



Building Near Realtime Contextual Recommendations for Active Communities on LinkedIn

LinkedIn's Path toward Transforming
Interactions with its Members

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LinkedIn

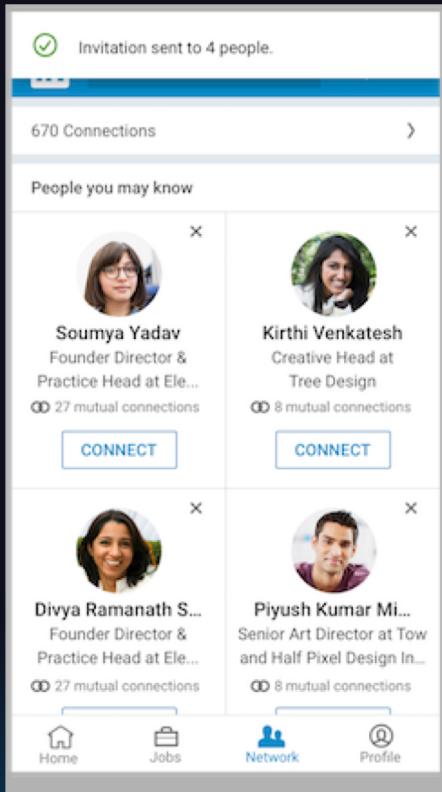
OUR VISION

Create economic opportunity for every
member of the global workforce

OUR MISSION

Use AI to **connect** the world's professionals to make them more productive and successful

What is People You May Know (PYMK)



Mission:

Connect our members to the people who matter to them professionally enabling them to access opportunities within the LinkedIn ecosystem.

Strategy:

Mine data sources including the LinkedIn Economic Graph and member activities and use large scale ML algorithms to recommend members to connect to people they might know.

Building a network is a foundational value prop for **LinkedIn**

PEOPLE YOU MAY KNOW

Stay connected,
stay informed

e.g. connections for feed liquidity

Advance my
career

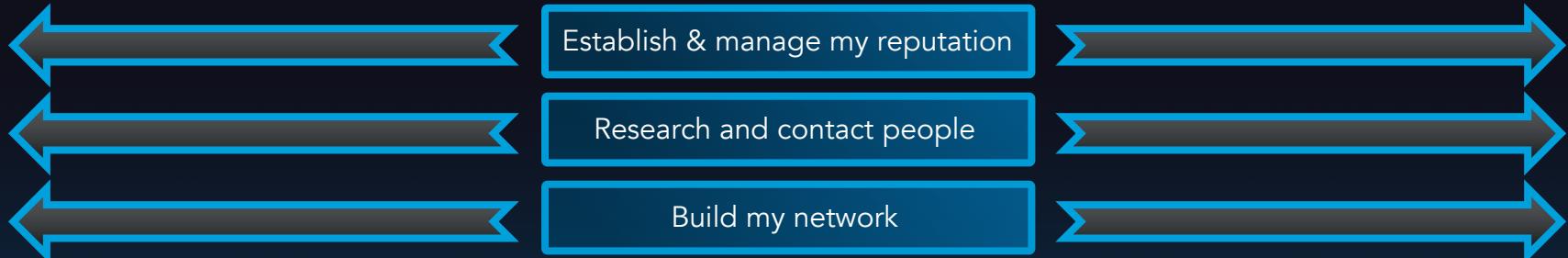
e.g. job seekers using connections
for job introductions

Work
smarter

e.g. hiring managers using their
networks to find candidates



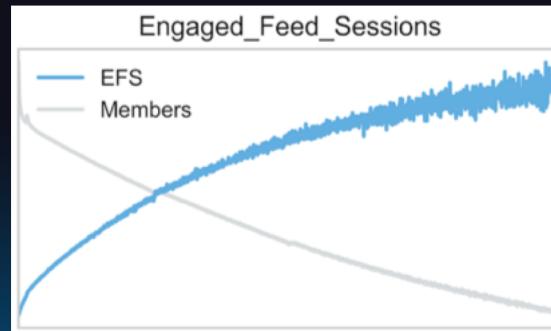
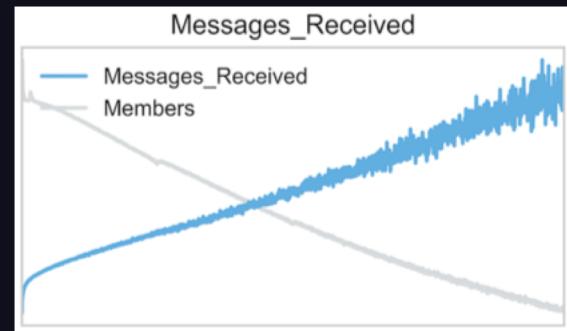
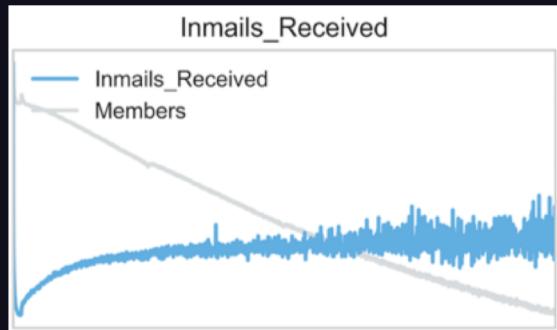
Establish & manage my reputation



Research and contact people

Build my network

High Quality Relevant Connections Matters!



x-axis: #connections

Developing a true north metric



True North

Our vision to
values



Developing a true north metric



Metric Development to have a true north success of the product



Strategic analysis to identify product opportunities



A/B testing to make informed product decision

Metric Development

- **True north:** Engaged members with High Quality Connections
- **Proposed Metric:** “PYMK invitation sent and accepted” instead of “PYMK invitation sent”

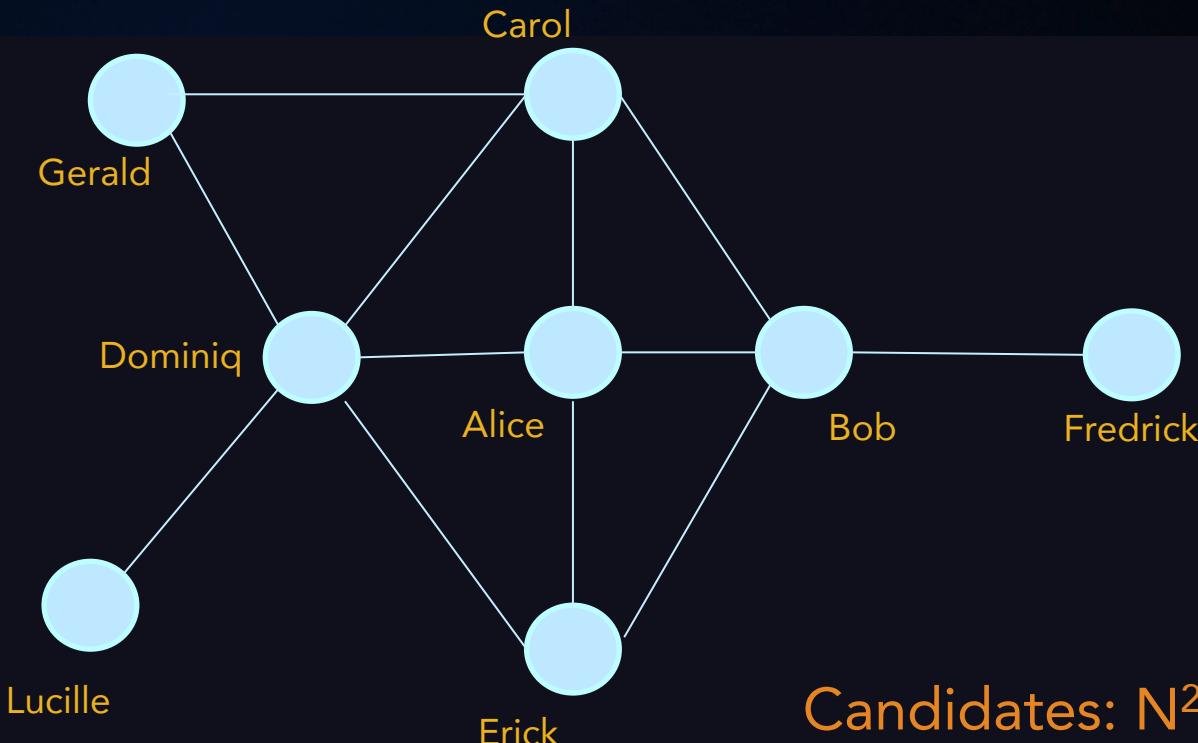


Metric Development

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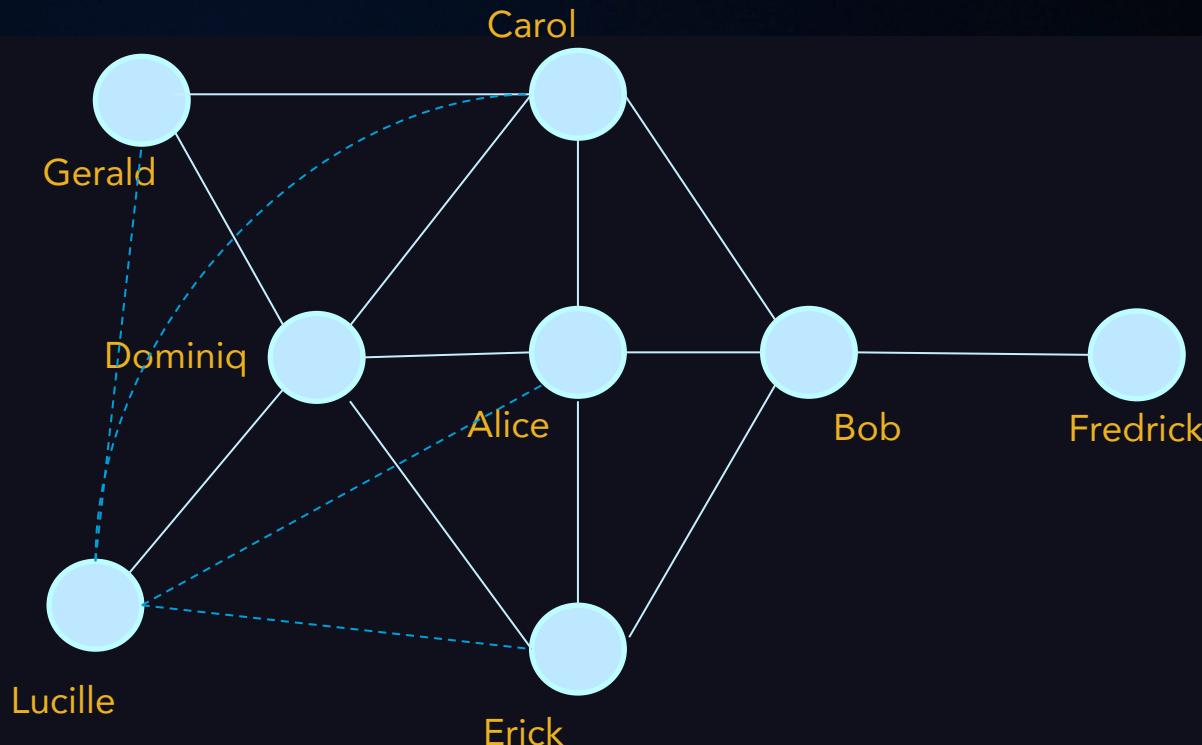
Connecting the worlds professionals



Connecting the worlds professionals

Intuition: Friends of my Friends are
likely to be my Friends

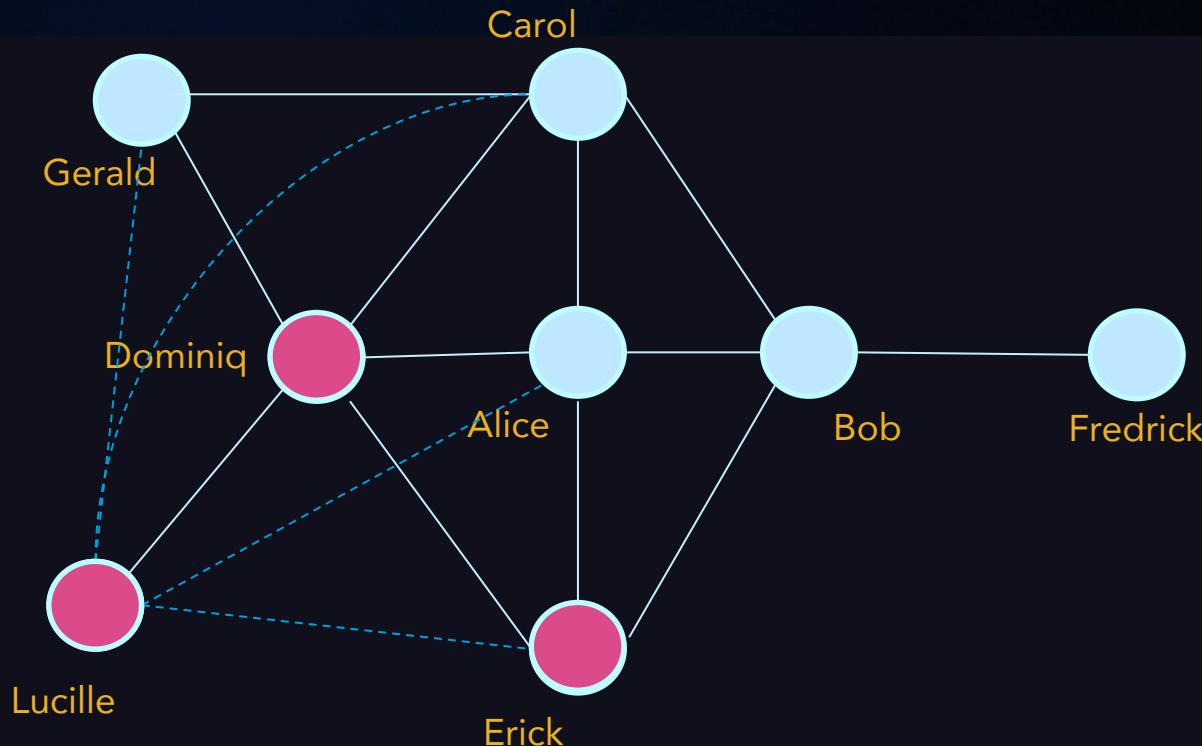
Connecting the worlds professionals



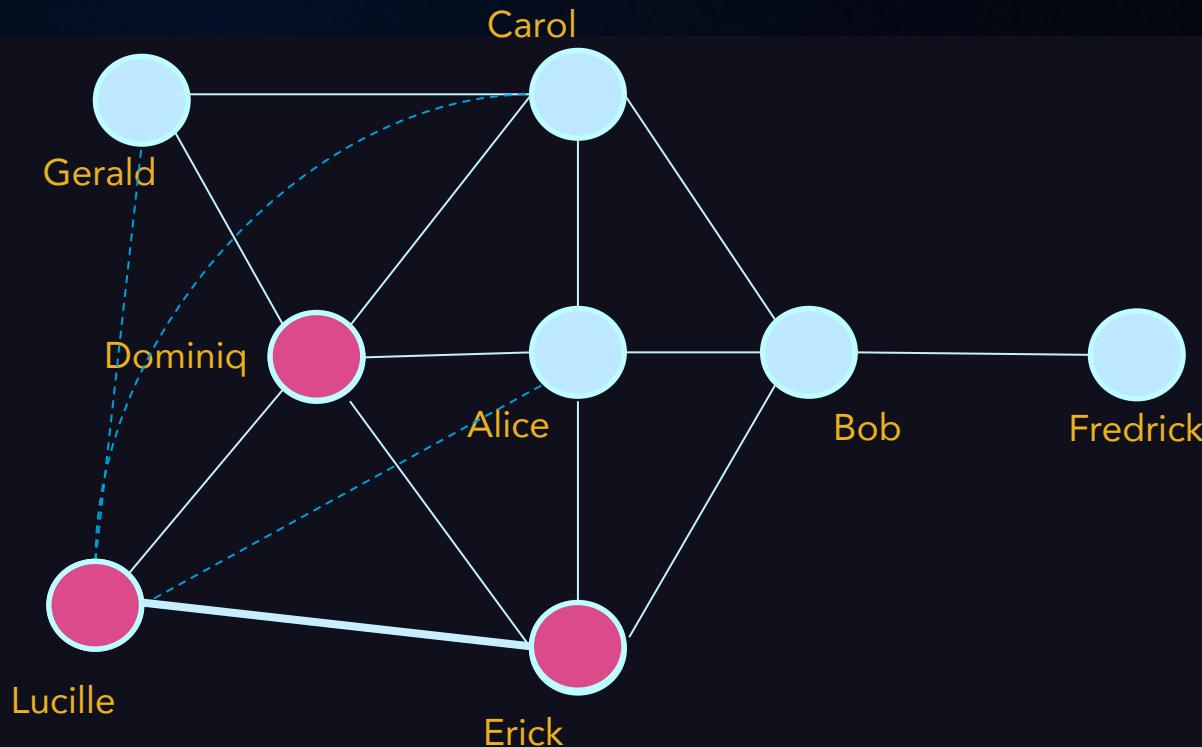
Connecting the worlds professionals

Intuition: People I know may share common connections, common institutions, skills etc.

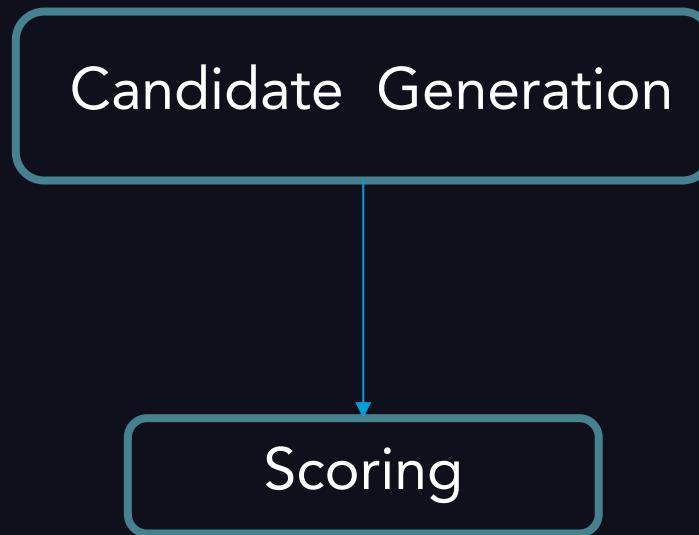
Connecting the worlds professionals



Connecting the worlds professionals



Typical Playbook for Recommendation Systems



Candidate Generation

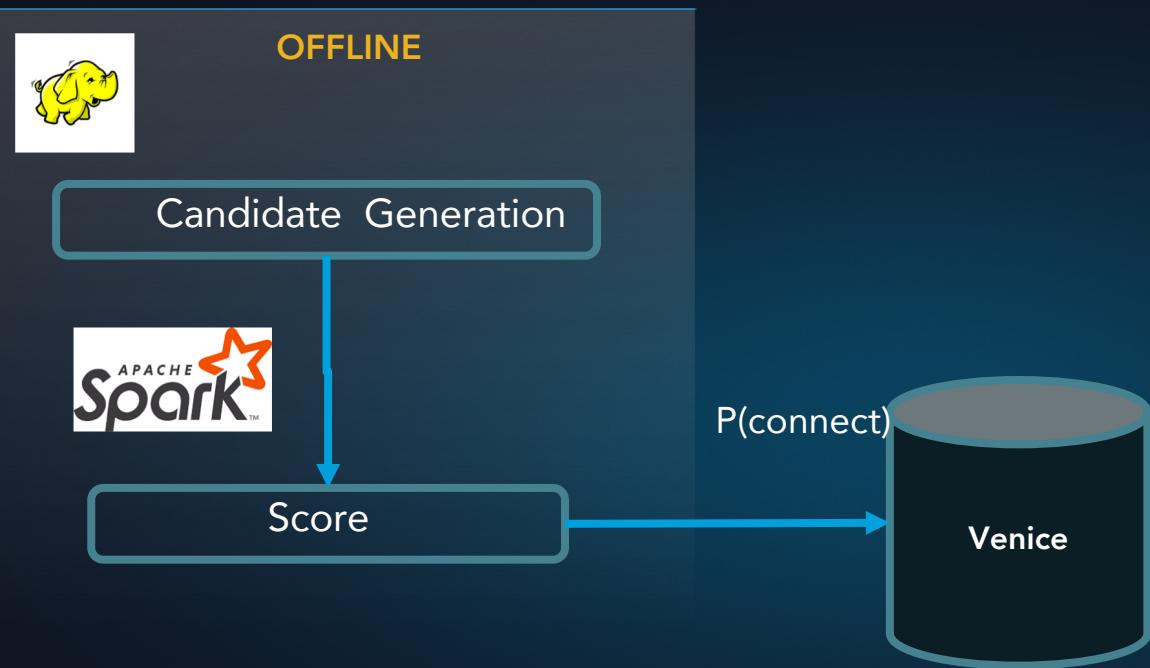
- Friends of Friends
- Extensions: Personalized Page Rank

Scoring

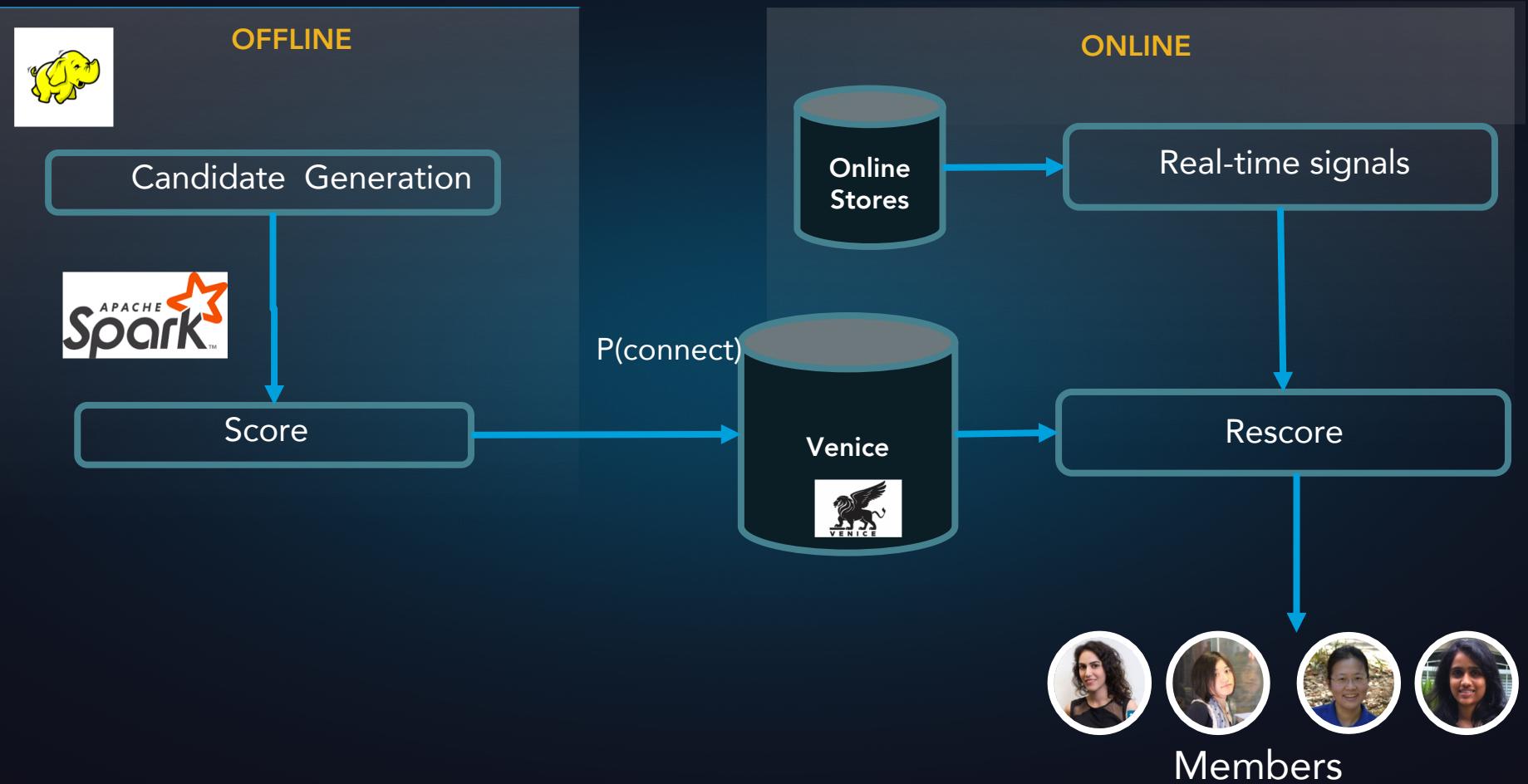
P(connect)

- Node features: skill, school, company, P(invite),
P(accept|invite) ...
- Edge features: common connections, same school, same
company ...

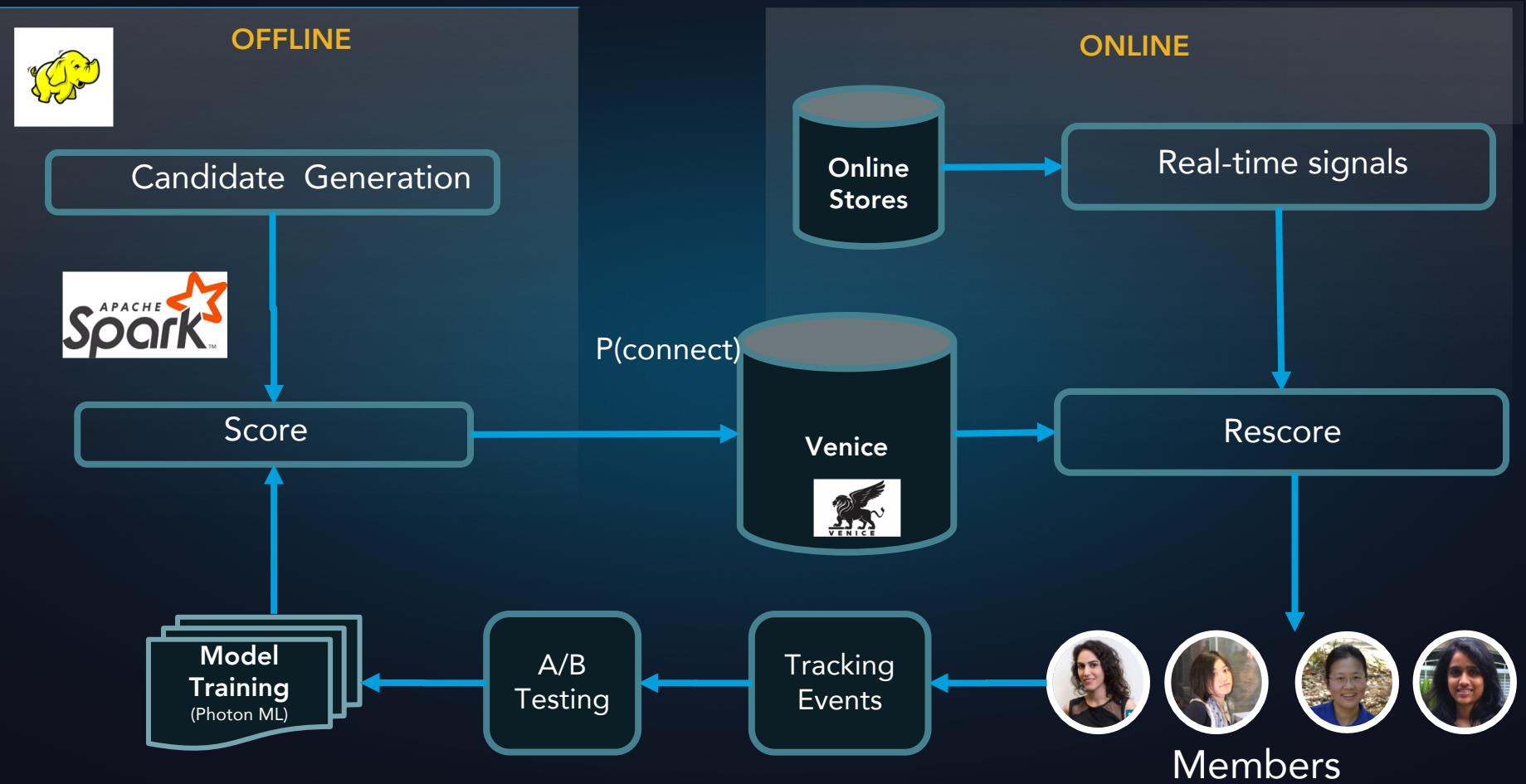
PYMK Architecture (circa 2015)



PYMK Architecture (circa 2015)



PYMK Architecture (circa 2015)



Data Processed grows linearly



Records scored



Records scored grows super linear in member growth

Scalability of Batch Offline

node_features

mid	feature

pair_features

source_mid	dest_mid	features

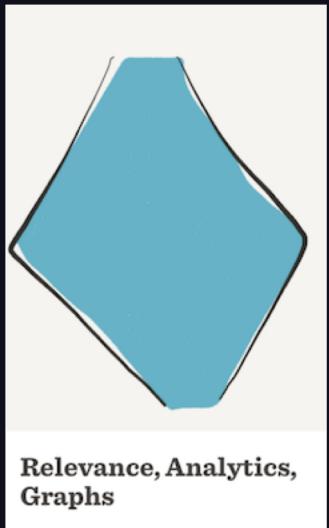
1. inter = JOIN node_features WITH pair_features table WHERE mid == source_mid
2. result = JOIN inter WITH node_features WHERE mid == dest_mid

source_mid dest_mid source_features dest_features pair_features

Wide middle

Score (result)

Need Smart Joins



Problem	Strategy	Before	Now
Scoring	2D Hash Join	6 hours	10 seconds
Triangle Closing	Matrix Multiply	3-4 hours	10 minutes

[Managing Exploding Big Data](#) (Linkedin Engineering Blog Post)

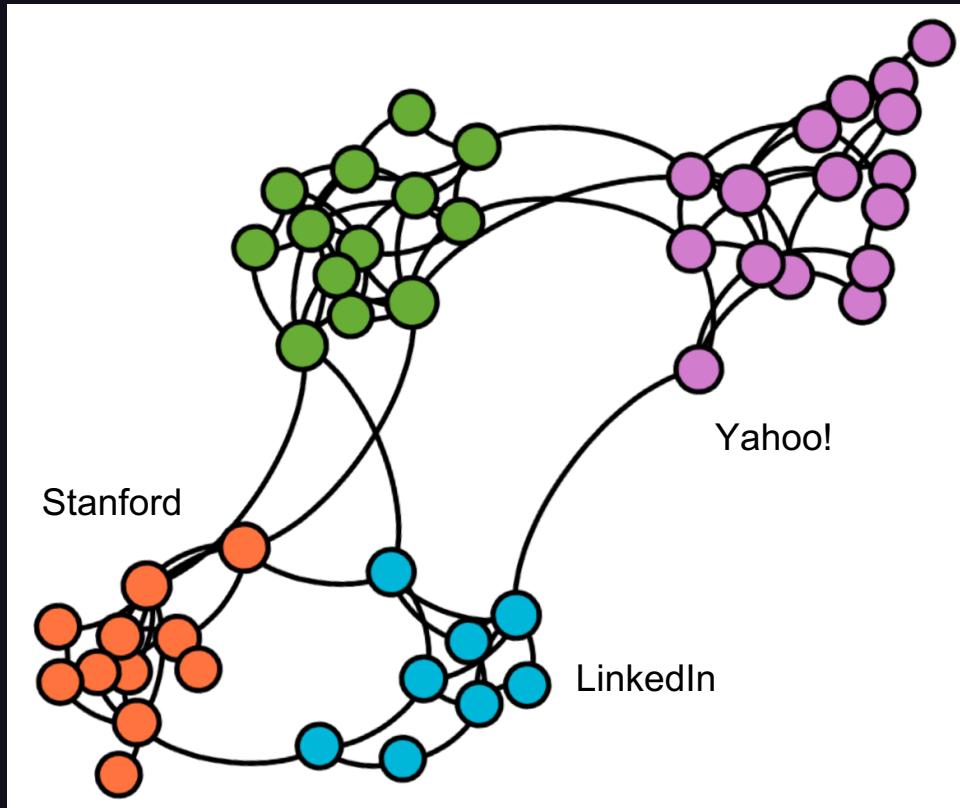
Observation: Freshness matters!



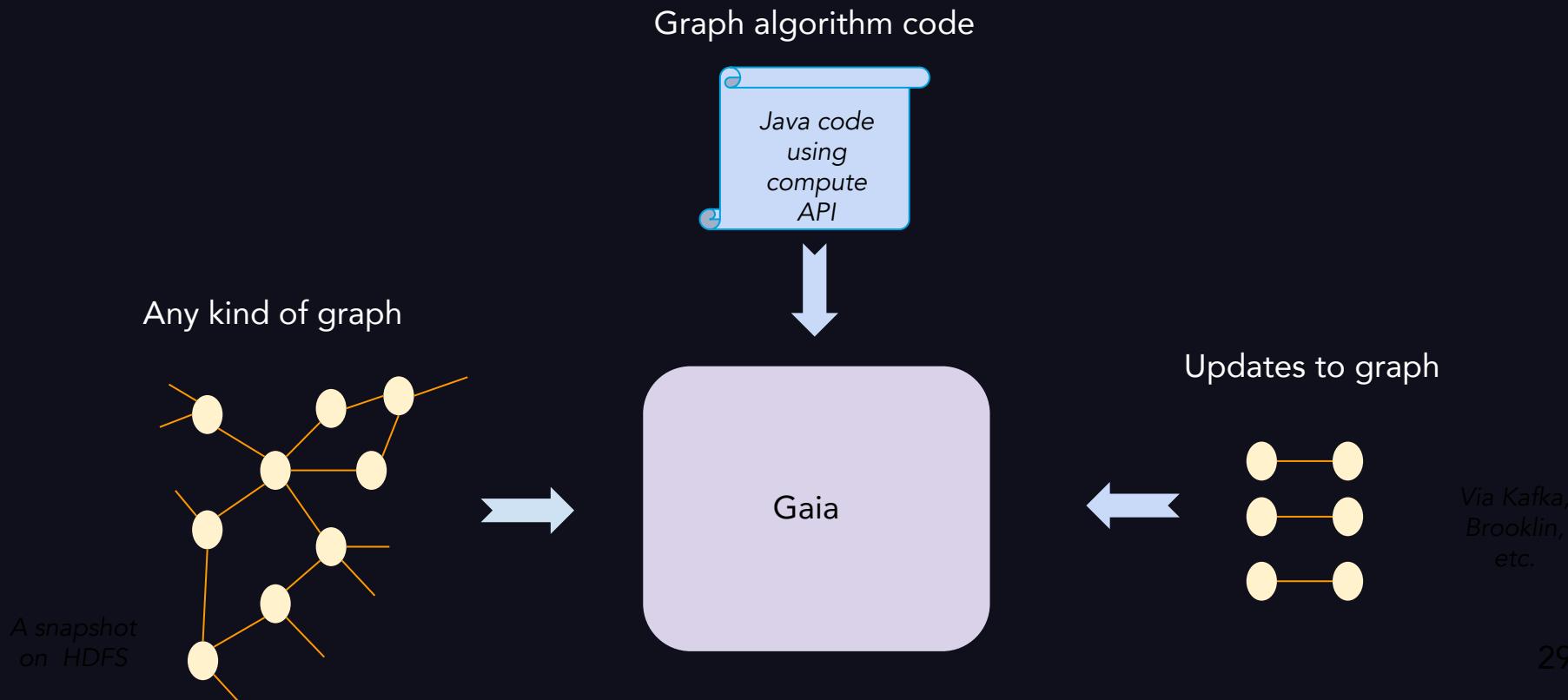
Why?

Why Near real-time PYMK

- Network building is contextual.
- Context often involves exploring a cohort/subnetwork with common properties
- People build networks in few long sessions (not a daily use case).



Near Realtime Recommendation Platform: GAIA



Near Realtime Recommendations

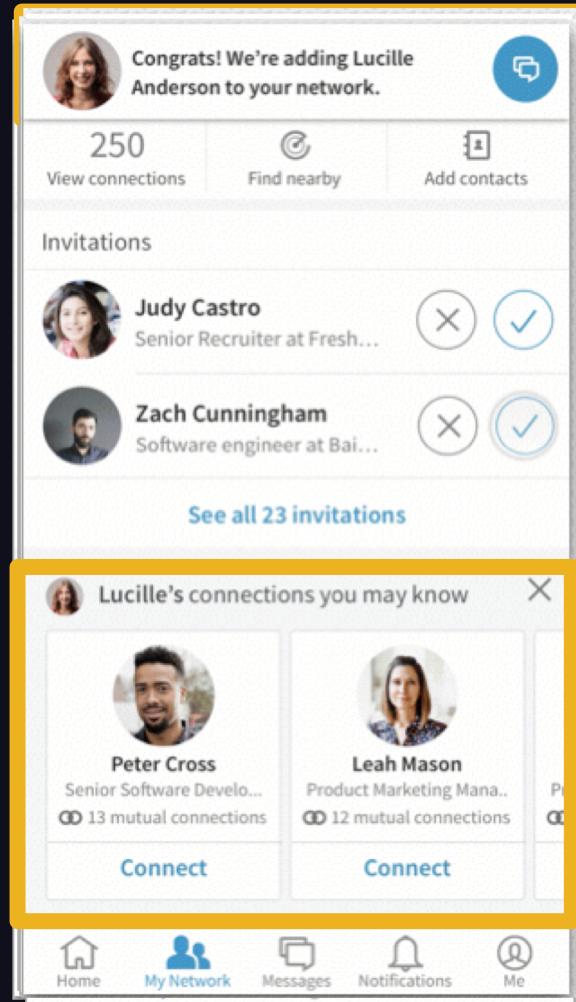
One of the biggest Site-wide
improvements in connections

- ++ achieve 30 connections
- ++ quality signups

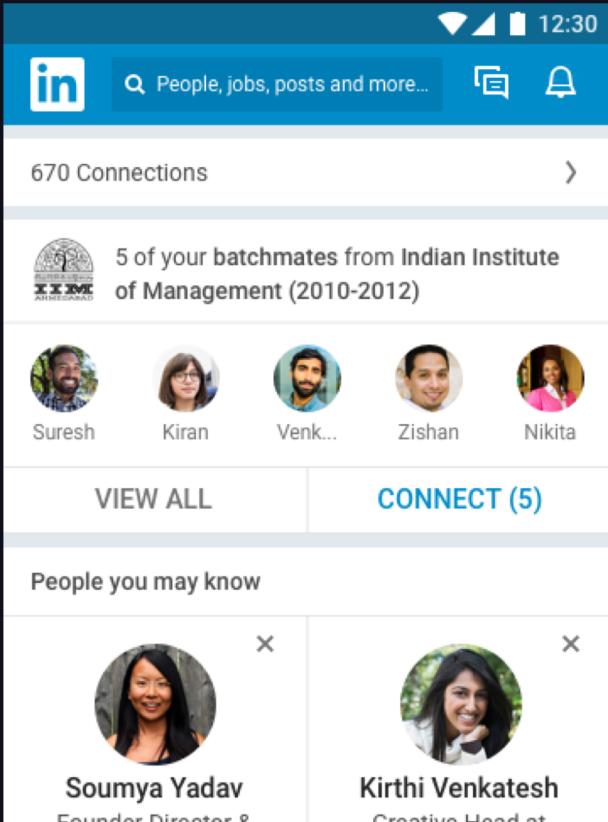
....

A Conversational “Network Builder”

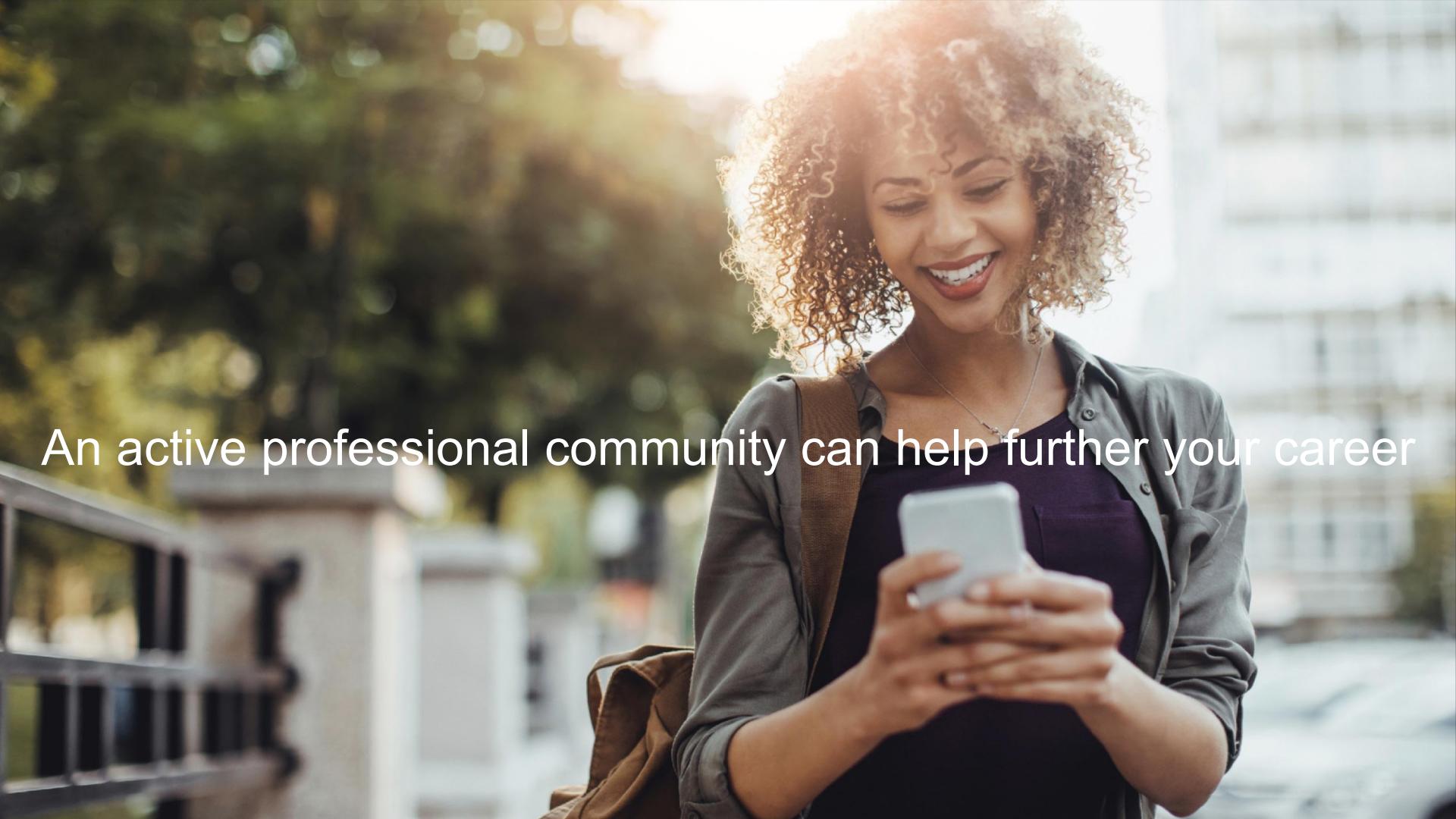
Fast, contextualized responses in the App to Member conversation have a large impact on the network



Platforms unlock new product experiences

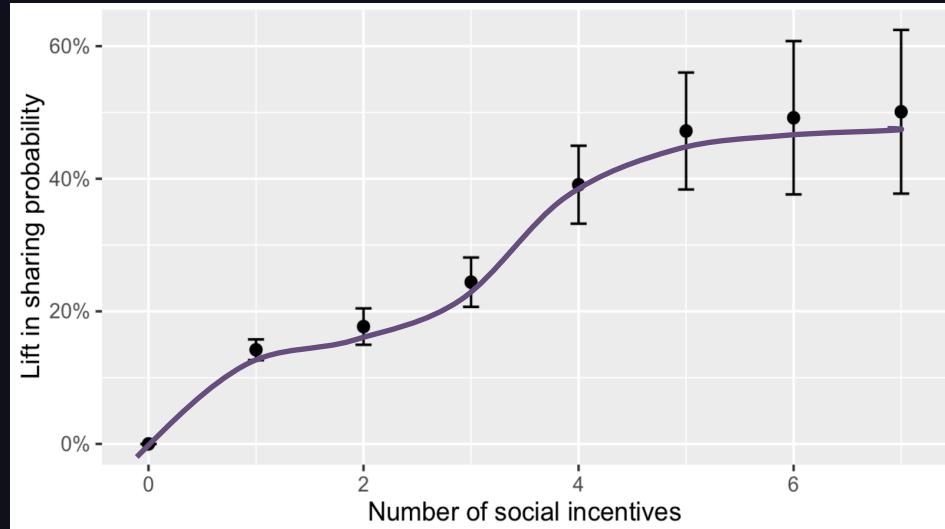


Context matters

A woman with curly hair is smiling while looking at her phone. She is wearing a grey jacket over a purple shirt. A brown backpack strap is visible on her shoulder. The background is blurred, showing trees and a building.

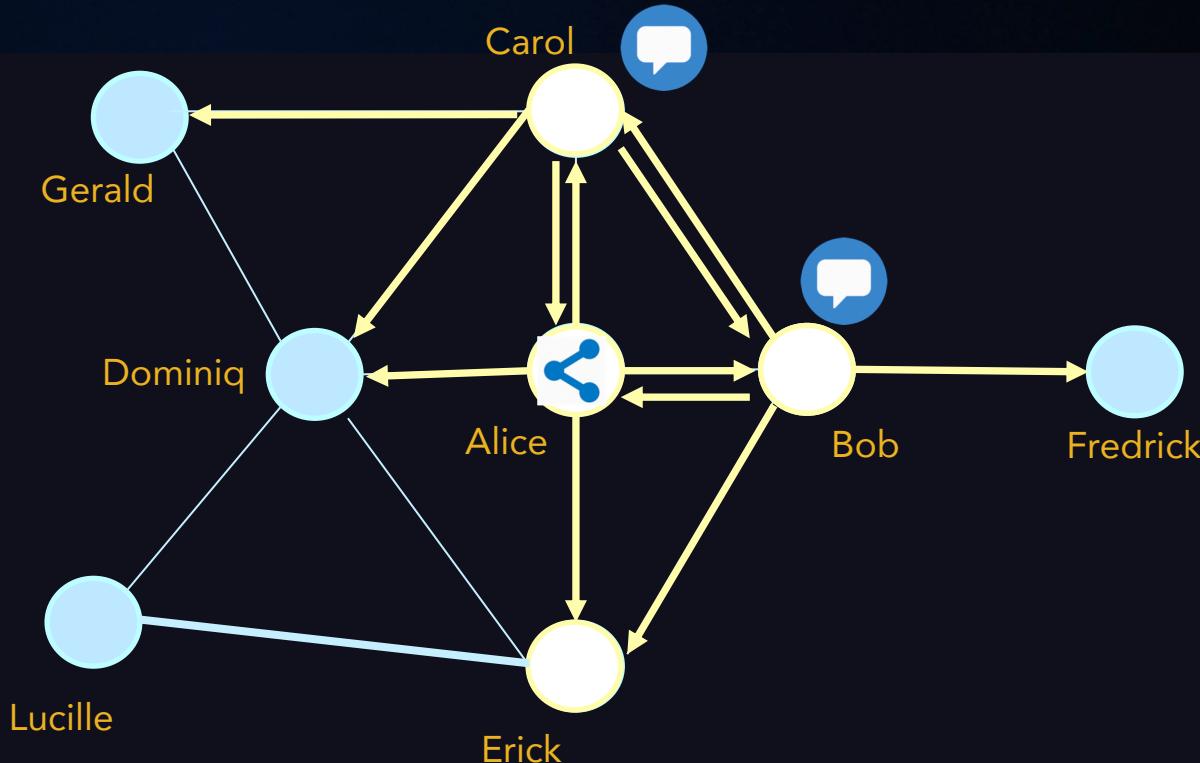
An active professional community can help further your career

Building active communities

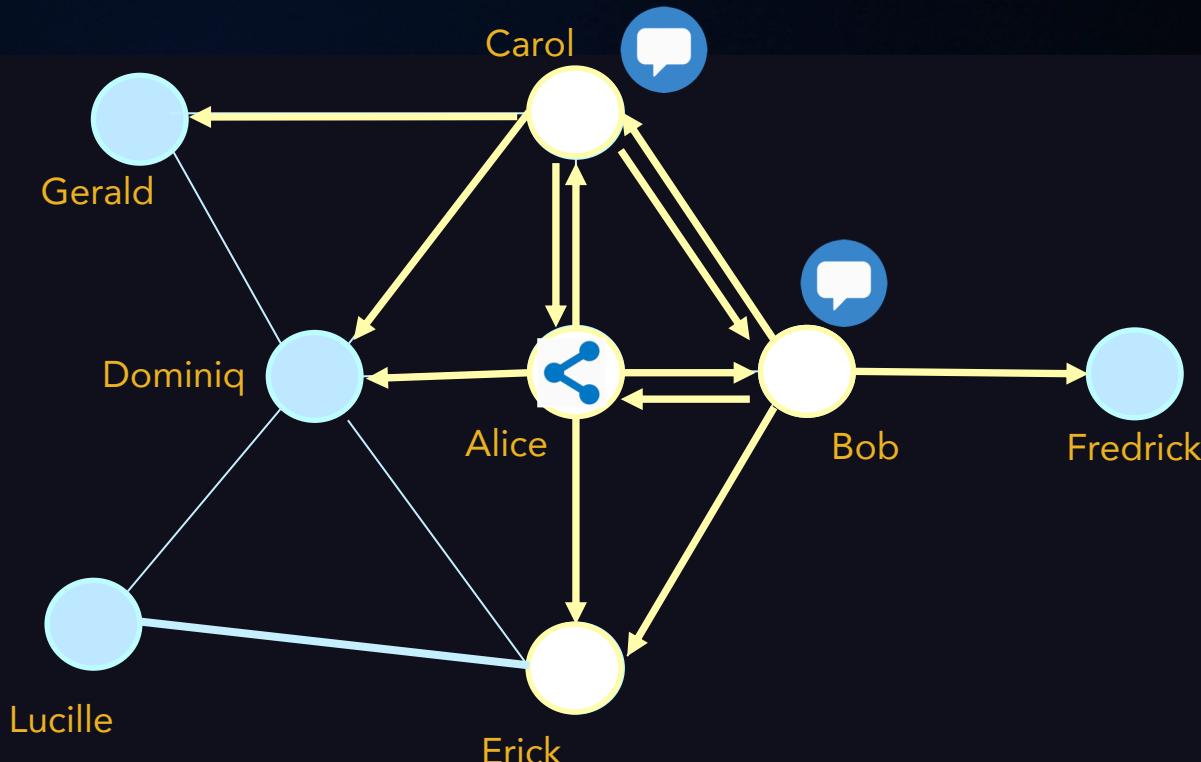


Observation:
more responses to creation
(contributions) → more
frequent future creations →
long-term engagement

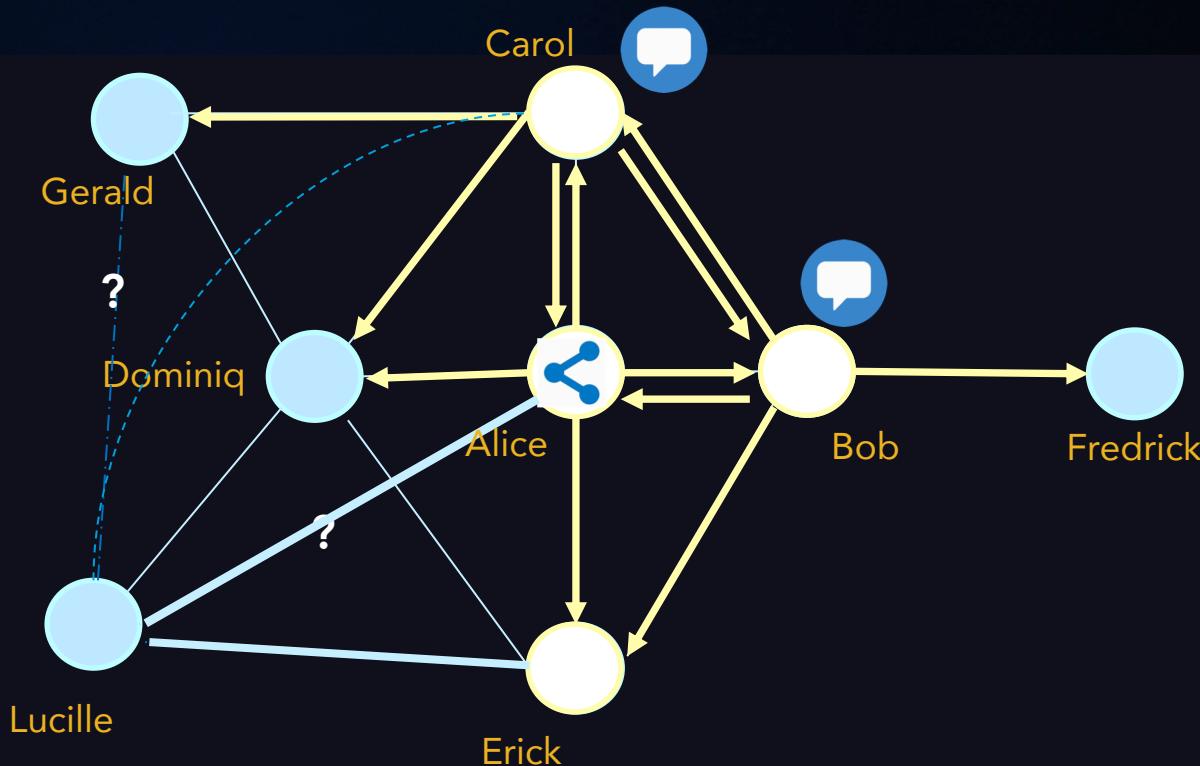
An active professional community



Biasing connection recommendations for an active community



Biasing connection recommendations for an active community



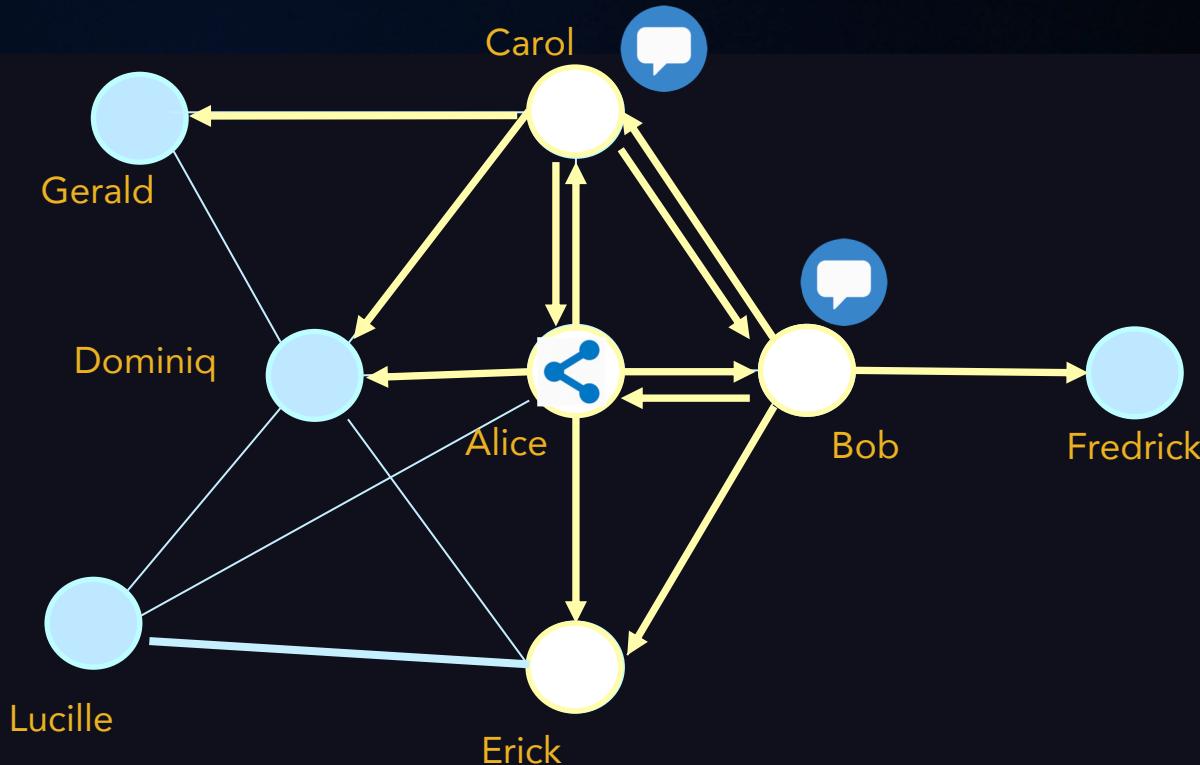
Tuning Connection Recommendations to Conversations

$$\begin{aligned} Score(m1, m2) = & P(\text{connect} | m1, m2)(1 + \\ & + \alpha P(\text{conversation} | \text{connection}_{m1, m2})) \end{aligned}$$

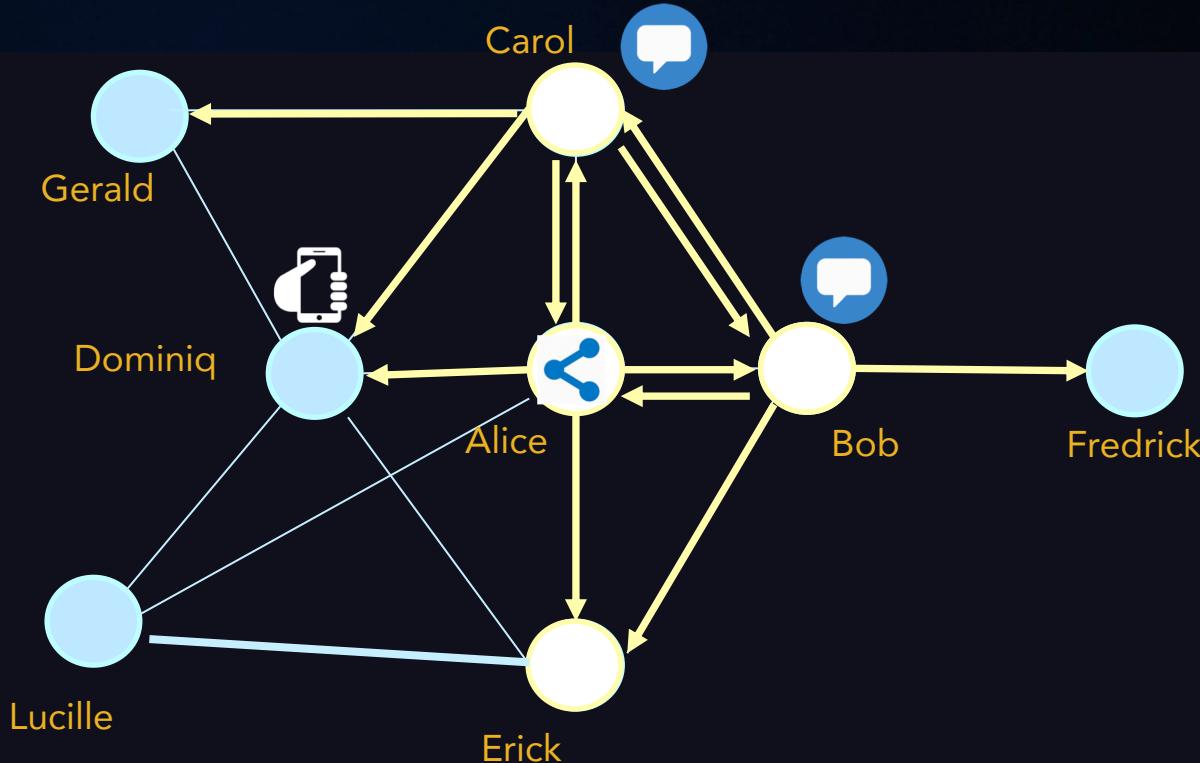
Notifications

The role of notifications for active communities

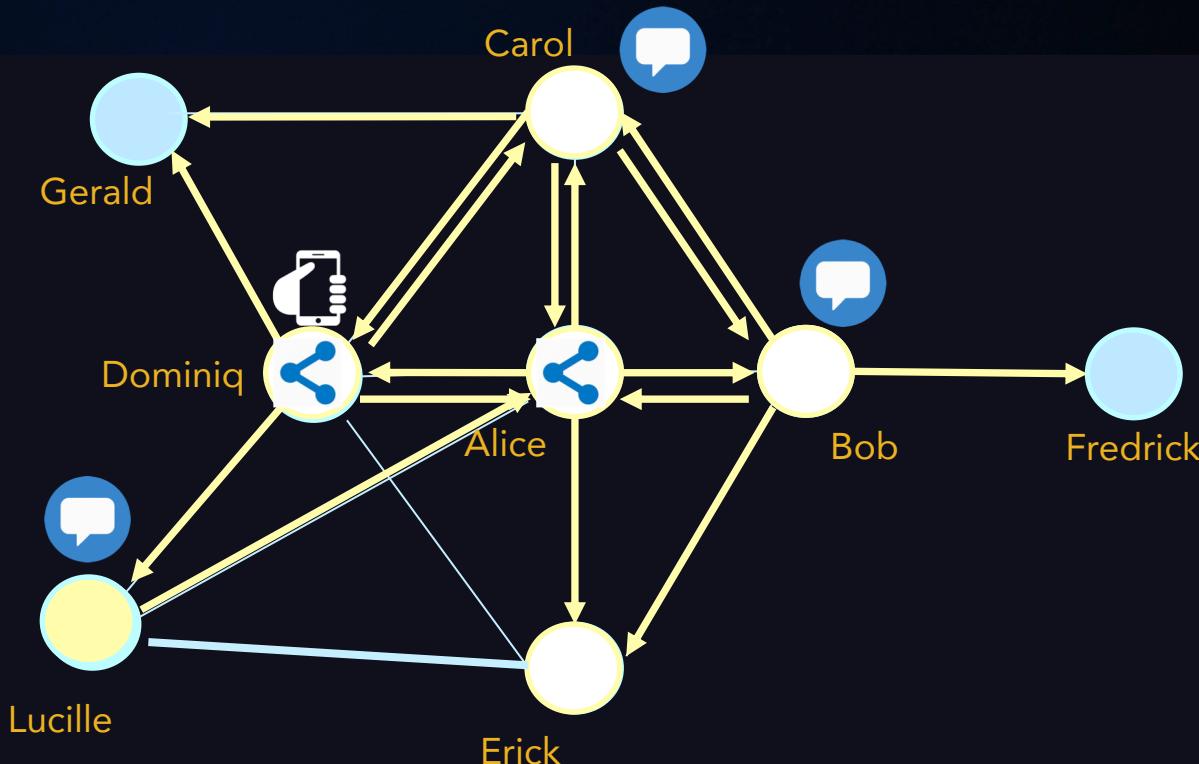
Notifications to never miss a conversation



Notifications to never miss a conversation



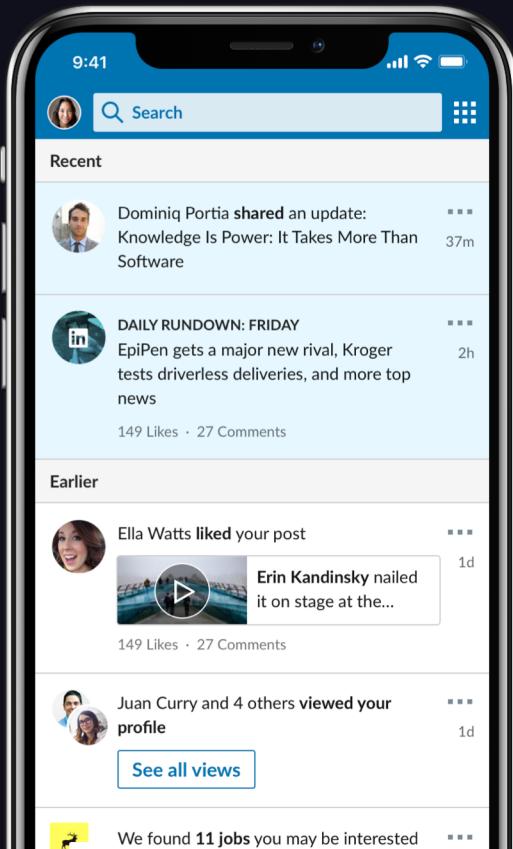
Can result in further viral actions



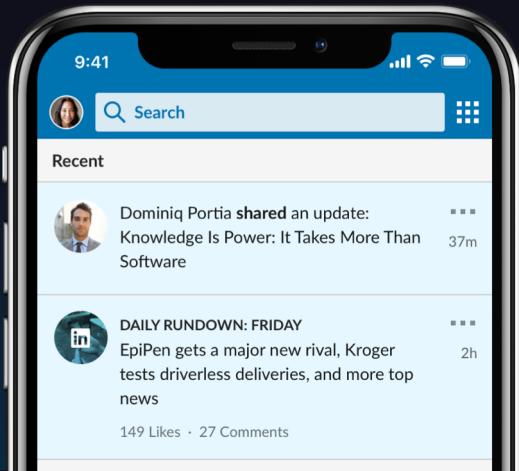
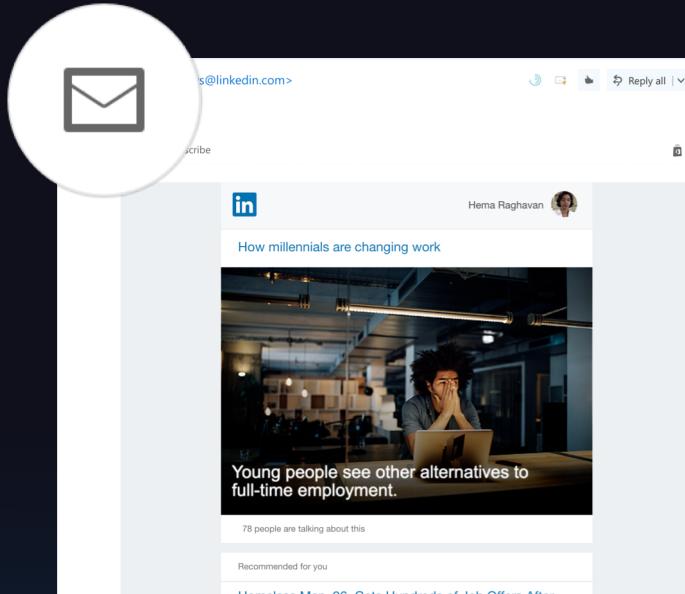
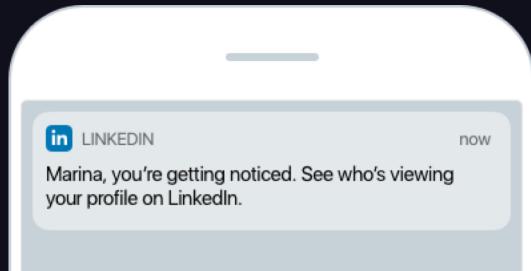
Shared by your network notification

Ensures a member does not miss out
on a conversation!

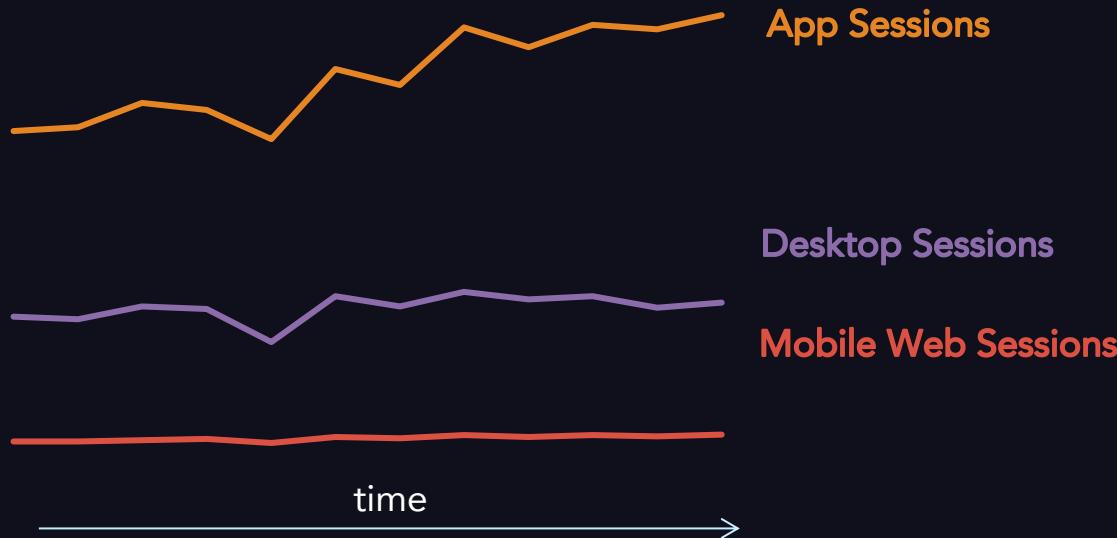
Shared by your network notifications



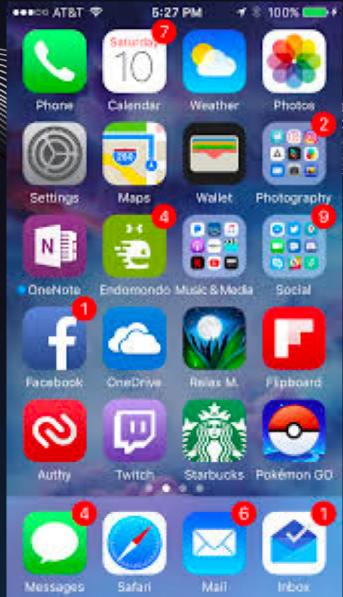
Notification Channels



Increase in number of sessions from the Mobile App



Must Avoid Notification Fatigue!



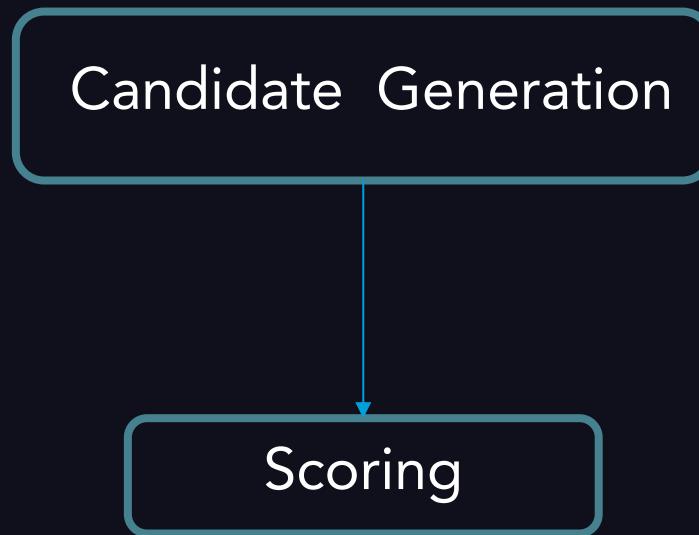
Notification Relevance Problems

- Right message, at the right time, on the right channel.
- As few notifications as possible.

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Typical Playbook for Recommendation Systems



Notification ecosystem

Candidate Generation

Concourse
Near real-time fanout
and scoring eg., Shared
By Your Network

Offline
Recommendations
Eg., Job You May be
Interested in

Notifications candidate generation: Batch Offline or Near Realtime

- Sometimes batch offline as a solution is obvious.
 - eg., A is having a work anniversary, who in A's network should get a notification?
- In some cases a timely notification is critical eg., breaking news, not missing out on a conversation.

Why Near Real-time Candidate Generation?

- Decrease in notification latency from hours to seconds can foster a real time experiences and active communities for LinkedIn members
- Can support richer targeting capabilities to reach the optimal audience

Concourse: Near real-time candidate generation



1. Alice creates a LinkedIn post

Results: Near real-time candidate generation

Product impact

Moving Activity Based Notifications from Offline to Online

- ++ Macrosessions
- + Public contributors
- + Private contributors

Scoring

$$\text{Score} = (P(\text{visit}|\text{notif}) - \overline{P(\text{visit}|\text{notif})}) * E(\text{Value(session}|\text{notif}))$$

Incremental probability of visiting Value of the additional session

P(visit) models described in WSDM 2019 paper

Notification Relevance Problems

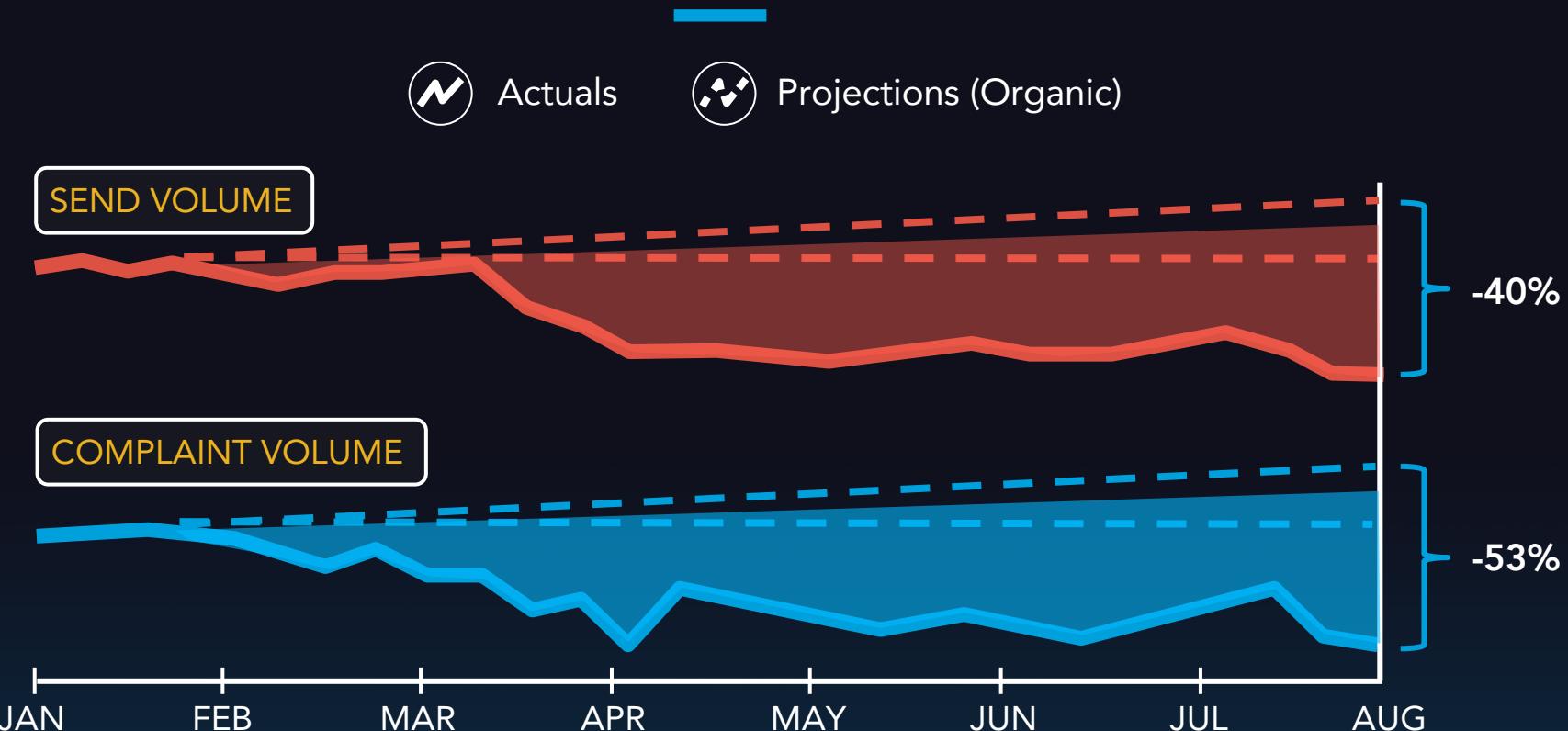
- Right message, at the right time, on the right channel.
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Air Traffic Controller (ATC): Volume Optimization

Minimize(sends)

such that $\text{clicks} > \text{clicks_target}$
 $\text{conversations} > \text{conversations_target}$
 $\text{disables} < \text{disables_target}$

ATC: It actually works!



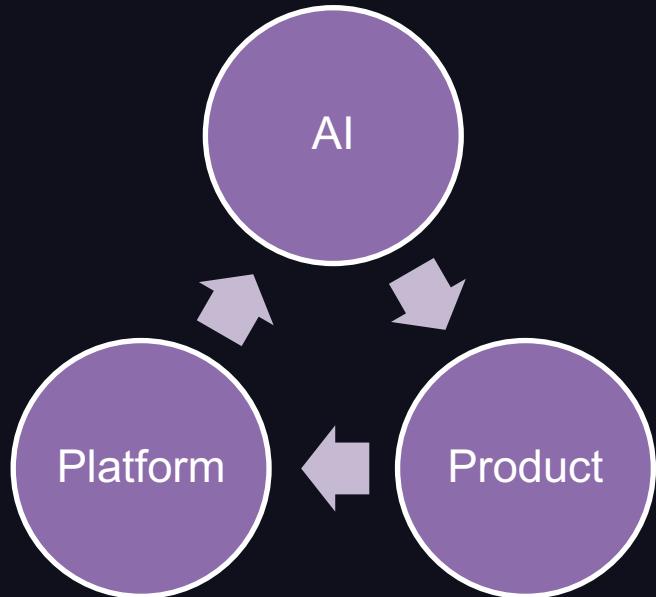
Holistic Optimization of a Product

- Avoid duplicate content on feed and notification channels

Summary

Online/Nearline Computations
capture the user *in the moment.*

The Platforms that drive your AI
are critical in shaping the
experience and product
roadmap.



A complex, abstract network graph is visible in the background, composed of numerous small, glowing blue and yellow nodes connected by thin lines, creating a sense of data flow and connectivity.

Q & A

<https://engineering.linkedin.com/>