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ivPair: Context-Based Fast Intra-Vehicle Device Pairing for Secure Wireless Connectivity

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Emerging IVI Systems

- **In-vehicle infotainment (IVI) systems utility maximized with user's mobile devices**
- **More sensitive data exchange than conventional car audio**
- **Traffic information, social networking, voice recognition**

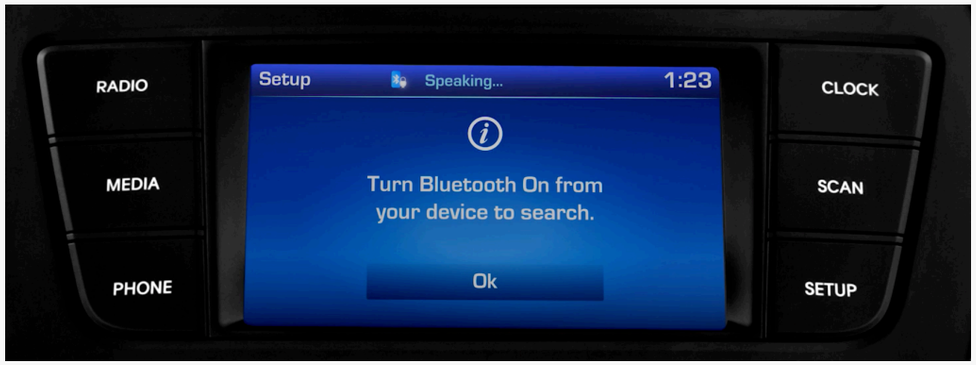
Importance of Secure IVI System

- **Privacy4Cars exploited infotainment systems of several makes via the Bluetooth protocol.**
- **Access stored contacts, call logs, text logs, and full text messages**

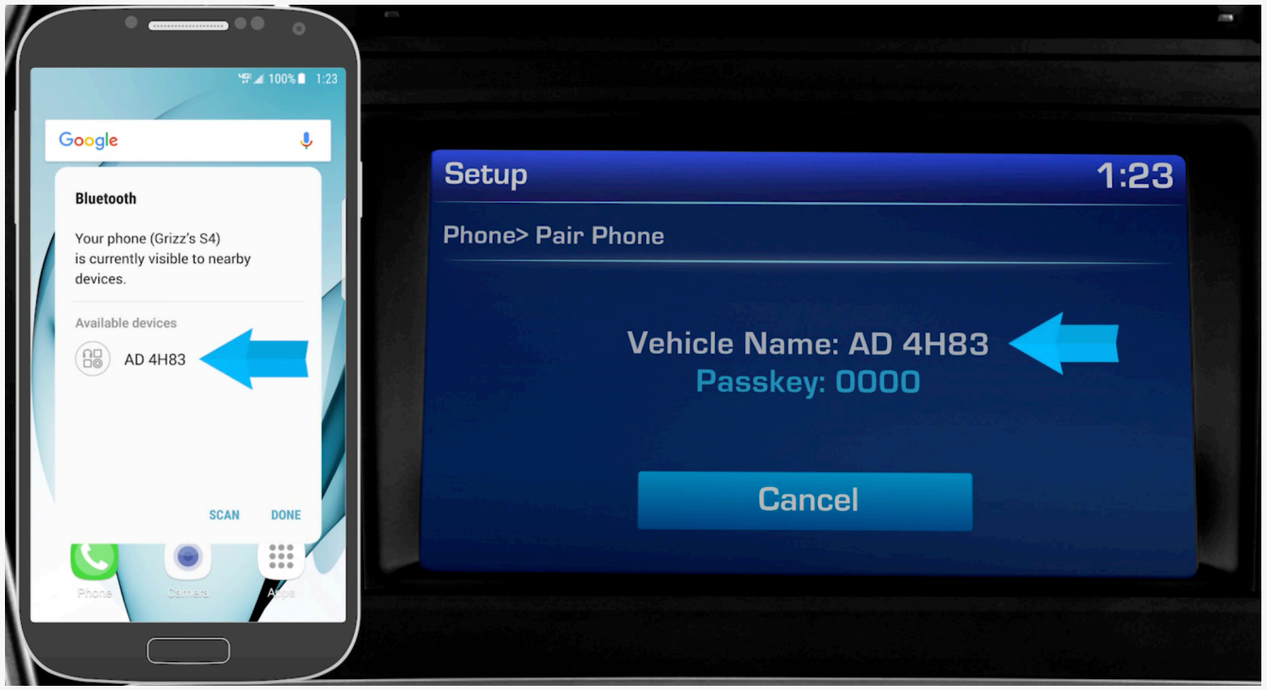
https://www.privacy4cars.com/can-my-car-be-hacked/default.aspx

CarsBlues©

Current IVI Pairing Procedure



1. Turn Bluetooth on and search



2. Passkey generated by the host

3. Confirm or enter the passkey

Goal and Requirement

Goal

Simple pairing process → **Periodic password update**

= **Low security vulnerability**

Requirements

Usability : Minimal or no user involvement

Low overhead : Small footprint and low-cost hardware

Security : Generated key or pin should be local and random

Context-based Pairing and Authentication

- Observing common **random** physical contextual information to generate authentication or pairing key:
  - Devices are in the **same place** at the **same time**
  - Devices belong to the **same user**

RSSI

Audio

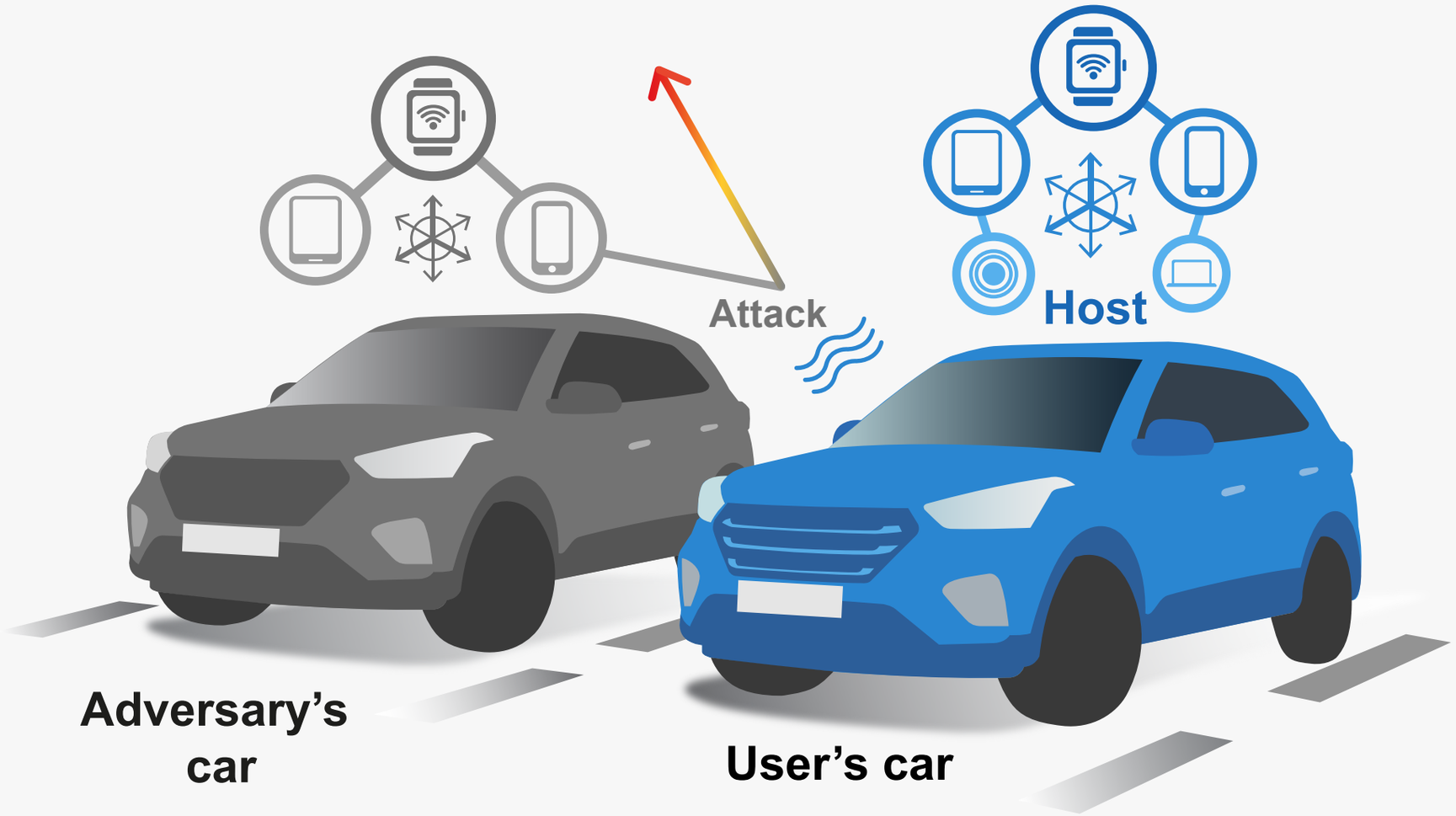
Luminosity

Image

. . .

Eliminates human-involvement during authentication

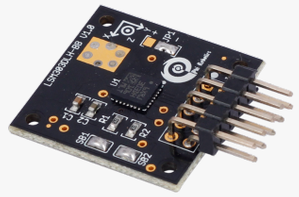
ivPair: Intra-vehicle device pairing

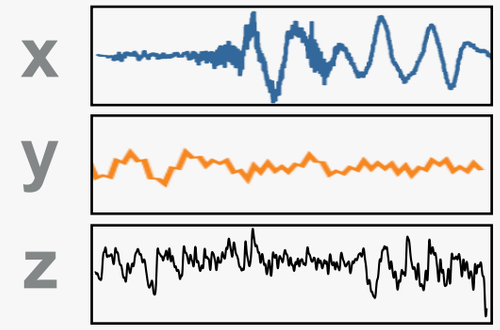


- Protocol to generate authentication pins for devices within the same car using vehicular vibration signal
- Adversary is trying to pair with the legitimate victim's (Host) vehicle or their mobile devices

IVPAIR: INTRA-VEHICLE DEVICE PAIRING

Mobile device



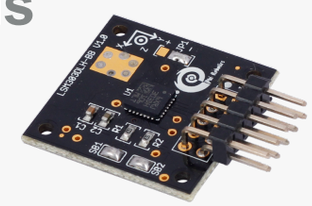


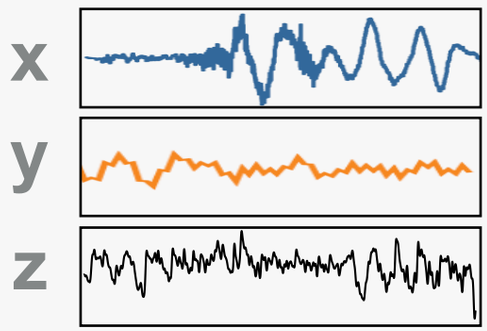
z-axis

acc.

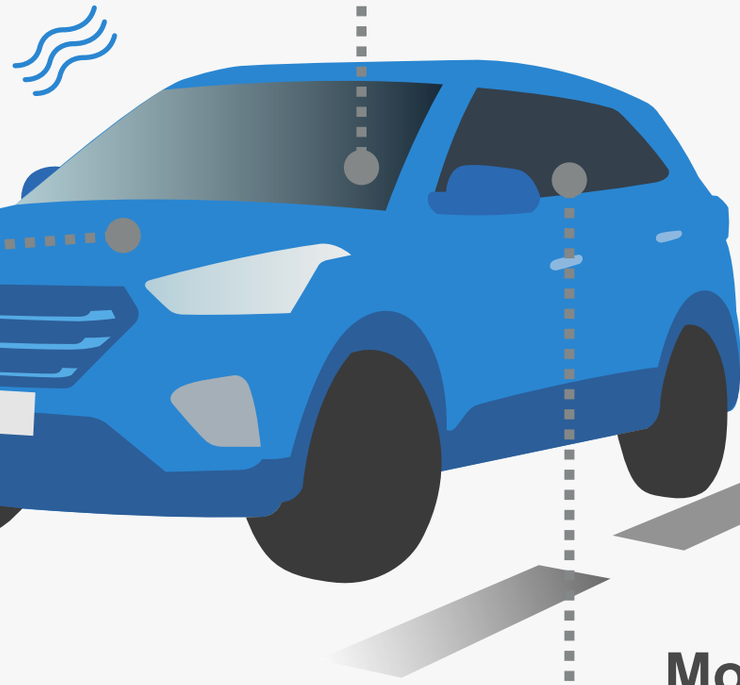
x-axis

y-axis

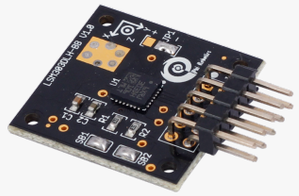


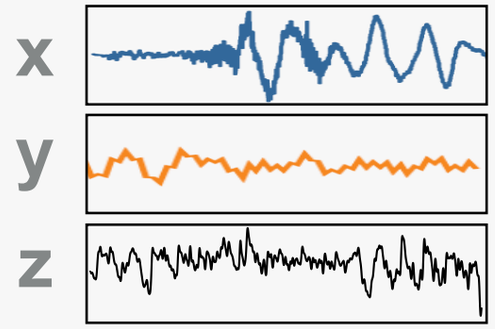


Host

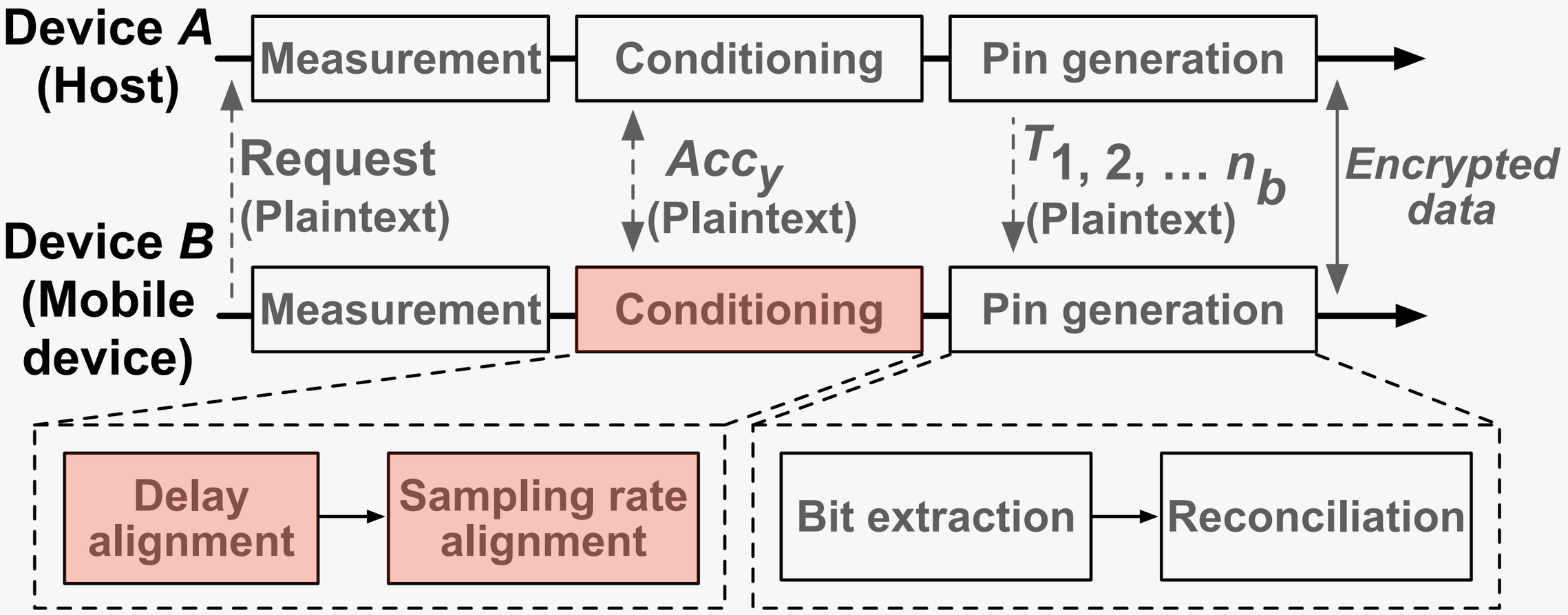


Mobile device

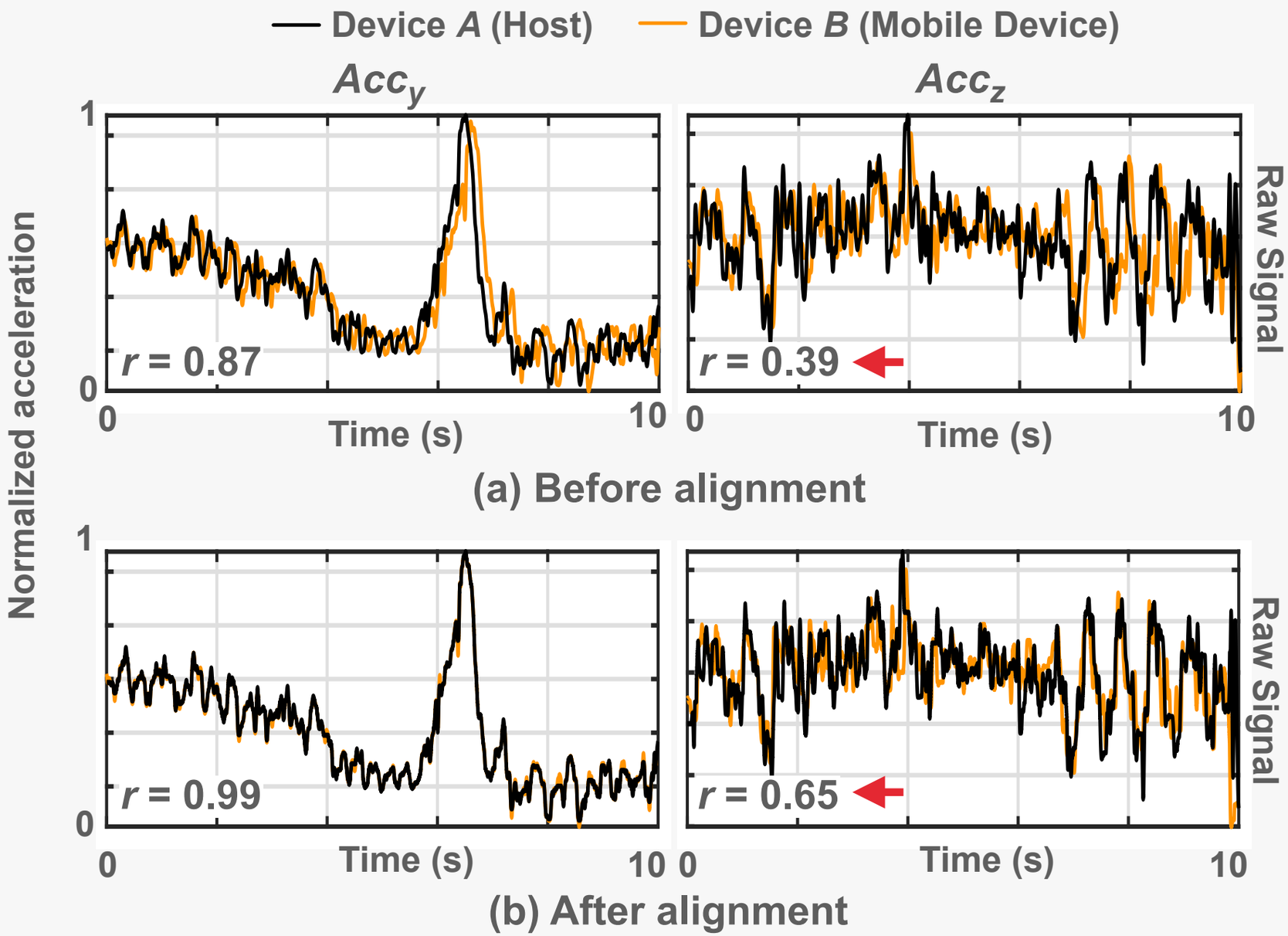




Proposed pairing protocol

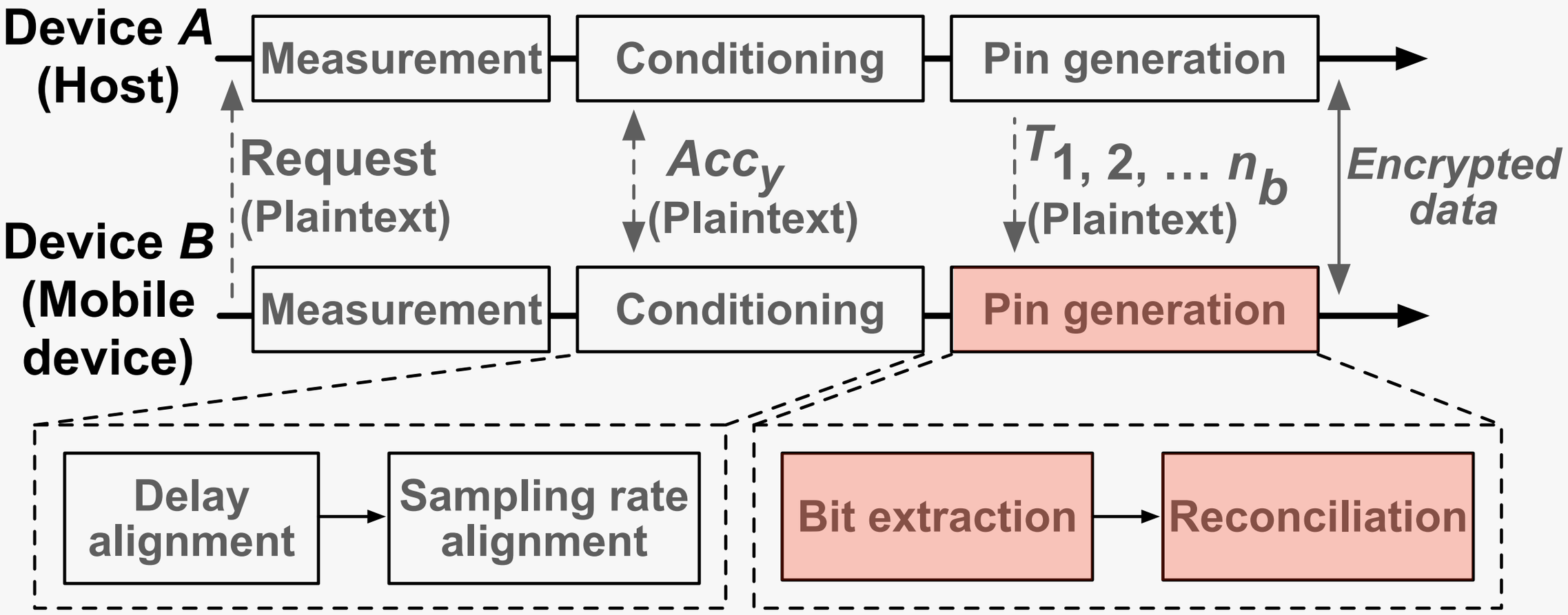


Conditioning Phase

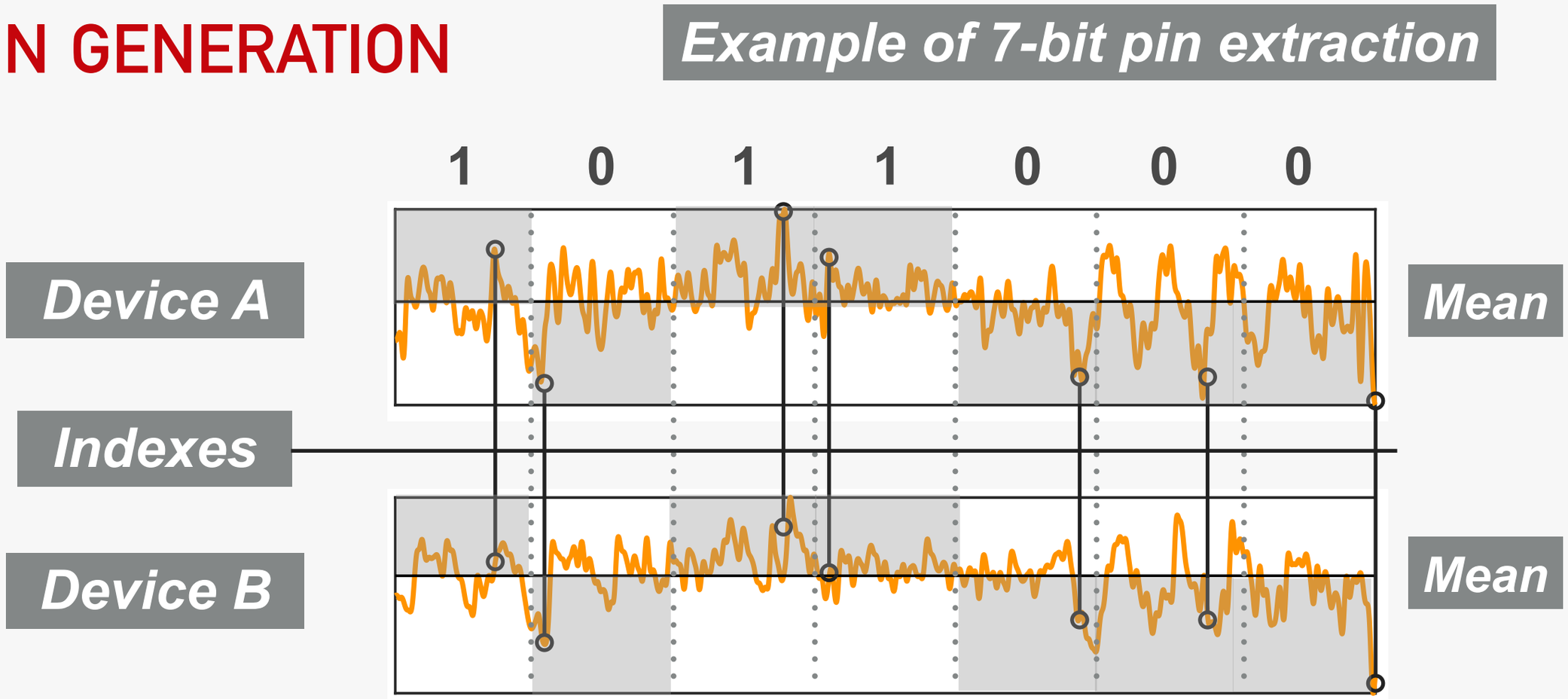


- y-axis acceleration is exchanged between devices to extract warping path using dynamic time warping (DTW)
- Warping path applied on z-axis
- z-axis used for pin extraction

Pin generation



PIN GENERATION



- Pin generation
    1. Device A divides its fingerprint into *7* bins
    2. If index of maximum absolute value within the bin is greater than mean of bin, bit **1**. Else, bit **0**.
    3. Indexes are transferred to Device B for same procedure
- Error correction is based on Hamming(*n,k)* correction scheme

Evaluation setup and metrics

- Hardware
    - Arduino UNO with ADXL345 MEMS accelerometer
    - Sampling frequency of **800 Hz**
- Pairing pin length: **14-bit**
- Signal measure time: **10 s**
- Hamming (7,4) error correction scheme
- Metric
    - *Bit agreement rate*: bit-wise comparison rate
    - *Success rate*: rate of 100% matching pins

Driving Environment

Vehicle type

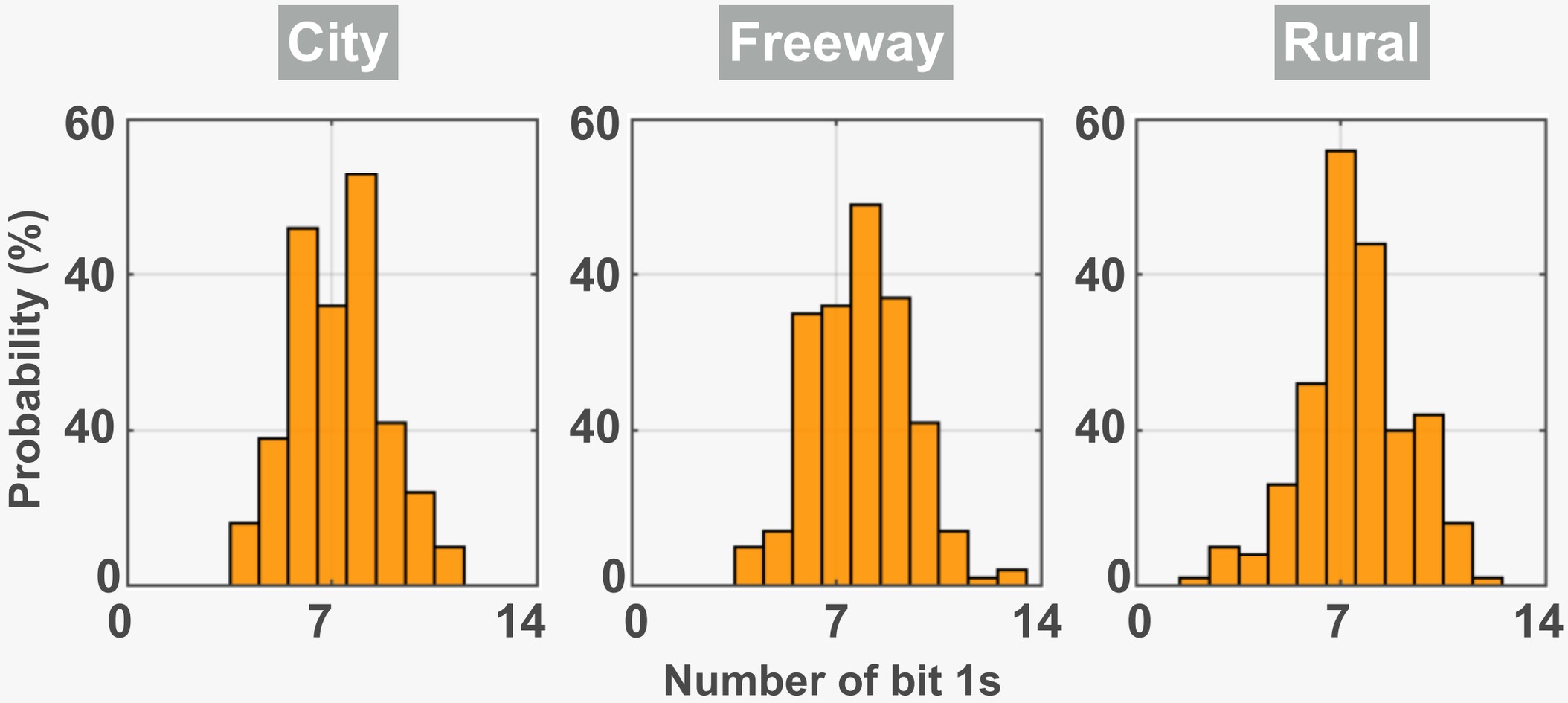
Sport utility vehicle (SUV)

Sedan

Road type

Madison, WI

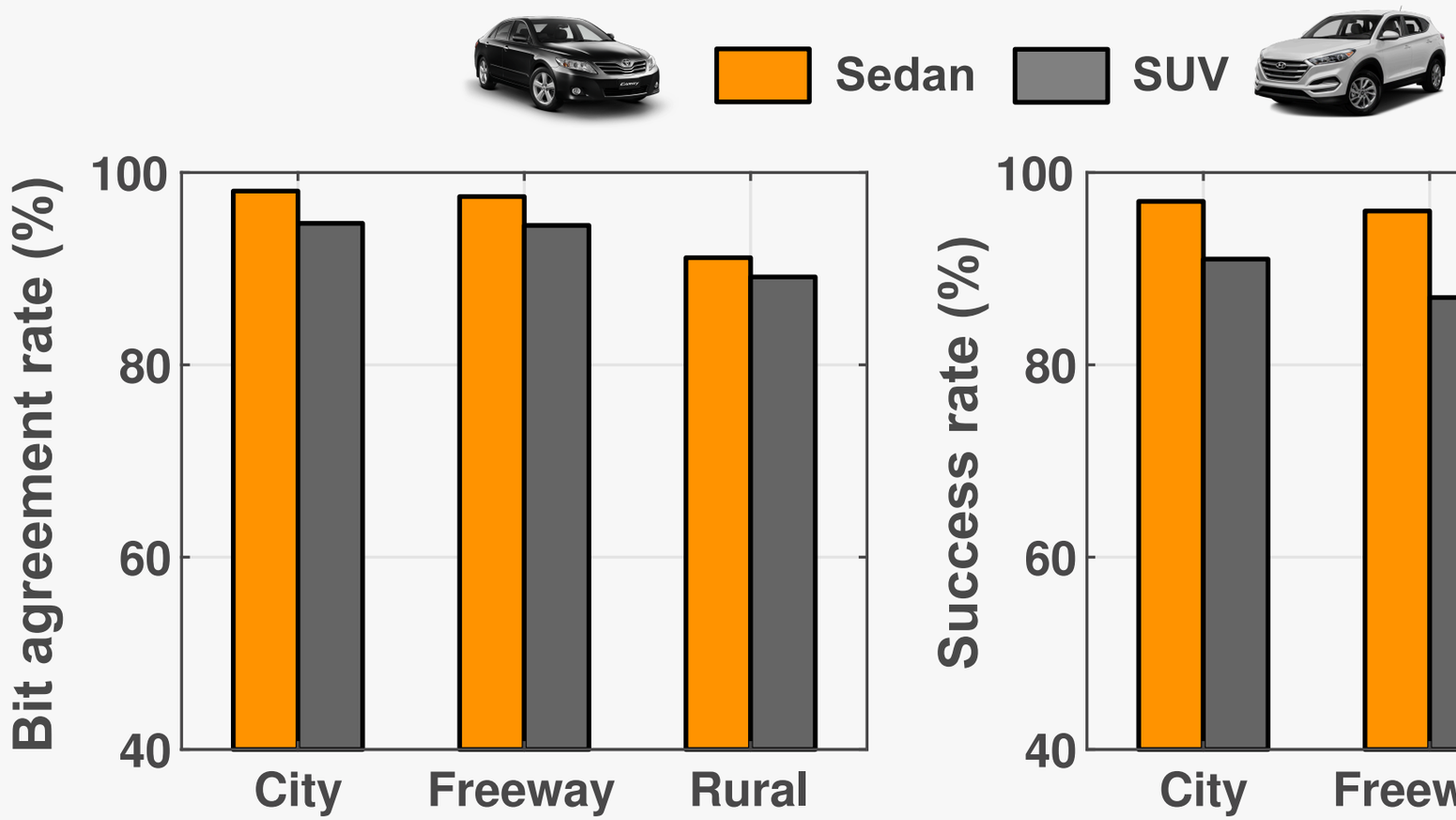
BIT RANDOMNESS



- Number of bit 1s in 14-bit pin
- Ideal number should be 7 (50%)

Exhibit binomial distribution under different road conditions

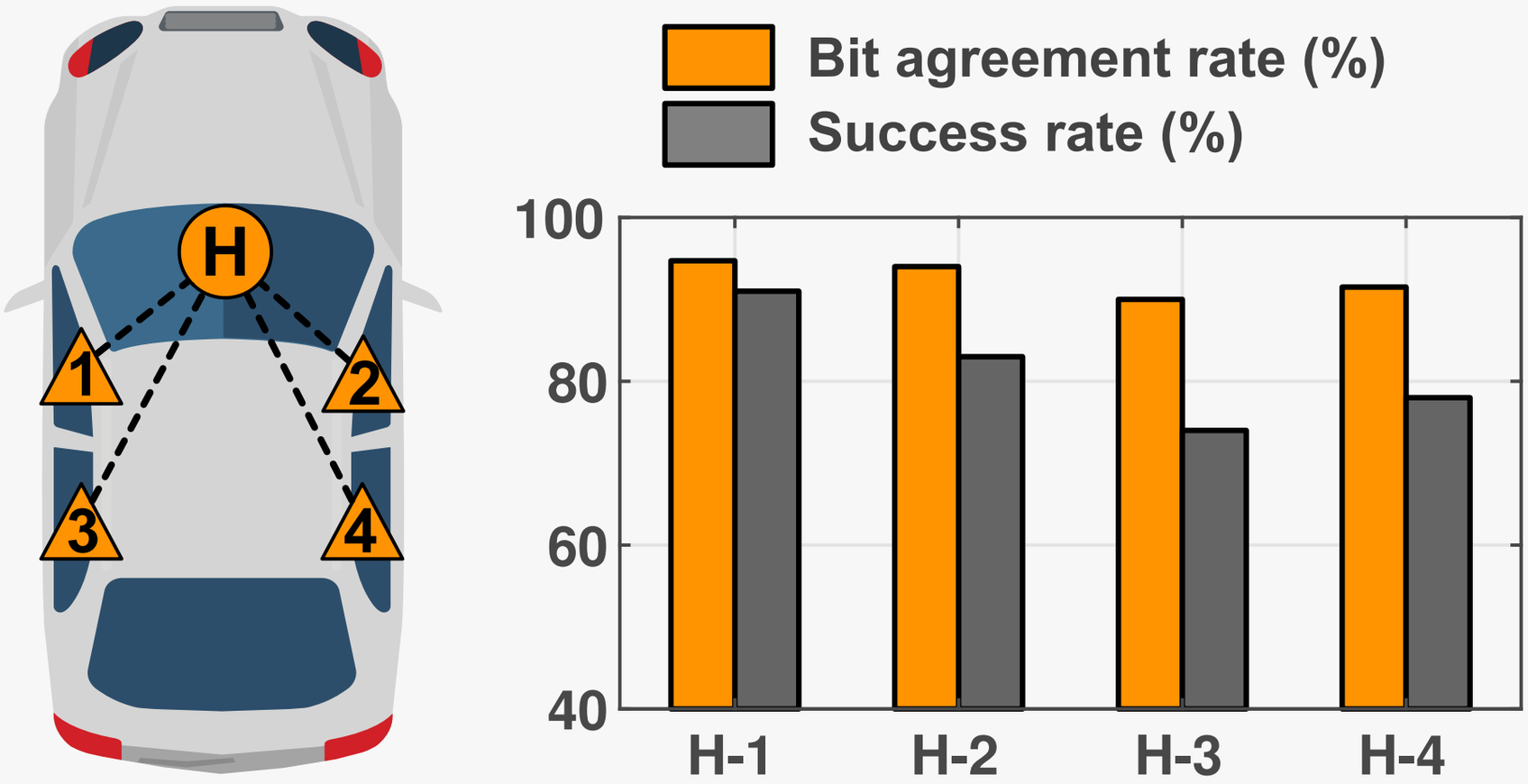
VEHICLE AND ROAD TYPES



- One device fixed to driver side door panel
- On each road type, 100 pairing requests are attempted

Above 85% success rate on city and freeway

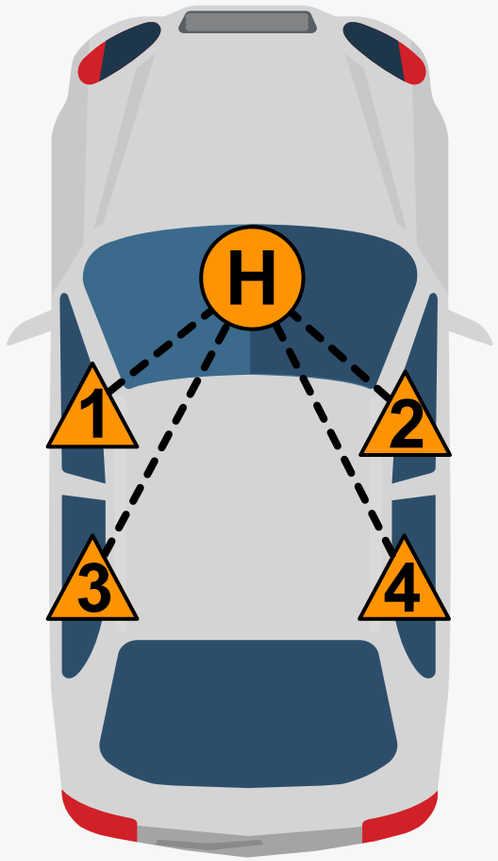
Device locations



- Each location pairs attempts 100 pairing requests

Above 85% success rate on average in all locations

Device locations

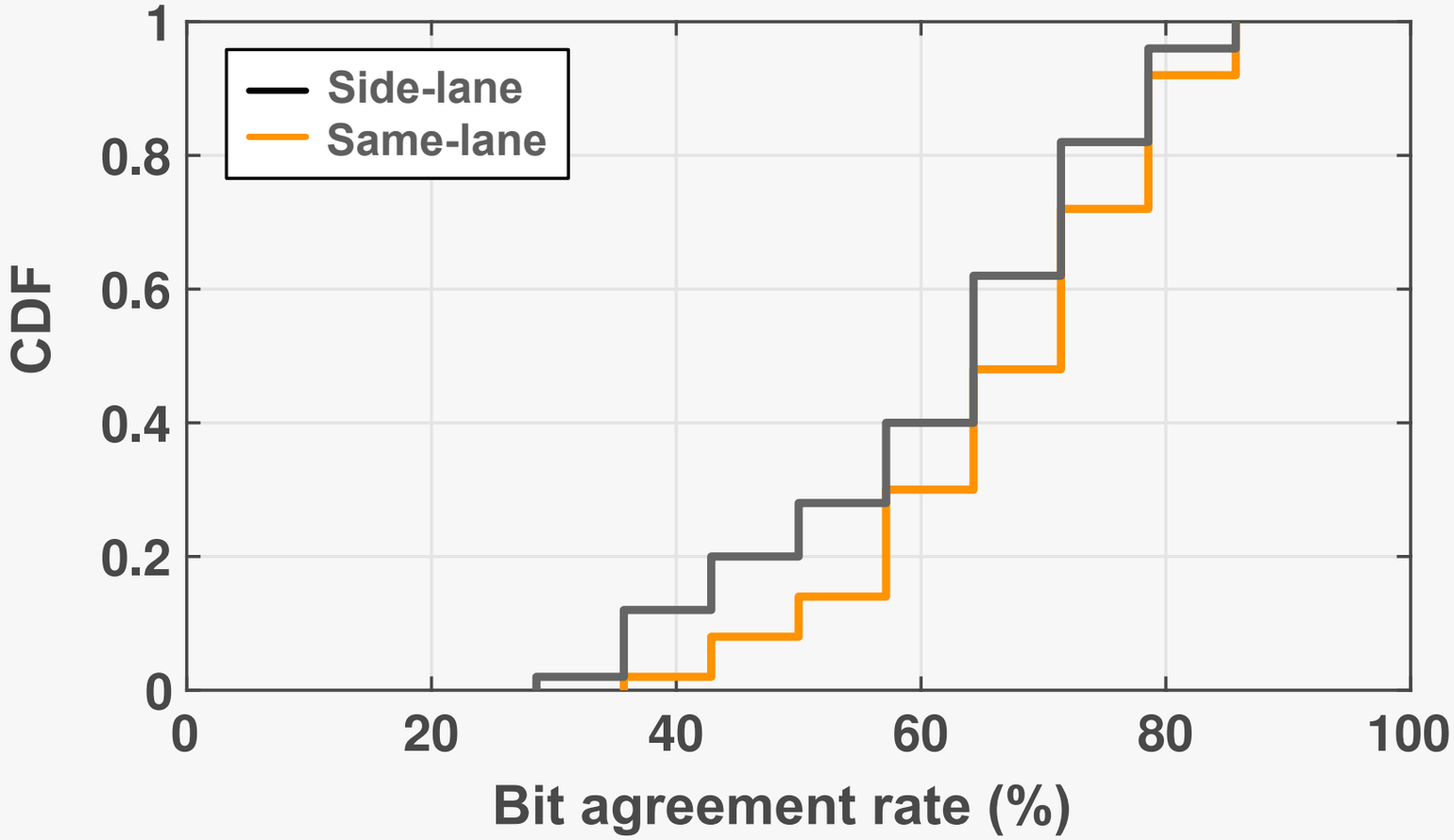


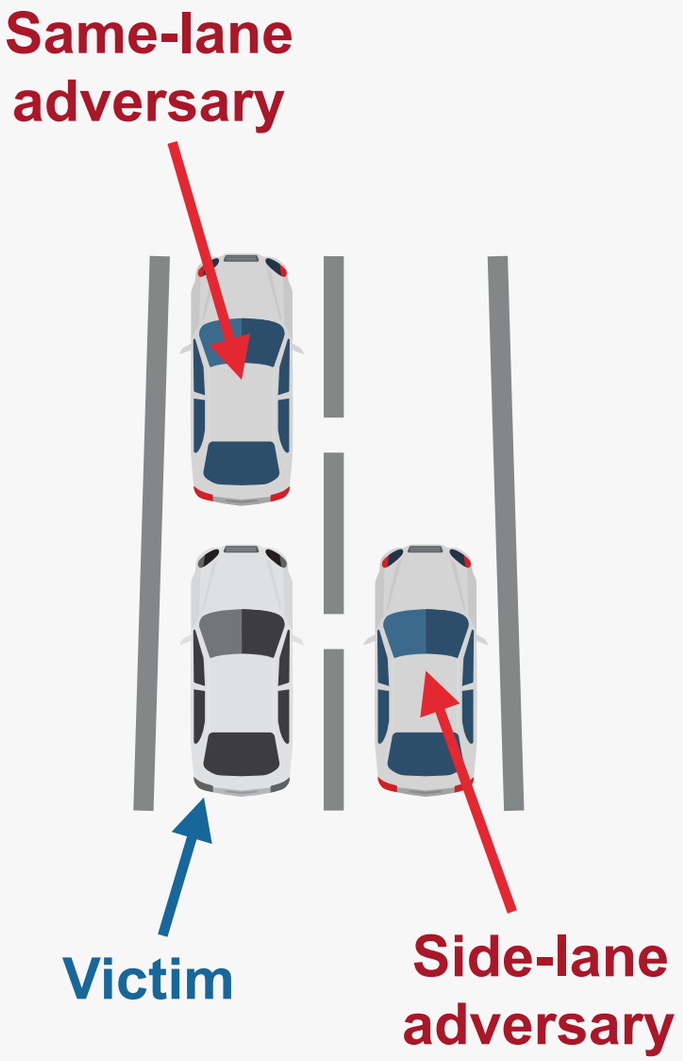
Device Pair	Correlation coe.	Expected Time
Host - 1	0.11 → 0.79	11.0 s
Host - 2	0.06 → 0.78	12.0 s
Host - 3	0.32 → 0.65	13.5 s
Host - 4	0.09 → 0.61	12.8 s

- **Expected pairing time: inversely proportional to the success rate times duration of measurement (10 s)**

Less than 14 s pairing time from any passenger location

Adversarial Scenarios

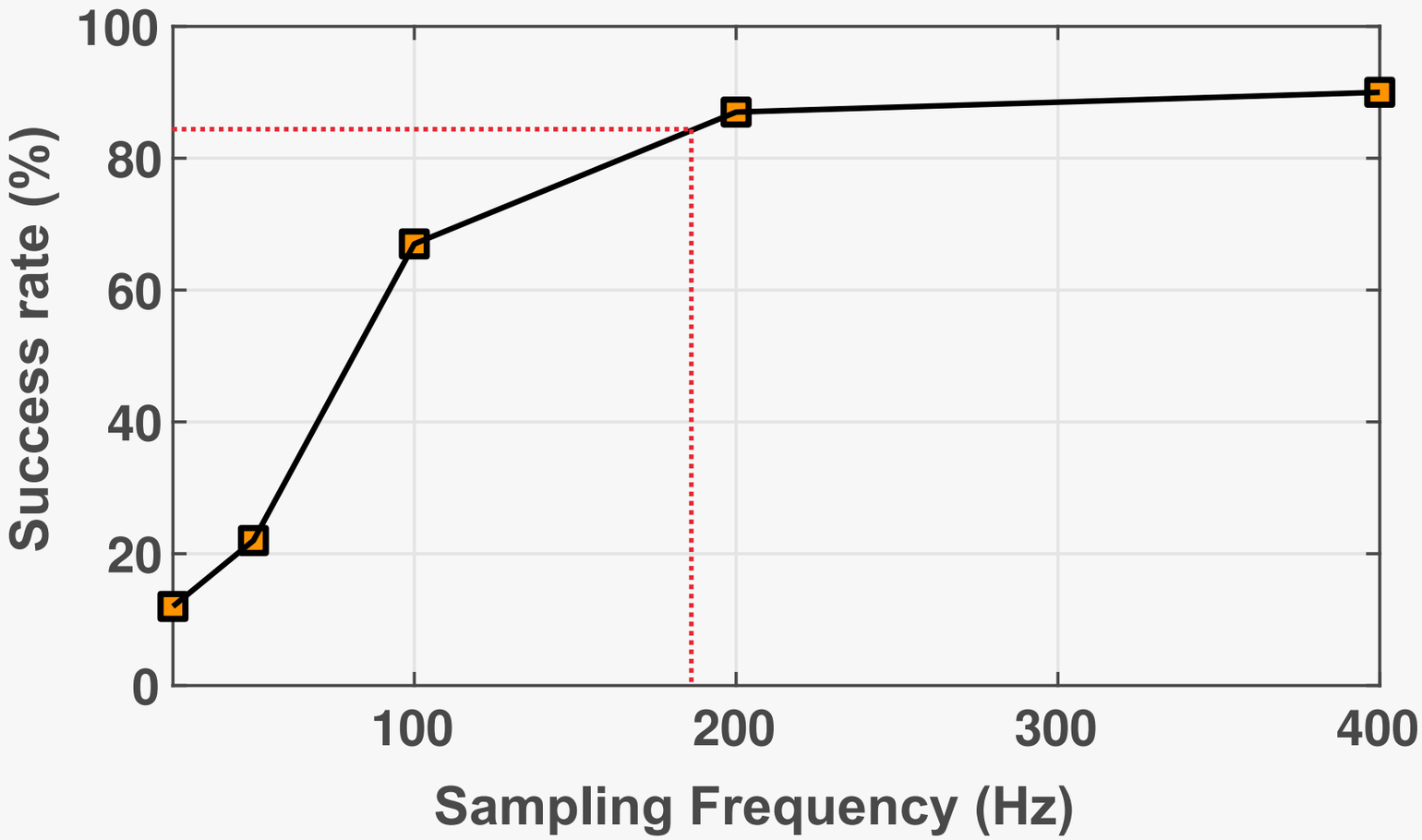




- Side-lane: adversary driving in next lane as victim vehicle
- Same-lane: adversary driving in front of victim vehicle

None of the attacks were successful

Minimum Sampling Rate



- Downsample fingerprints from 800 Hz to 25 Hz
- Sampling rate above 200 Hz maintains high success rate

Above 170 Hz sampling rate to maintain 85% success rate

Computational Overhead

- The main computation overhead of ivPair
    - Dynamic-time warping (DTW)
- Android application on LG Nexus 5X (Android 5.0)
    - Mid-range smartphone with 1.8 GHz processor
- Compute warping path of two time-series of 8,000 samples (10 s long fingerprint)

Computing alignment path takes only 546 ms

Conclusion

- Context based pairing method based on vehicular vibration context
- IVPair removes hassle of manual pairing procedure in vehicular scenario
  - Safe and usable for drivers and passengers
- Expected pairing time is around 11 s for 14-bit pairing pin

Key Features of IVPair

- **Usability** : Simple contact action from user
- **Low overhead** : Accelerometers are ubiquitously available
- **Security** : Context-based authentication pins