Understanding and Managing Notifications

Swadhin Pradhan[1], Lili Qiu[1], Abhinav Parate[2], and Kyu-Han Kim[3].

[1]UT Austin **[2]Lumme Inc.** **[3]Hewlett-Packard Laboratories**

INFOCOM 2017

May 4, 2017

Problem with notifications

Tara Moore via Getty Images

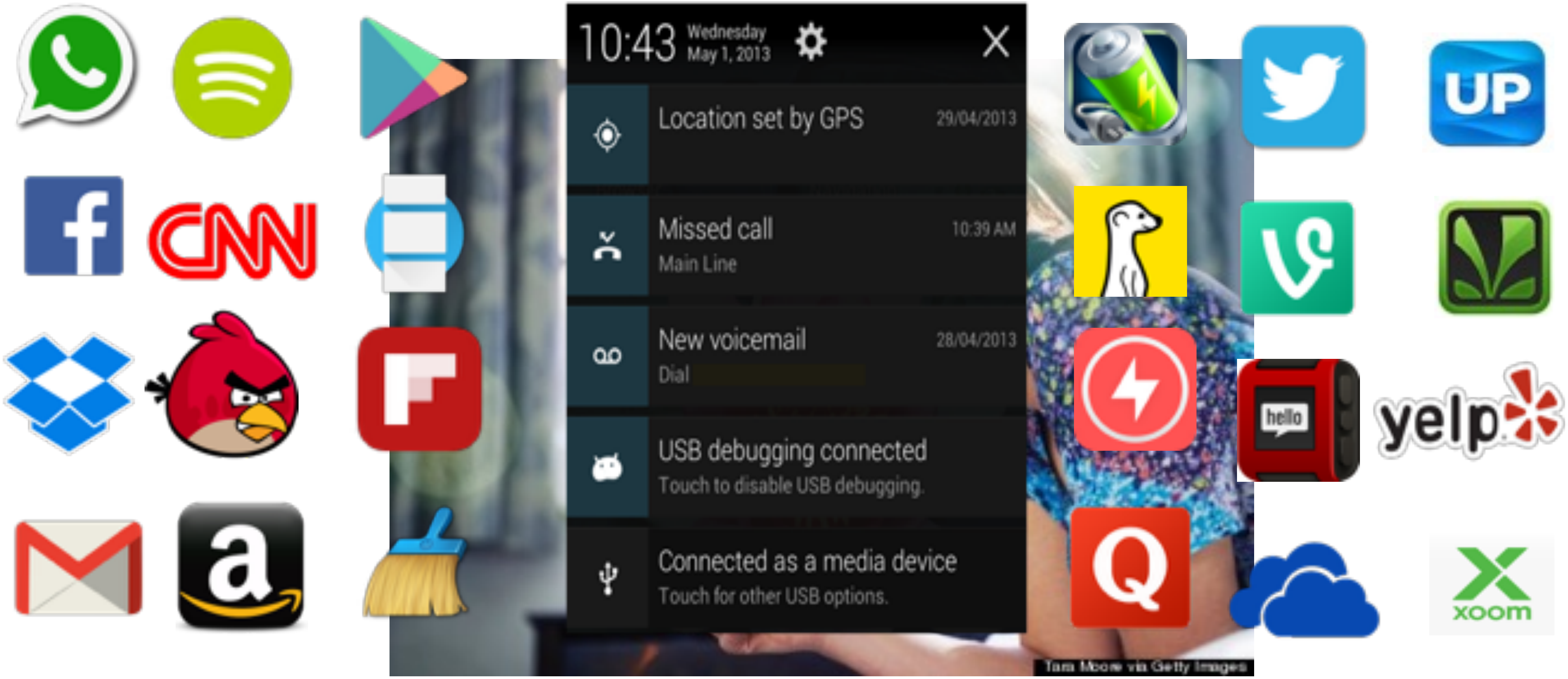
Problem with notifications

Tara Moore via Getty Images

Problem with notifications

Tara Moore via Getty Images

Problem with notifications



10:43 Wednesday May 1, 2013

Location set by GPS 29/04/2013

Missed call 10:39 AM
Main Line

New voicemail 28/04/2013
Dial

USB debugging connected
Touch to disable USB debugging.

Connected as a media device
Touch for other USB options.

Tom Moore via Getty Images

Problem with notifications

Problem with notifications

- Too many
  - ➢ Overwhelming
  - ➢ Information overload

Problem with notifications

- Too many
  - Overwhelming
  - Information overload

Problem with notifications

- Too many
  - ➢ Overwhelming
  - ➢ Information overload

- Interrupting at inopportune moments
  - ➢ Disrupting tasks
  - ➢ Interfering lifestyle
- Demanding high responsiveness
  - ➢ High attention demand .. (Stress)

How to schedule notifications ?

- Scheduling *important notifications* at *opportune moments*

How to schedule notifications ?

- Scheduling *important notifications* at *opportune moments*

Importance

How to schedule notifications ?

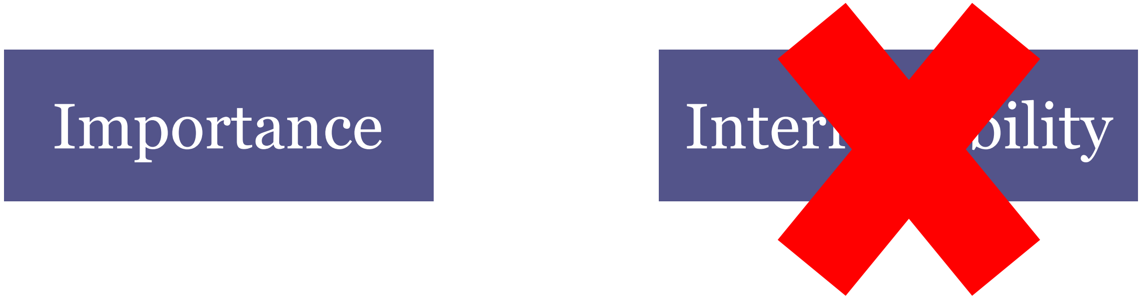
- Scheduling *important notifications* at *opportune moments*

Importance

Interruptibility

How to schedule notifications ?

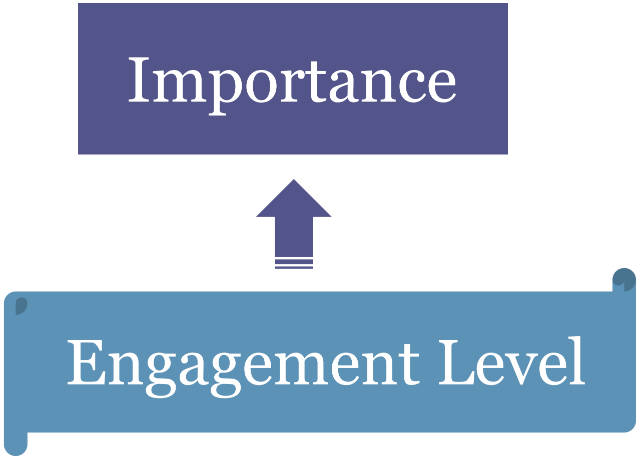
- Scheduling *important notifications* at *opportune moments*



CHI ‘03
TOCHI ‘05
CHI ’10
TOCHI ‘13
UBICOMP ’14
…

How to schedule notifications ?

- Scheduling *important notifications* at *opportune moments*



Importance

Engagement Level

- App Launch
- Reading
- Dismissing
- Ignoring
- *Context* …

Remaining Outline

- Datasets
- Insights gained from the data
- Assessing notification importance
- Building a notification manager
- Conclusion

Evaluation datasets

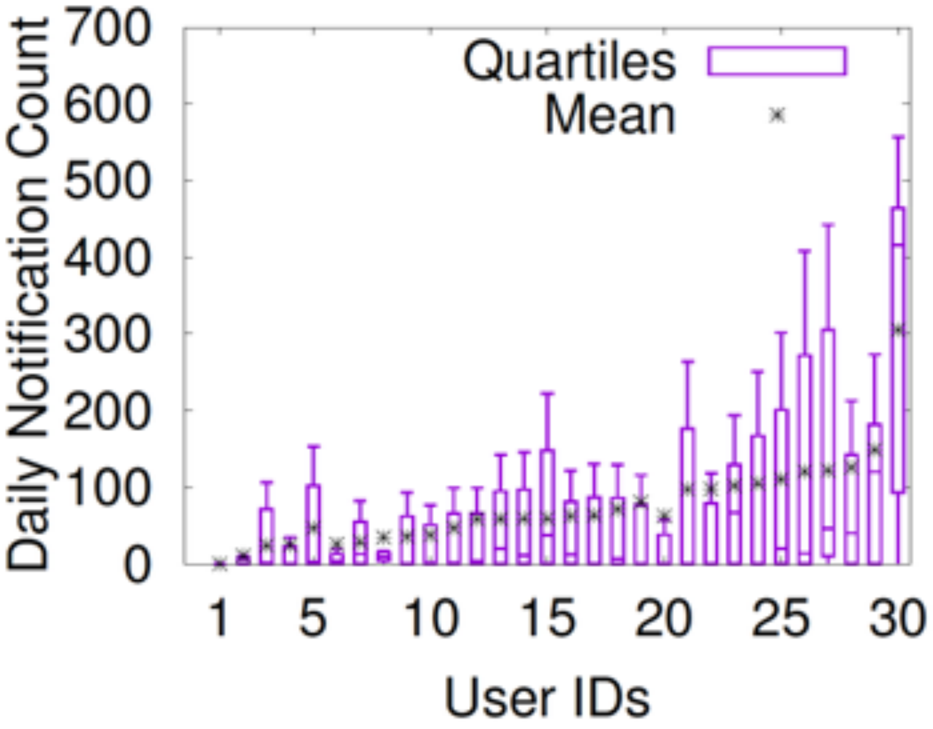
Evaluation datasets

- Data Set – I (*Notifbase App*)
  - ➢ **40** users recruited (30 users data > 2 weeks)
  - ➢ App usage, Screen on/off, Wi-Fi status, ringer mode, sound level, notification properties, shade opening, notification action etc.
  - ➢ Android Accessibility service used

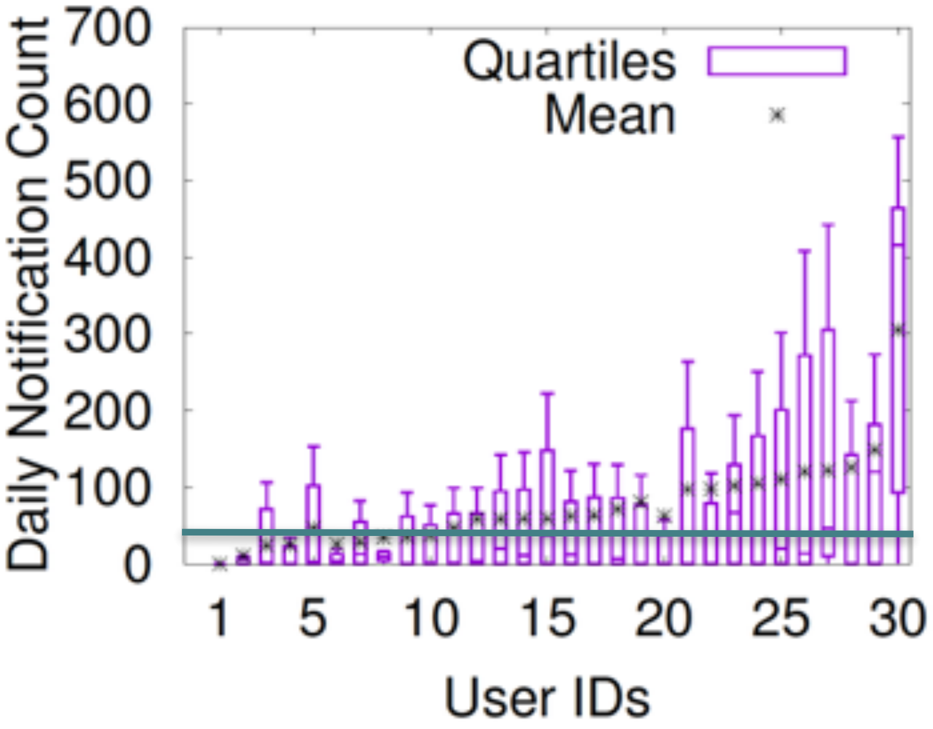
- Data Set – II (*Snotify App*)
  - ➢ **12** users recruited from the above set
  - ➢ **Explicit feedbacks** from users for perceived importance (Online survey of **402** users)

Notifications are disrupting

Notifications are disrupting

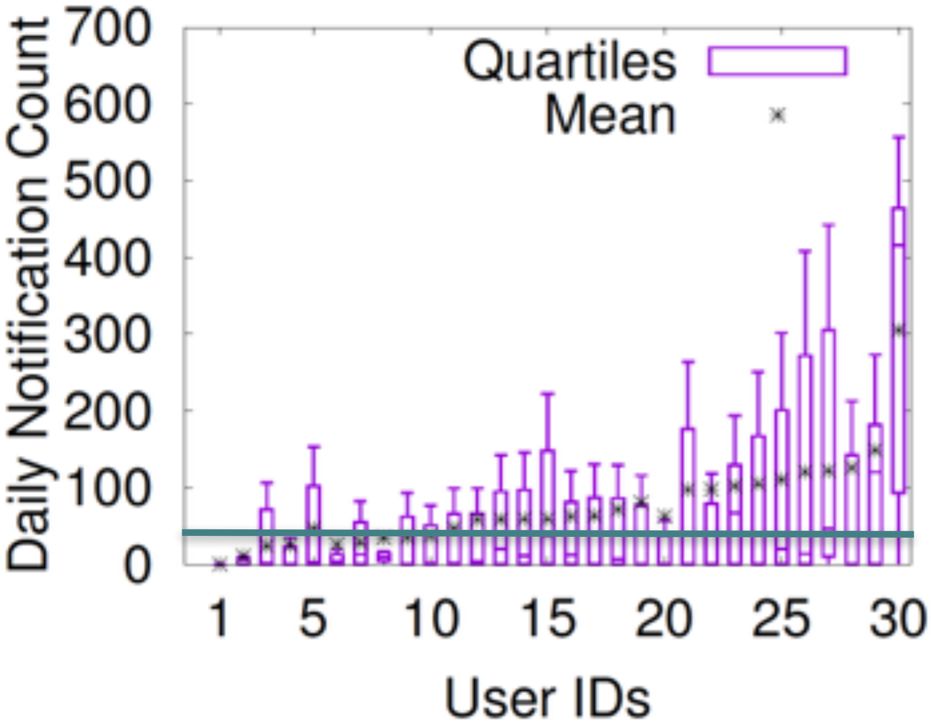


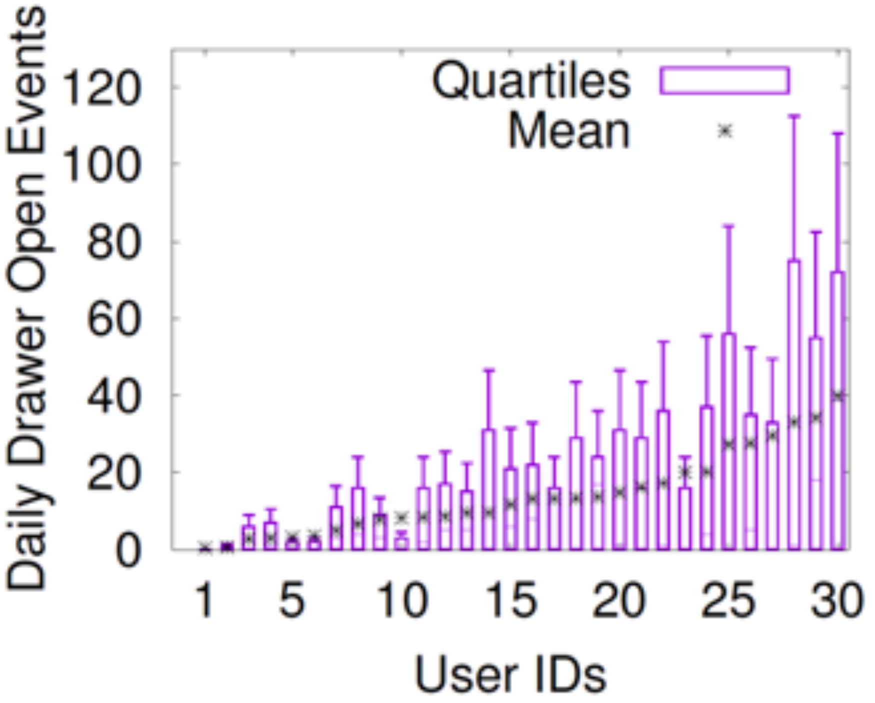
Notifications are disrupting



Receives **~60 notifications/**day

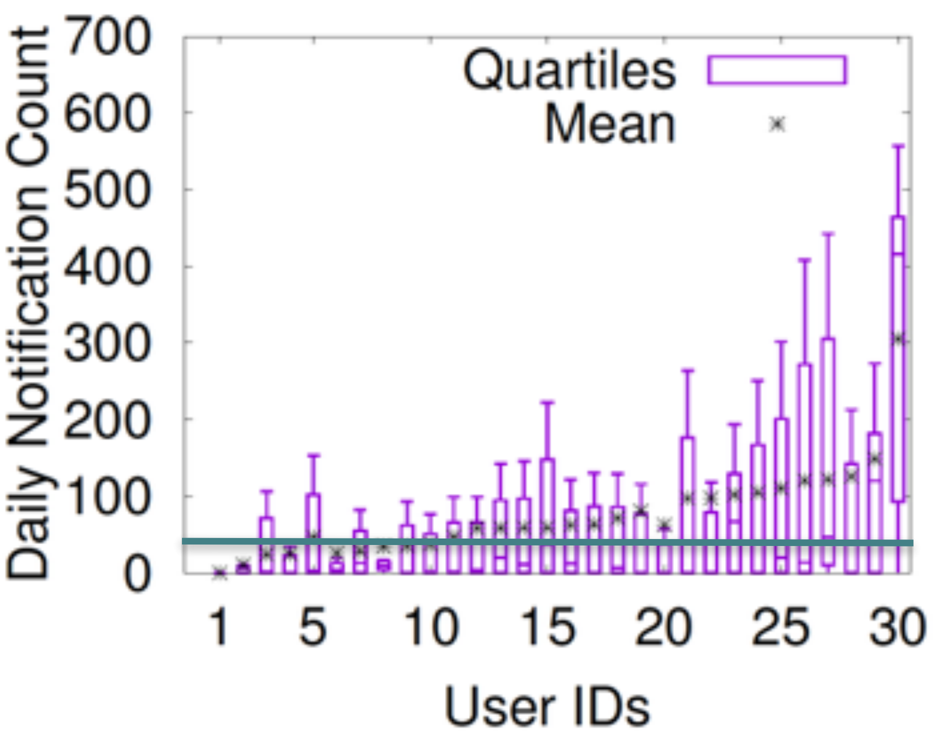
Notifications are disrupting

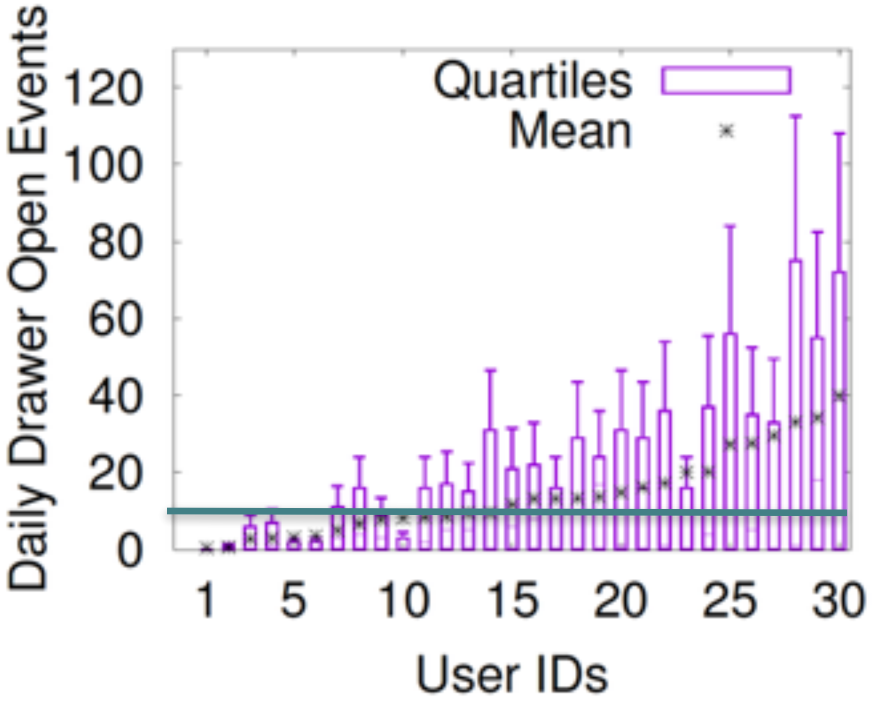




Receives **~60 notifications/**day

Notifications are disrupting



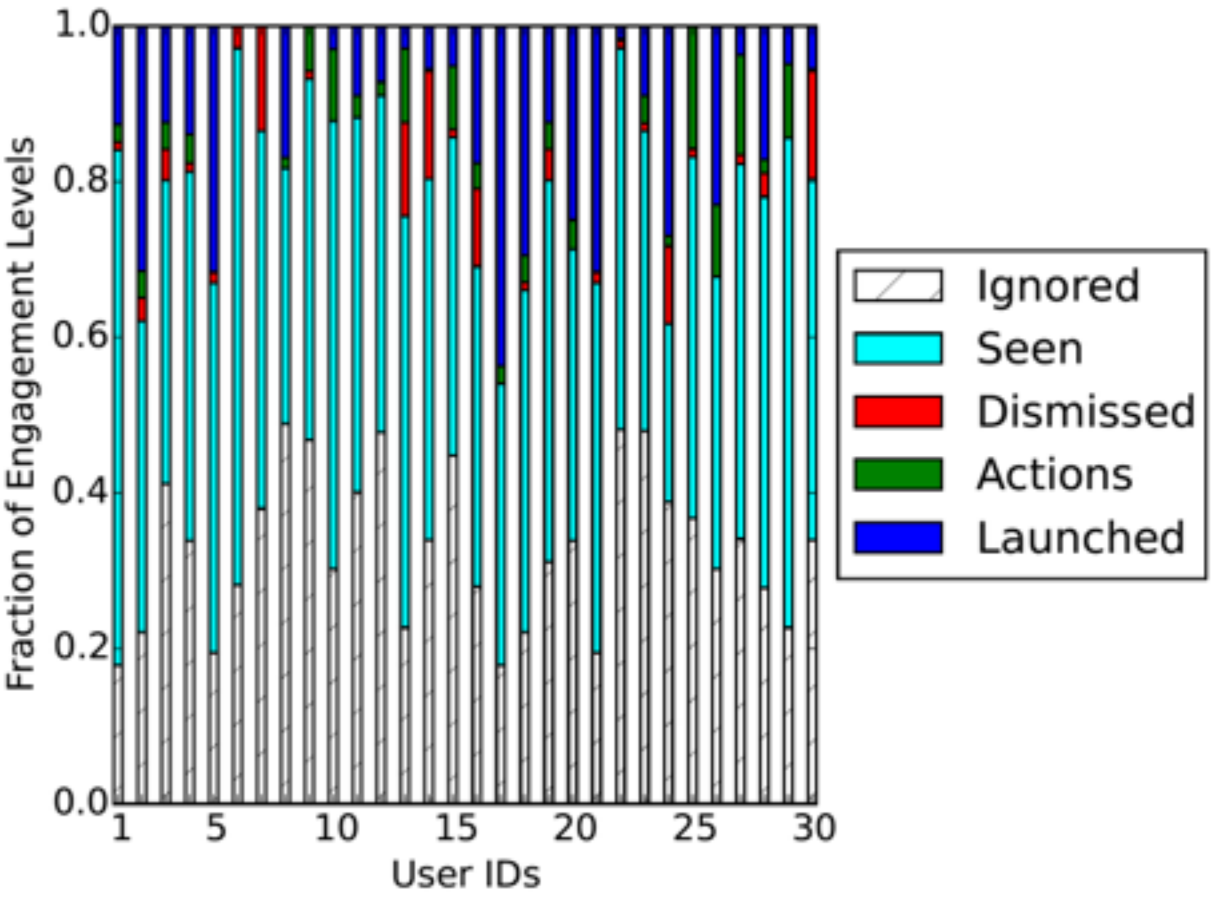


Receives **~60 notifications/**day

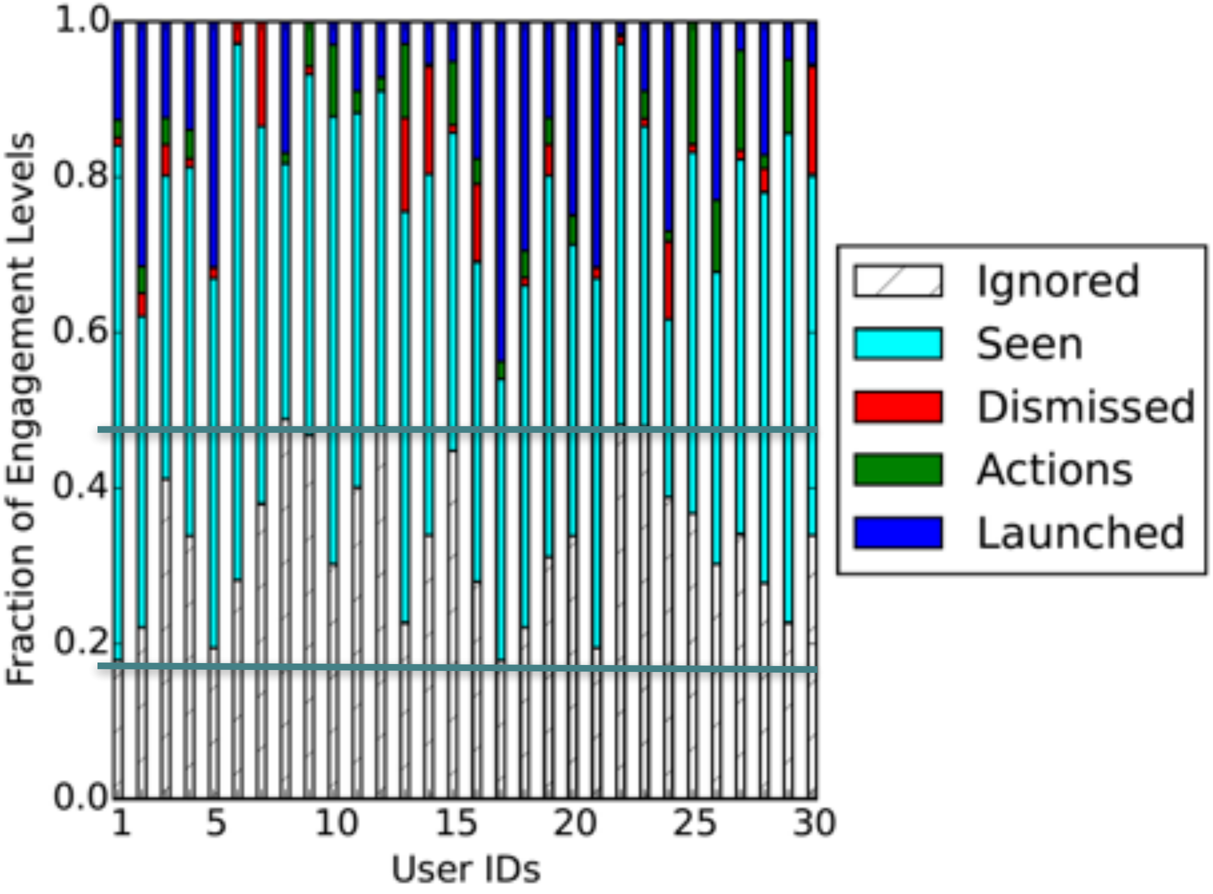
Opens notification drawer
~15 times/day

Users ignore most notifications

Users ignore most notifications



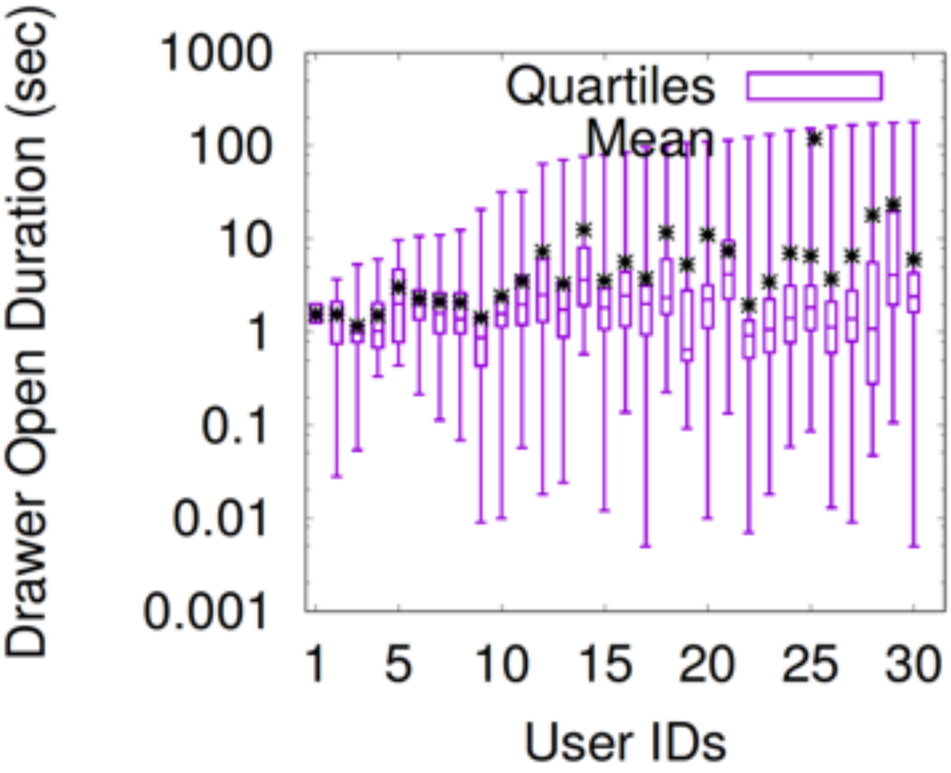
Users ignore most notifications



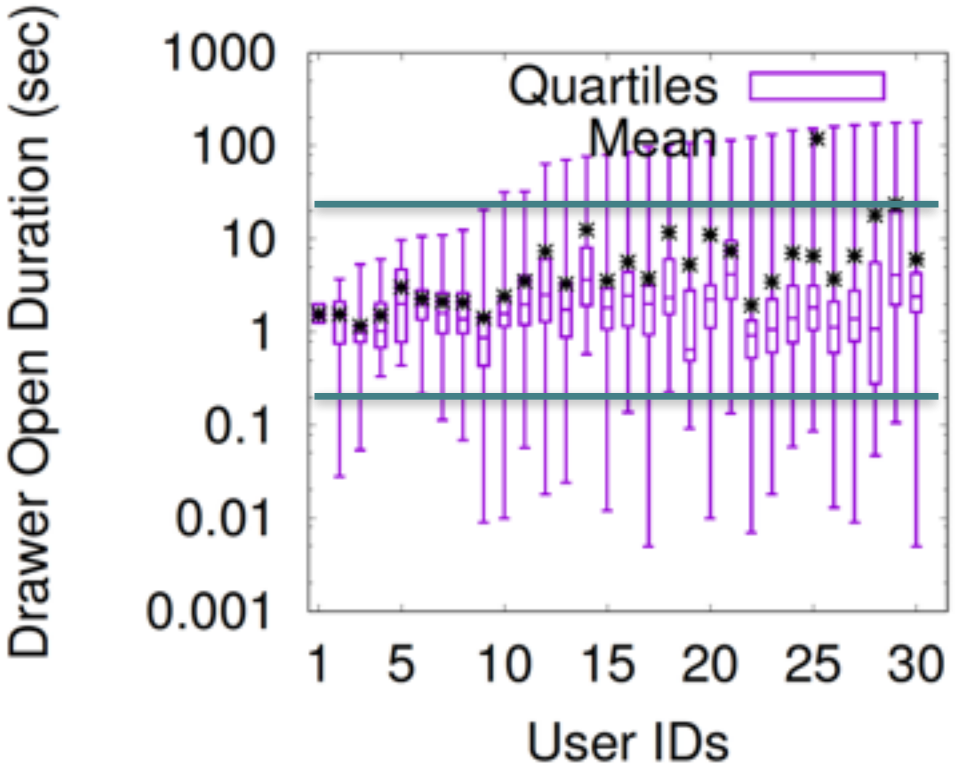
- Users tend to ignore **20-50%** of the generated notifications.
- Less than **20%** of these are causing app launch events.

Users have limited attention span

Users have limited attention span

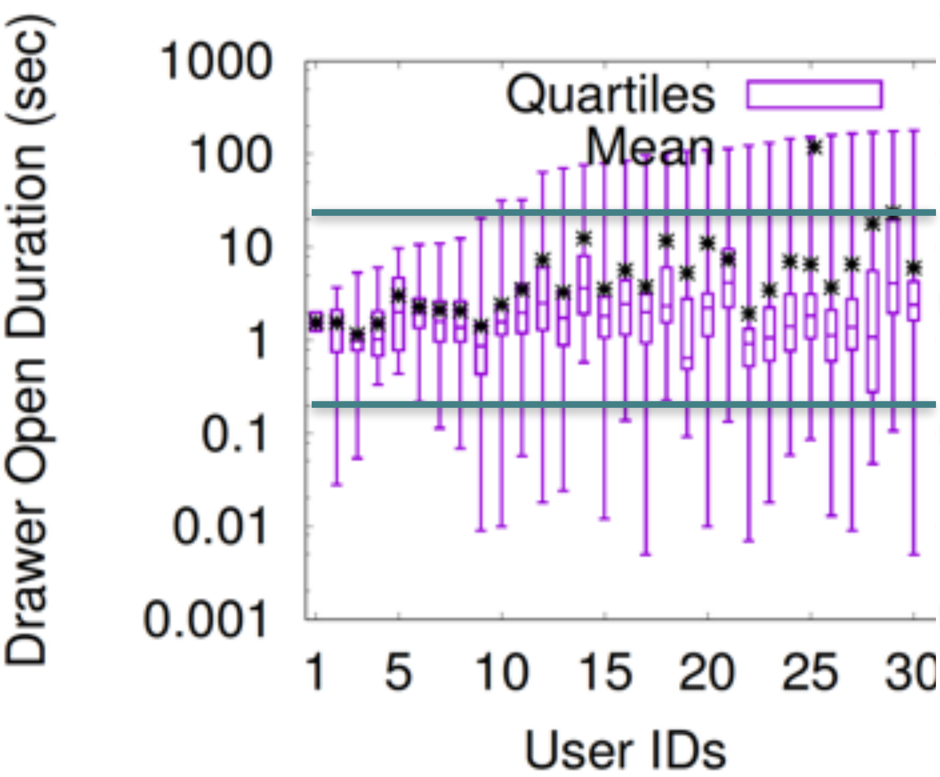


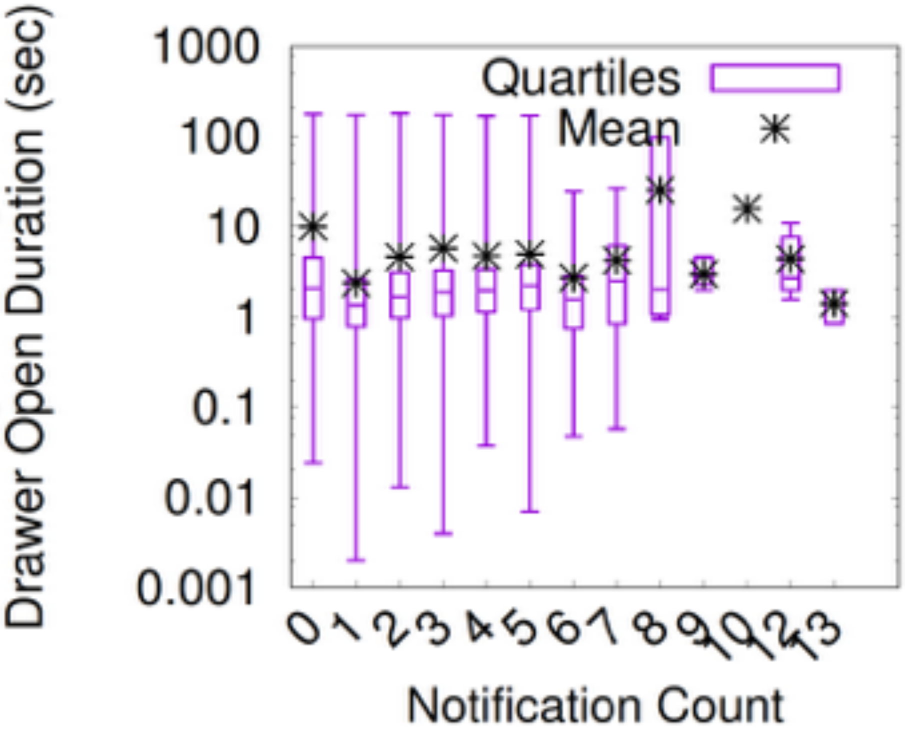
Users have limited attention span



Takes **~1-20 seconds** within a notification drawer session

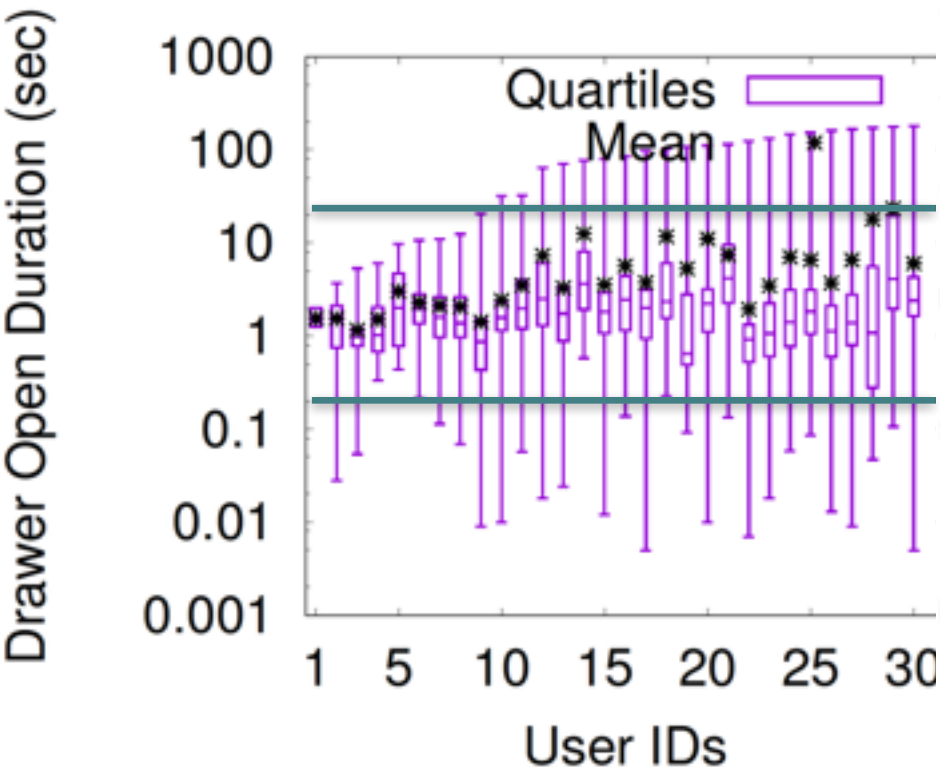
Users have limited attention span



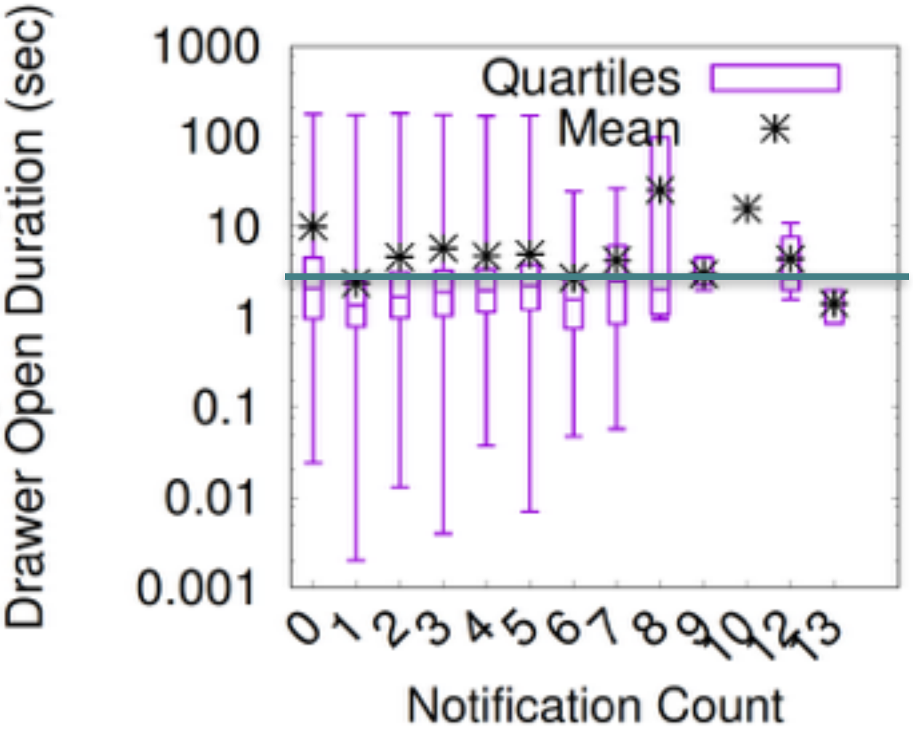


Takes **~1-20 seconds** within a notification drawer session

Users have limited attention span



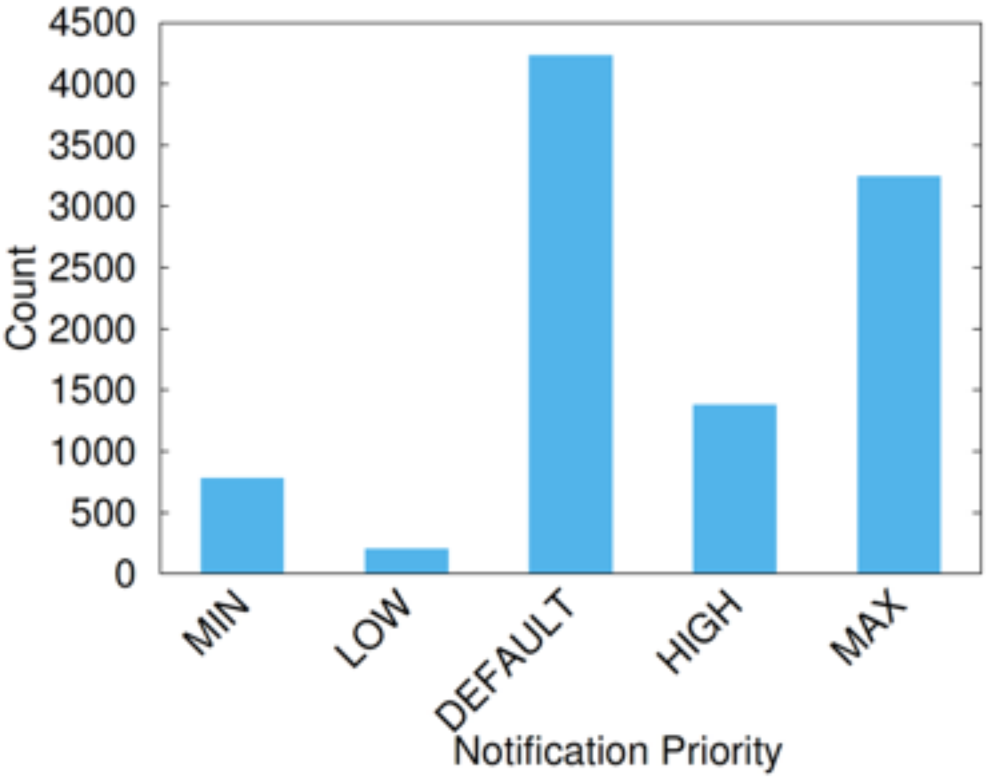
Takes **~1-20 seconds** within a notification drawer session



Attention span *does not vary* with number of notifications

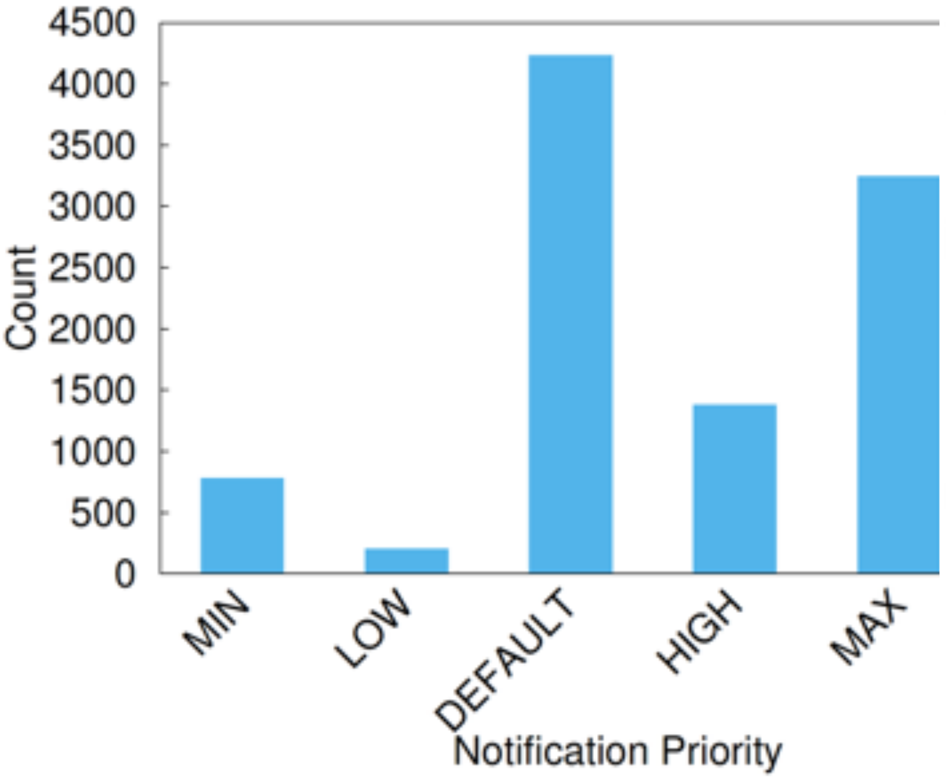
Apps fail to evaluate ‘importance’

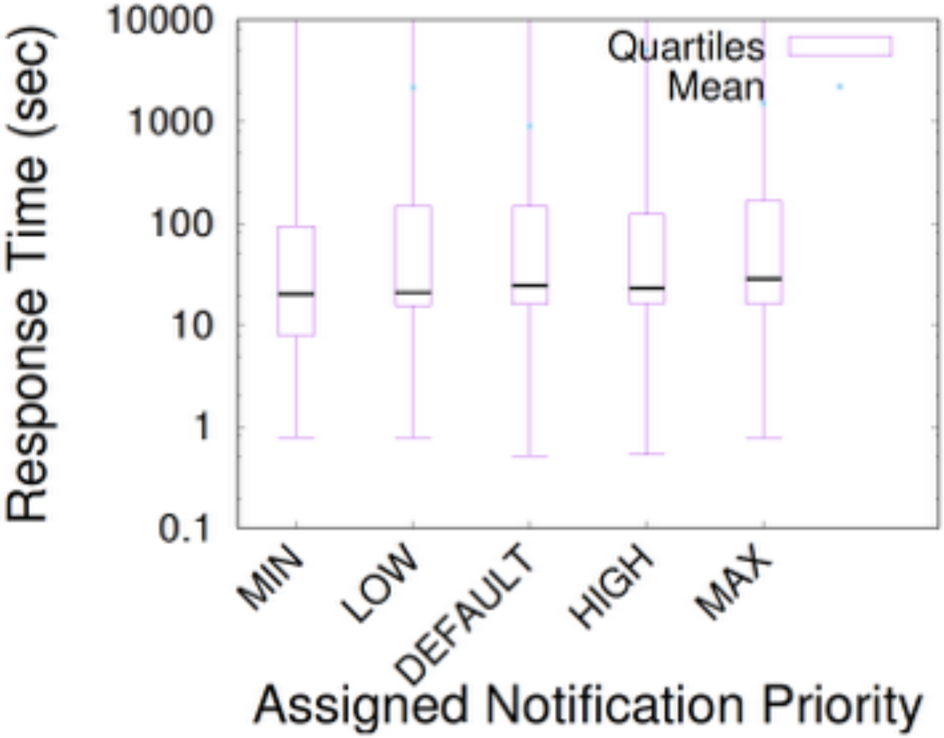
Apps fail to evaluate ‘importance’



Developers assign Default or High Priority to notifications

Apps fail to evaluate 'importance'





Developers assign Default or High Priority to notifications

Users' response time almost constant

Summary of Insights

- Users receive large number of notifications
- Users take action to prevent disruption
- Users ignore most notifications (20%-50%)
- Users have limited attention span (~10s)
- Apps tend to assign overly high priorities

Summary of Insights

- Users receive large number of notifications
- Users take action to prevent disruption
- Users ignore most notifications (20%-50%)
- Users have limited attention span (~10s)
- Apps tend to assign overly high priorities

Correct assessment of notification importance is critical towards removing unwanted notifications and utilizing users' limited attention span

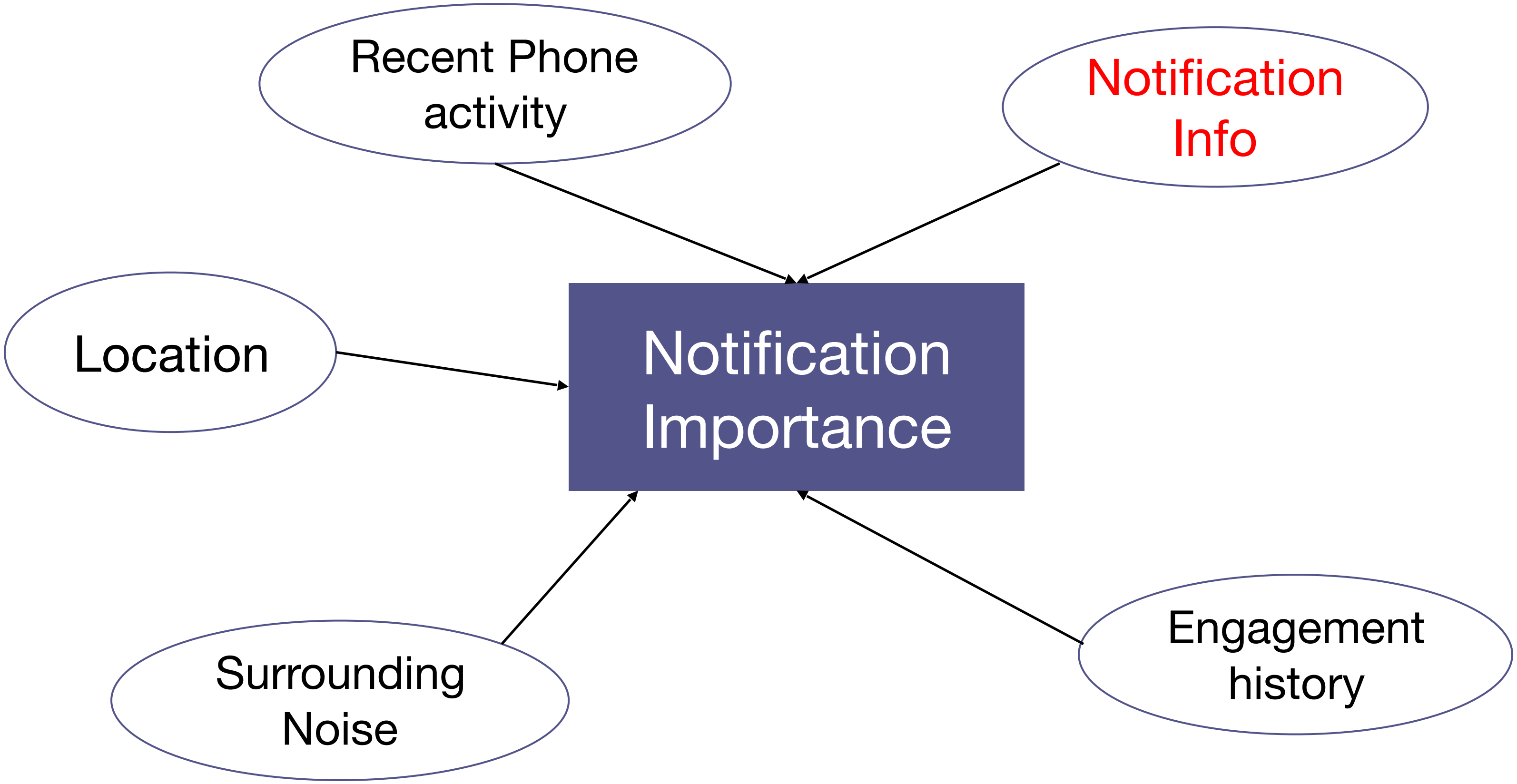
Predicting notification importance

- *Engagement level* as an indicator.

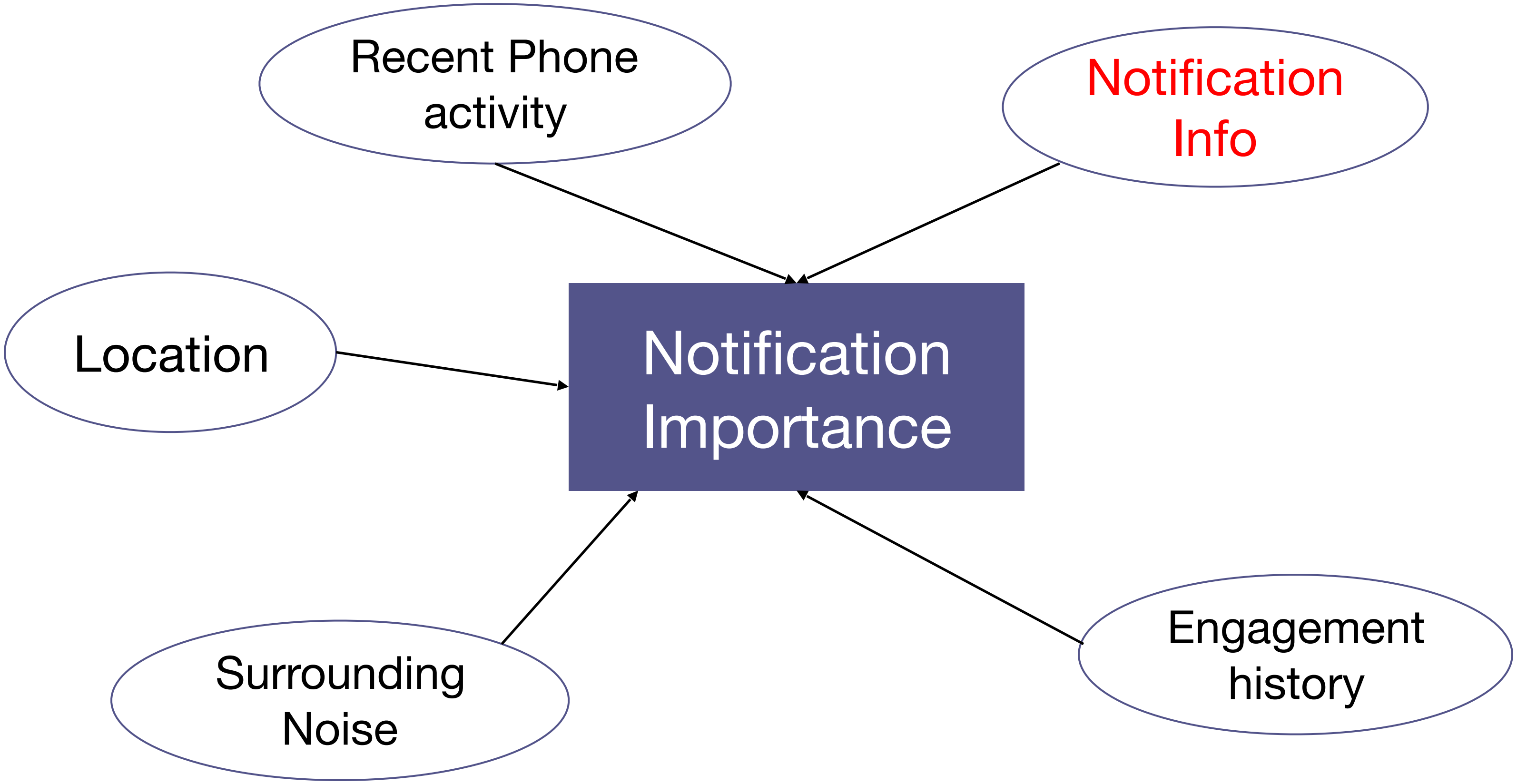
Predicting notification importance

- *Engagement level* as an indicator.
- Users engage with notifications in several ways :
  - ➢ Ignore
  - ➢ Read (e.g. notification drawer open)
  - ➢ Read and dismiss
  - ➢ Take some action (e.g. "Archive" or "Delete" a mail)
  - ➢ Launch an app

Predicting notification importance



Predicting notification importance

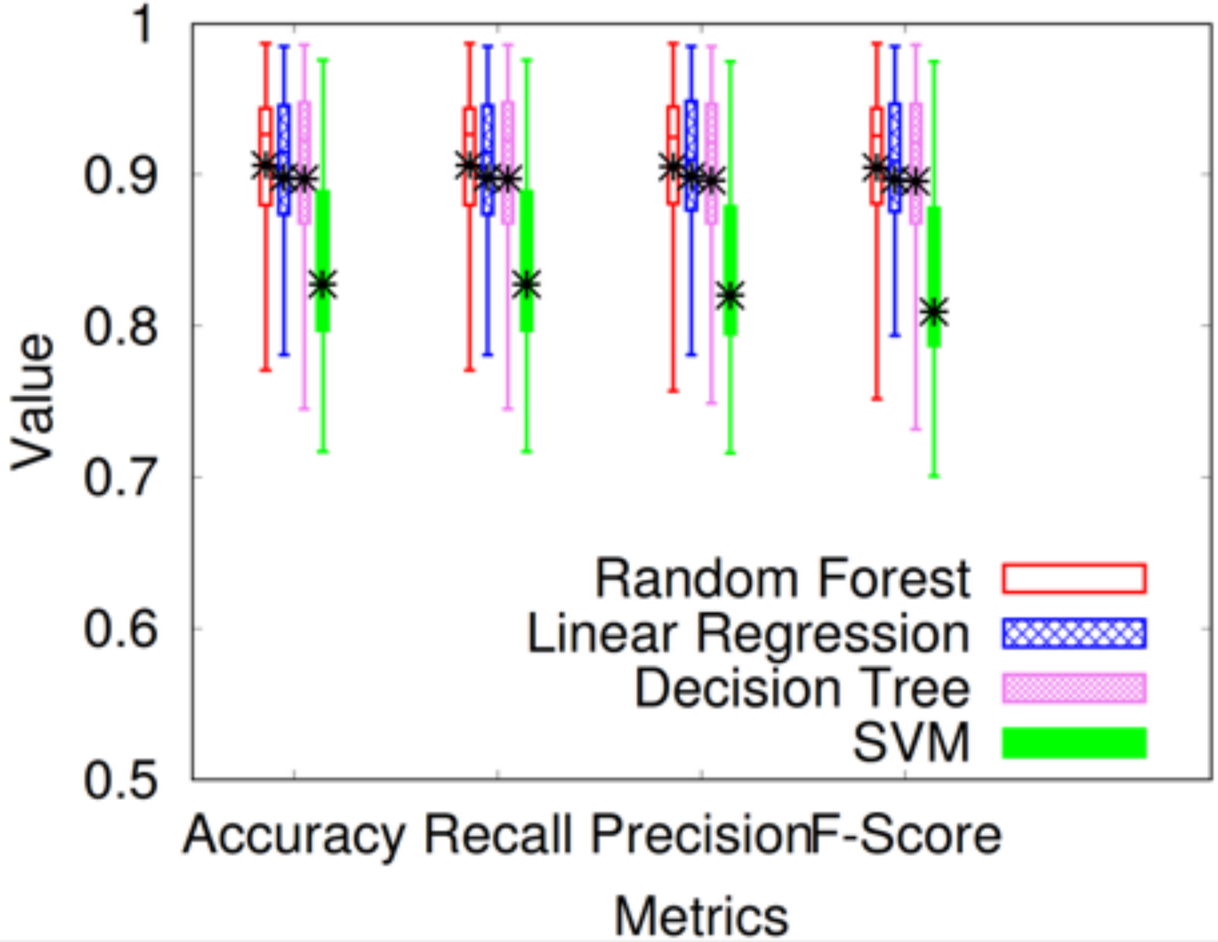


Binary classification : C4.5 Decision tree, Linear Regression, Random forest, SVM using 22 features

Feature Ranking

- Application name of notification
- Temporal features related to interaction (e.g. notification post time, clear time etc.)
- Hour of the day
- Notification title
- Ringer mode of the phone
- Weekend status
- Location cluster etc.

Evaluating a personalized predictor

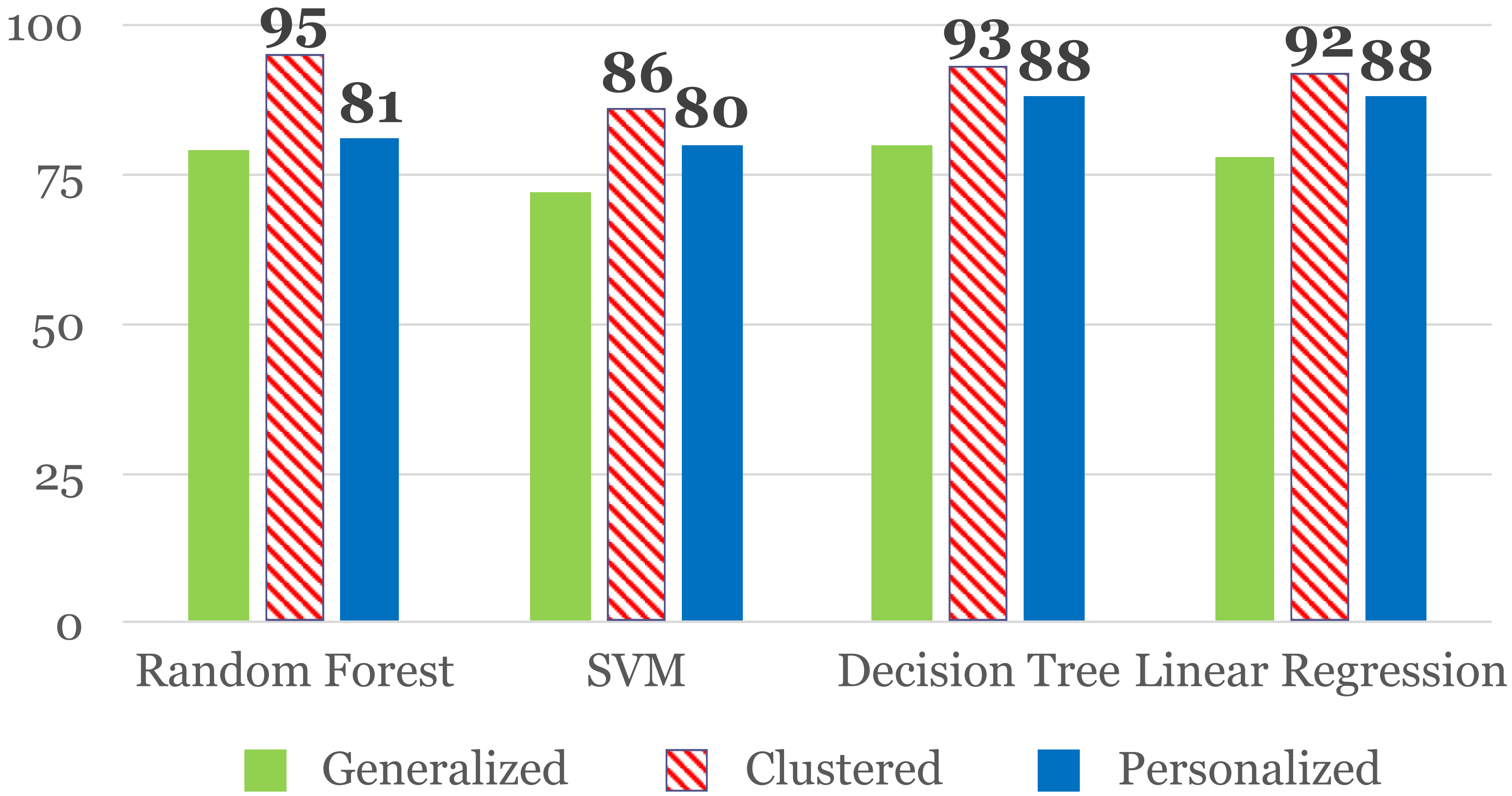


Results shown on 10-fold cross validation (ground-truth via explicit feedback) and can achieve ~**87% accuracy**

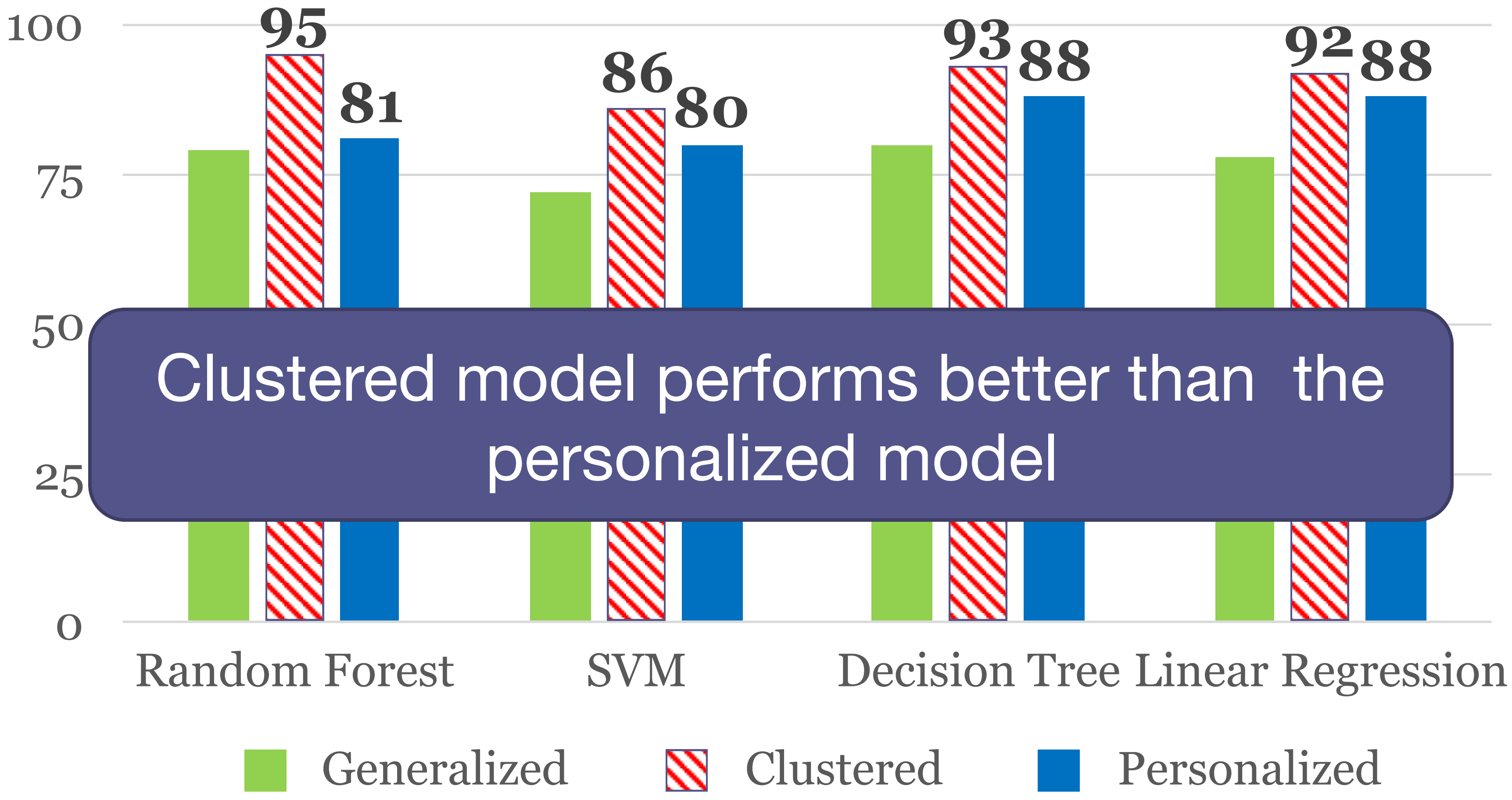
Generic v Personalized v Clustered

- A generic model trained on a subset users' data and predict the rest.
- 10-fold cross validation on personal data of each users.
- Cluster users based on #applications used, #unique locations visited … Predict within cluster.

Generic v Personalized v Clustered



Generic v Personalized v Clustered

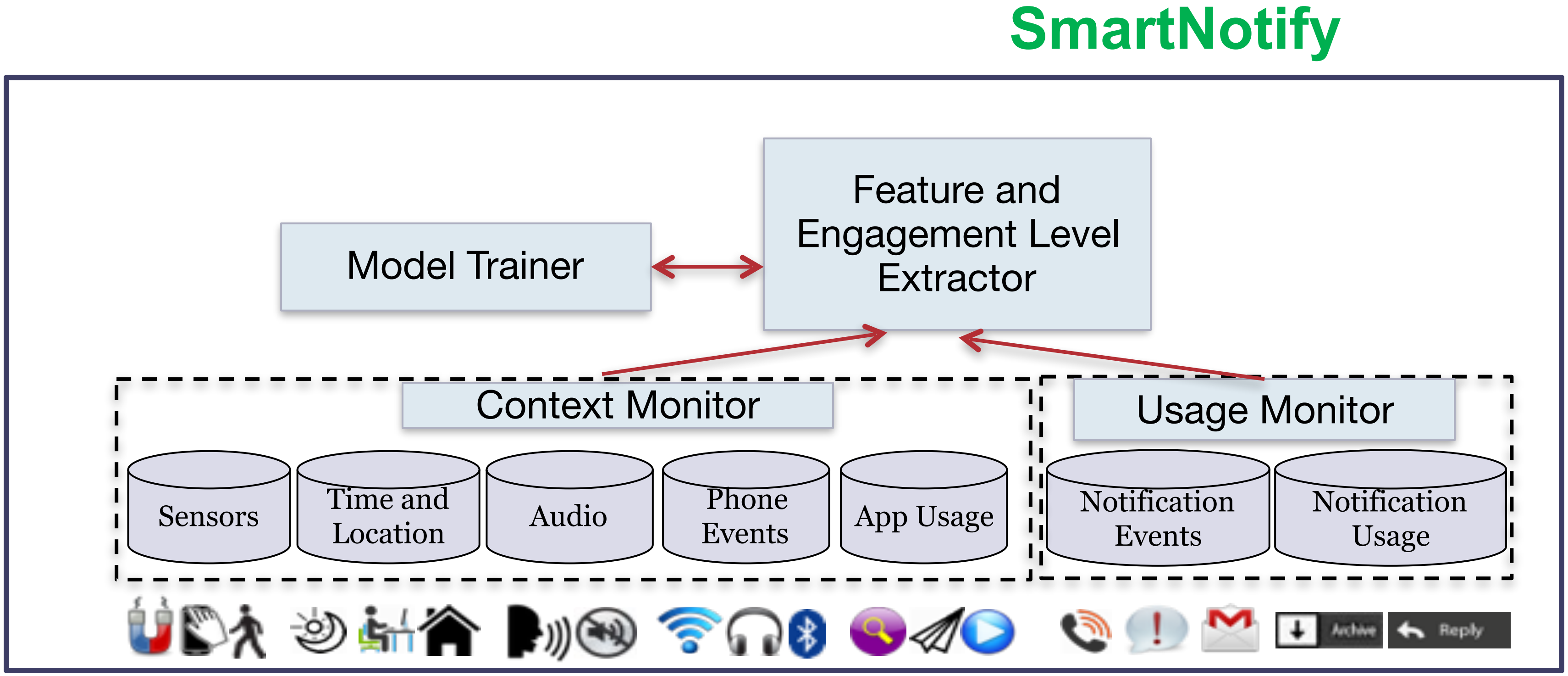


Clustered model performs better than the personalized model

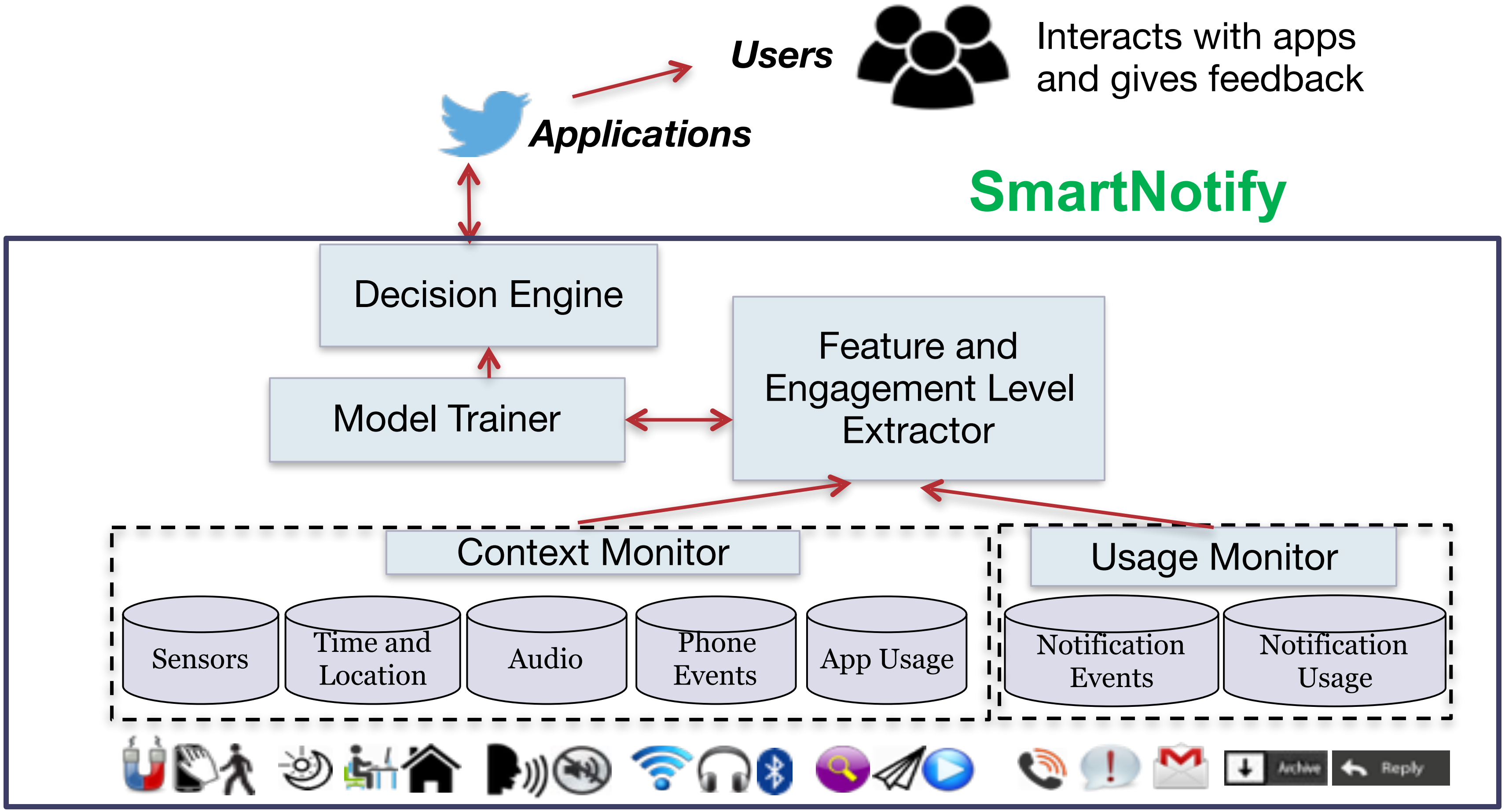
A smarter notification manager

SmartNotify

A smarter notification manager



A smarter notification manager



Users

Interacts with apps
and gives feedback

Applications

SmartNotify

Decision Engine

Model Trainer

Feature and Engagement Level Extractor

Context Monitor

Sensors

Time and Location

Audio

Phone Events

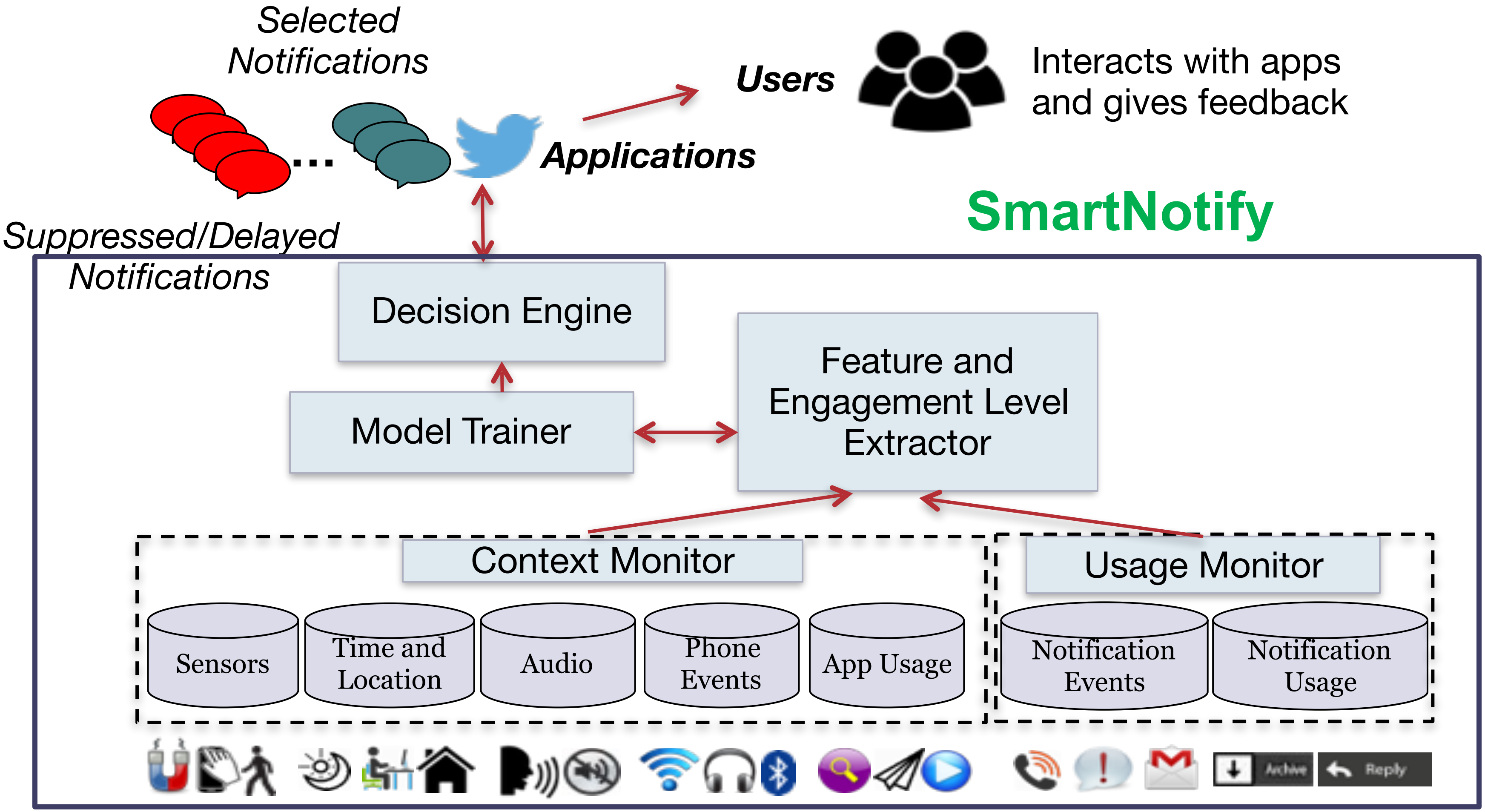
App Usage

Usage Monitor

Notification Events

Notification Usage

A smarter notification manager

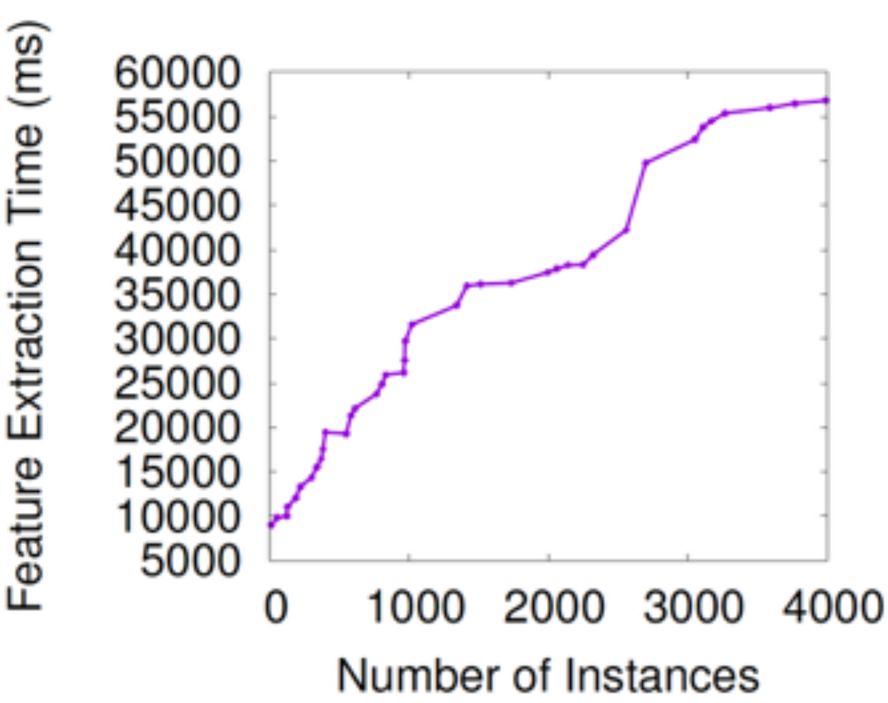


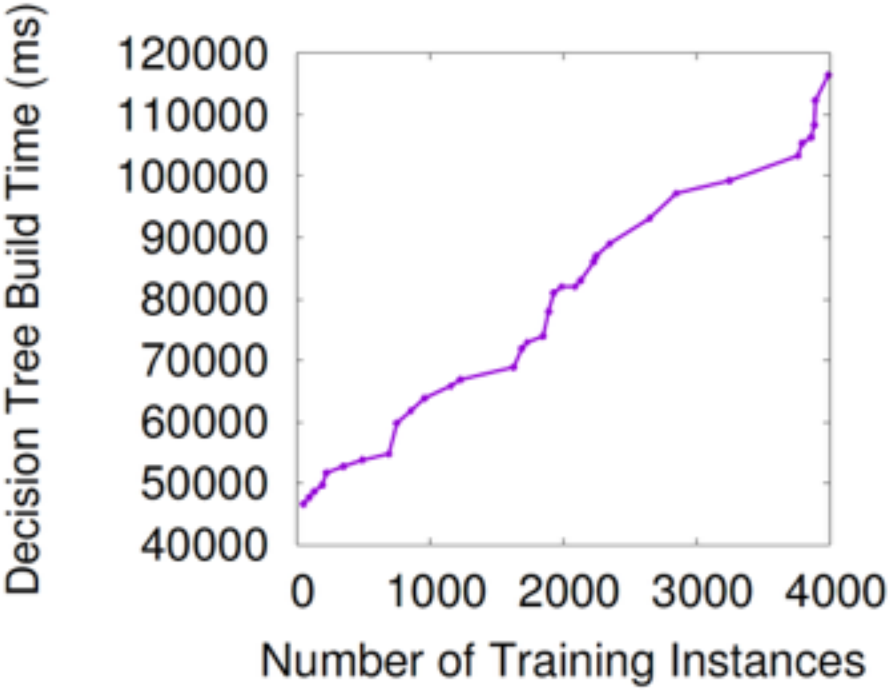
Notification manager performance

- Used Weka based C4.5 decision tree for model training and *InterruptMe* library.

Notification manager performance

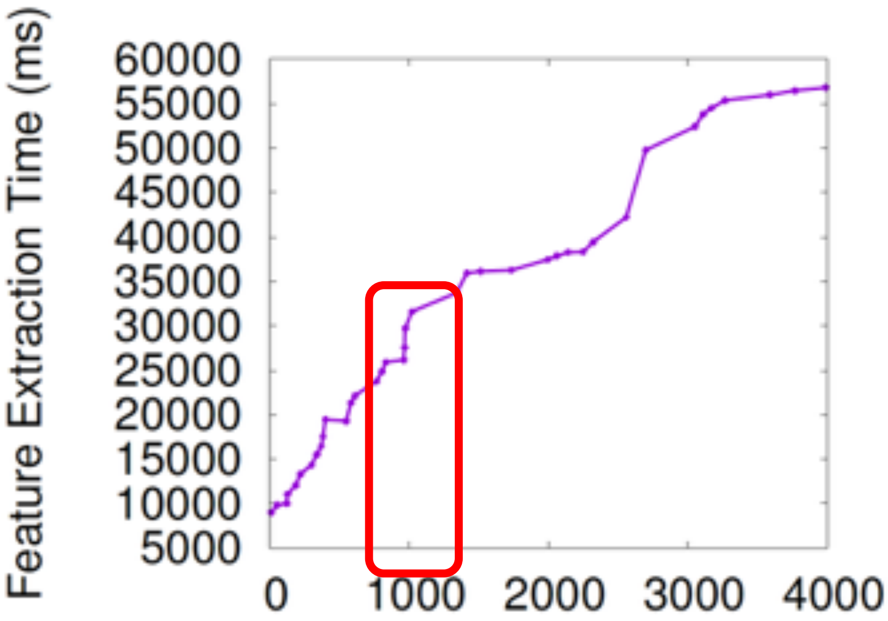
- Used Weka based C4.5 decision tree for model training and *InterruptMe* library.

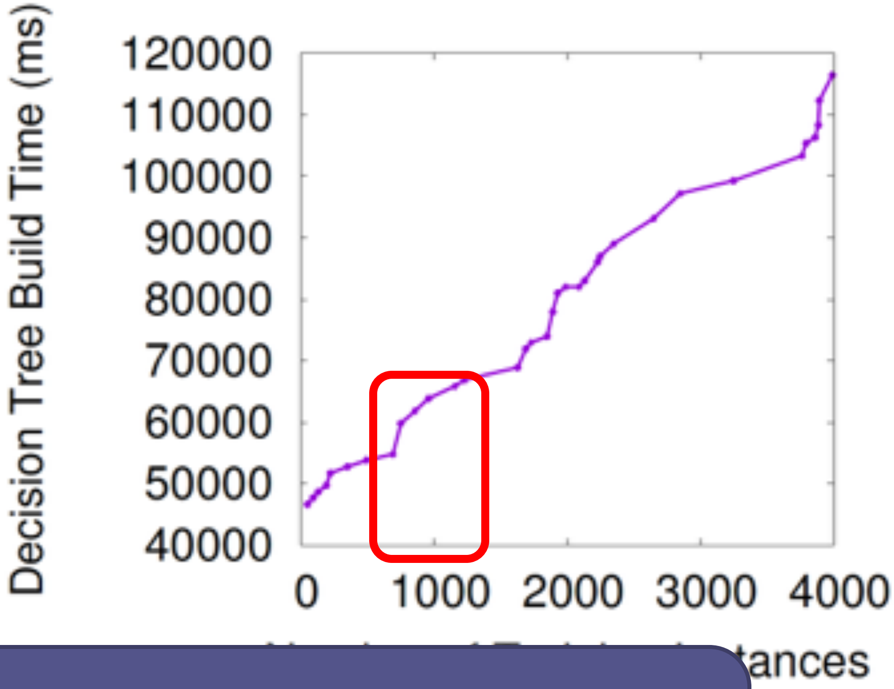




Notification manager performance

- Used Weka based C4.5 decision tree for model training and *InterruptMe* library.





Feature extraction ~10s for and Tree building ~50s for 1000 instances

Conclusion

- Users are getting disrupted by notifications
- Can *suppress* unwanted notifications if we can predict *user's engagement level*
- Implemented a *smarter* notification manager which can predict notification importance with *~87% accuracy*

Future works

- A first step toward understanding *micro user interaction* with notification.

- Prediction model can be used to decide *display order* or *modality* of notifications *across multiple devices*

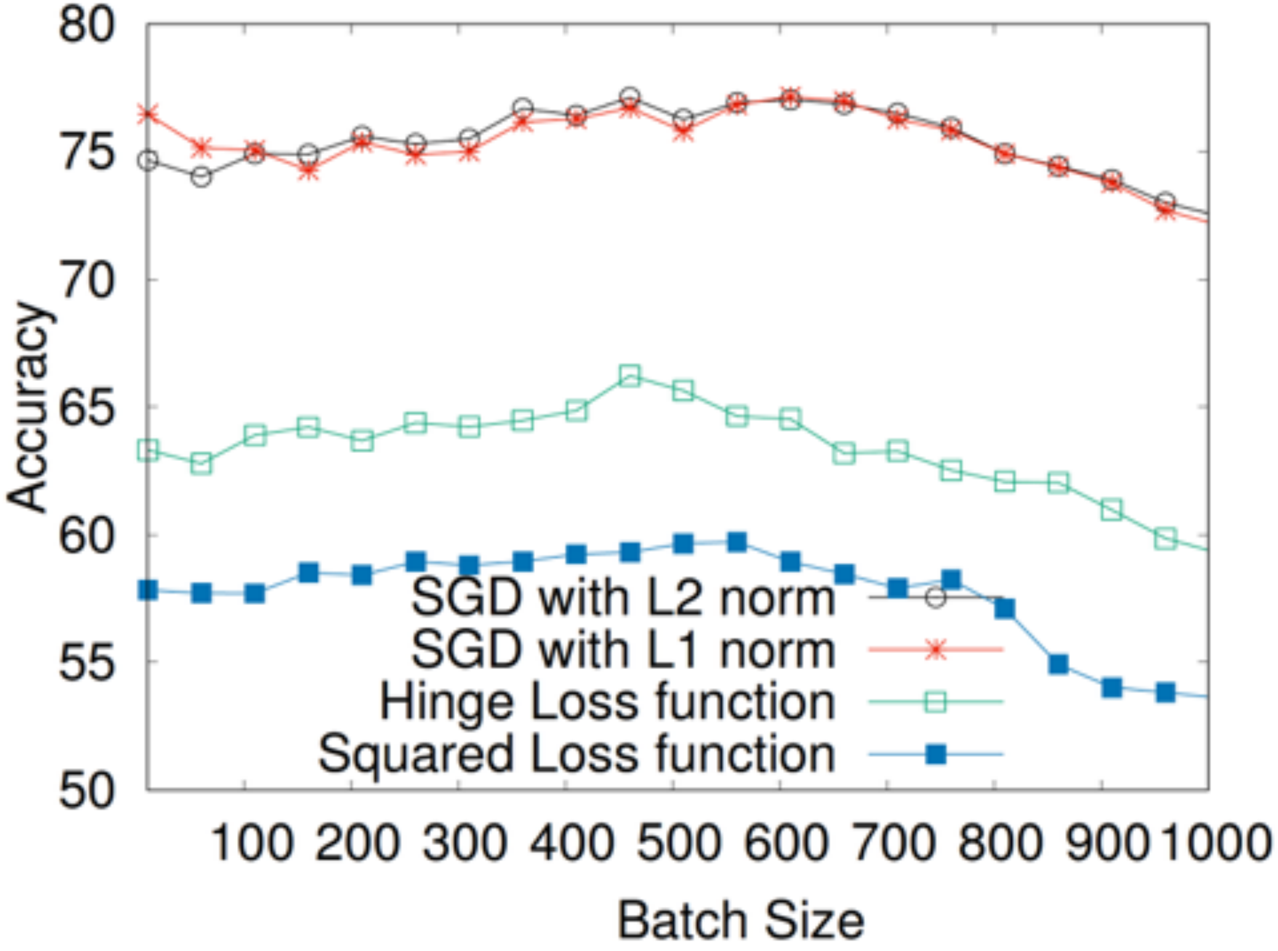
Thank you & any question ?

Codes for data collector apps:
https://bitbucket.org/swadhinp/notifbase
https://bitbucket.org/swadhinp/snotify

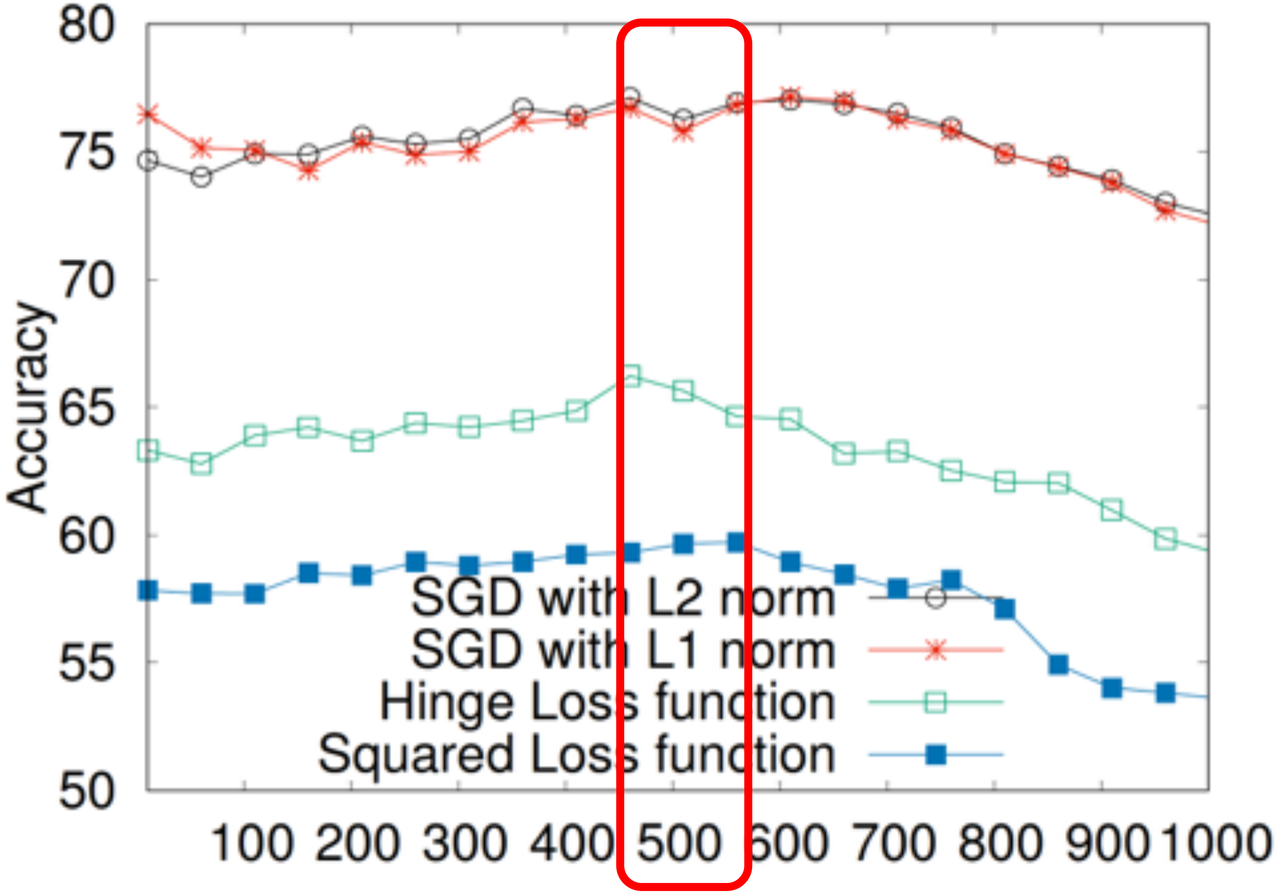
Google Play: https://play.google.com/store/apps/details?id=org.swadhin.app

Extra

Online learning based prediction



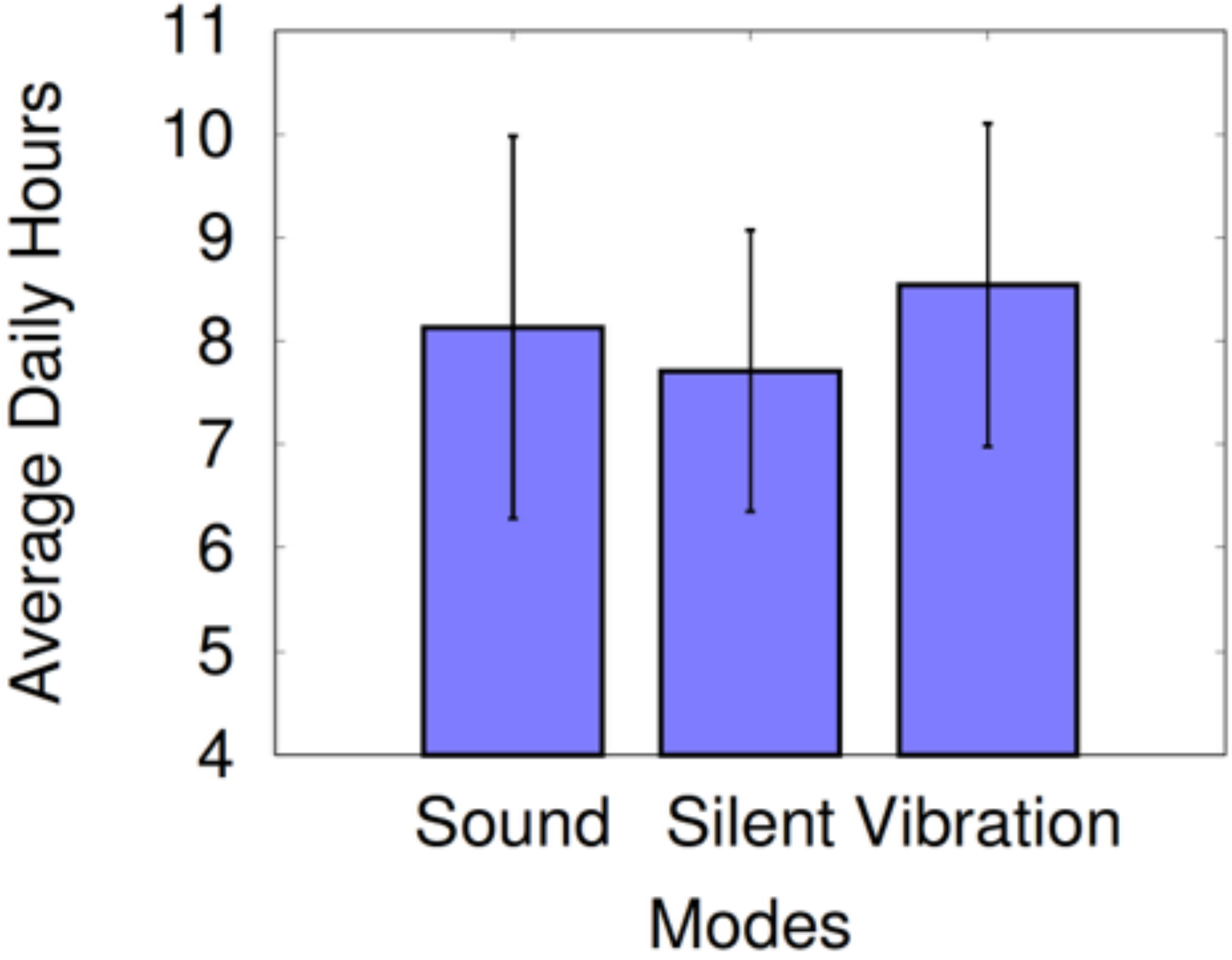
Online learning based prediction



Stochastic Gradient Descent with L2 norm gives best performance and stabilizes with 500 batch size

How do users avoid disruptions ?

How do users avoid disruptions ?



Setting their devices
to silent or
vibrating mode