Pitfalls in Designing Zero-Effort Deauthentication: Opportunistic Human Observation Attacks

Otto Huhta[*], Prakash Shrestha[†], Swapnil Udar[*], Mika Juuti[*],
Nitesh Saxena[†] and N. Asokan[‡]

[*]Aalto University
[†]University of Alabama at Birmingham
[‡]Aalto University and University of Helsinki

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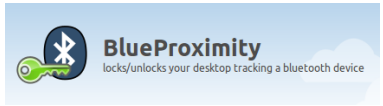
The deauthentication problem

- Threat:
  - **unauthorized access** to a terminal
  - **after** legitimate user has walked away
- What we actually want is **zero-effort** deauthentication
- Both **innocent** and **malicious** adversaries

Zero-effort deauthentication systems

- Already in use!
  - BlueProximity
  - Keyless Entry in high end cars
- Based on short-range wireless channels: RSS from user devices



http://sourceforge.net/projects/blueproximity/

Terminal

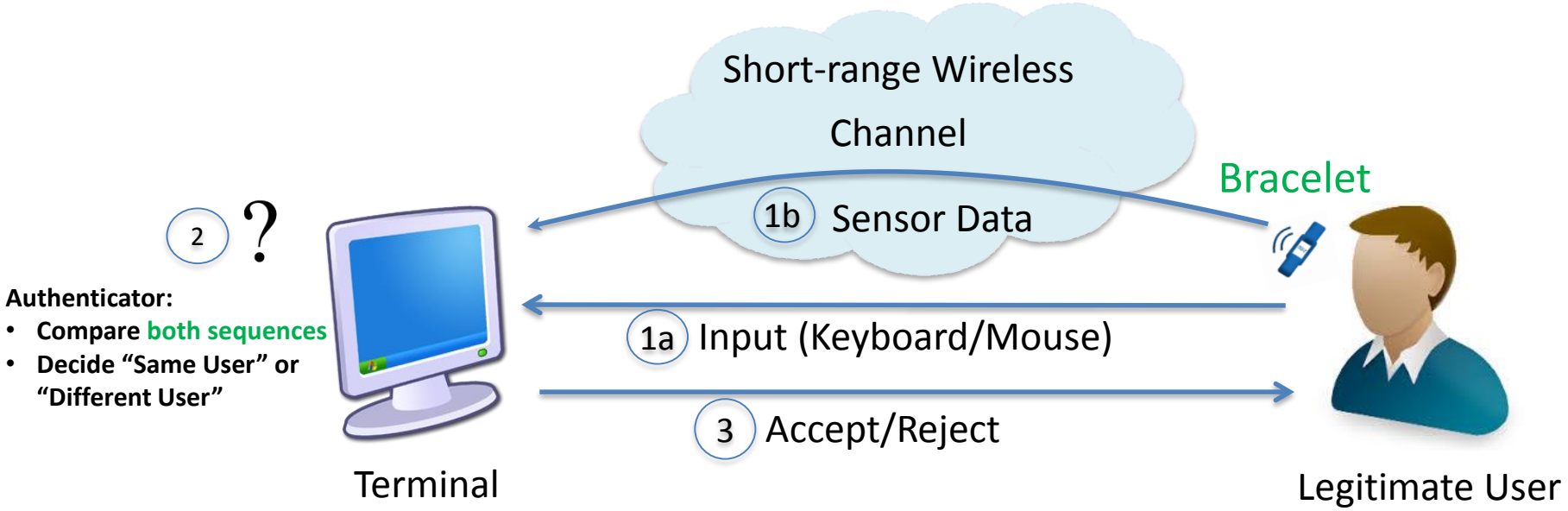
Attacker

Legitimate User

ZEBRA: a recent proposal for deauthentication

Targeted for hospital wards, factory floors, …

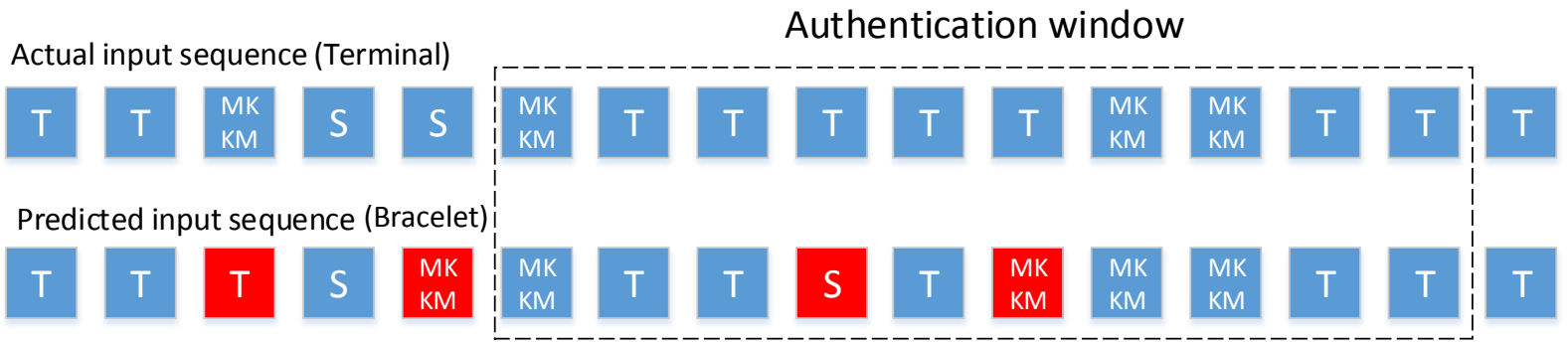
User may step away from Terminal but lingers nearby



- **No user profiling!**

[1] Mare, et al., "**ZEBRA: Zero-effort bilateral recurring authentication.**" ***IEEE Symposium on Security and Privacy (SP) 2014***
http://dx.doi.org/10.1109/SP.2014.51

ZEBRA works by averaging out misclassifications [1]



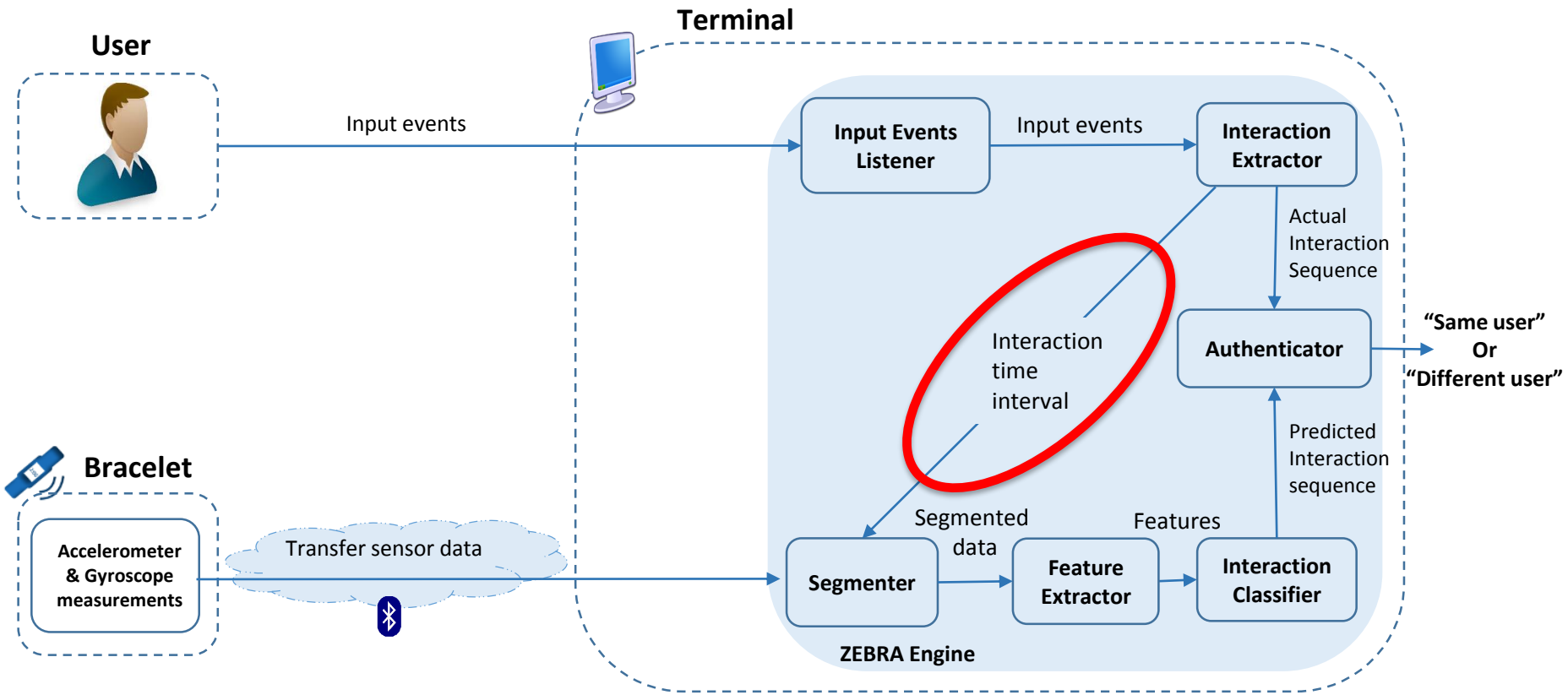
Window size 10,
Threshold 70%

8/10 matches ≥ 70%
User remains logged in

Bracelet data → classes:

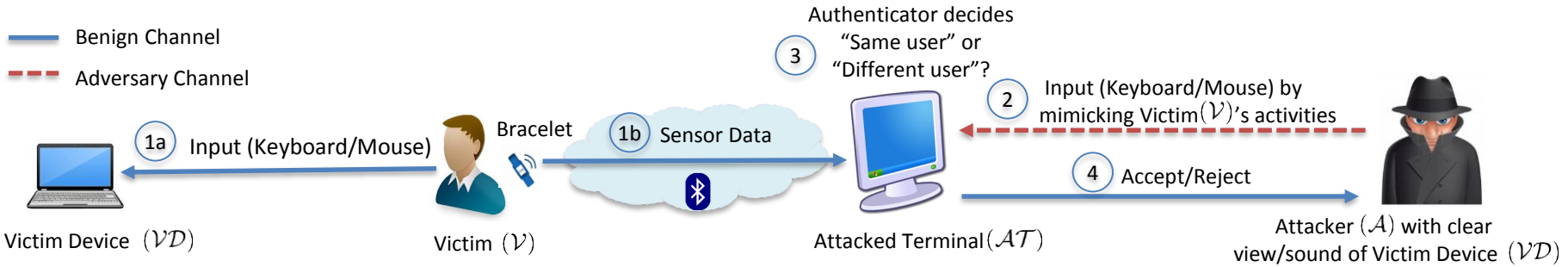
1. (any) typing
2. (any) scrolling
3. mouse ↔ keyboard movements (MKKM)

Only interactions seen at Terminal considered [1]



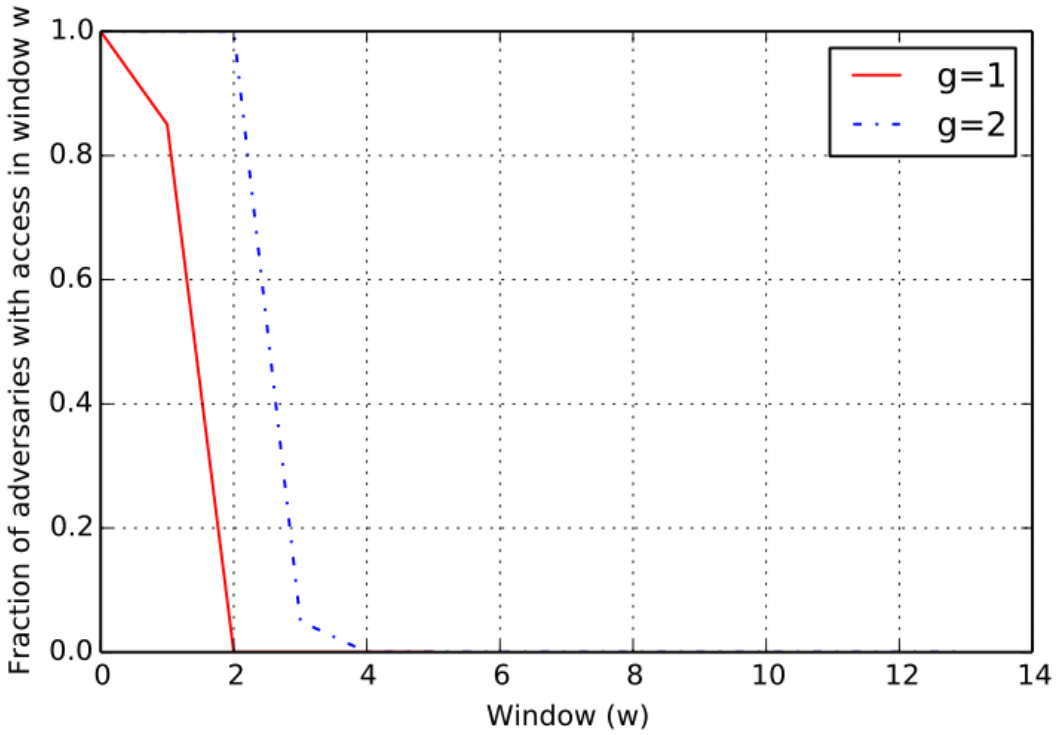
– Why? User privacy [1], accuracy of classifier?

ZEBRA vs malicious attackers [1]



- Attacker required to mimic all of victim's interactions
- 20 participants as attackers; researchers as victims
  - Victims verbally announce their interactions

Does ZEBRA resist malicious attackers? [1]



Fraction of adversaries remaining logged in (window size = 21, threshold=60%)

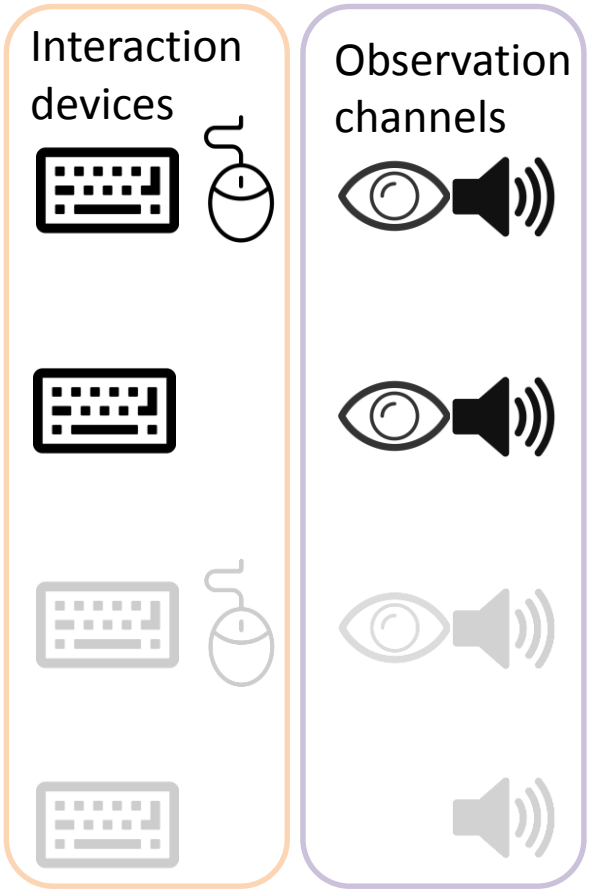
g = deauthentication at # failed windows

Average window length = 6s

Is this a reasonable adversary model?

More realistic adversary models

1. Naïve all-activity
   – As in Mare et al [1]: mimics all
2. Opportunistic keyboard-only
   – Mimics selected typing
3. Opportunistic all-activity
   – Mimics selected activities
4. Audio-only opportunistic KB-only
   – Mimics selected typing,
   but no line of sight



Our implementation of ZEBRA

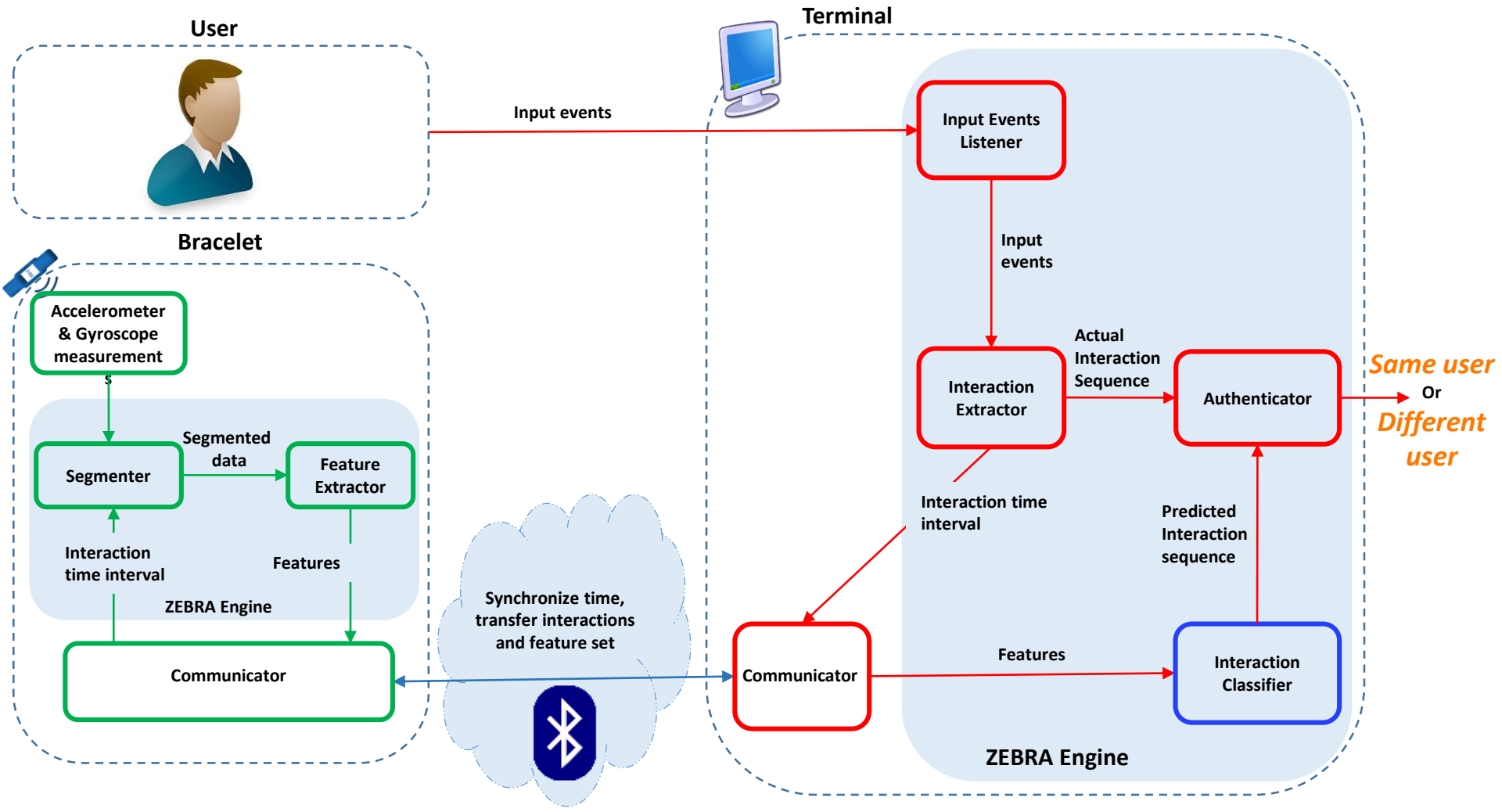
- Implemented end-to-end ZEBRA from scratch
- Using off-the-shelf Android Wear smartwatch
  - Wider applicability: existing affordable models
- Re-use ZEBRA parameters/methodology wherever possible

Parameter comparison

Parameter name	Original implementation	Our implementation
Minimum duration	25 ms	25 ms
Maximum duration	1 s	1 s
Idle threshold	1 s	1 s
Window size	21	20
Match threshold	60%	60%
Overlap fraction	**Not reported**	**0**
Grace period	1, 2	1, 2
Classifier	Random forest	Random forest
Classifier training data	Form filling	Form filling
Validation methodology	**Not reported**	**Leave-one-user-out**

- Bracelet hardware, datasets used...

Our implementation Architecture

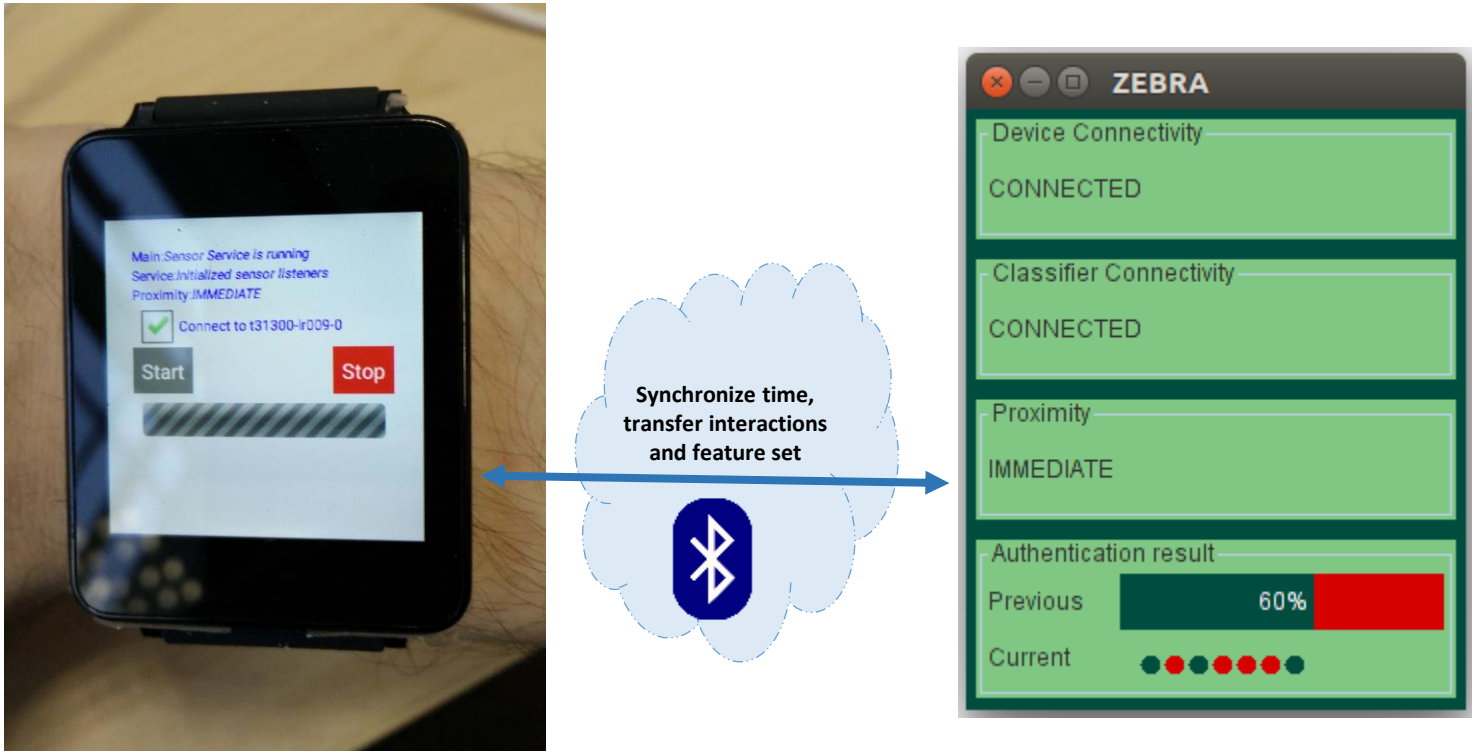


Android Wear application for smartwatch

Matlab Random Forest classifier for interaction classification

Java application for Terminal

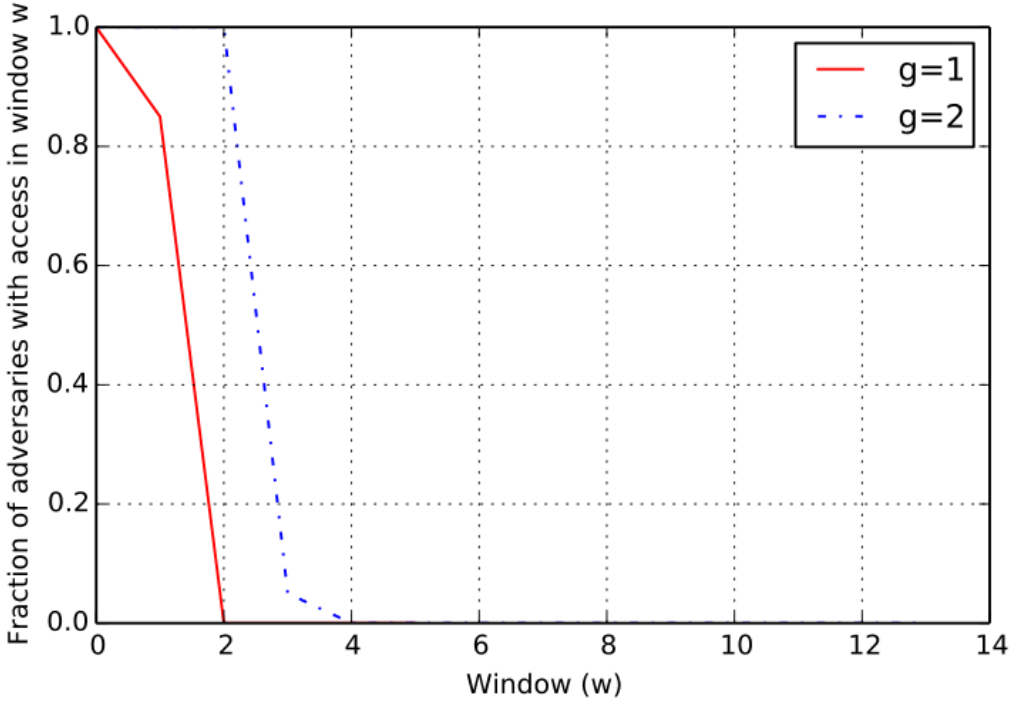
Our implementation of ZEBRA (2)



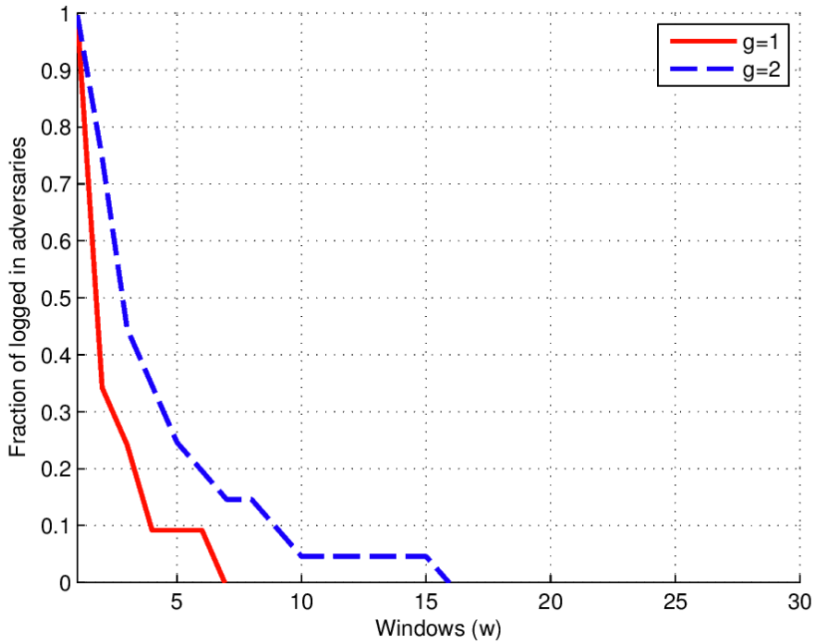

```
Zebra/java$ find -name *.java -print | xargs grep -v "\\\\" |
grep -v "1$" | grep -v "*" | wc -l
Zebra/java$ 7706
```

Naïve malicious attackers: comparison

g = deauthentication at # failed windows



Original malicious attacker (naïve) [1]

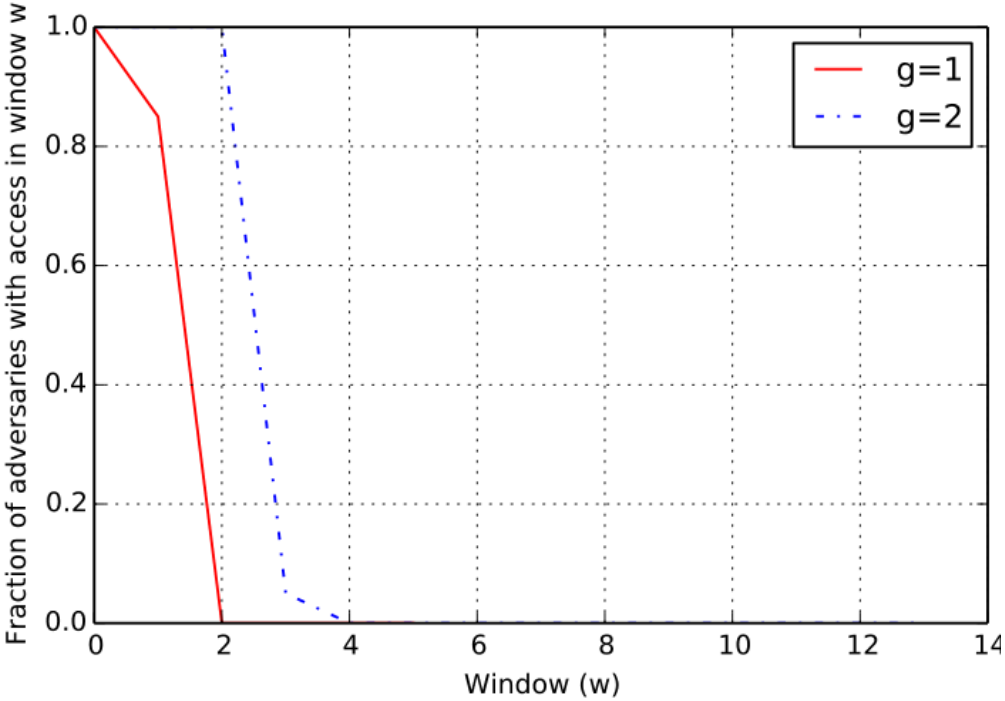


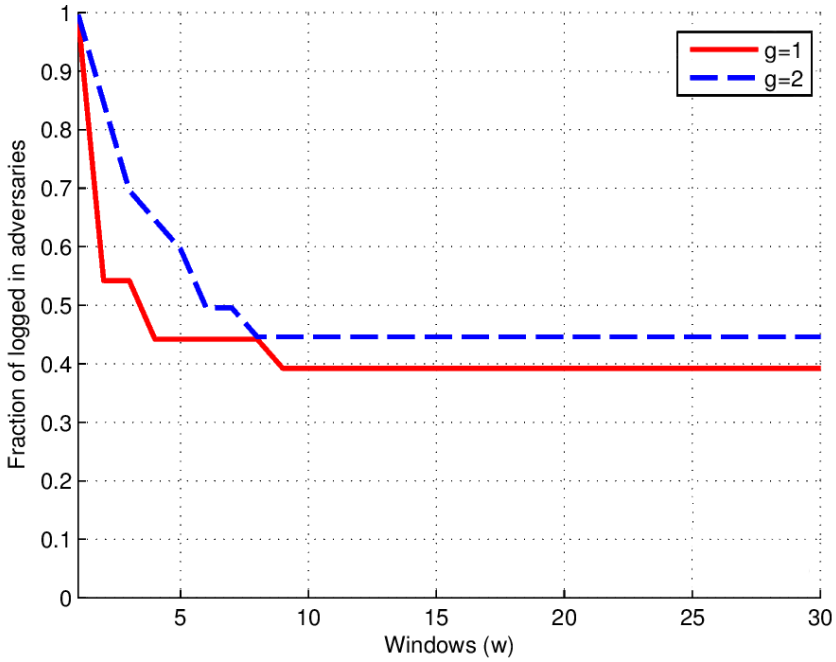
Our naïve all-activity attacker

- 20 participants as victims; researchers as attackers
- All attackers are deauthenticated

ZEBRA does not resist opportunistic malicious attackers

g = deauthentication at # failed windows





Original malicious attacker (naïve)

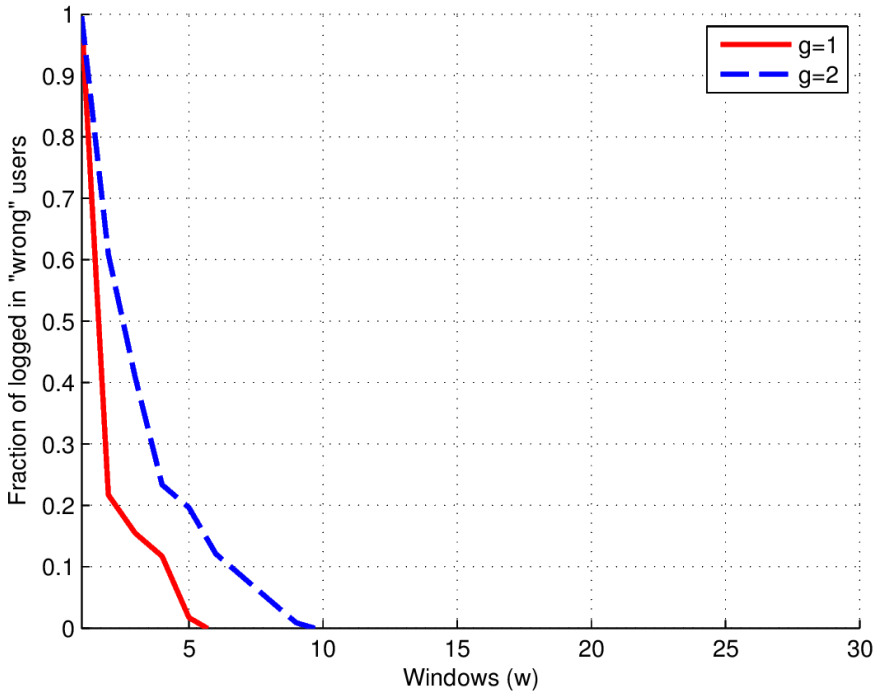
Our opportunistic KB-only attacker

- 20 participants as victims; researchers as attackers
- Attackers do not eventually get logged out

Can still protect against innocent "attackers"

- mismatched traces model innocent attackers
- All users eventually deauthenticated
- Avg. window length = 14s

g = deauthentication at # failed windows



Mismatched user traces

What went wrong? [1]

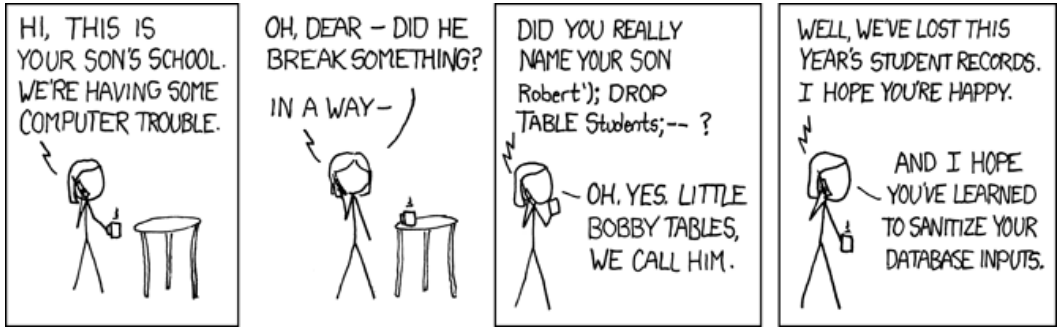
1. Inadequate **adversary modeling** in [1]!
2. Fundamental design flaw in ZEBRA:

   ”Authentication based on input source controlled by adversary”

   – Attacker controls Terminal:

   - Can choose type/timing of interactions

   – A case of **tainted input:**



https://xkcd.com/327/

Strengthening ZEBRA [1]

- Recognizing more terminal interactions
- Recognizing off-terminal interactions!
- Black/whitelisting, sanitizing input
- Augmenting with trusted input: RSS

Take-home message

1. **Zero-effort security** is appealing
   - Balance between usability and security
   - Care in defining adversary model

2. ZEBRA susceptible to **opportunistic attackers,** still effective for preventing **accidental misuse**

Ask me for a demo!