



# Realtime & Personalized Notifications @Twitter

**@pathak\_s**

**@lamgary**

**March 8 2017**



**“I was following it on Twitter, I didn't actually see it live. I kept on refreshing my notifications, I saw people were tweeting and then I realised that Pune had got me.”**

**Ben Stokes, Cricketer**



**Stay Informed about the world**



**Notify users about what's happening  
in their world in realtime**



**Notify users about what's happening  
in **their** world in **realtime****



**Saurabh Pathak**  
Engineering Manager  
@pathak\_s



**Gary Lam**  
Staff Engineer  
@LamGary



# Agenda

- **Notifications Overview**
- **Notifications Infrastructure**
- **Triggered Notifications**
- **Personalized Fanout**
- **Recommendations**



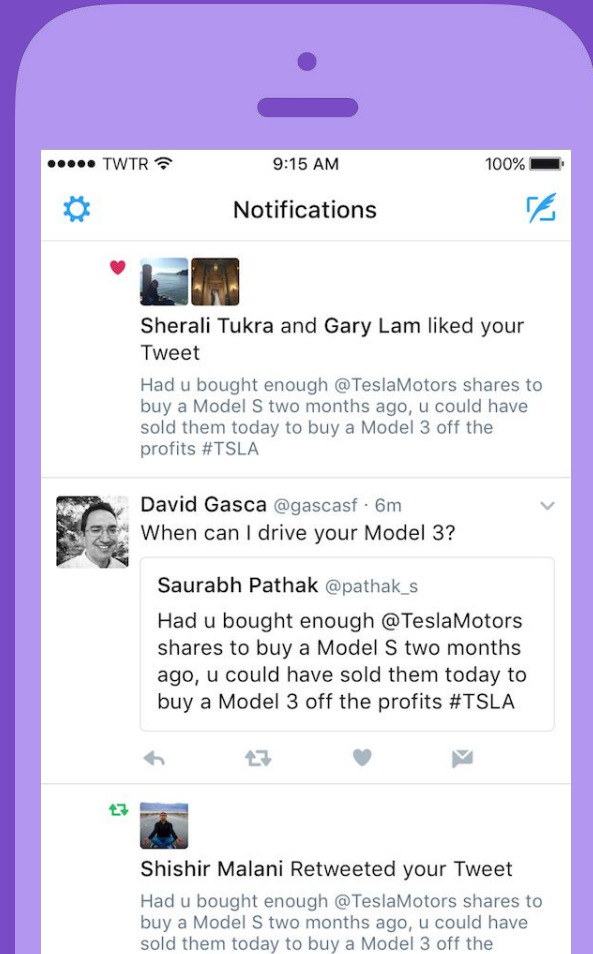
# Notifications

## Overview

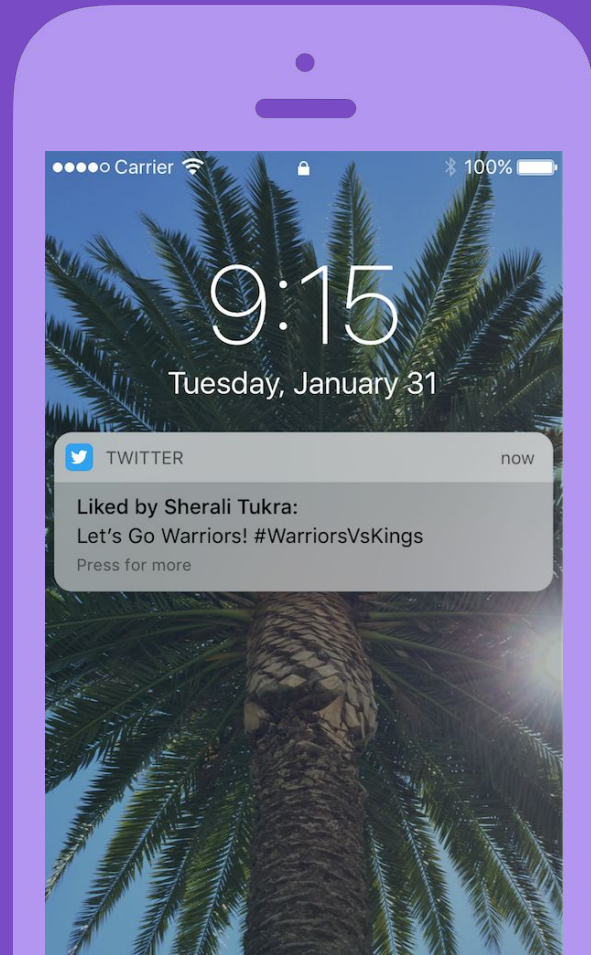




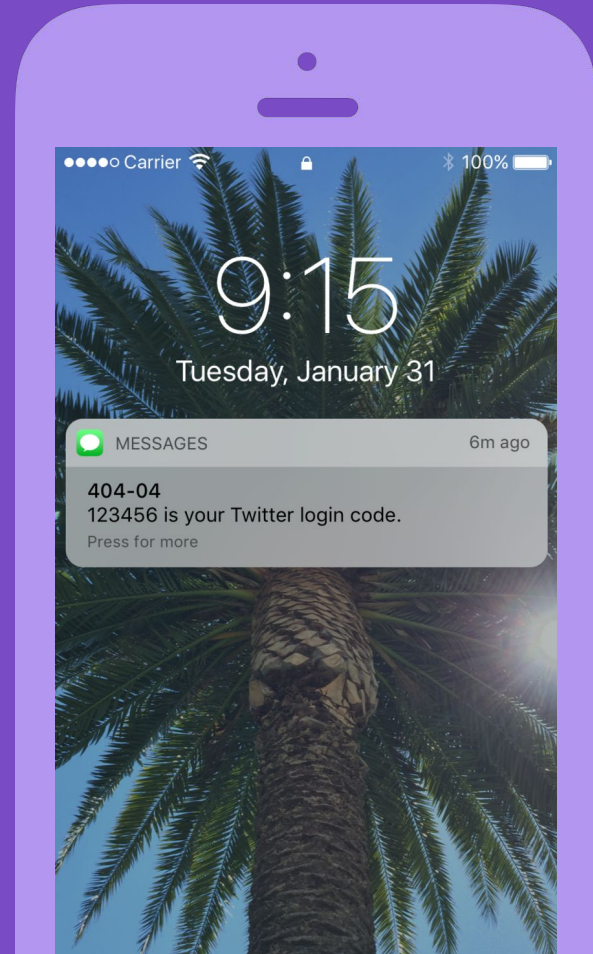
# Notification Timeline



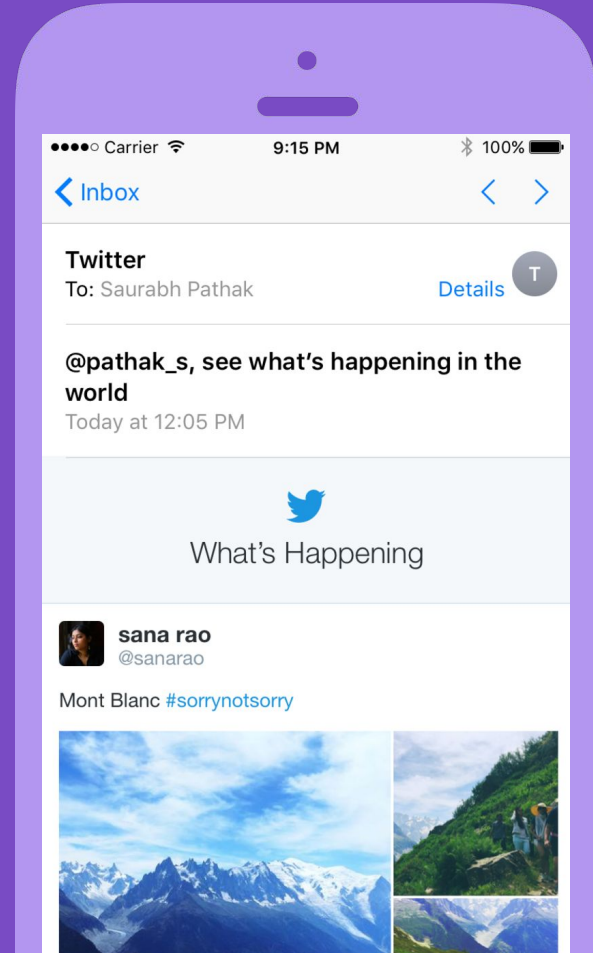
# Push



# SMS



# Email

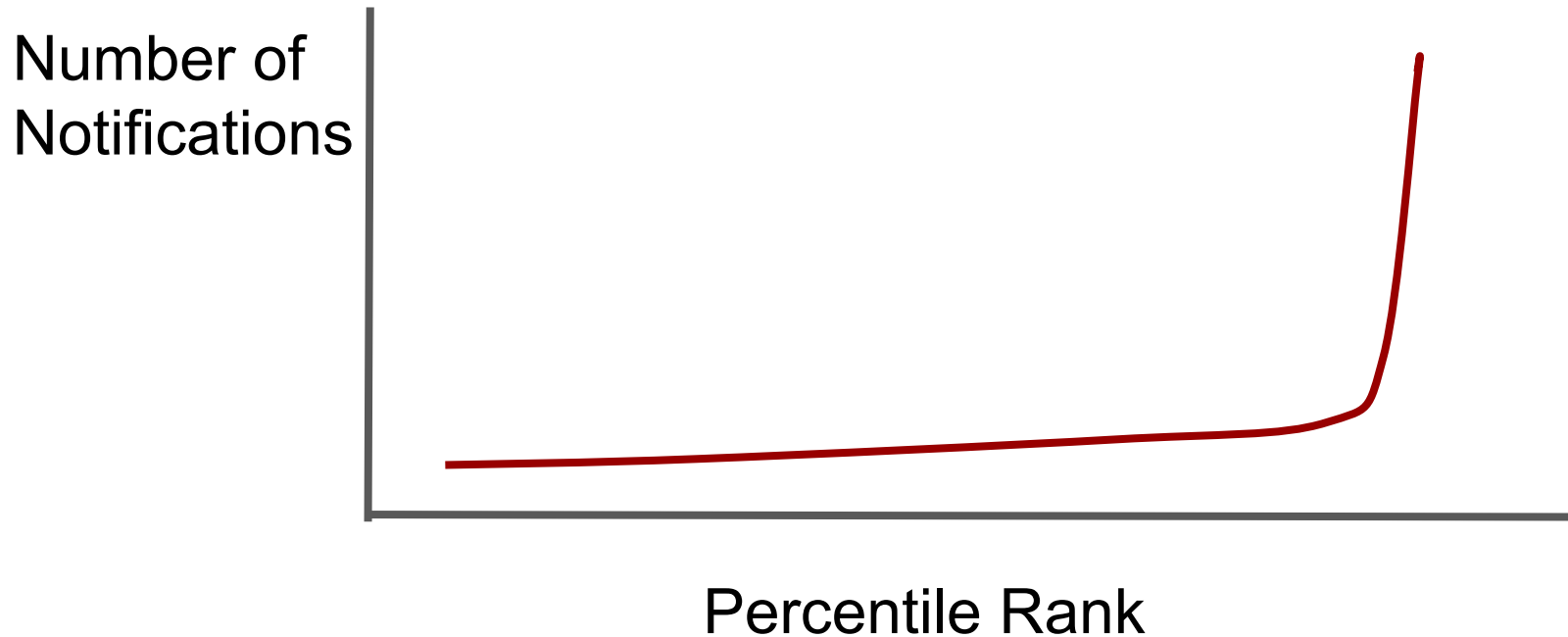




# Notification Challenges

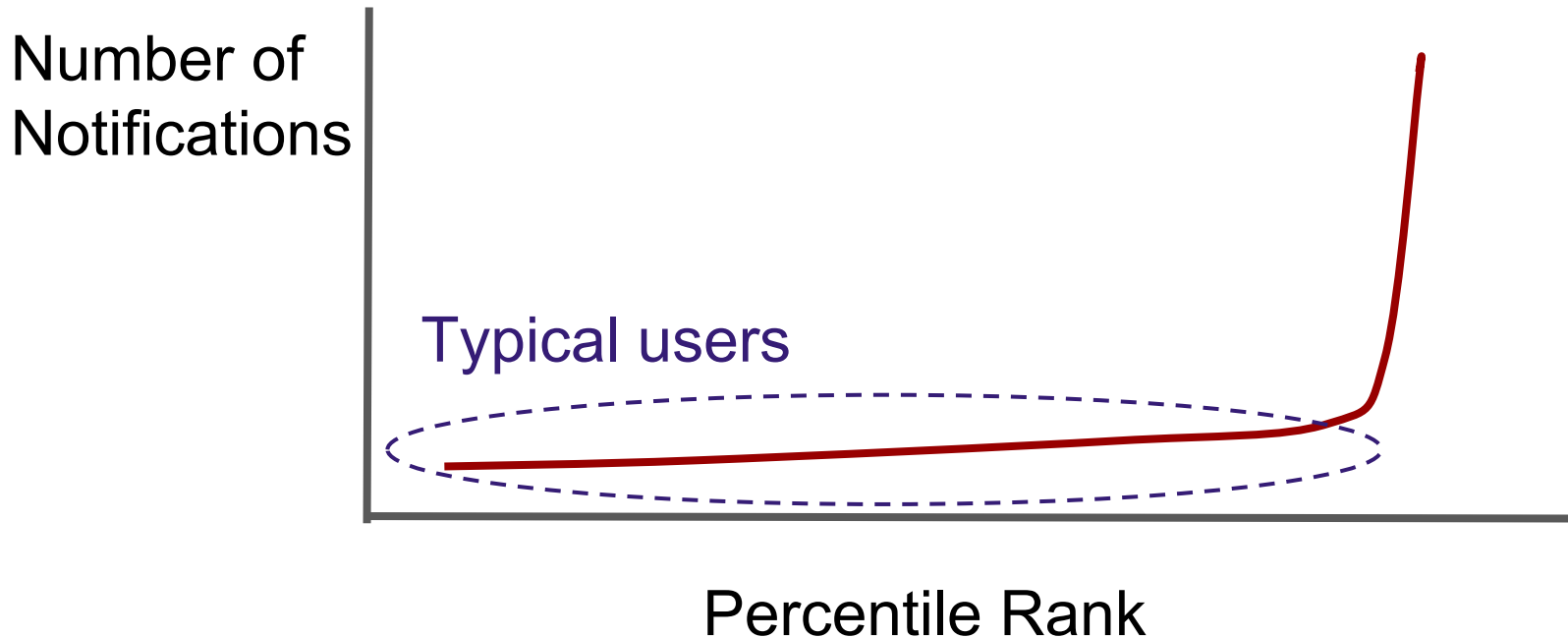


# Notifications are bimodal



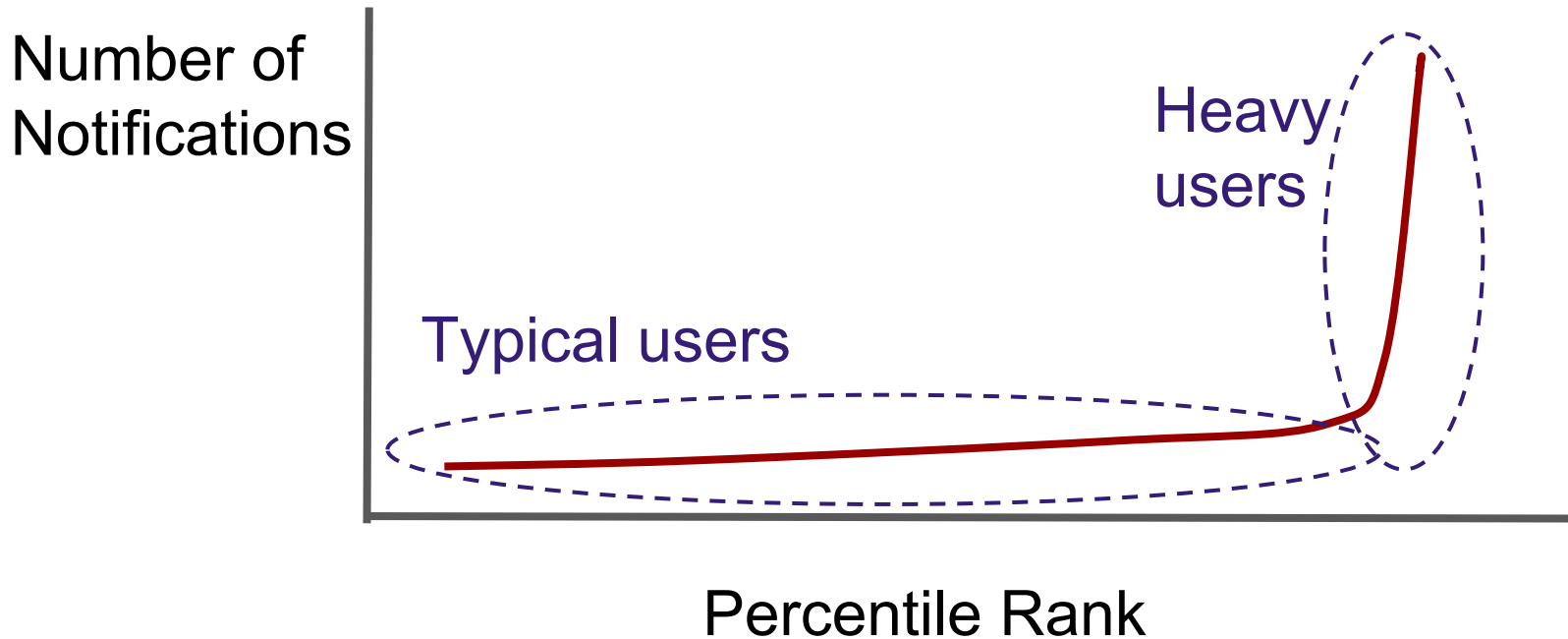


# Notifications are bimodal





# Notifications are bimodal

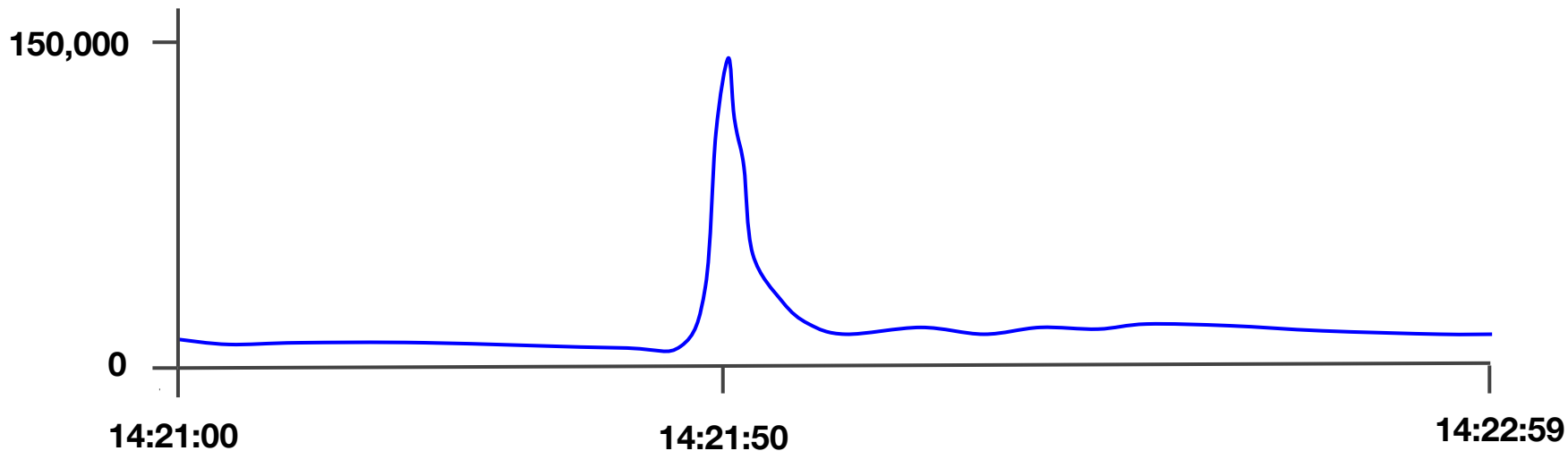






# Notification are spiky

Castle in the Sky



**Tweets Per Second spike from Aug 2013**



# Notifications Fanout

7.49M Followers

TWEETS	FOLLOWING	FOLLOWERS	LIKES
2,689	40	7.49M	380

**Elon Musk** ✓  
@elonmusk  
Tesla, SpaceX, Tunnels & OpenAI

Tweets   Tweets & replies   Media

**Elon Musk** ✓ @elonmusk · Feb 27  
SpaceX could not do this without NASA.



# Notifications Fanout



**Elon Musk** 

@elonmusk

Following



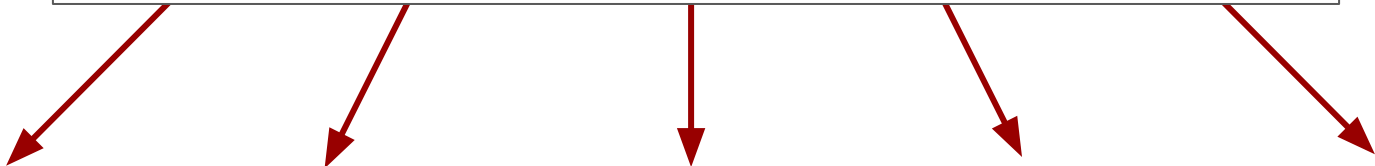
Fly me to the moon ... Ok



# Notifications Fanout



A screenshot of a tweet from Elon Musk (@elonmusk). The tweet text is "Fly me to the moon ... Ok". The interface shows the user's profile picture, name, and handle, a "Following" button, and a dropdown arrow. Five red arrows point from the bottom of the tweet box to five follower labels below.



FollowerA

FollowerB

FollowerC

FollowerD

FollowerE



# Main Challenges

**1 Latency**

**2 Notification Spikes/Fanout**

**3 Heterogeneous Calls**

**4 Multi DC**



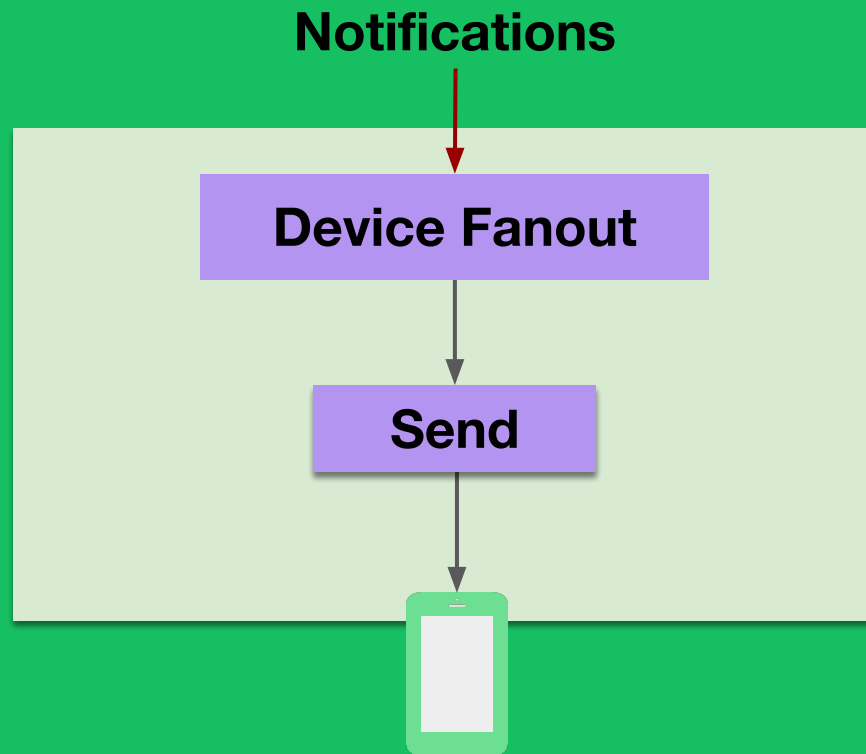
# Notifications Infrastructure



# Push/SMS/Email

## Main Challenges

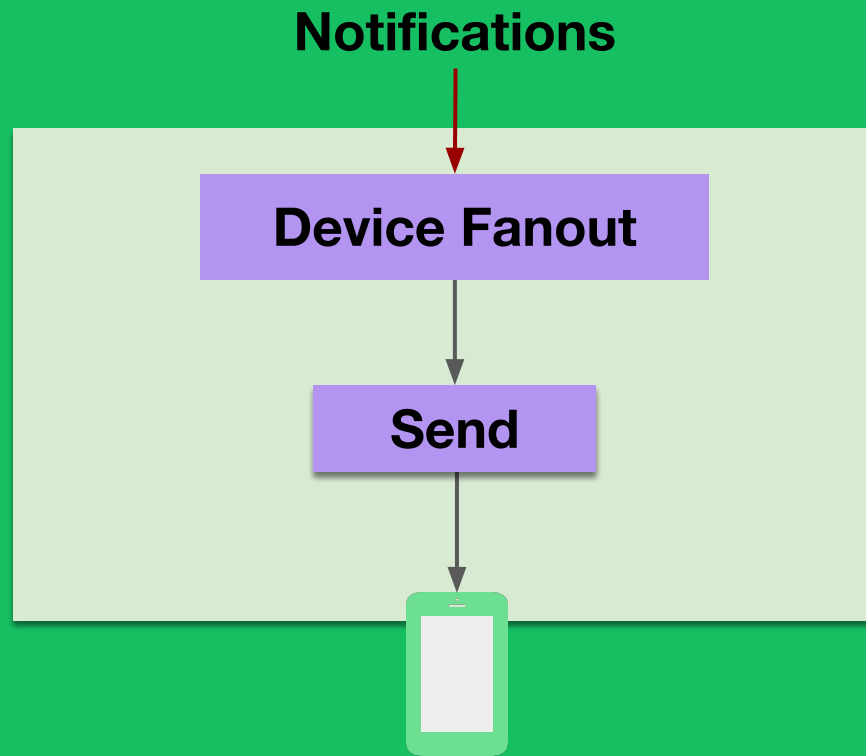
- Latency
- Spikes
- Heterogeneity





# Latency & Spikes

- **Scaling**
- **Short lived caches**

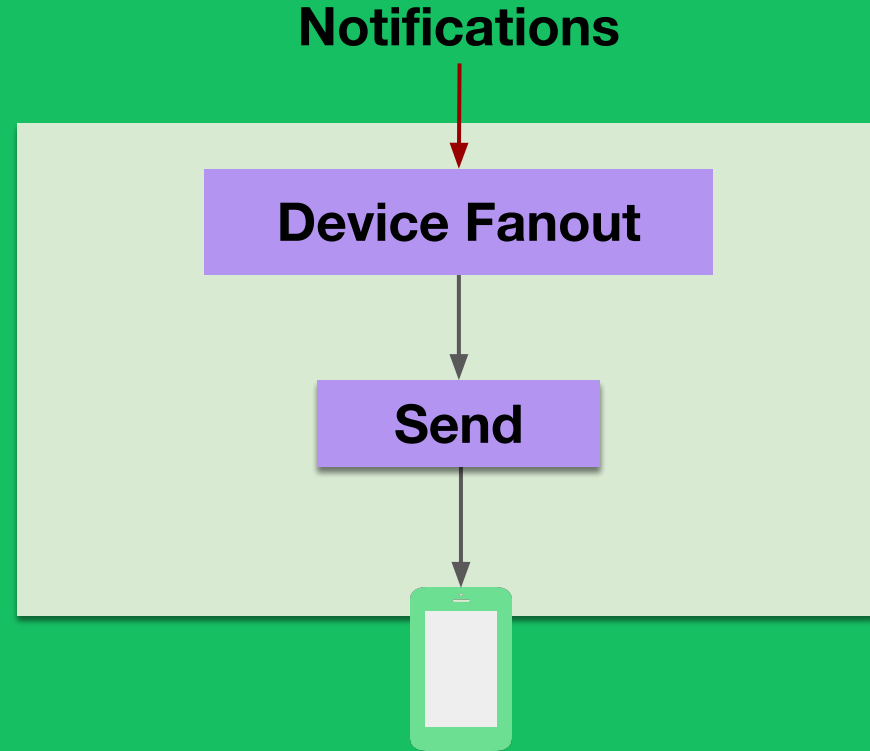






# Heterogeneity

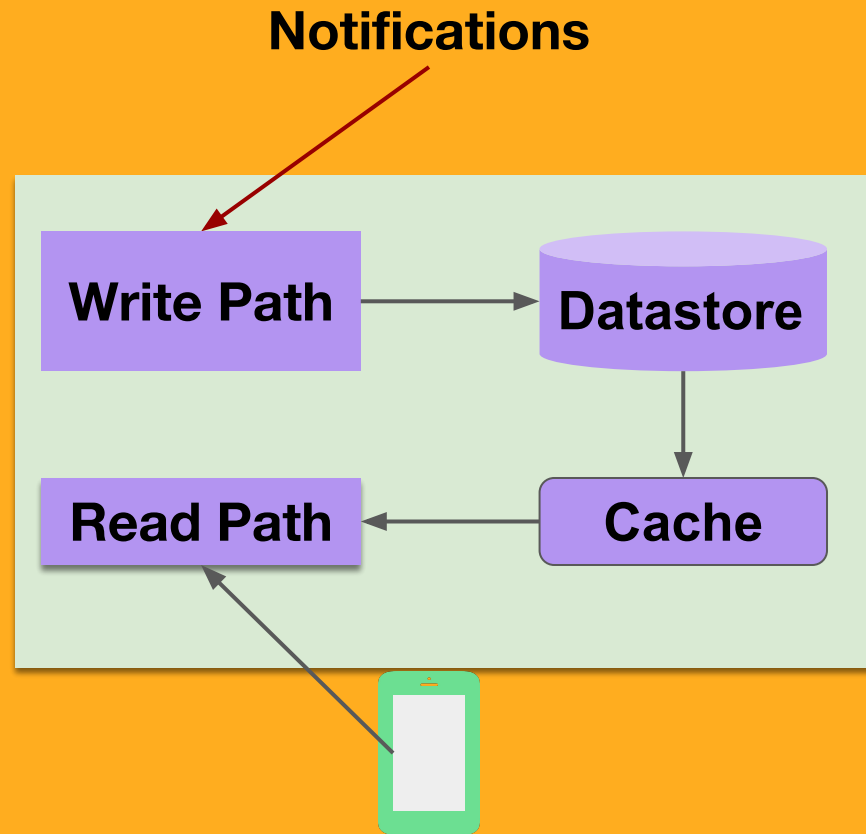
- **Priority Queues**
- **Decouple Send**



# Notification Timeline

## Main Challenges

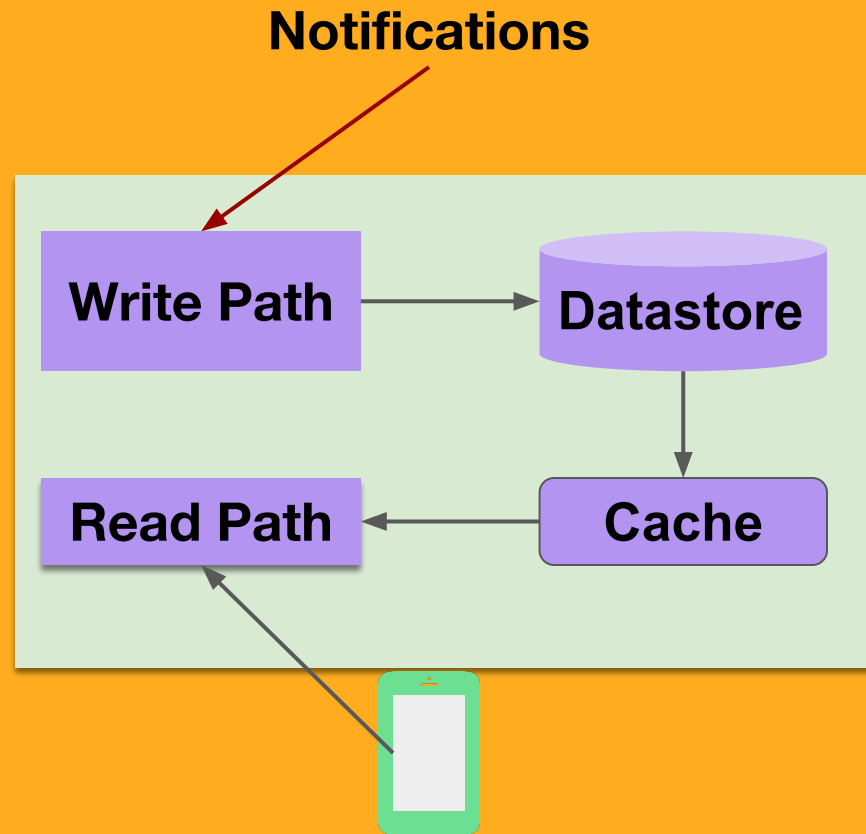
- Latency
- Multi DC





# Latency

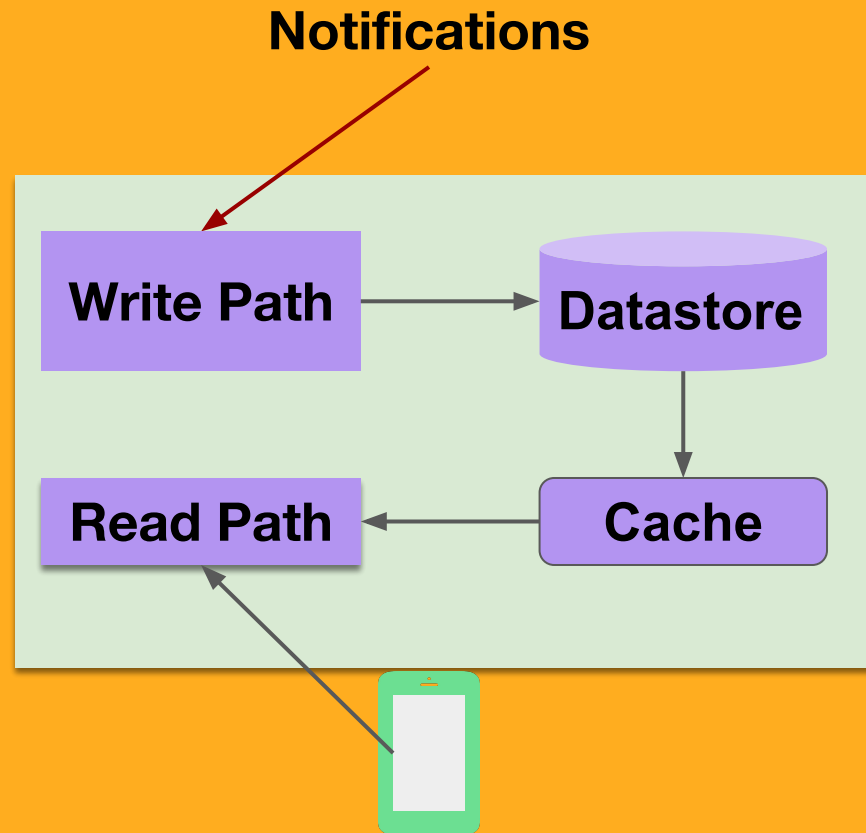
- Redis\*
- Manhattan





# Multi DC

- **Cross DC Replication**
- **Immutable Operations**
- **Maintenance / Cleanup**

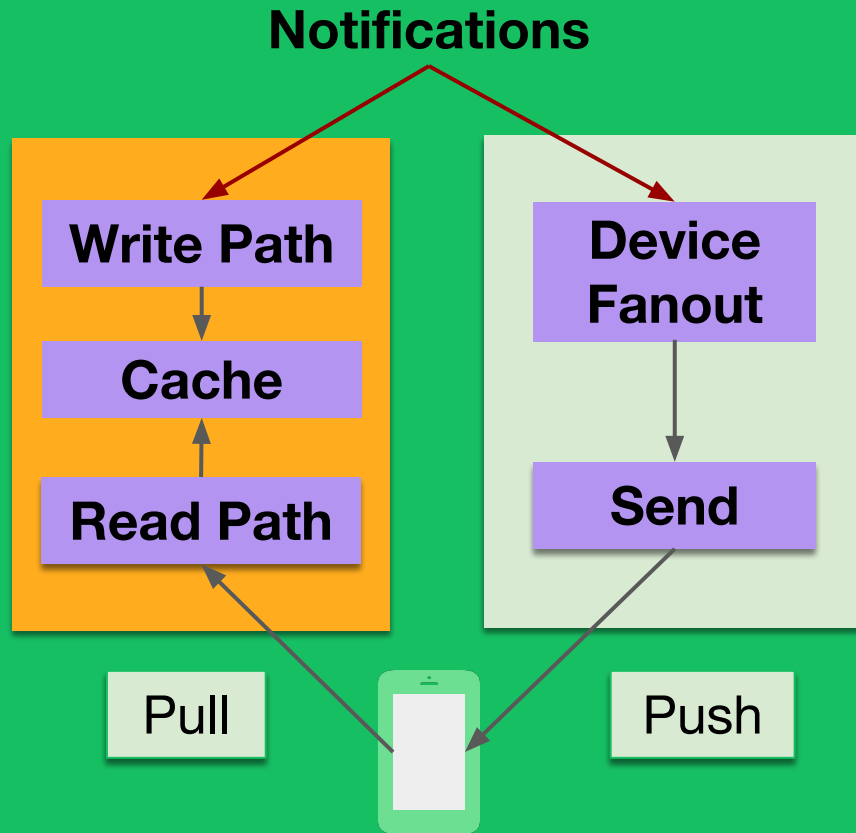




# Notifications

## Infrastructure

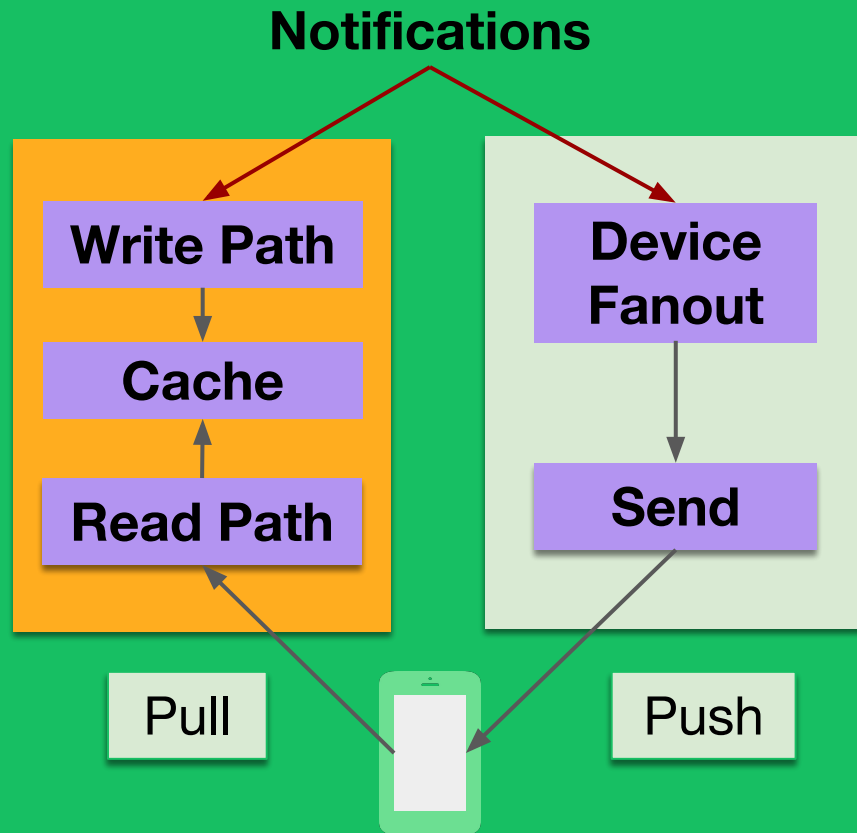
- **Self Serve**
- **Server side driven**





# Key Takeaways

- **Sync vs Async**
- **Write v Read**
- **Multi-DC**





# Triggered Notifications

# Triggered

1 Likes, Mentions, Follows, Retweets...

2 High Volume

3 Bimodal

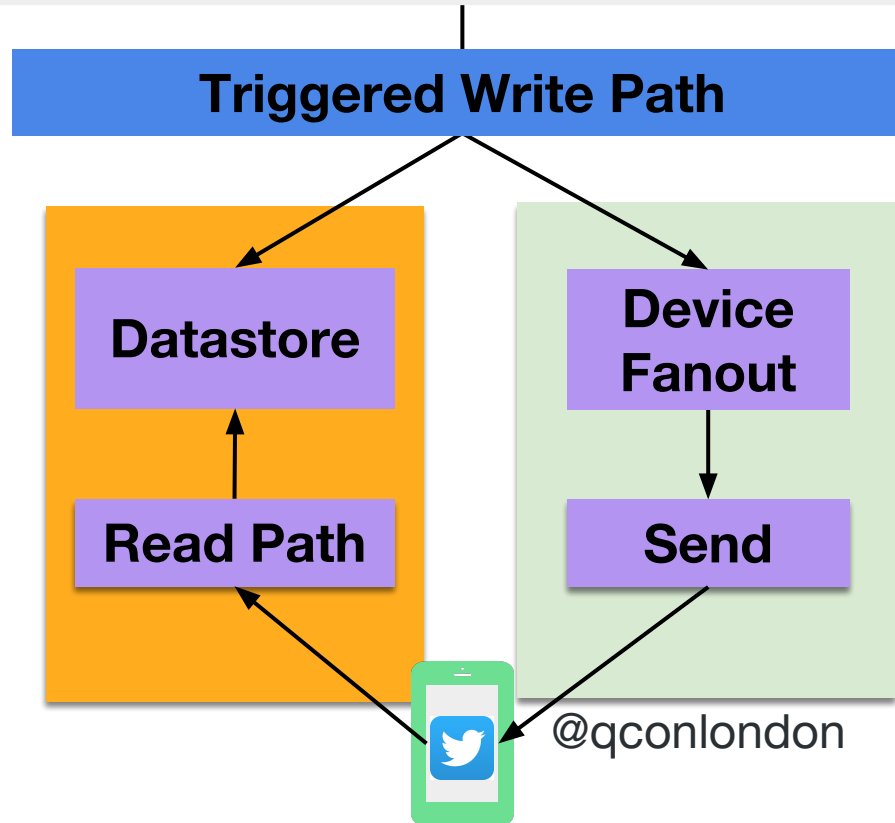




@pathak\_s



Thanks @qconlondon for all the awesome talks...





# Why Personalization?



**Notify users about what's happening  
in **their** world in **realtime****



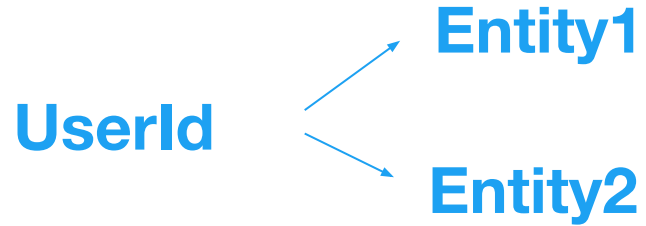
**Notify you about your interests**



# Personalized Fanout



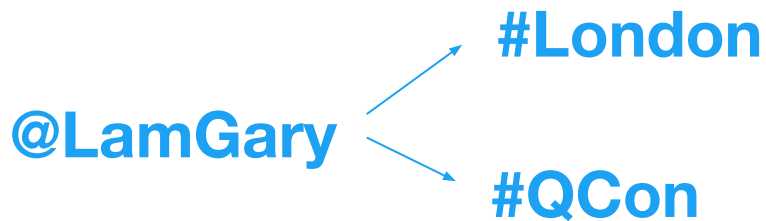
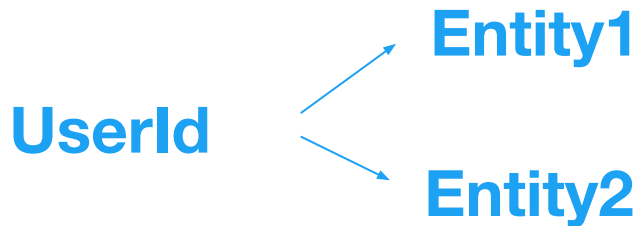
# Personalized Fanout



**Recent Engagements  
On Entities**



# Personalized Fanout



**Recent Engagements  
On Entities**



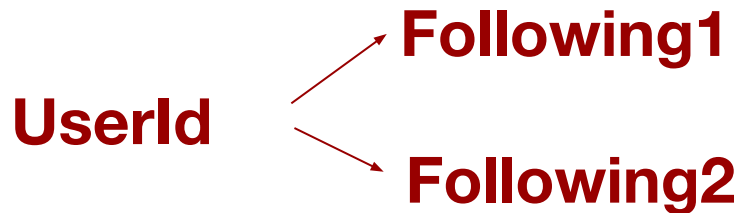
# Recent Engagements on Entities

1. Engagements => Interests
  
2. 'Recent' Engagements
  - a. Twitter is live
  - b. Your interests are changing





# Personalized Fanout

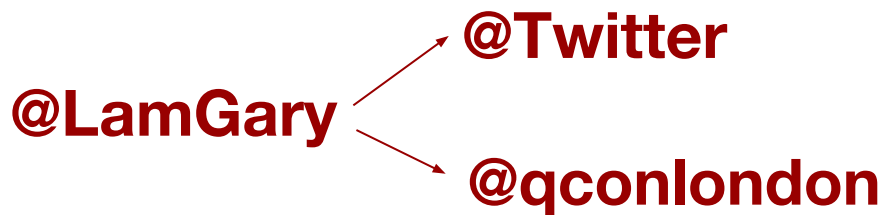
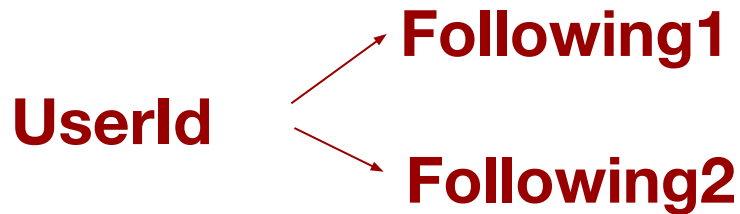


A user's followings are people the user follows

Top N Followings



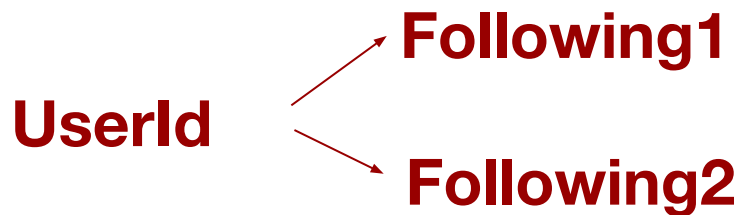
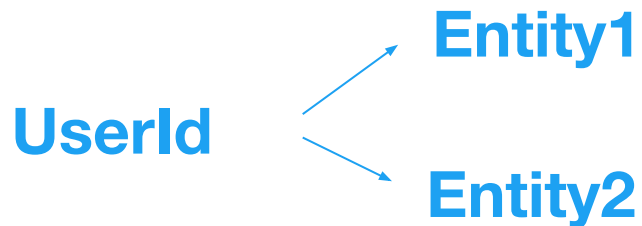
# Personalized Fanout



**Top N Followings**



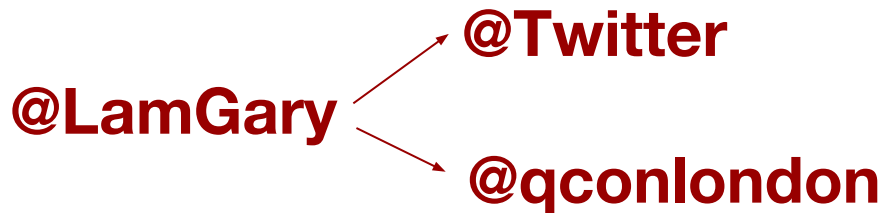
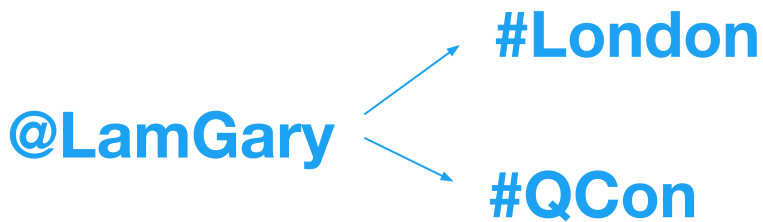
# Personalized Fanout



**Recent Engagements  
On Entities**

**Top N Followings**

# Personalized Fanout



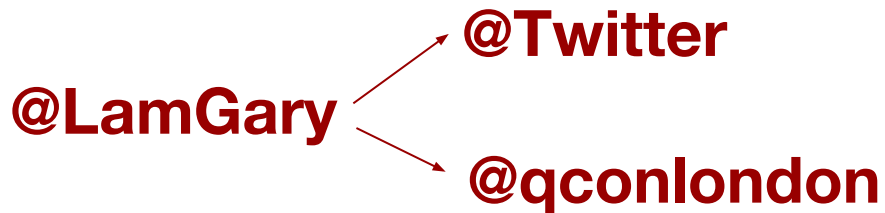
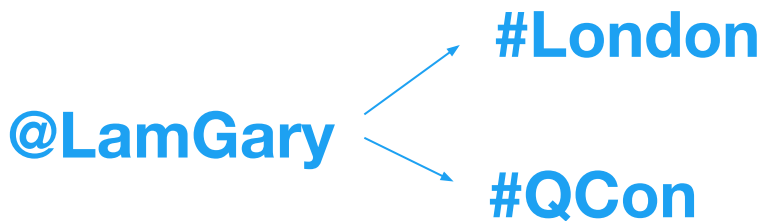
**QCon London**  
@qconlondon

#London is awesome!

**Recent Engagements  
On Entities**

**Top N Followings**

# Personalized Fanout



**QCon London**

@qconlondon

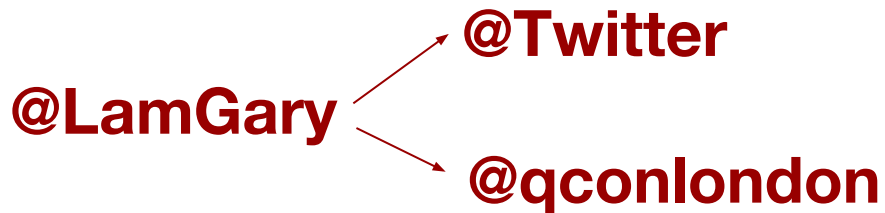
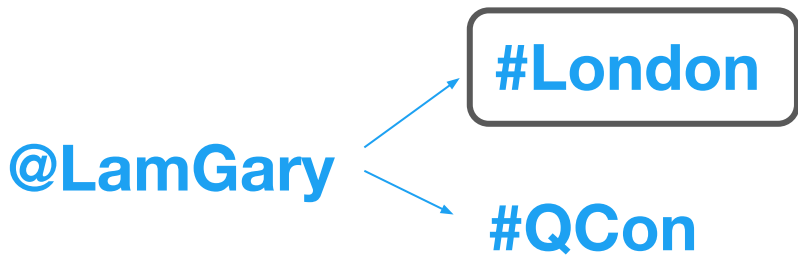
#London is awesome!

**Recent Engagements  
On Entities**

**Top N Followings**



# Personalized Fanout



QCon London

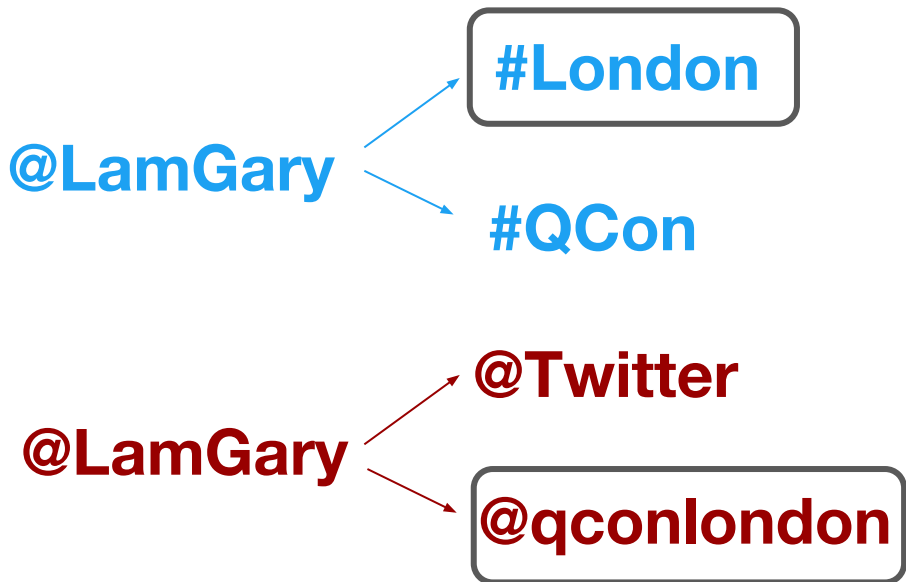
@qconlondon

#London is awesome!

Recent Engagements  
On Entities

Top N Followings

# Personalized Fanout



**Recent Engagements  
On Entities**

**Top N Followings**

# Personalized Fanout Asymmetry



KATY PERRY ✓  
@katyperry

Millions of Katy Perry  
Fans





# Personalized Fanout Asymmetry



**KATY PERRY** ✓  
@katyperry

**Millions of Katy Perry  
Fans**



**Gary Lam**  
@lamgary

**My mom**



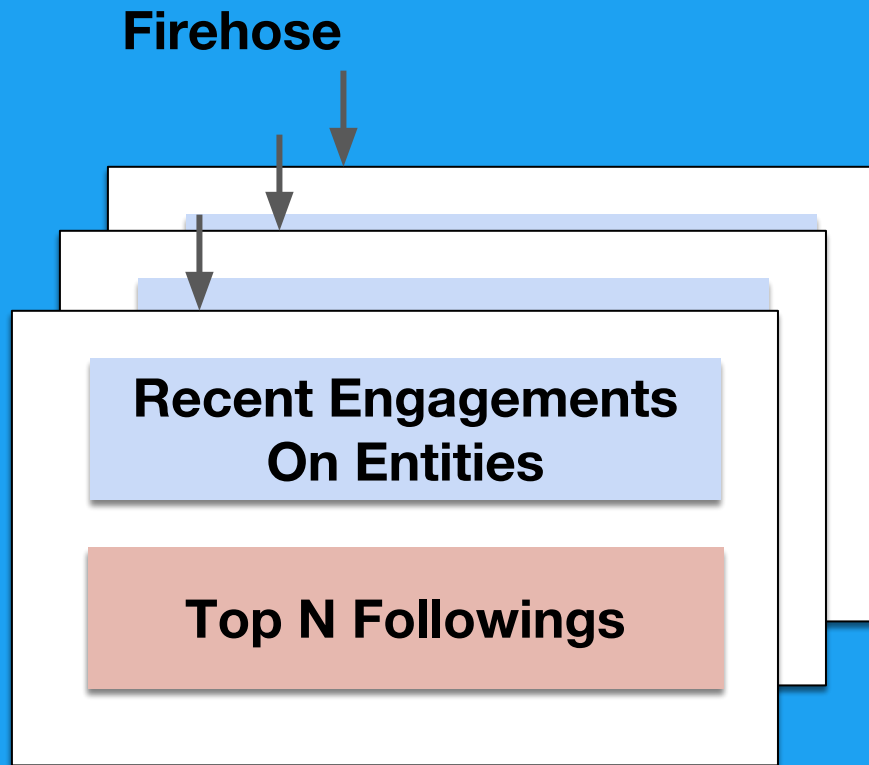


**Co-location: no network lookups**



# Co-location & Sharding

- **Shard by user**
- **For a given user**
  - **Engagements and Top Followings co-located**
- **No network lookups!**





**KATY PERRY** ✓

@katyperry

Follow



KATY HERE. I lost a bet for best picture (I wanted moonlight...

**FollowersA**

**FollowersB**

**Recent Engagements  
On Entities**

**Recent Engagements  
On Entities**

**Top N Followings**

**Top N Followings**

**Shard 1**

**Shard 2**



**KATY PERRY** ✓

@katyperry

Follow



KATY HERE. I lost a bet for best picture (I wanted moonlight...

**FollowerA**

**Engagements: La La Land**

**Top Following: @katyperry**

**Shard 1**

**FollowerB**

**Recent Engagements  
On Entities**

**Top N Followings**

**Shard 2**



**KATY PERRY** ✓

@katyperry

+ Follow



KATY HERE. I lost a bet for best picture (I wanted moonlight...

**FollowersA**

**FollowersB**

**Engagements: La La Land**

**Top Following: @katyperry**


**Engagements: Moonlight**

**Top Following: @katyperry**

**Shard 1**

**Shard 2**



 **KATY PERRY** ✓  
@katyperry

[+ Follow](#) ▾

KATY HERE. I lost a bet for best picture (I wanted moonlight..)

**FollowersA**

**Engagements: La La Land**

**Top Following: @katyperry**

**Shard 1**


**FollowersB**

**Engagements: Moonlight**

**Top Following: @katyperry**

**Shard 2**



 **KATY PERRY** ✓  
@katyperry

[+ Follow](#) ▾

KATY HERE. I lost a bet for best picture (I wanted moonlight..)

**FollowersA**

**Engagements: La La Land**

**Top Following: @katyperry**

**Shard 1**

**FollowersB**


**Engagements: Moonlight**

**Top Following: @katyperry**

**Shard 2**





 **KATY PERRY** ✓  
@katyperry

[+ Follow](#) ▾

KATY HERE. I lost a bet for best picture (I wanted moonlight..)

**FollowersA**

**FollowersB**

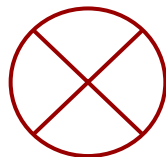
**Engagements: La La Land**

**Top Following: @katyperry**

**Engagements: Moonlight**

**Top Following: @katyperry**

**Shard 1**



**Shard 2**

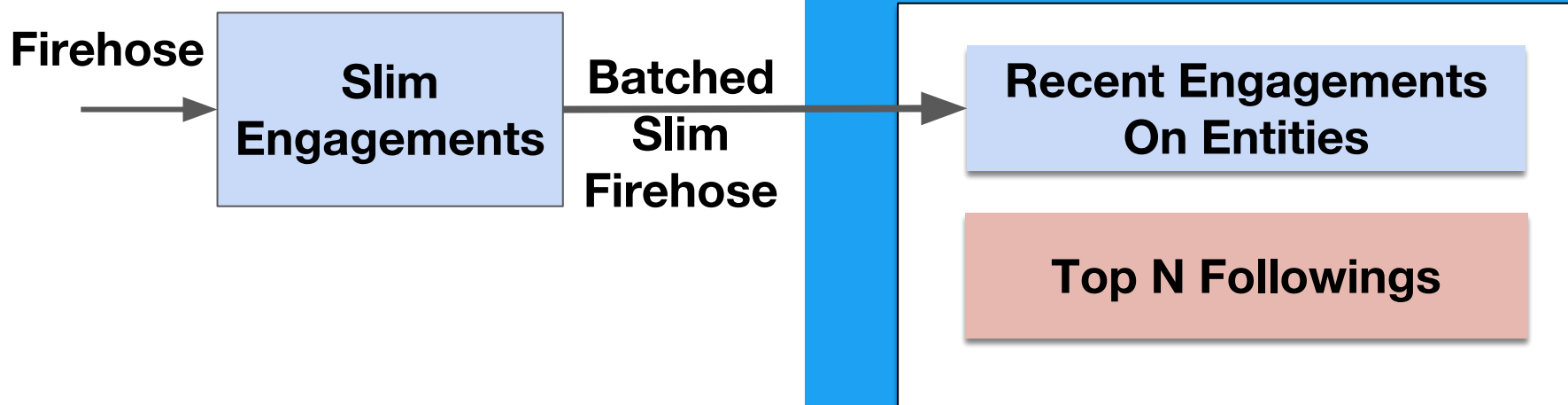




# Data preprocessing

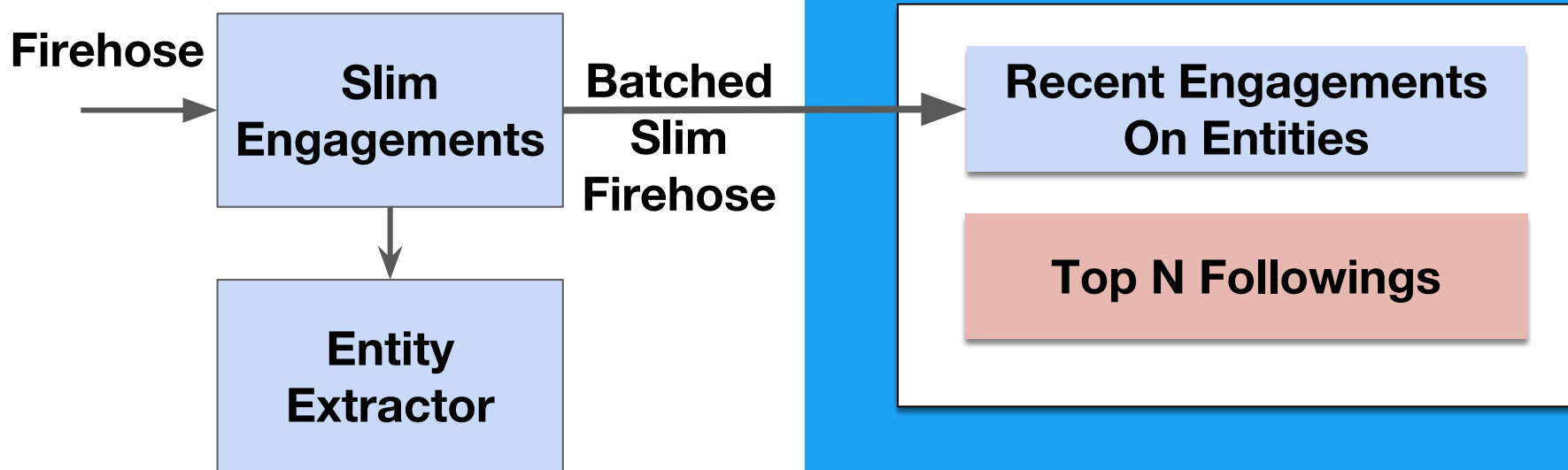


# Recent Engagements





# Recent Engagements





# Top N Followings

Find Top N followings  
for every user

Partition by userId

1

2

3

....

N

Partitioned Top Followings on  
HDFS



# Top N Followings

Find Top N followings  
for every user

Partition by userId

1

2

3

....

N

Partitioned Top Followings on  
HDFS

Recent Engagements

Top N Followings

Shard 3



# Personalized Fanout Key Takeaways

- **Co-location of data**
- **Data pre-processing**
- **Realtime Personalization is expensive**



# @HillaryClinton

Tweets about Clinton this year



Becomes Presumptive Democratic Nominee

Democratic National Convention

Presidential Debates



 #Election2016

Source - Twitter Internal Data 1/1/16 - 11/3/16



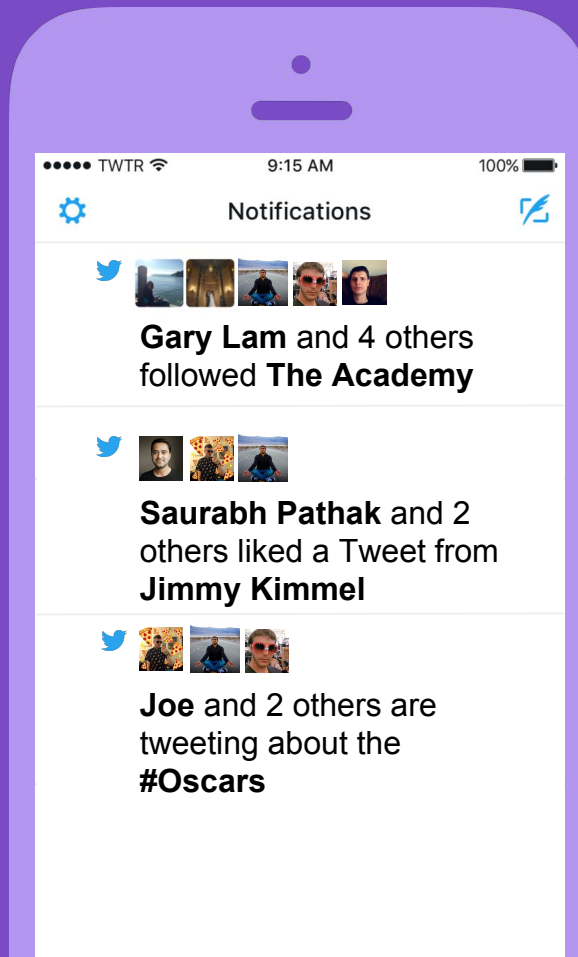


# Recommendations



# Recommendations

- Find content you love
- Find Interesting people





**Relax realtime constraint  
control your load**



# Recommendations

```
for each user {  
}
```

- $O(\text{Users})$  vs.  $O(\text{Events})$
- Latency in minutes vs. seconds

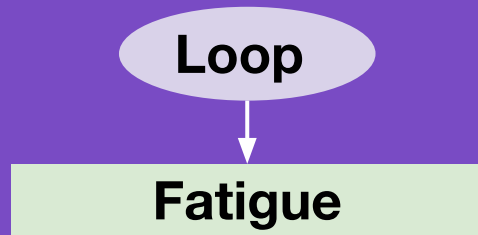
Loop



# Recommendations

Send at the right time

- History Store

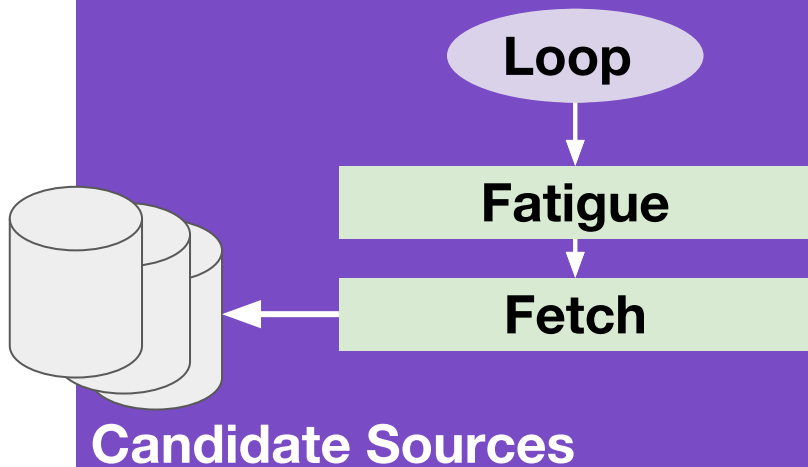




# Recommendations

Find content for user through  
'Candidate Sources':

- GraphJet
- Scalding

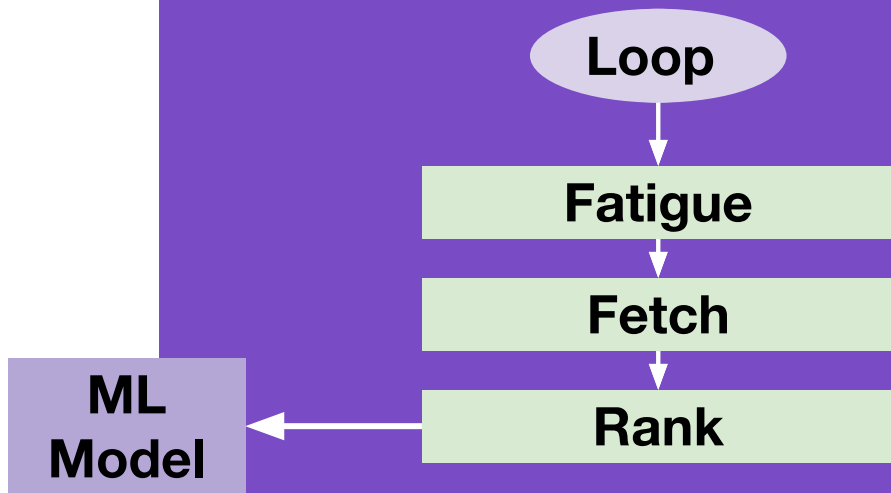




# Recommendations

Pick the best candidate

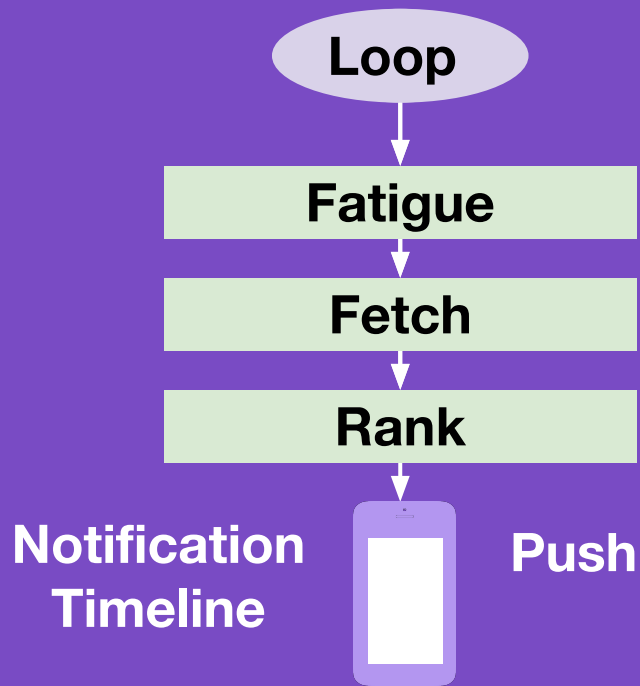
- e.g. Most social proof
- Historical Engagement





# Recommendations

- **Send through notification infrastructure**

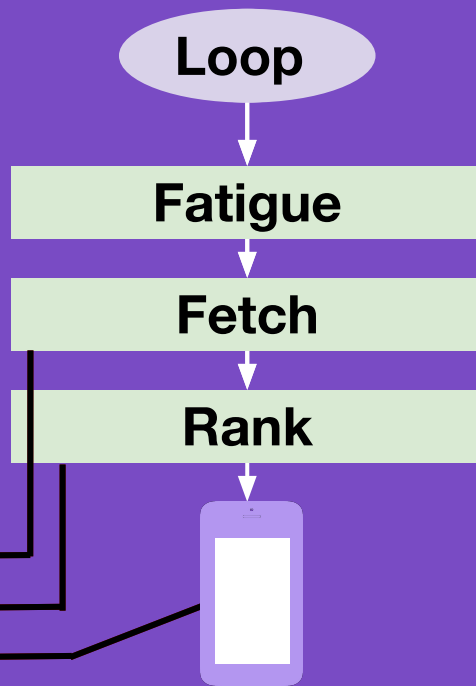






# Recommendations

Infrastructure





# Recommendations

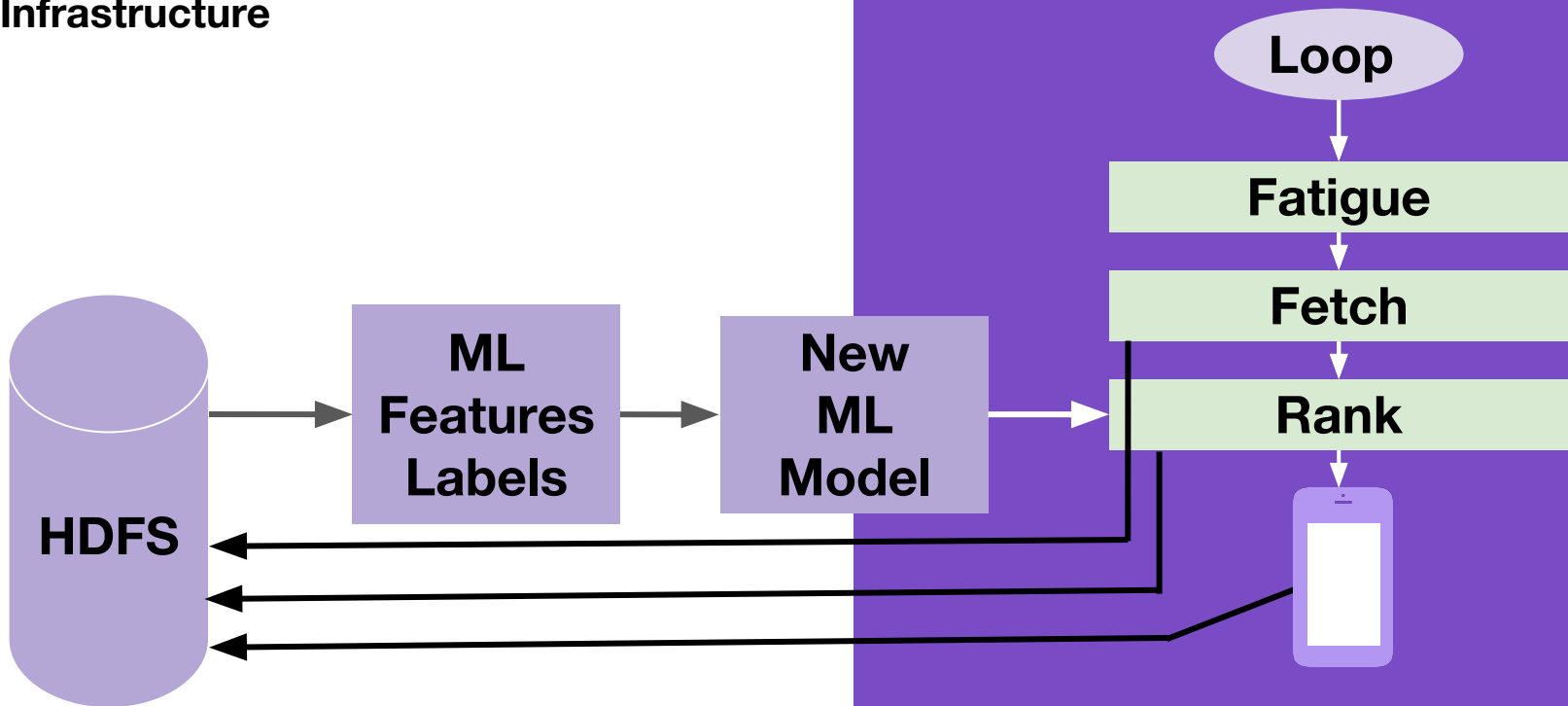
Infrastructure





# Recommendations

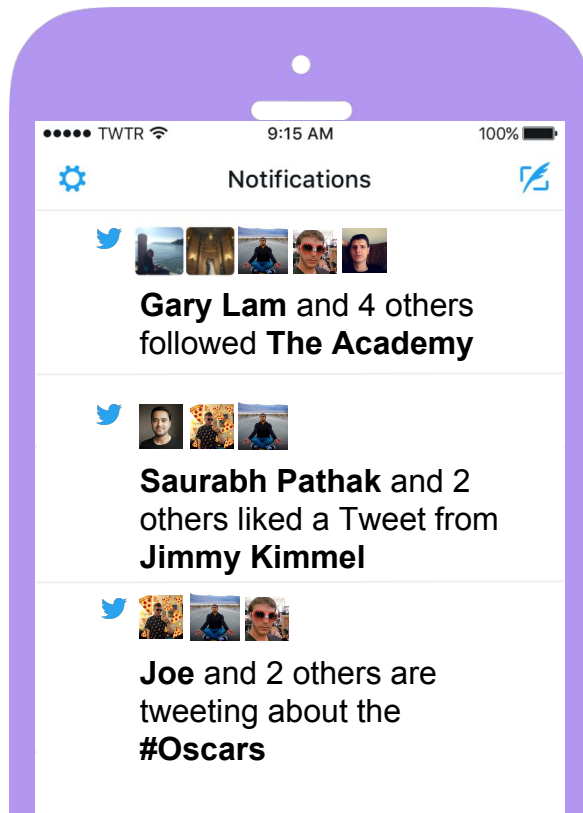
Infrastructure





# Recommendations Key Takeaways

- Relax realtime constraint
- Diverse set of content sources
- Data is key for personalization





**Putting it all together**





## Notifications Infrastructure



Realtime

Personalized



**Notifications  
Infrastructure**



**Realtime**

**Personalized**



**Triggered  
Notifications**



**Notifications  
Infrastructure**





# Realtime

# Personalized



**Triggered Notifications**

**Personalized Fanout**

**Notifications Infrastructure**



# Realtime

# Personalized



**Triggered Notifications**

**Personalized Fanout**

**Recommendations**

**Notifications Infrastructure**





# Thank you!

**Saurabh Pathak**      **@pathak\_s**

**Gary Lam**              **@LamGary**