Detecting Mobility Context over Smartphones using Typing and Smartphone Engagement Patterns

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Background

- IMU sensors provide **accurate mobility**

  - ❑ Facilitated by **permissionless** access

- Accurate **mobility** used to trace location[1]

- *Location Privacy* is breached even if **GPS** is

  explicitly turned off[2]

1. J. Han, E. Owusu, L. T. Nguyen, A. Perrig, and J. Zhang, "Accomplice: Location inference using accelerometers on smartphones," in 2012 Fourth International Conference on Communication Systems and Networks (COMSNETS 2012). IEEE, 2012, pp. 1–9.
2. A. Mosenia, X. Dai, P. Mittal and N. K. Jha, "PinMe: Tracking a Smartphone User around the World," in *IEEE Transactions on Multi-Scale Computing Systems*, vol. 4, no. 3, pp. 420-435, 1 July-Sept. 2018.

Problem Statement

*"Finding an **alternate modality** which can **detect mobility context** of a user, even if the IMU sensors are not used."*

Motivation -- Why Typing?

Static

Walking

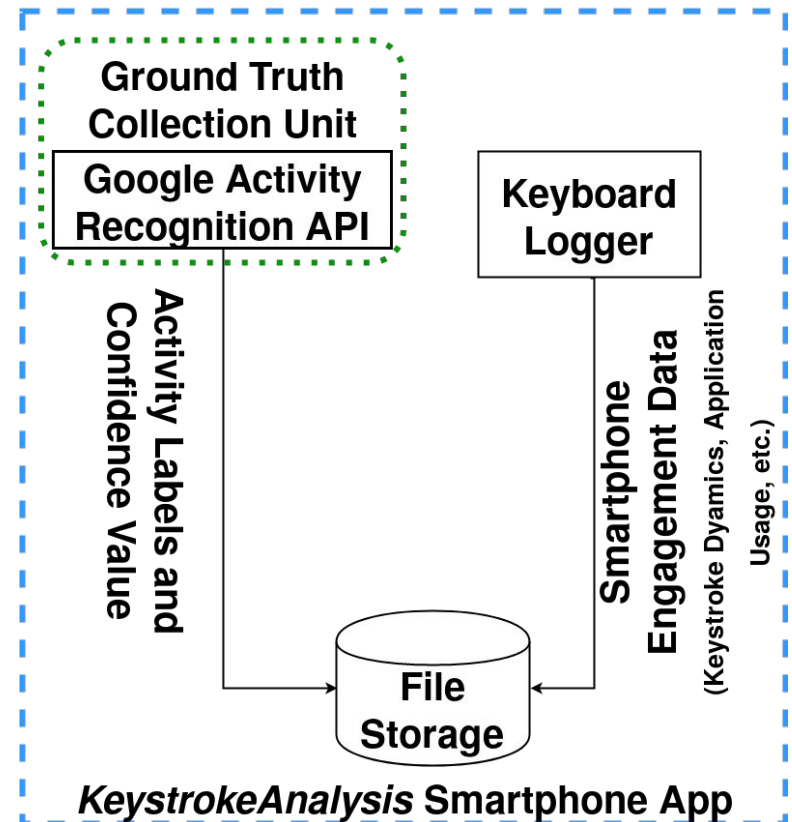- Mobility is indeed **correlated** with typing

Motivation -- Why Typing?

- **Application usage** and **mobility highly correlated**[3]

- Evaluate the opportunities with a pilot study

- **But data collection is challenging**

3. A. Mathur, L. M. Kalanadhabhatta, R. Majethia, and F. Kawsar, "Moving beyond market research: Demystifying smartphone user behavior in India," ACM IMWUT, p. 82, 2017.

Experimental Apparatus

KeystrokeAnalysis -- Application

- Android (8.0+) app

- Custom keyboard

- Ground-Truth: *Google Activity Recognition* API

Ground Truth Collection Unit

Google Activity Recognition API

Keyboard Logger

Activity Labels and Confidence Value

Smartphone Engagement Data (Keystroke Dyamics, Application Usage, etc.)

File Storage

KeystrokeAnalysis Smartphone App

KeystrokeAnalysis -- Keyboard

- QWERTY keyboard

- **We do not log user's messages**
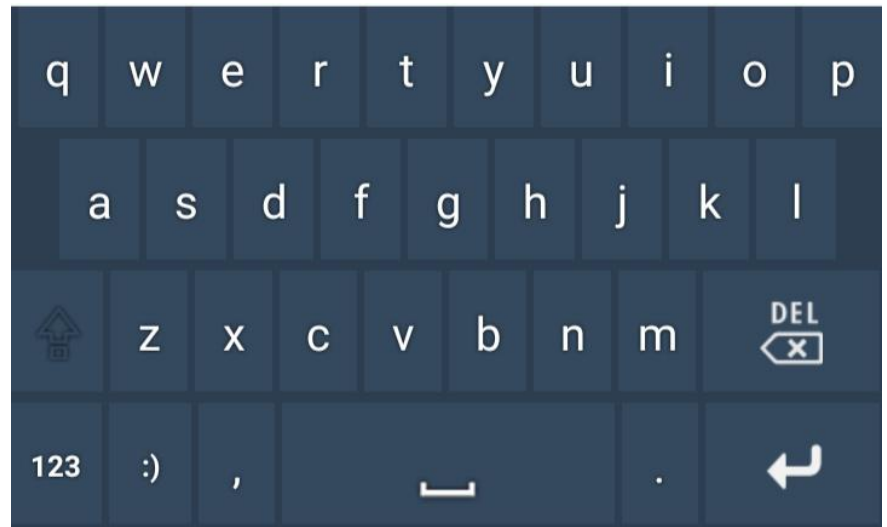
KeystrokeAnalysis -- Event Logger

■ Logs the following data and uploads to the server

Key-press Event Timestamp	The timestamp of the key-press event
Application	Name of the typing application
Special Key-codes	Keycodes of special characters like '@', '*', 'space-bar', 'backspace'
Pressure	Amount of pressure exerted on the touchscreen while typing
Velocity	The velocity of typing in *pixels/sec*
Tap Duration	The amount of time a key is kept pressed
Inter-tap Duration	The time between two subsequent key press events

KeystrokeAnalysis -- Ground-Truth

- **Automated** for *in-the-wild* data collection

- Google Activity Recognition API

  - ❏ Returns **8** physical activity labels

  - ❏ A confidence score

- We consider labels with **confidence score > 70**

Pilot Study

Pilot Study -- Observations
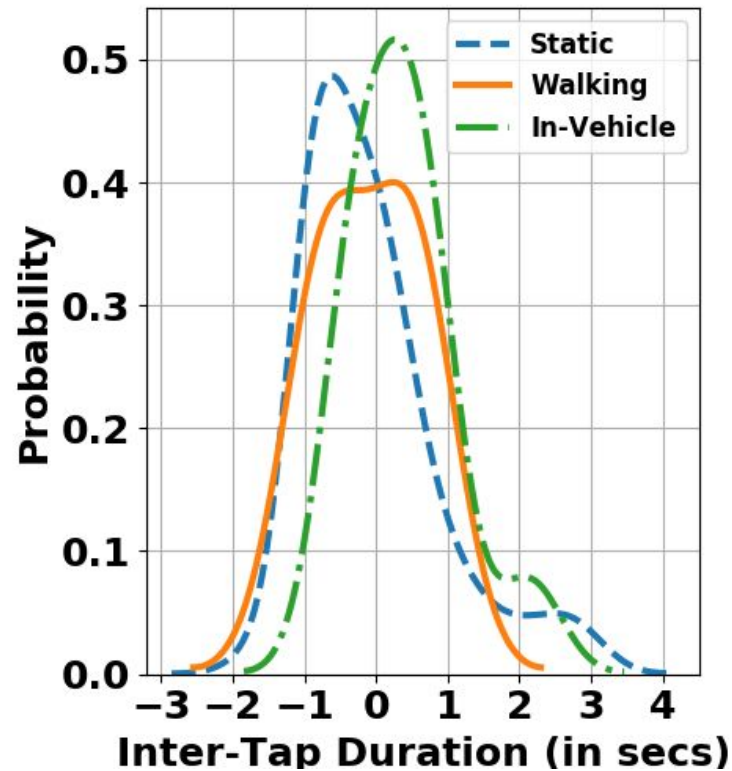
- Inter-tap duration varies with mobility

- **Signatures for detecting mobility present**

Pilot Study -- Observations
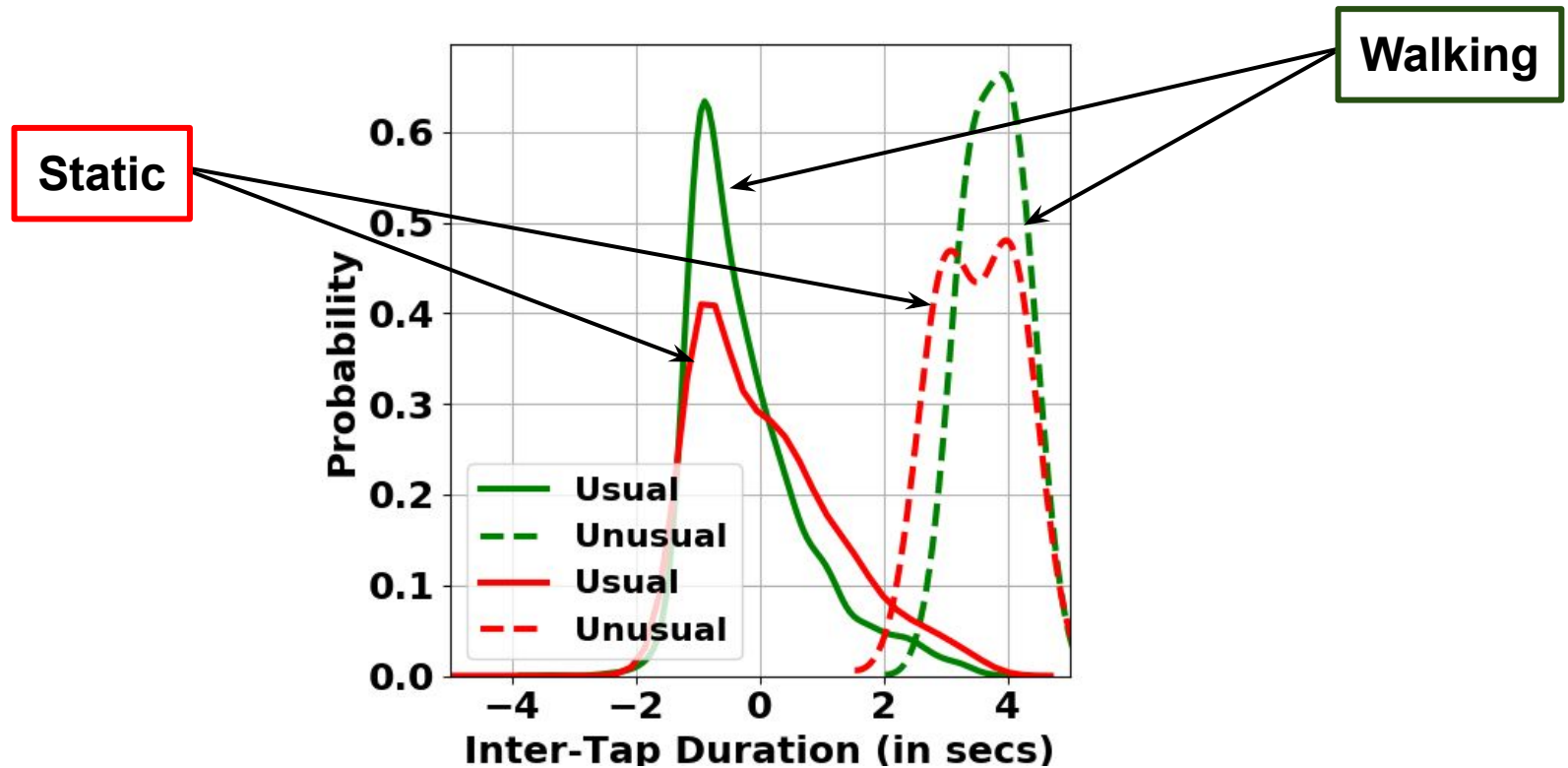
■ **Typing varies even in the same mobility**

Pilot Study -- Observations

1

2

3

■ **Factors like handedness come into play**

Objective

"*Development of a framework named **ConType** which can **detect mobility context** of a user from **typing and smartphone engagement patterns**.*"

Methodology

Handling Modes of Typing

Data Collected from
the Client App

Handling Modes of Typing

Data Collected from the Client App → **Clustering the Modes**

Handling Modes of Typing

```
┌─────────────────────┐        ┌─────────────────────┐
│ Data Collected from │───────▶│ Clustering the Modes│
│   the Client App    │        │                     │
└─────────────────────┘        └─────────────────────┘
                                          │
                                          ▼
                               ┌─────────────────────┐
                               │ Two Factors --      │
                               │ 1.  Tap Duration    │
                               │ 2.  Inter-tap       │
                               │         Duration    │
                               └─────────────────────┘
```
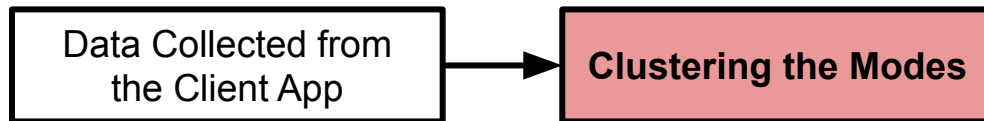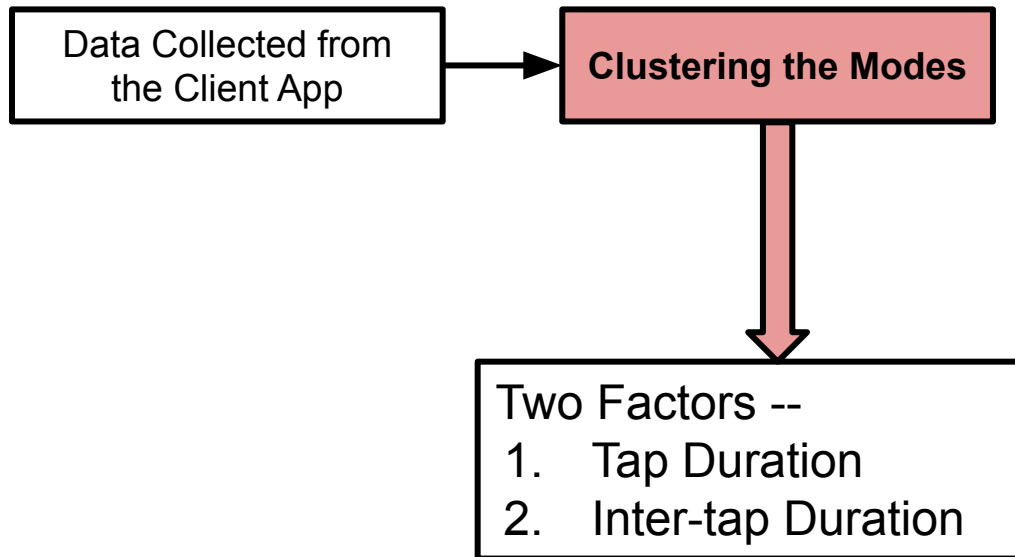
Handling Modes of Typing

Sessionization of Typing Data
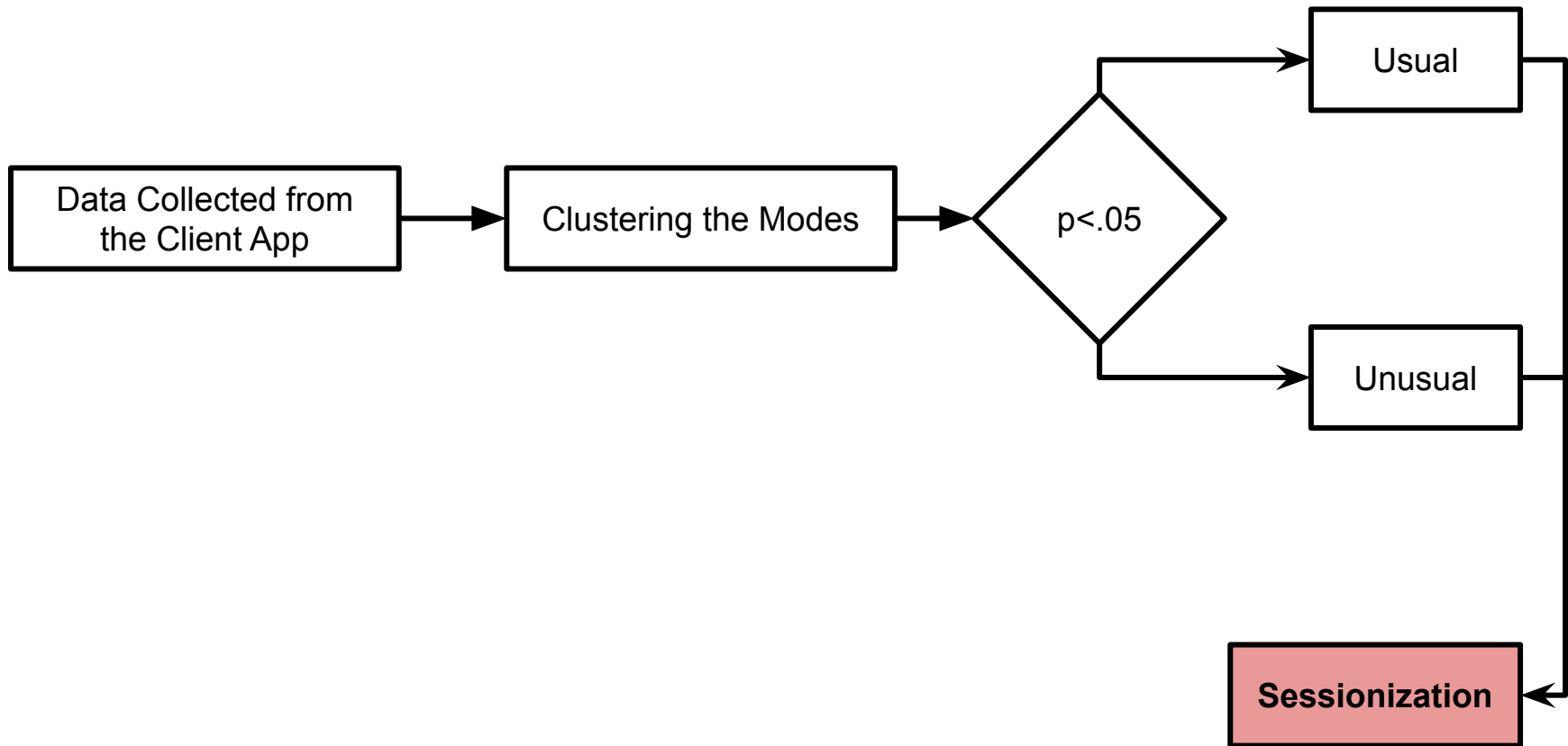
Sessionization of Typing Data
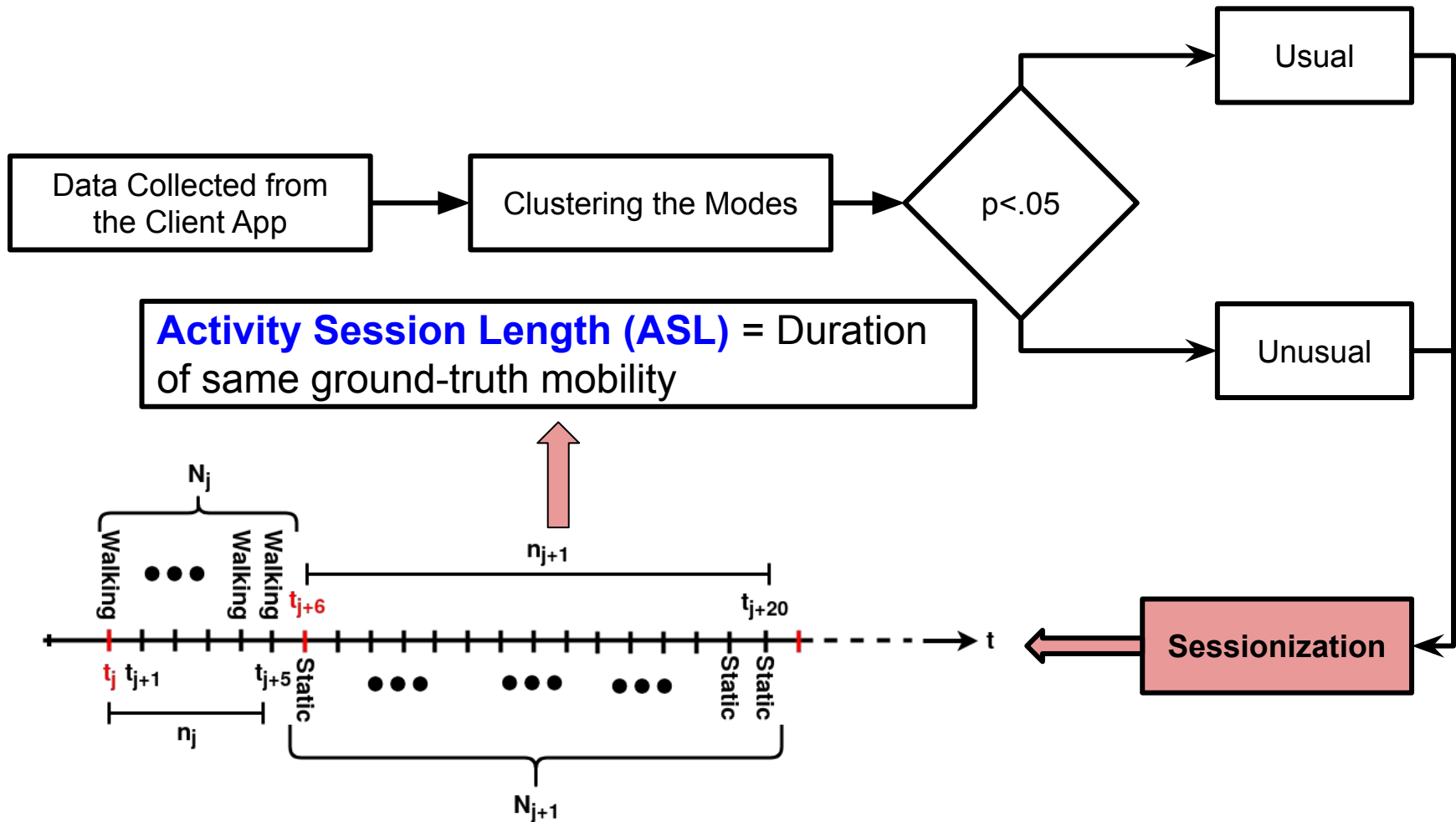
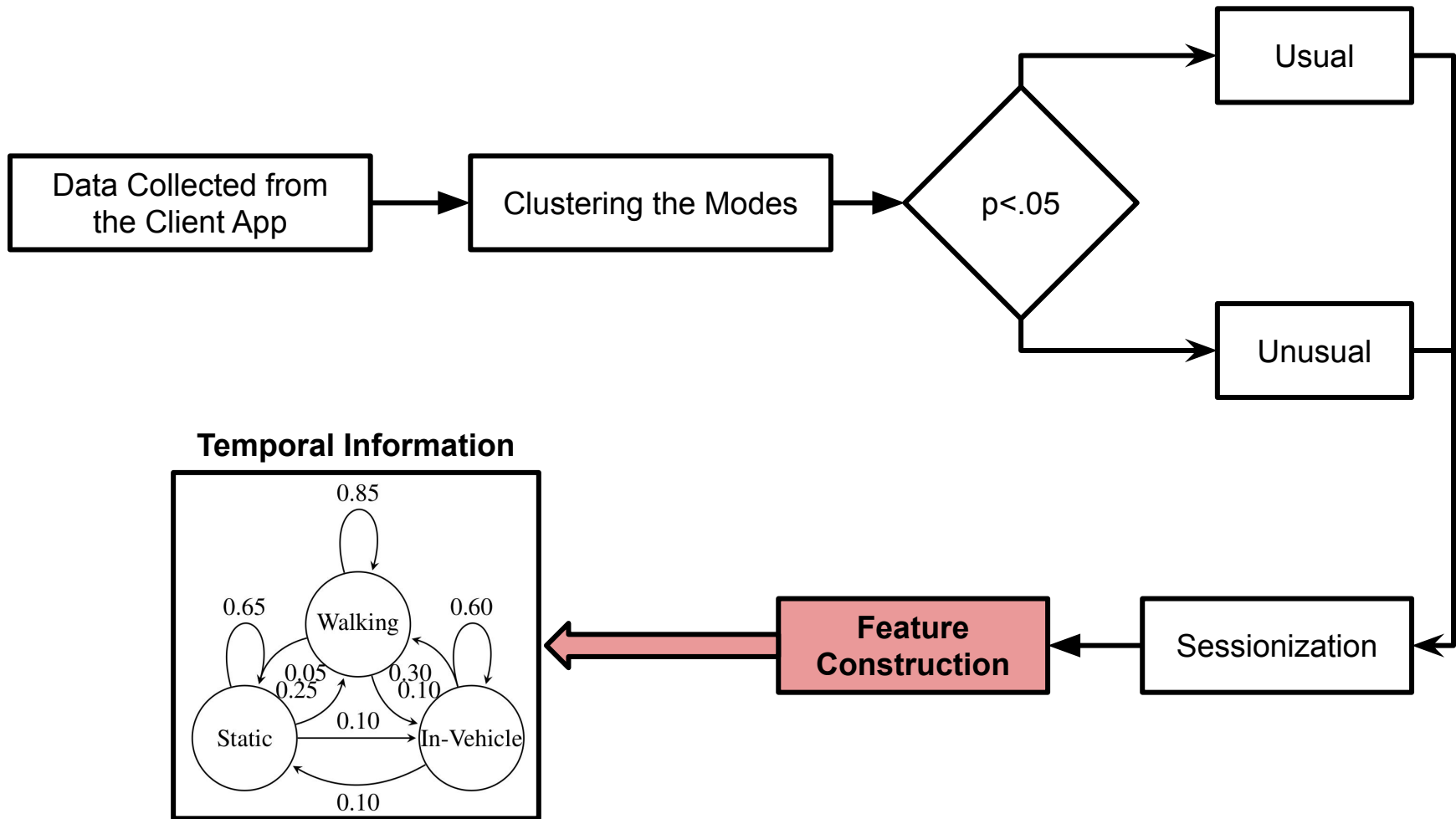# Sessionization of Typing Data

Feature Construction
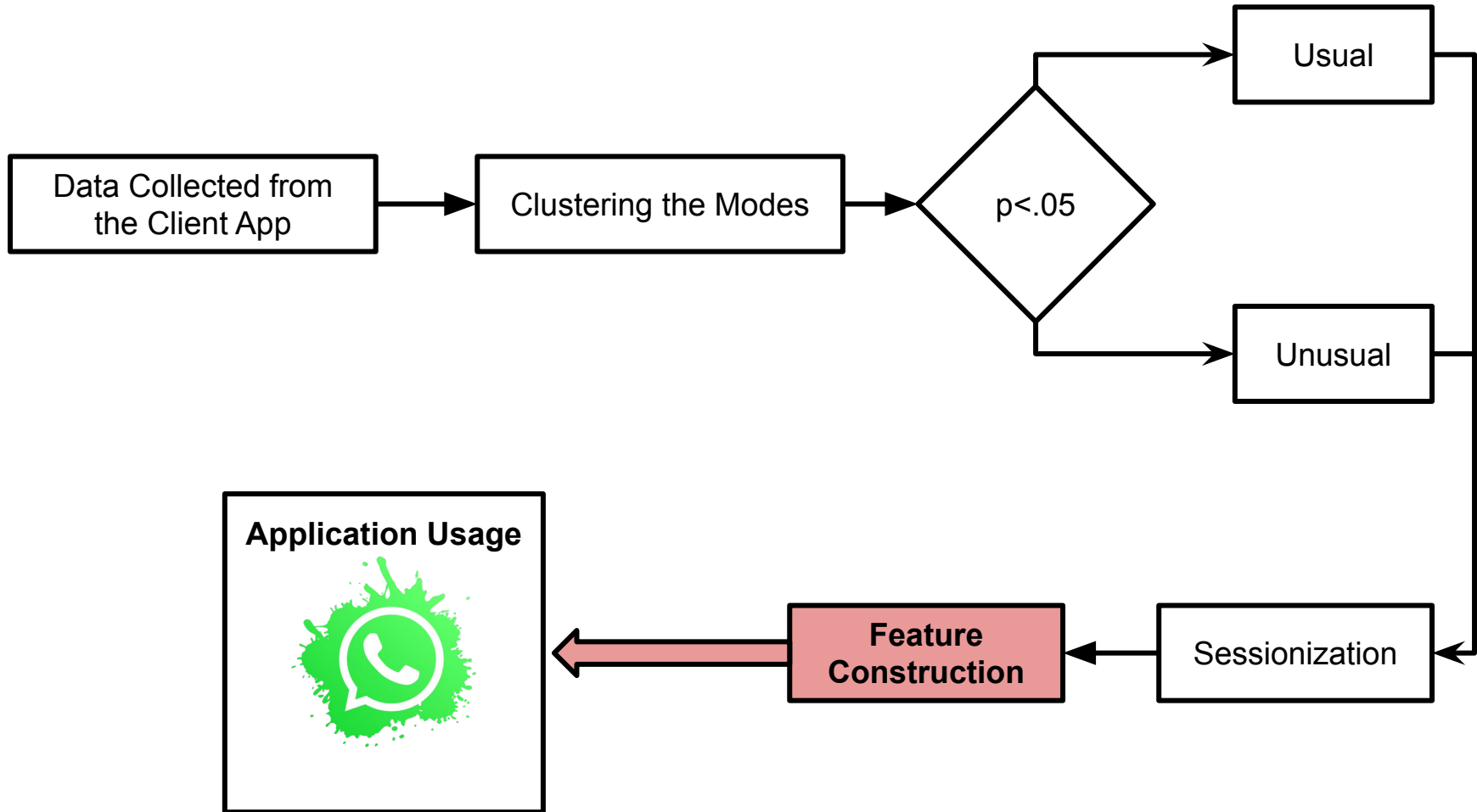
Feature Construction

Feature Construction

Feature Construction

Data Collected from the Client App → Clustering the Modes → p<.05

p<.05 → Usual

p<.05 → Unusual

Usual, Unusual → Sessionization → Feature Construction → Typing Mode

Feature Construction

Data Collected from the Client App → Clustering the Modes → p<.05 → Usual / Unusual

Typing Mode

Feature Construction ← Sessionization

Mobility Detection Model

Mobility Detection Model

Detects 3 mobility classes -- Static, Walking, In-vehicle
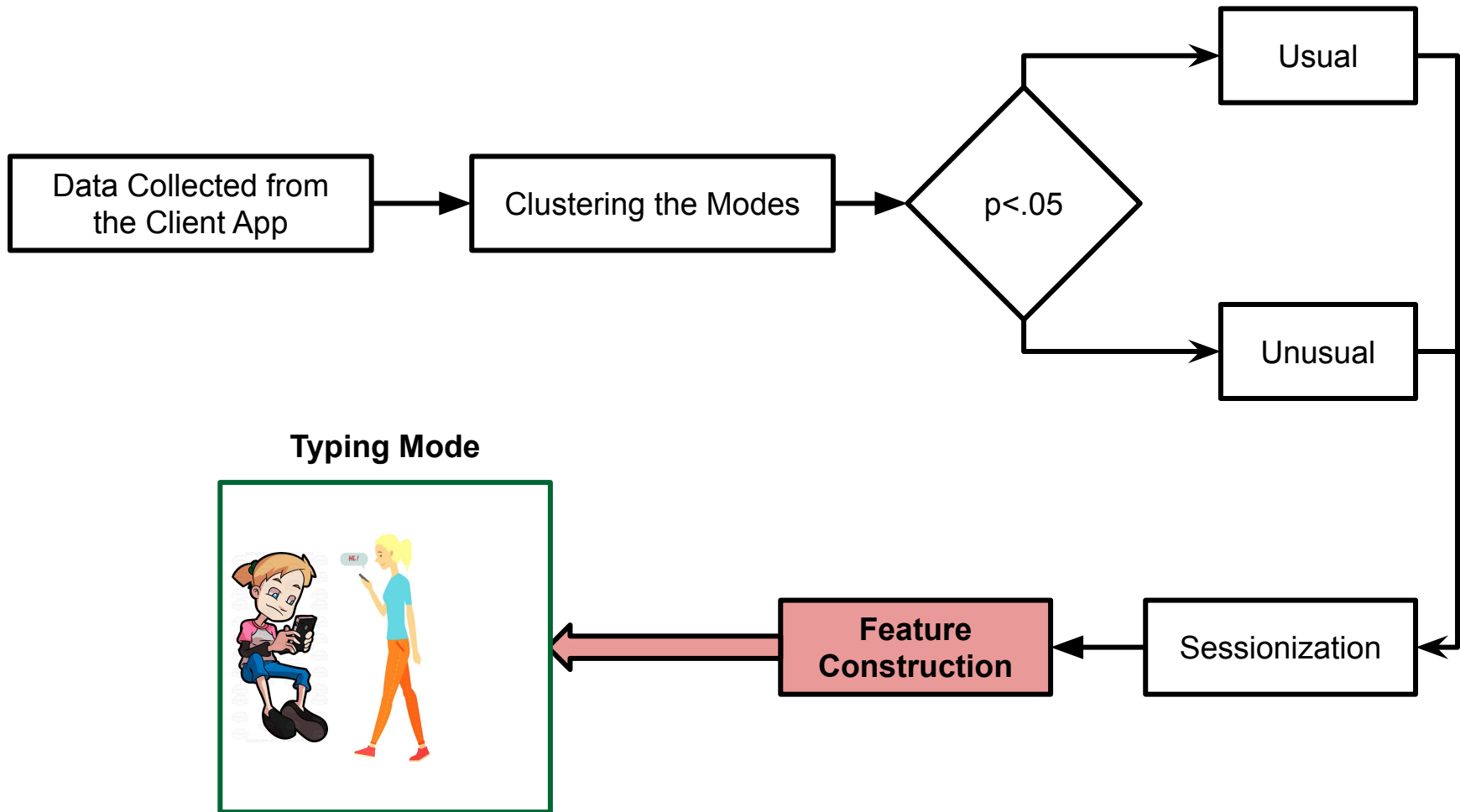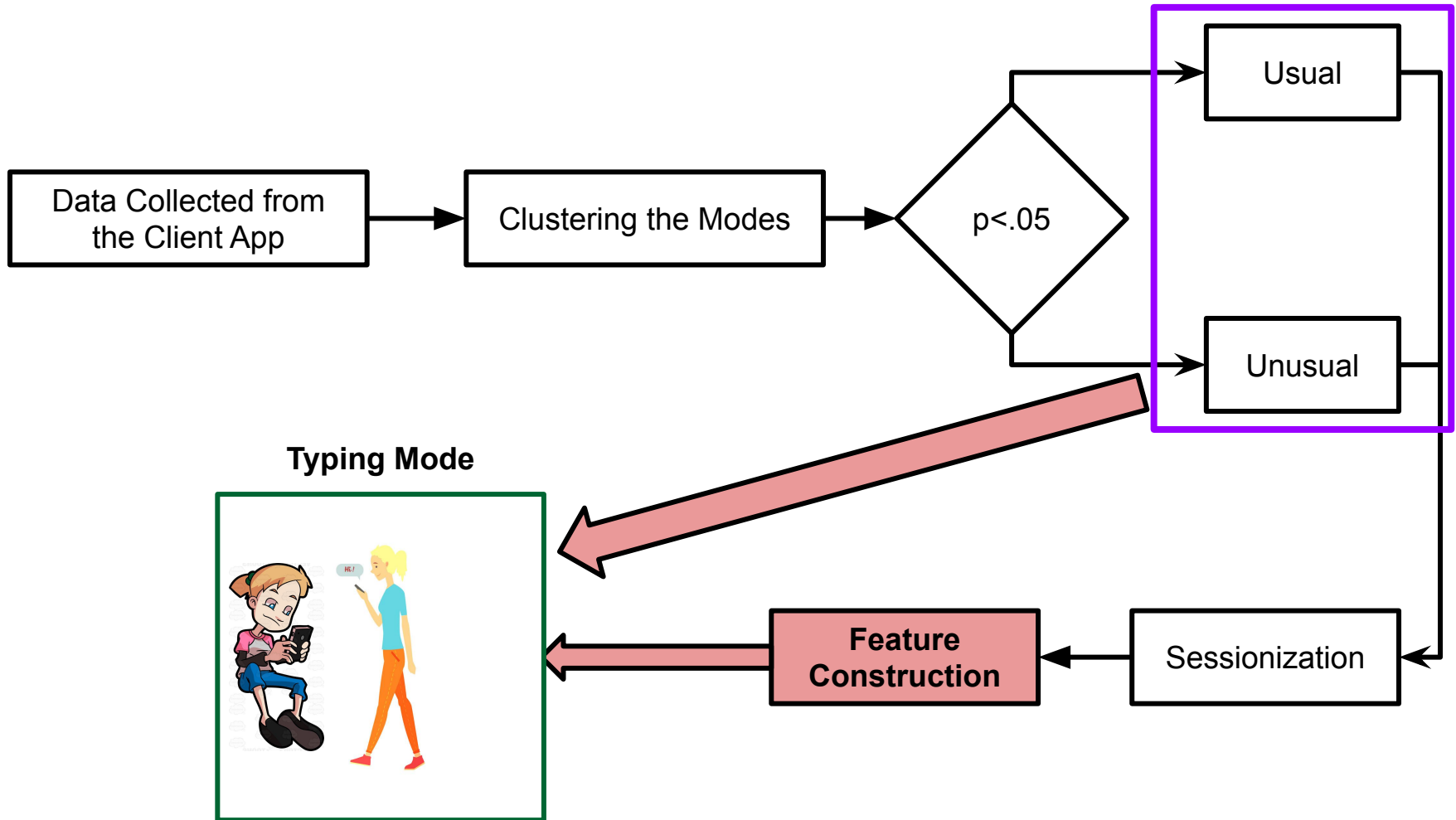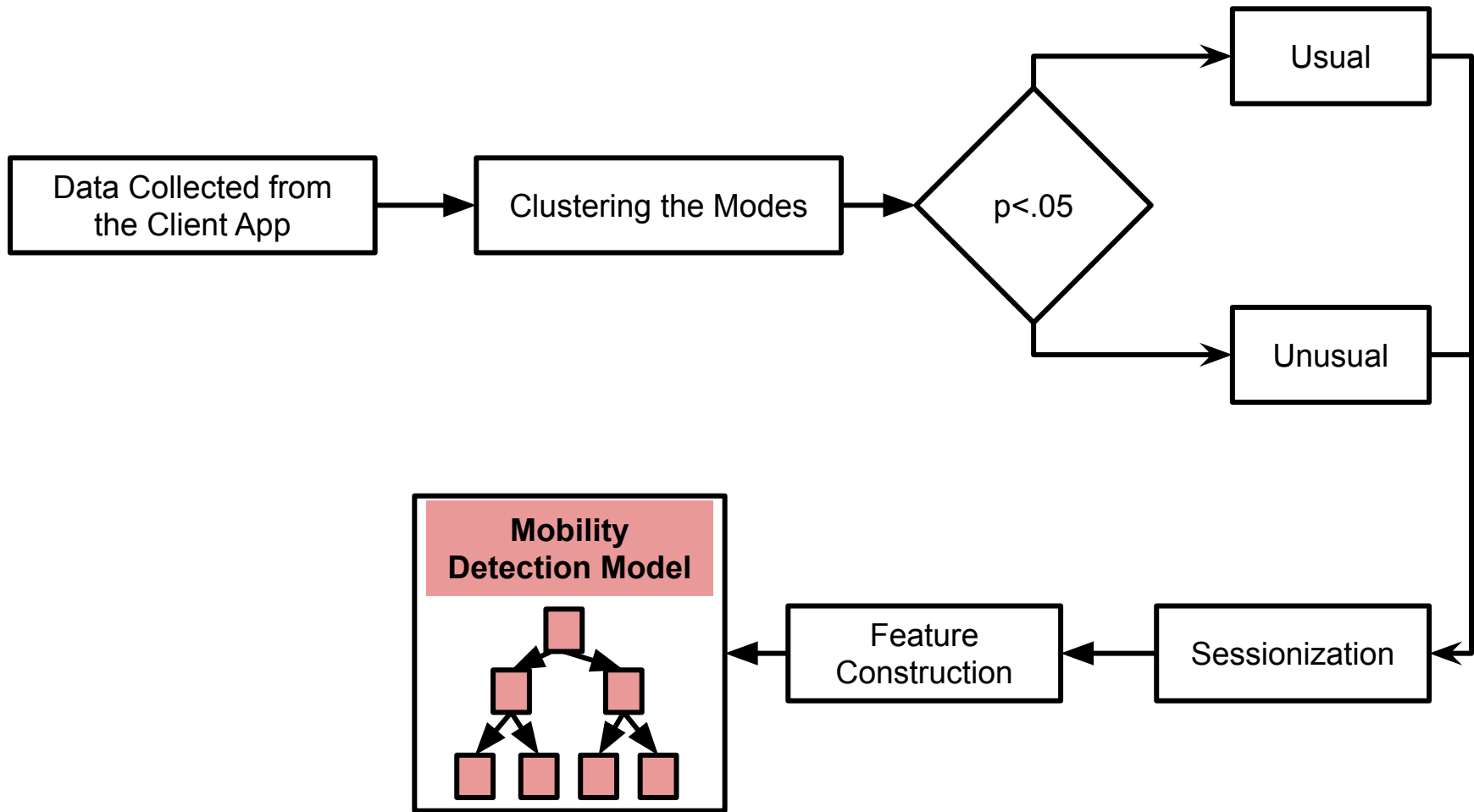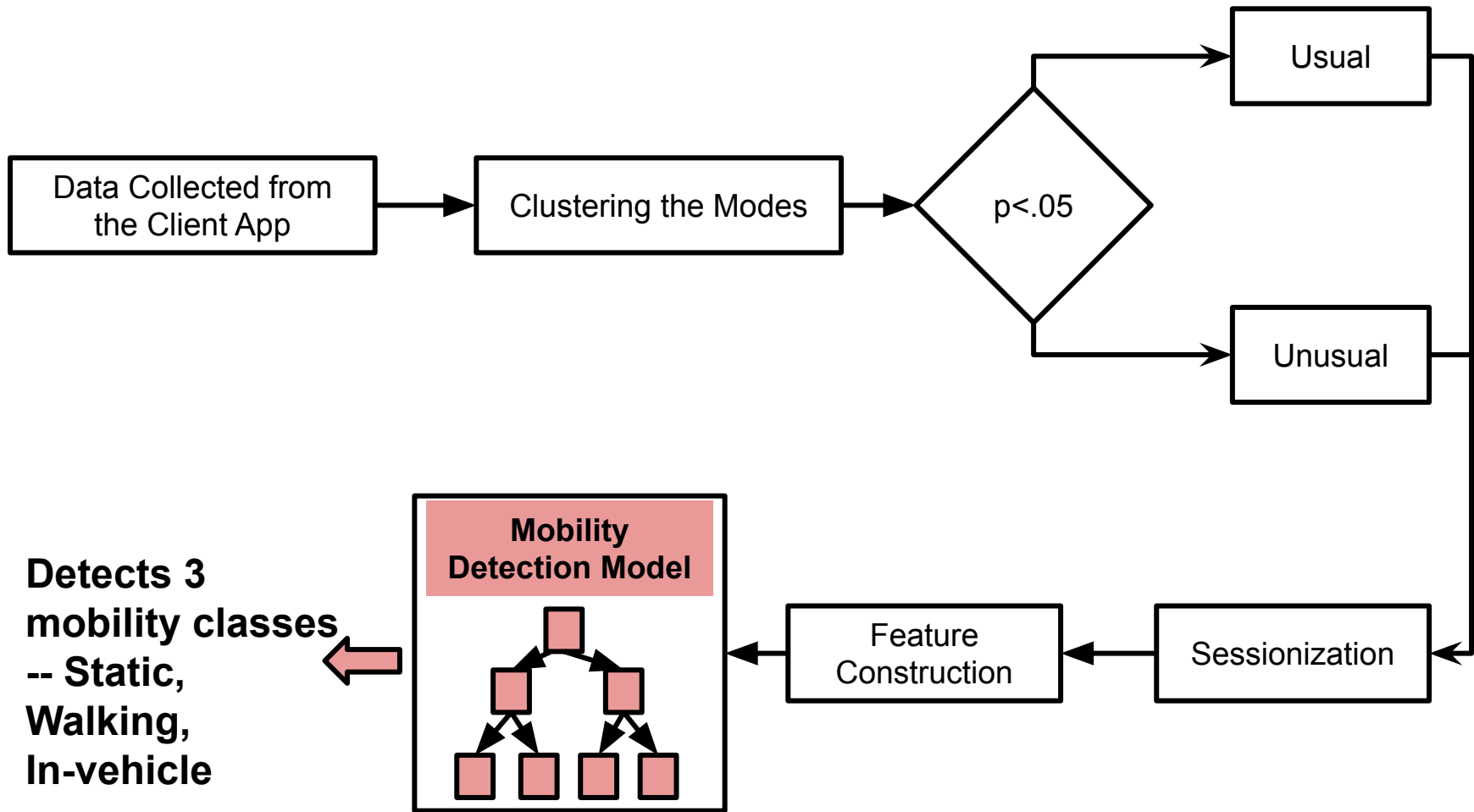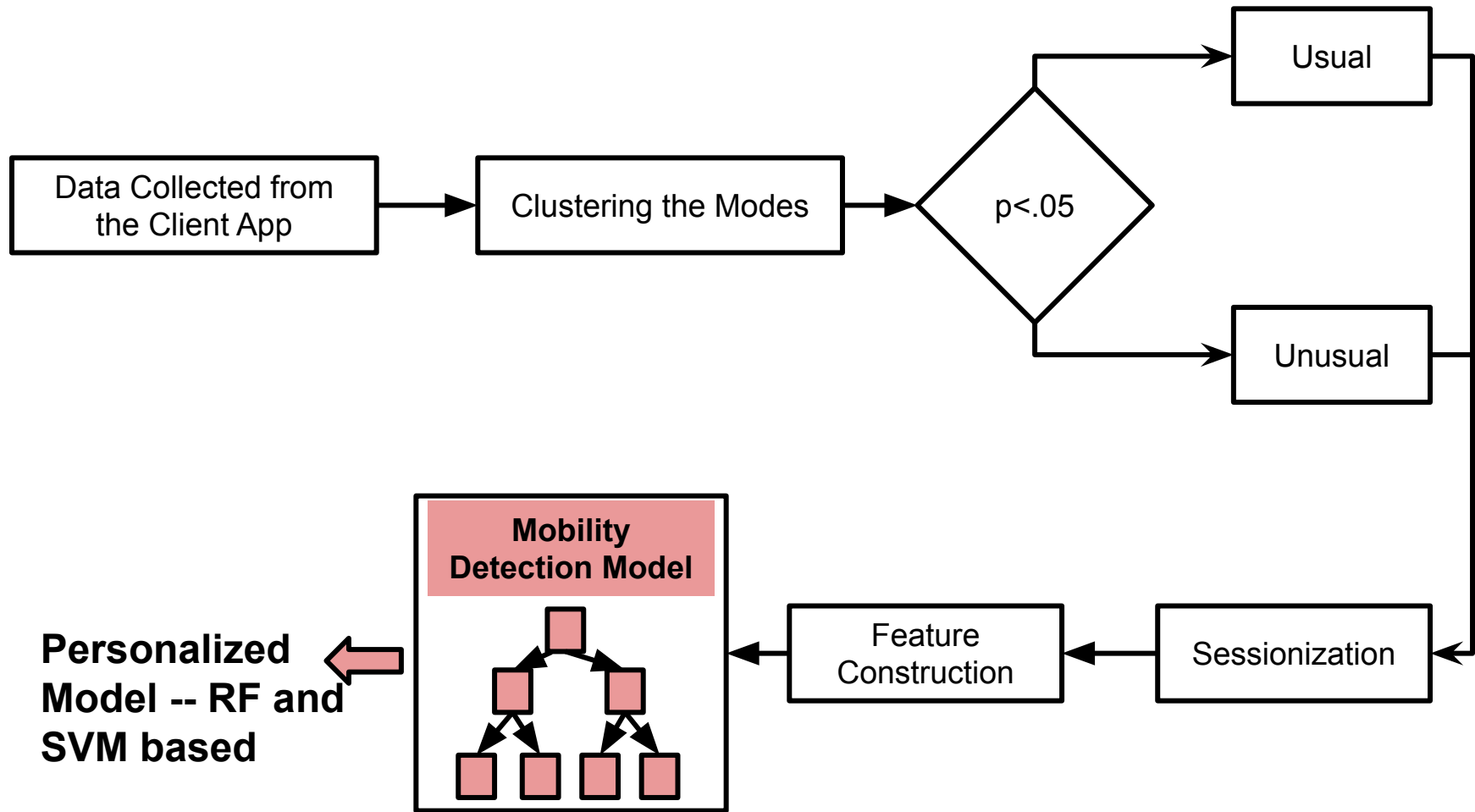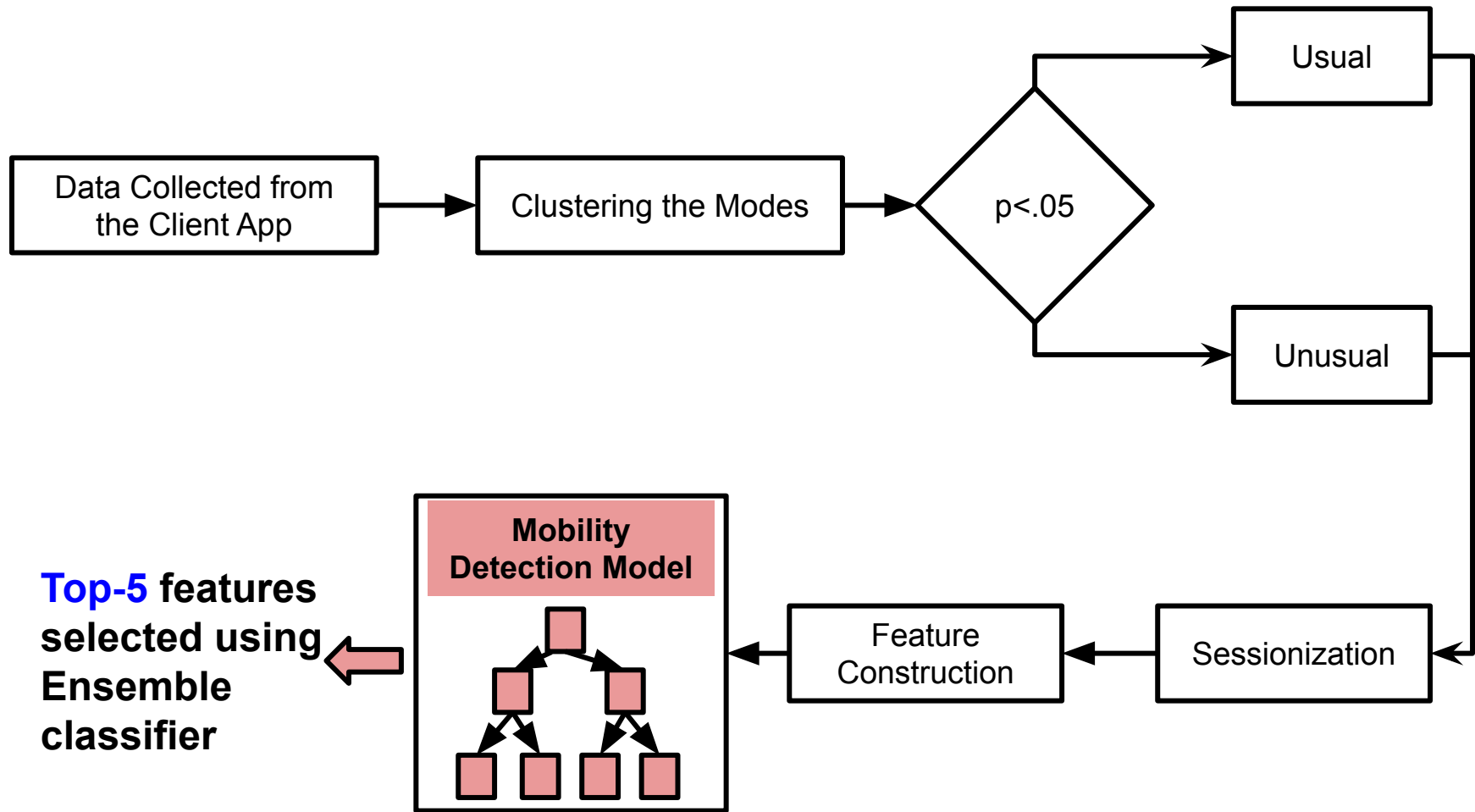
Mobility Detection Model
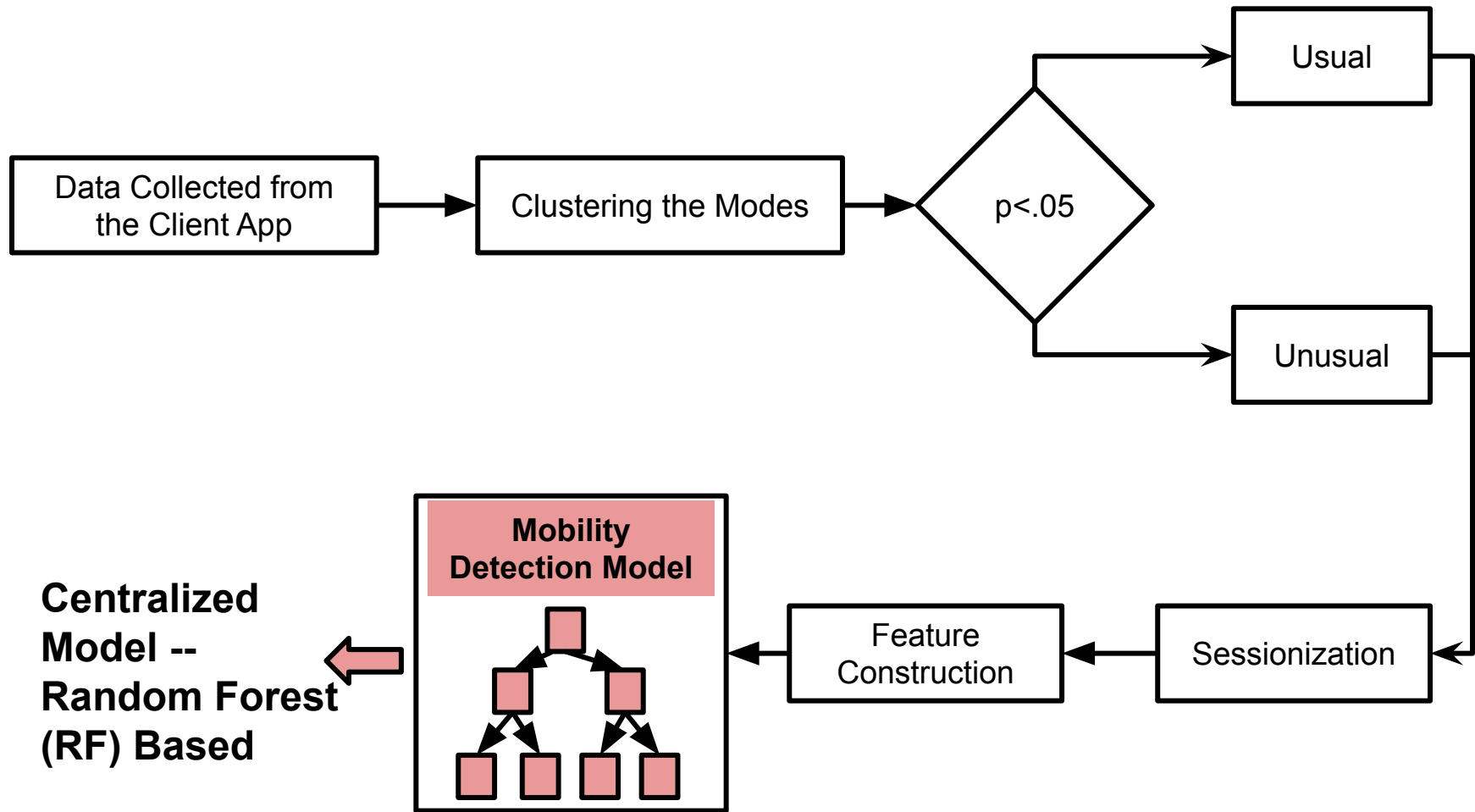
Mobility Detection Model

Mobility Detection Model

Evaluation

Dataset Details

- In-the-wild study

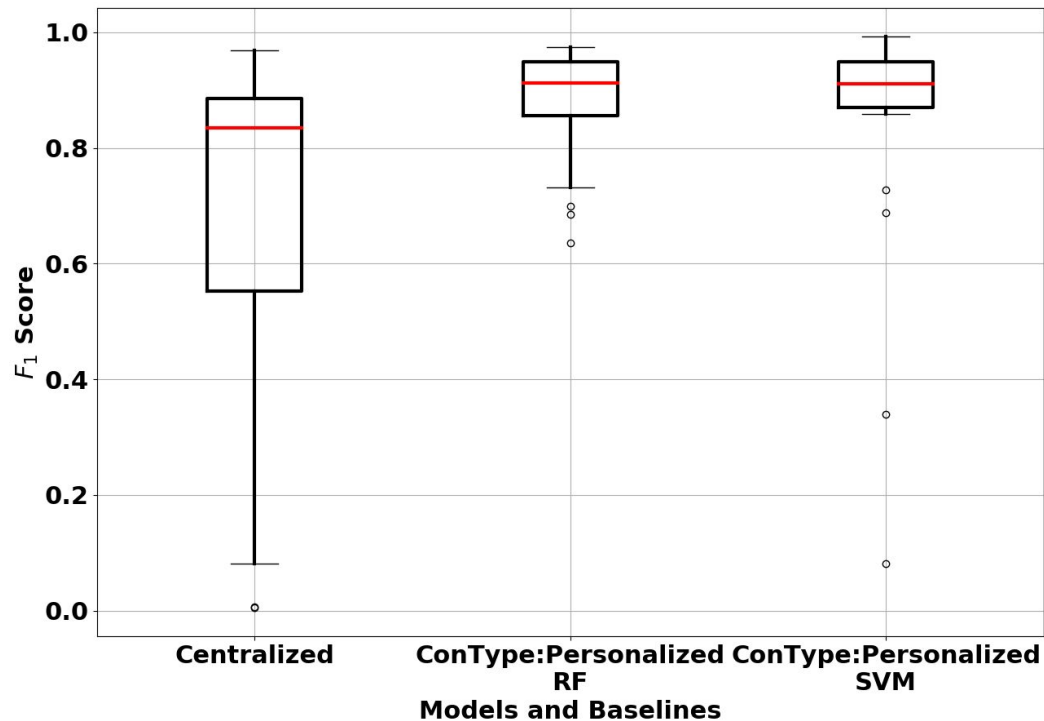| Total number of participants	53
Total number of valid participants	30
Total volume of valid typing instances	~3M
Total number of unique applications recorded	392
Mean duration of ground-truth contexts	984.57 hours
Total duration	2 months

Preparing the Data

■ Huge class imbalance

■ Balance using SMOTE[5]

■ Inadequate data for 5

users -- **Removed**

5.   N. V. Chawla, K. W. Bowyer, L. O. Hall, and W. P. Kegelmeyer, "Smote: Synthetic minority over-sampling technique," J. Artif. Int. Res., pp. 321–357, 2002.
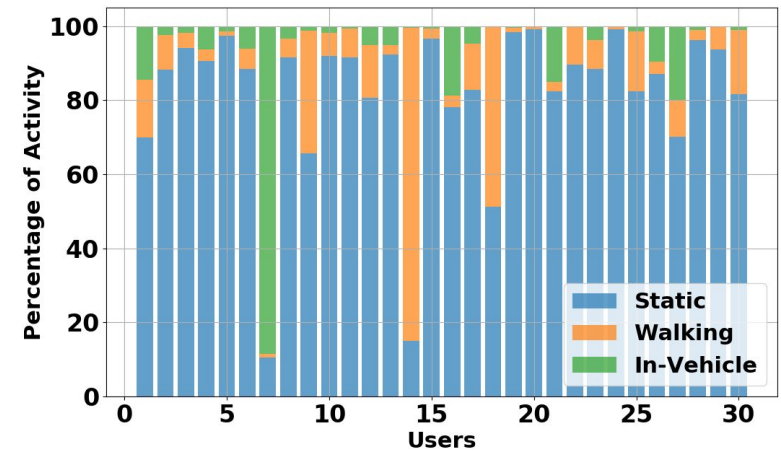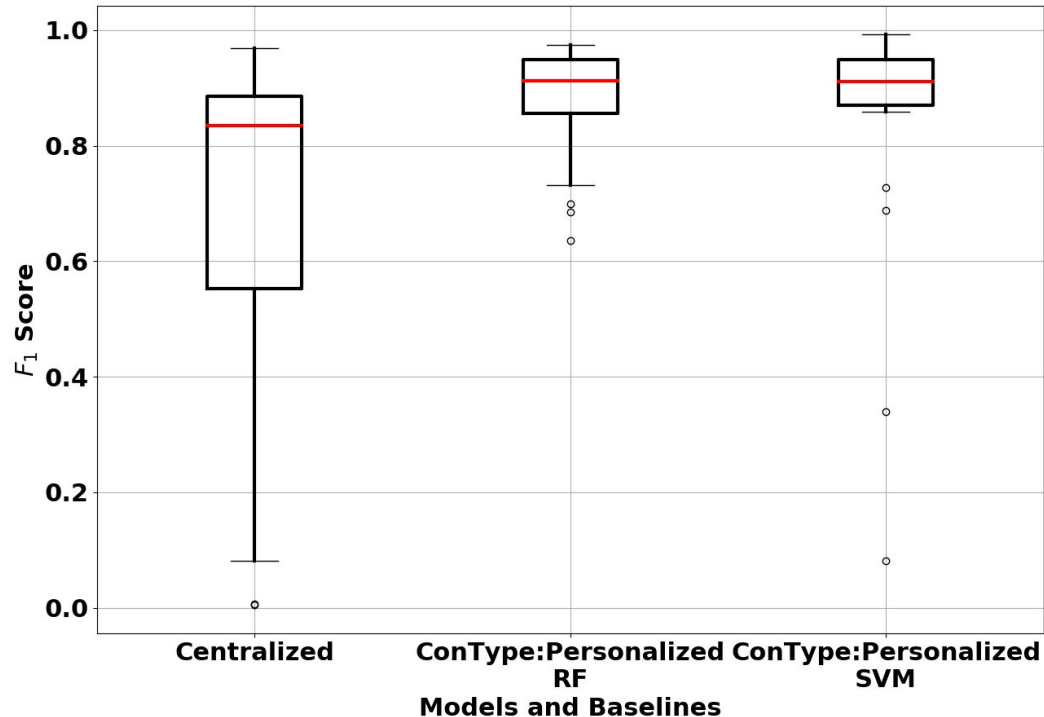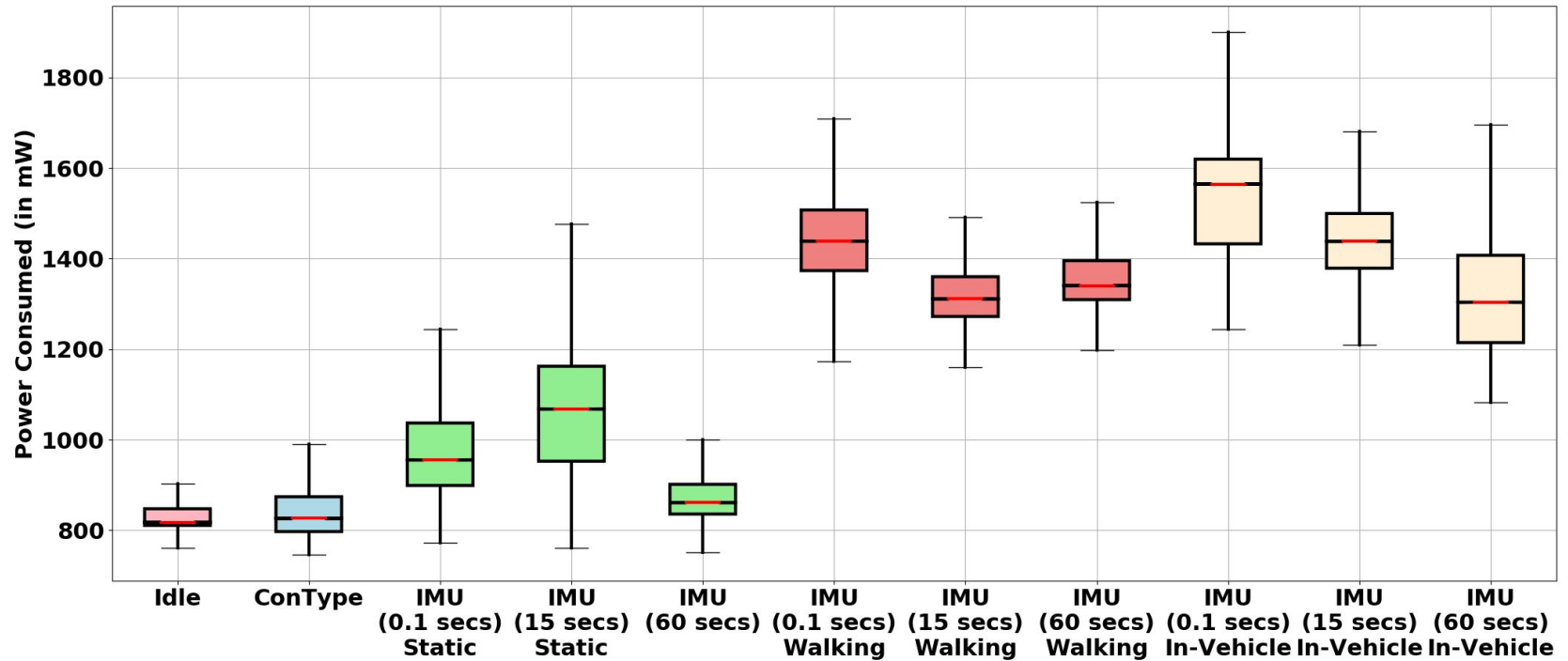
Centralised vs Personalised Model

- Centralised model (RF-based) **fails** to capture

  the personalised signatures

Significant Observations

- Typing Modes --

  ❑ **88%** of participants has two modes of typing

  ❑ Important feature for **8%** of the participants

Power Consumption

- **Stealthily** detects mobility contexts with low energy footprints

Conclusion

Conclusion

- Identified alternate modalities like typing and smartphone engagement for detecting mobility.

- We develop the framework *ConType*, which can sniff mobility from keystroke patterns.

- *ConType*, does not require IMU data for mobility detection.

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Thank You

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