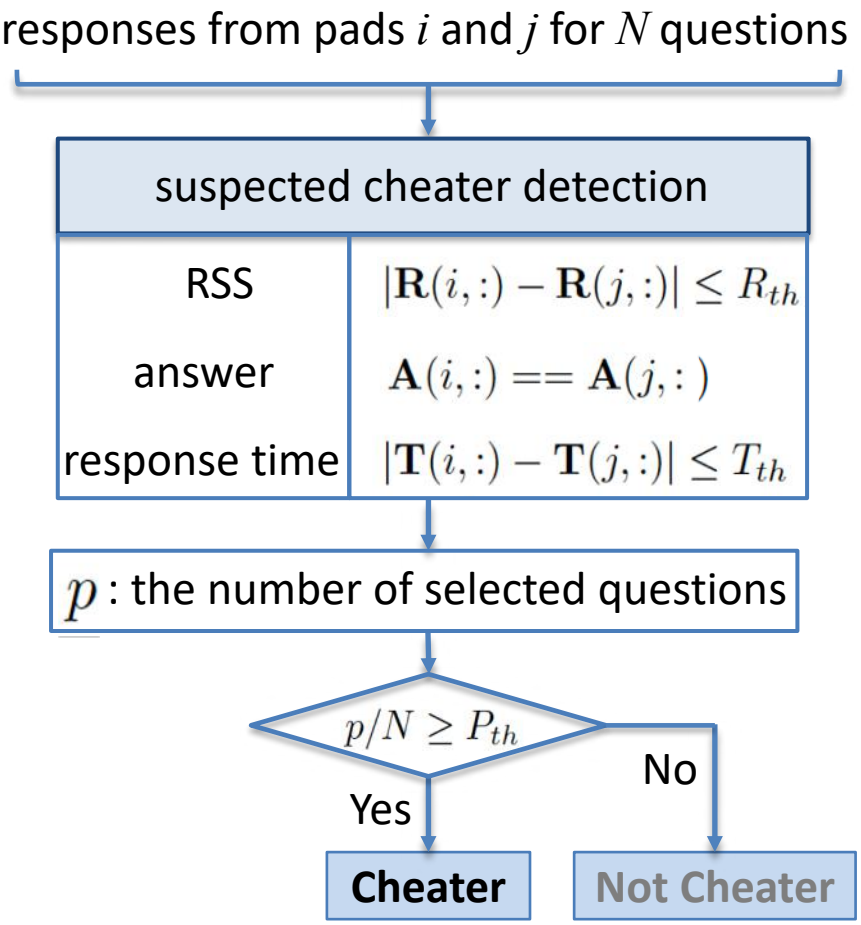
Key insights:

1. RSS measurements of cheating pads have similar values.
2. Answers from cheating pads are the same.
3. Response time from cheating pads are close.

Questionnaire	Will you choose the same answers for two clickers?		Will you press two clickers at almost the same time?	
Answer	**Yes**	No	**Yes**	No
The number of students	**67**	0	**63**	4

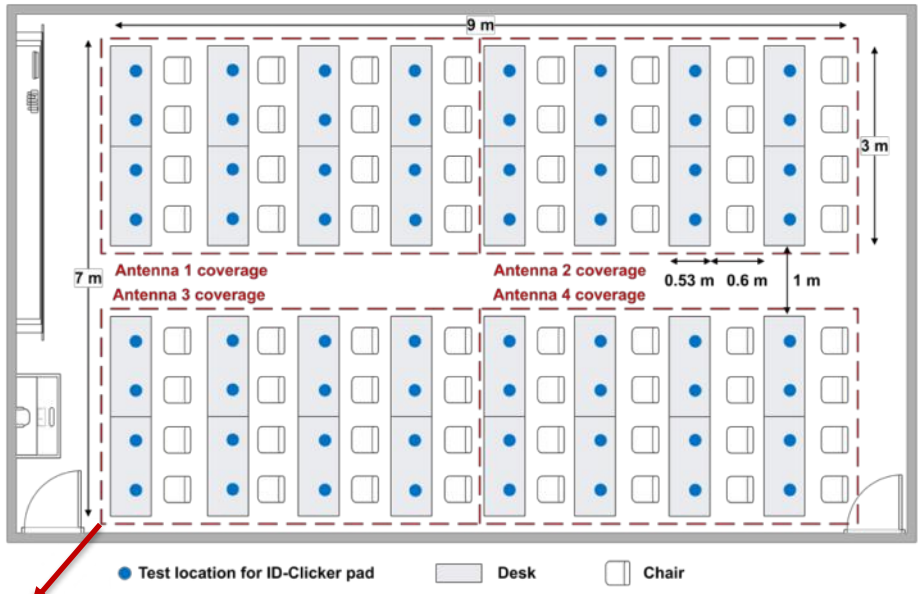
Cheater detection

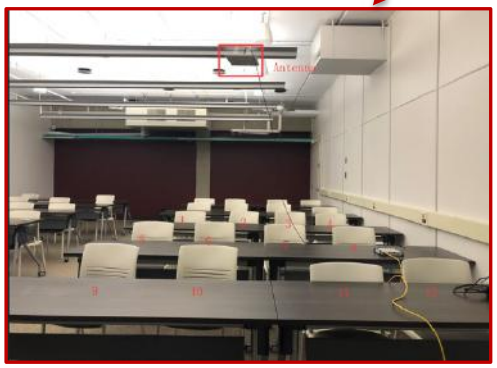
An example of detection process for two pads,



Experimental Setup

Deployment scene



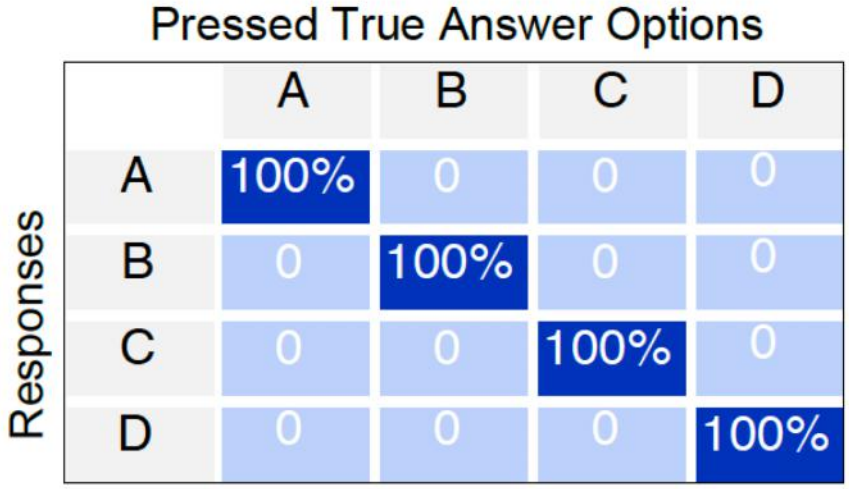


Impinj R420 reader

reader antenna

Overall response accuracy

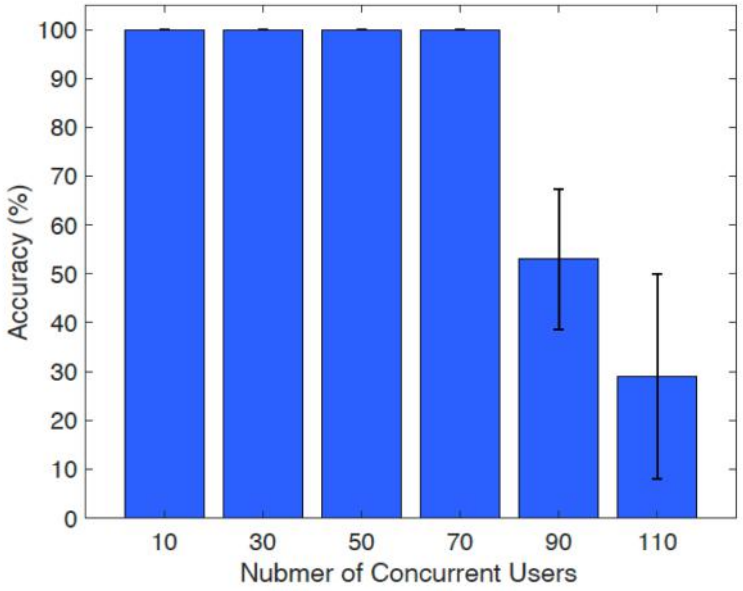
- 15 subjects, 15 random seats, press each option switch 20 times.
- Confusion matrix of identification results over 1200 tests.



Our system identifies every pressed answer option correctly.

Impact of Concurrent Responses

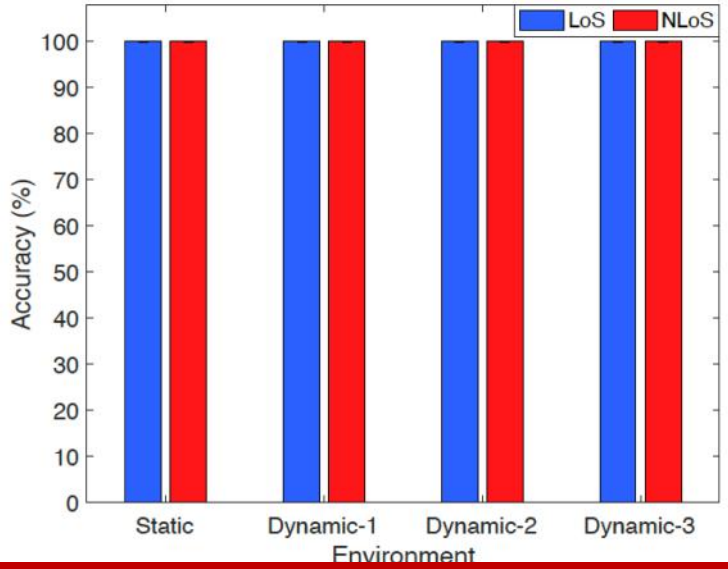
- Under one antenna, a subject press each option switch 50 times.
- Concurrent users: a number of unmodified tags.



The accuracy is 100% for up to 70 users.

Impact of Environment Changes

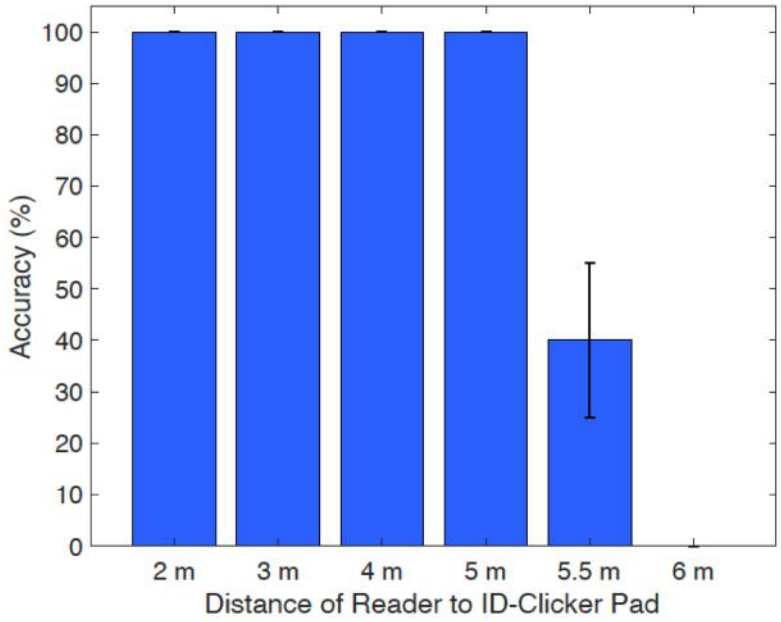
- ‘Dynamic 1’: 1 moving student,
- “Dynamic 2 and 3”: 3 and 5 moving students, respectively.
- NLoS: the direct pad-antenna path is blocked by student.



Our system is robust to environment changes in realistic settings.

Impact of Pad Range

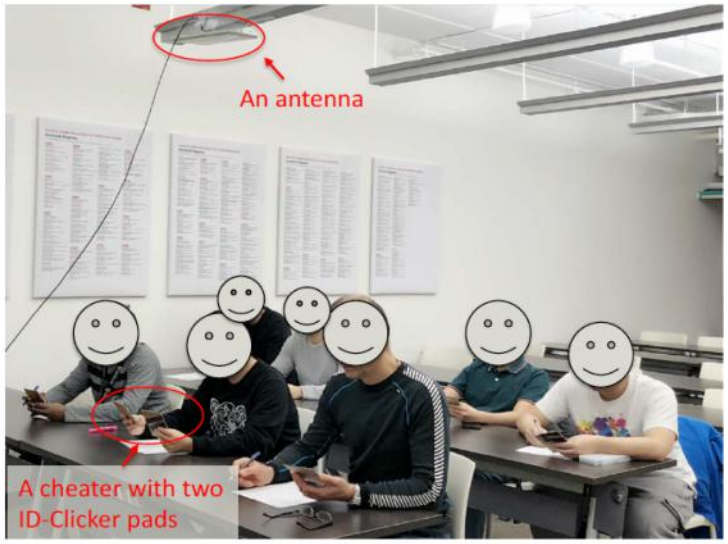
- The pad faces the antenna and we change the pad-antenna distance.
- Each answer option switch is activated 50 times.

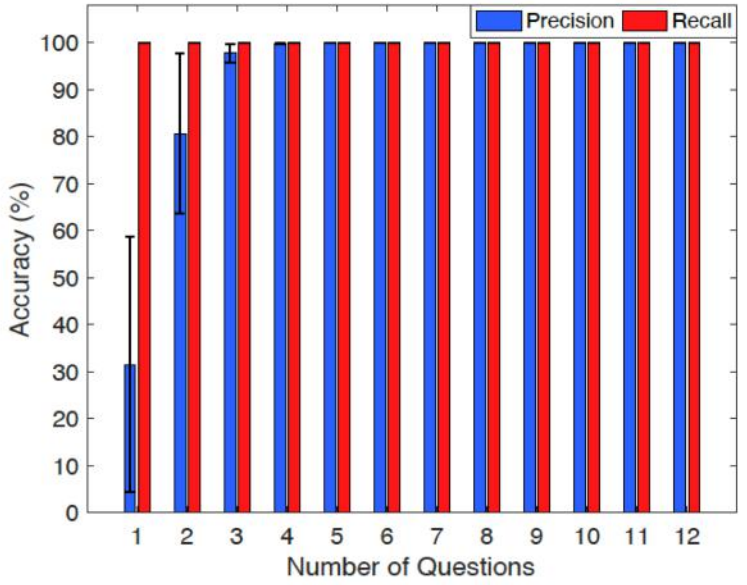


By mounting antenna on the ceiling, we achieve 100% accuracy in most indoor classrooms.

Impact of Cheating Detection

- 8 pads, 7 students, 12 questions.
- One of the students acts as a cheater and hold two pads.





When at least 4 questions are asked, all cheating pads are correctly detected without any false alarm.

Conclusion

- ID-Clicker provides students with a very affordable, battery-free alternative to existing ‘clicker’ systems.
- It can accurately detect cheating students with simple and effective algorithm.