



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

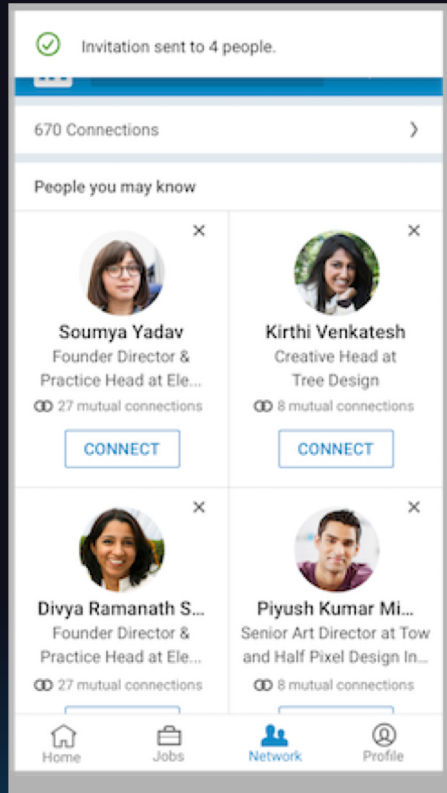
Create economic opportunity for every
member of the global workforce



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

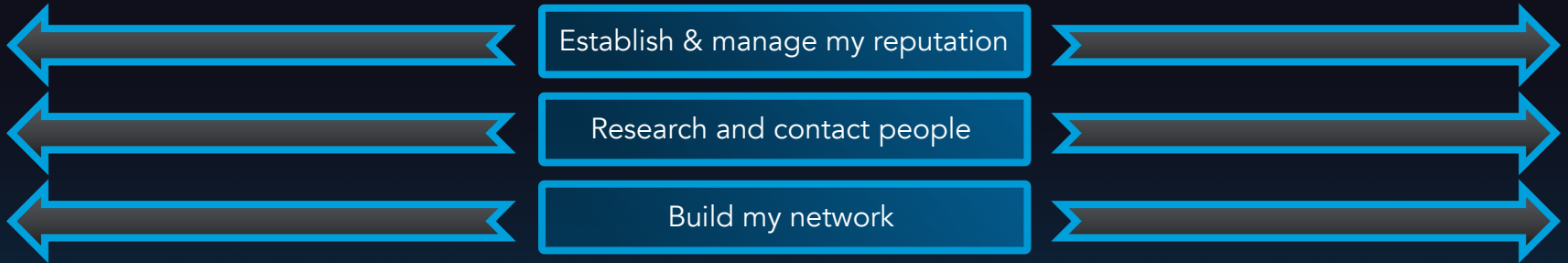
Work
smarter

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

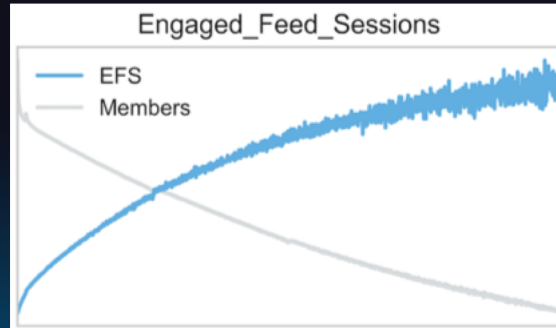
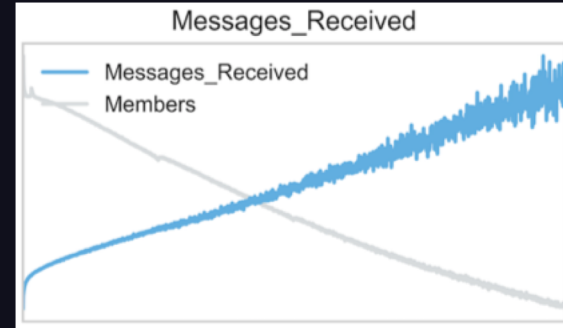
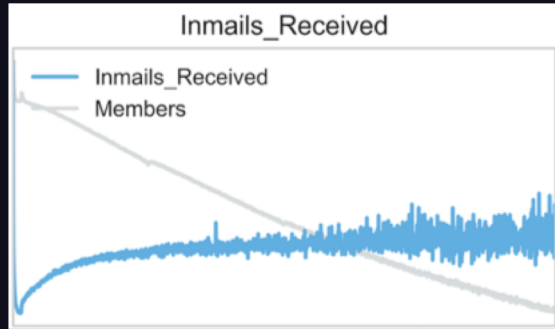
Establish & manage my reputation

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



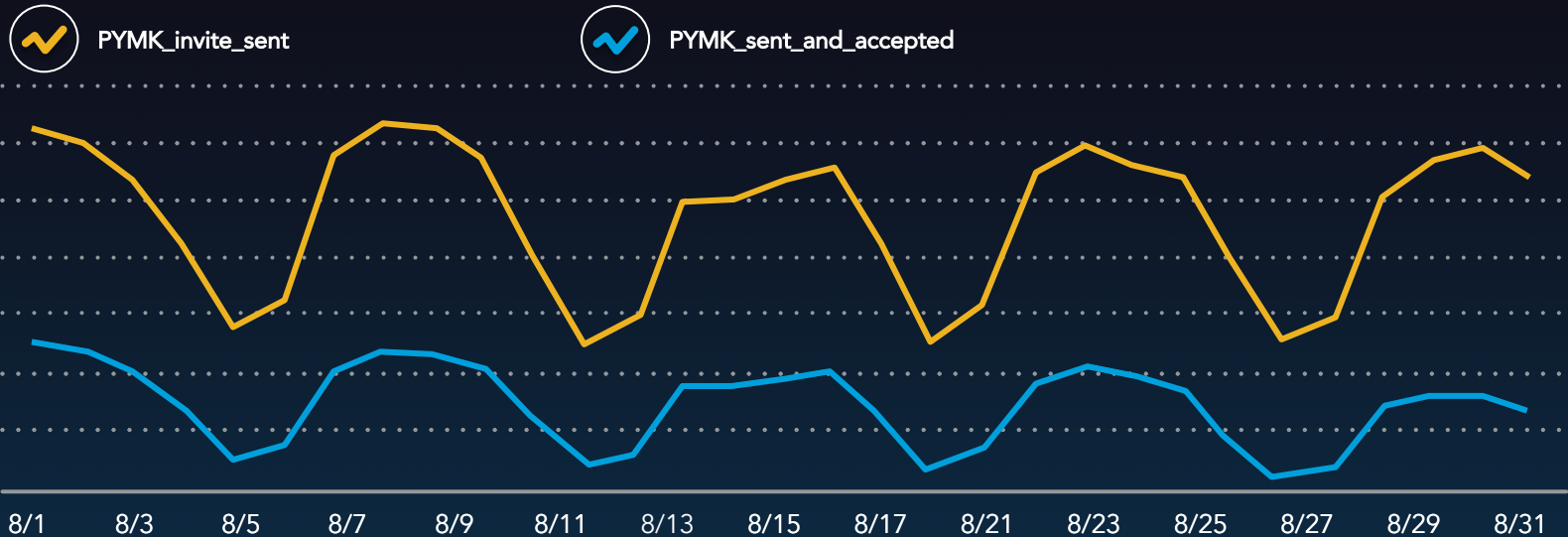
Strategic analysis to identify product opportunities



A/B testing to make informed product decision

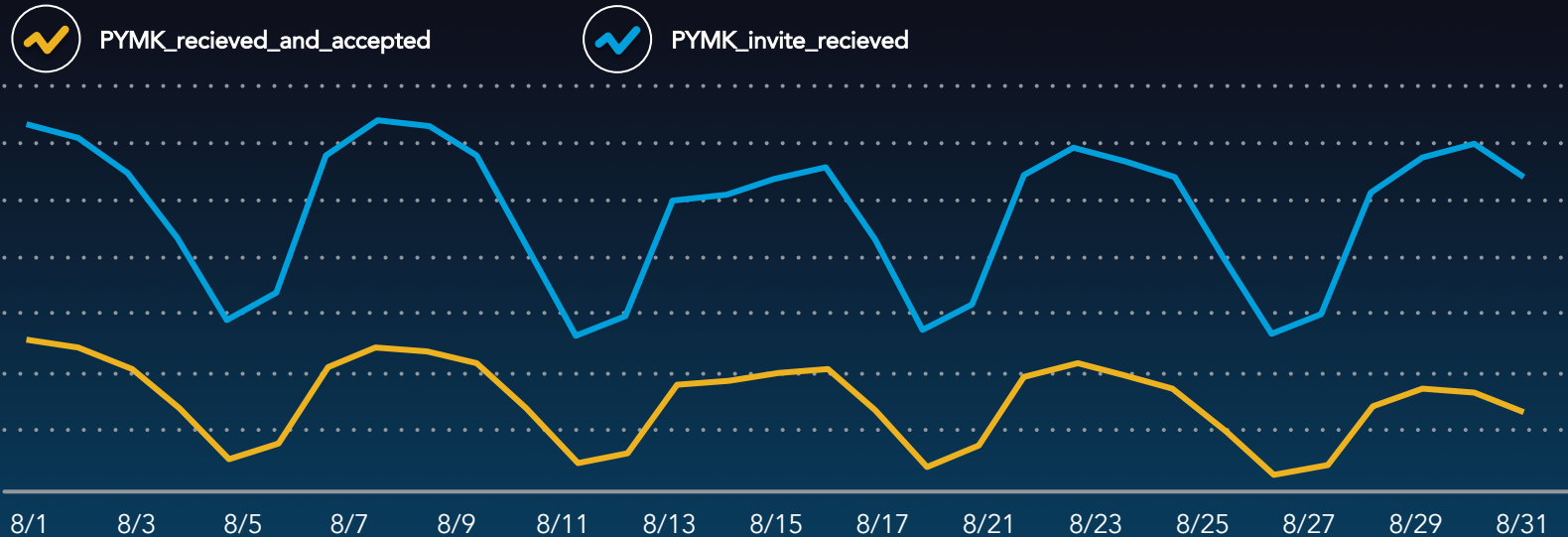
Metric Development

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

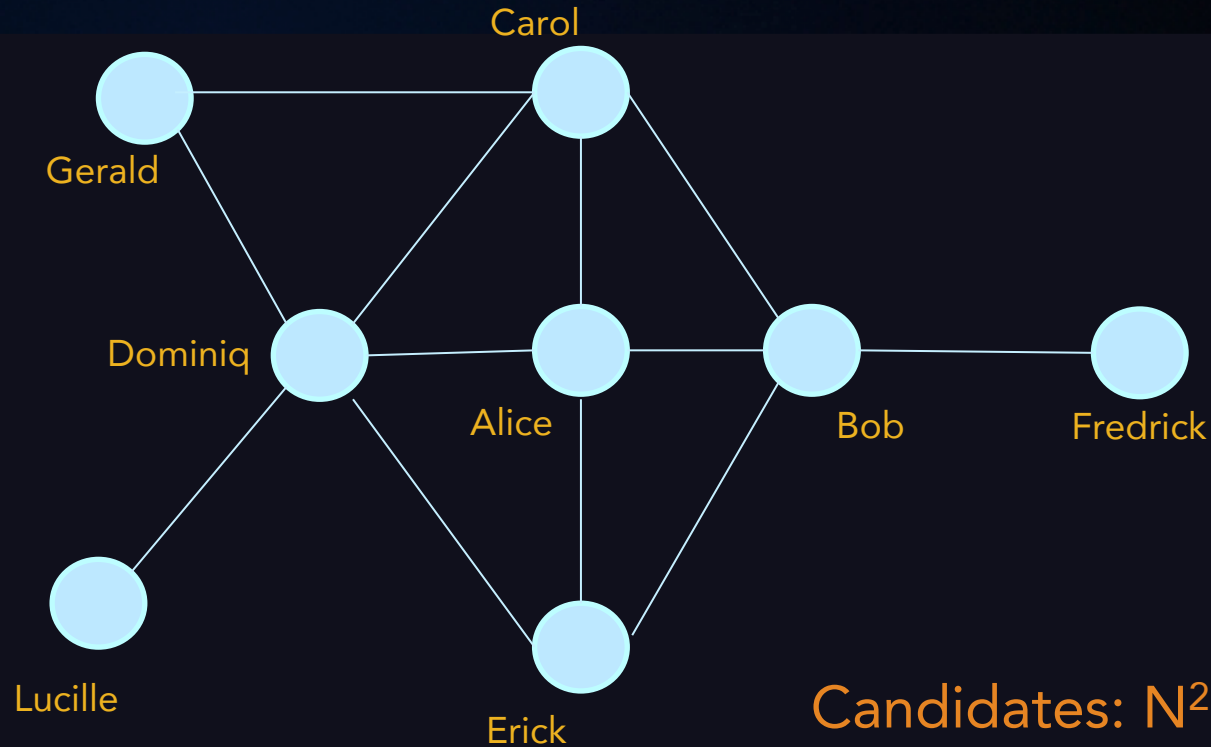


Metric Development

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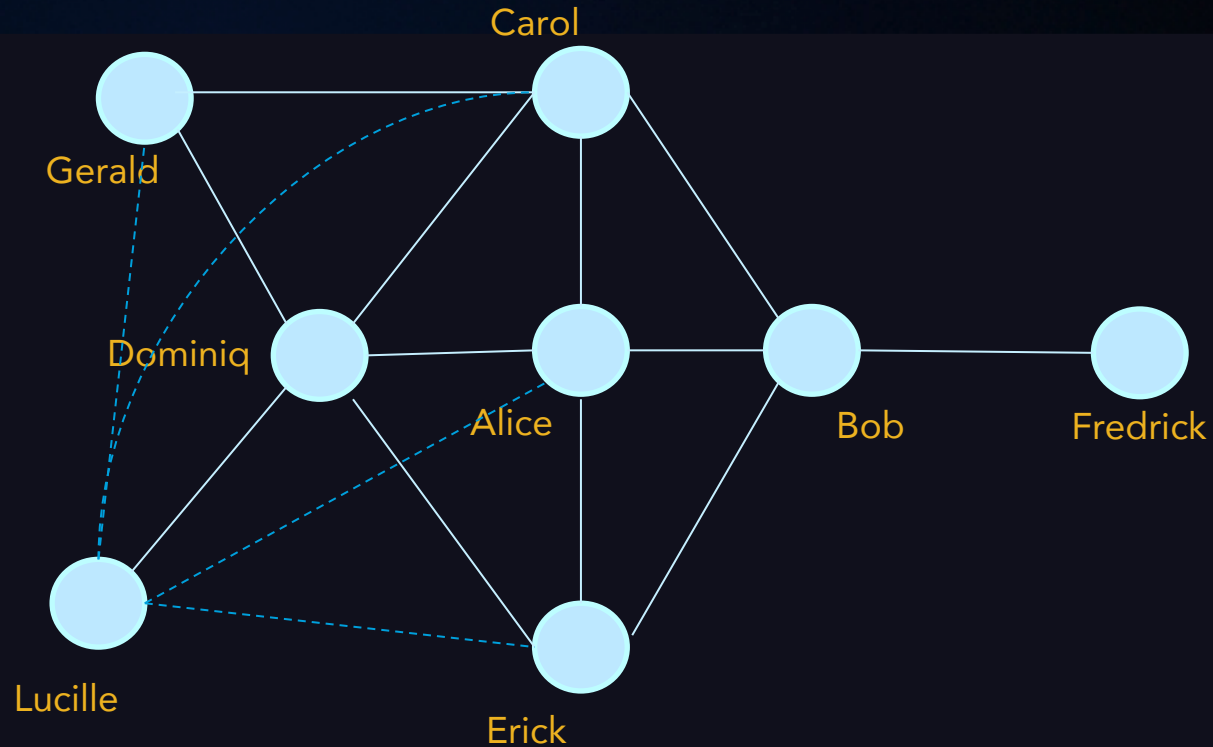
Connecting the worlds professionals



Connecting the worlds professionals

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

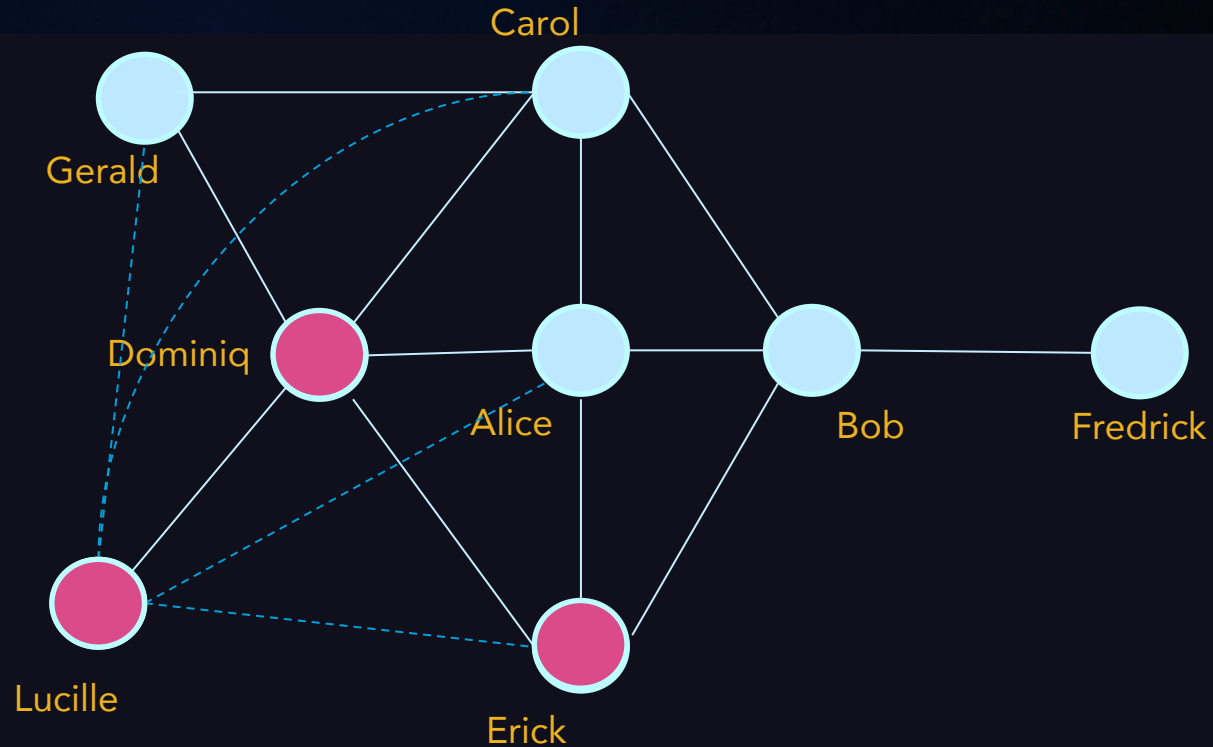
Connecting the worlds professionals



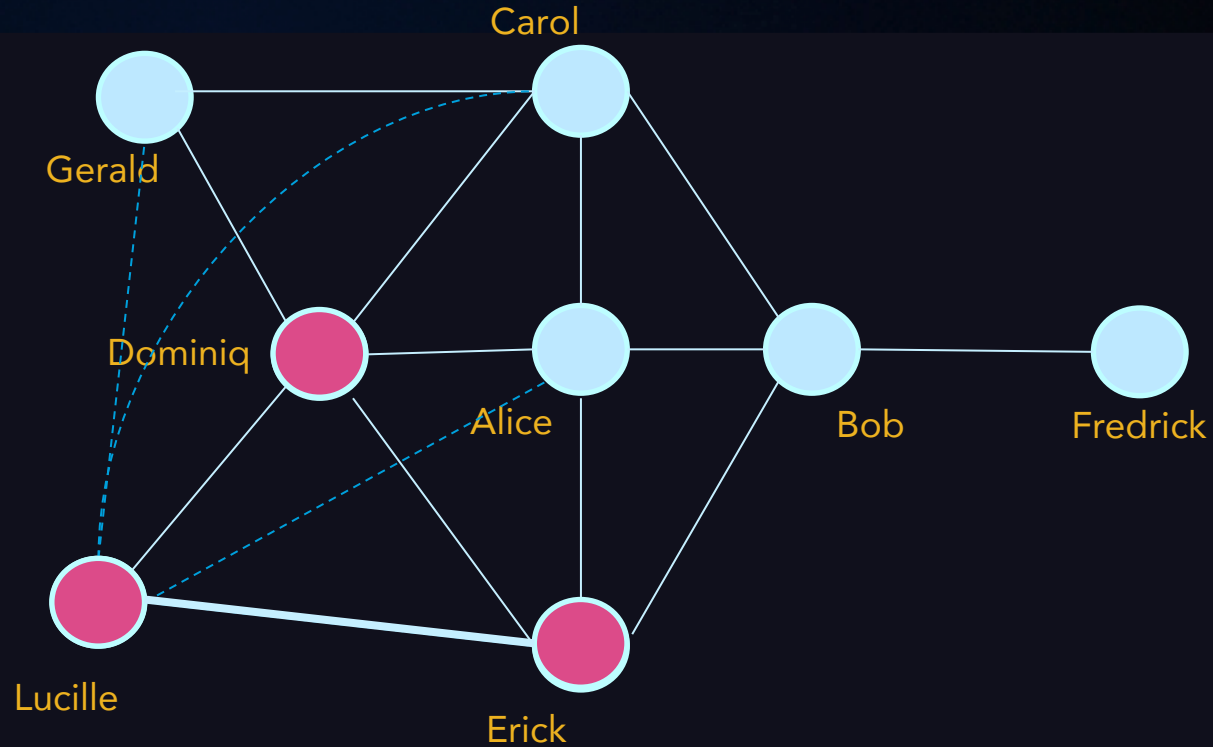
Connecting the worlds professionals

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

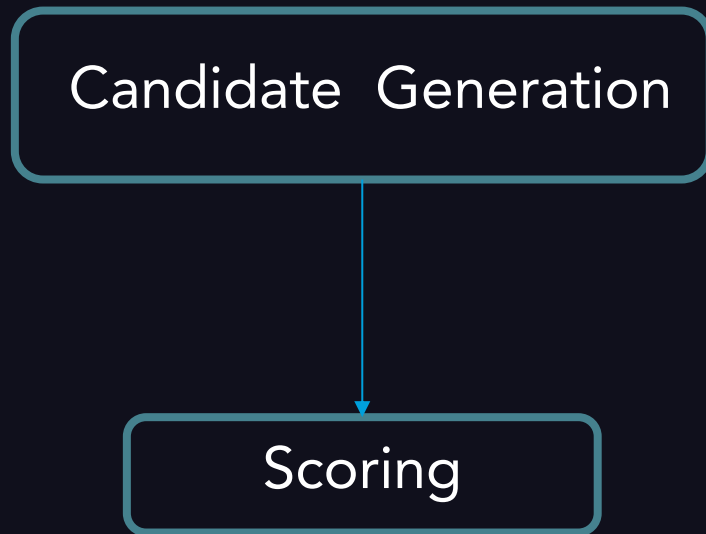
Connecting the worlds professionals



Connecting the worlds professionals



Typical Playbook for Recommendation Systems



Candidate Generation

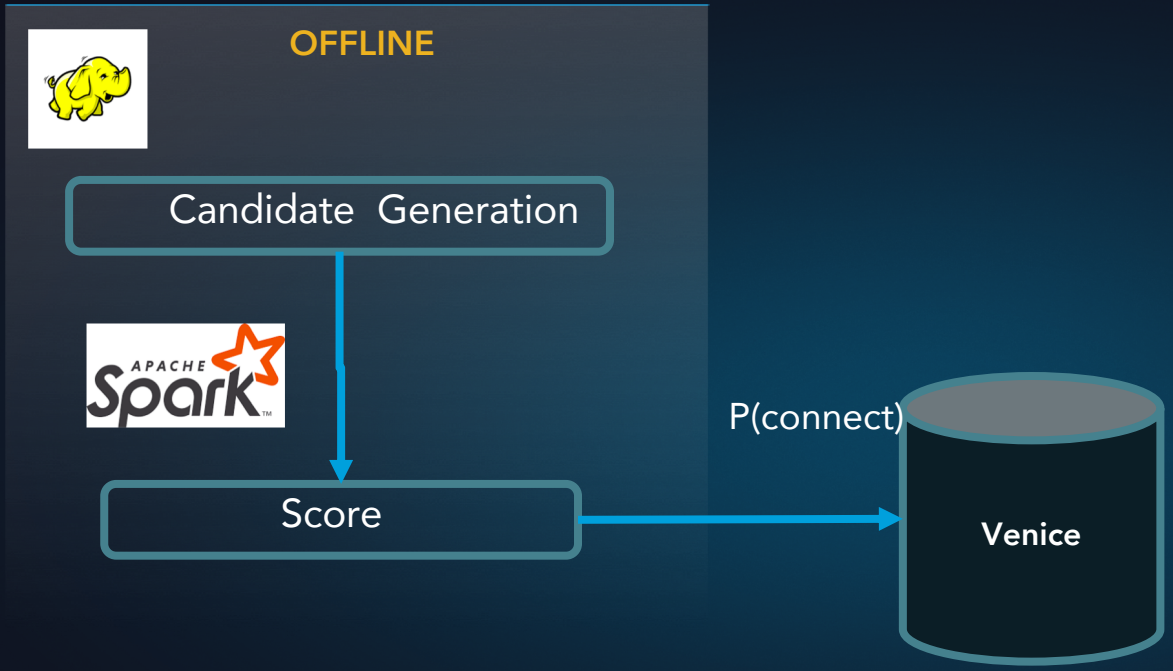
- Friends of Friends
- Extensions: Personalized Page Rank

Scoring

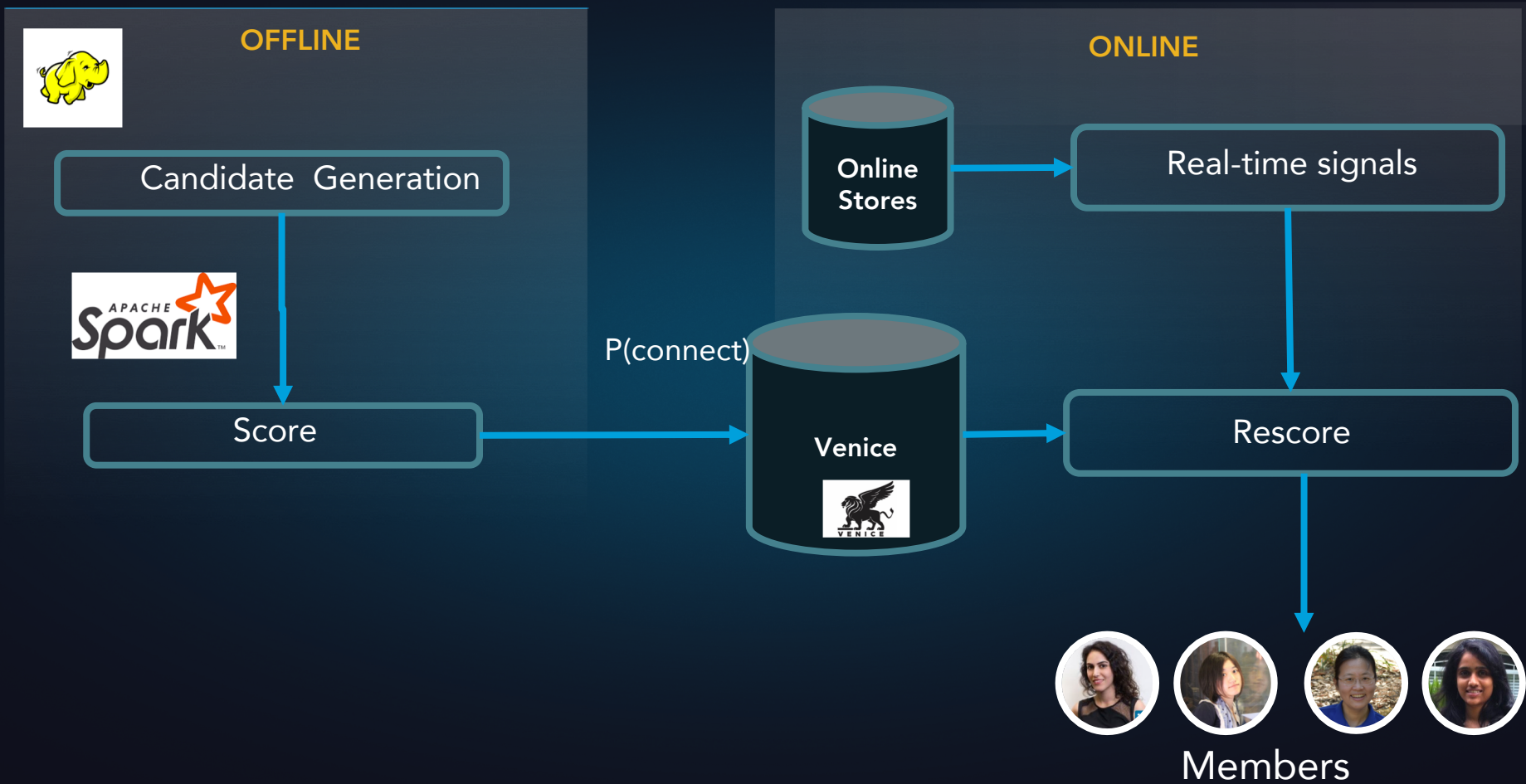
P(connect)

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

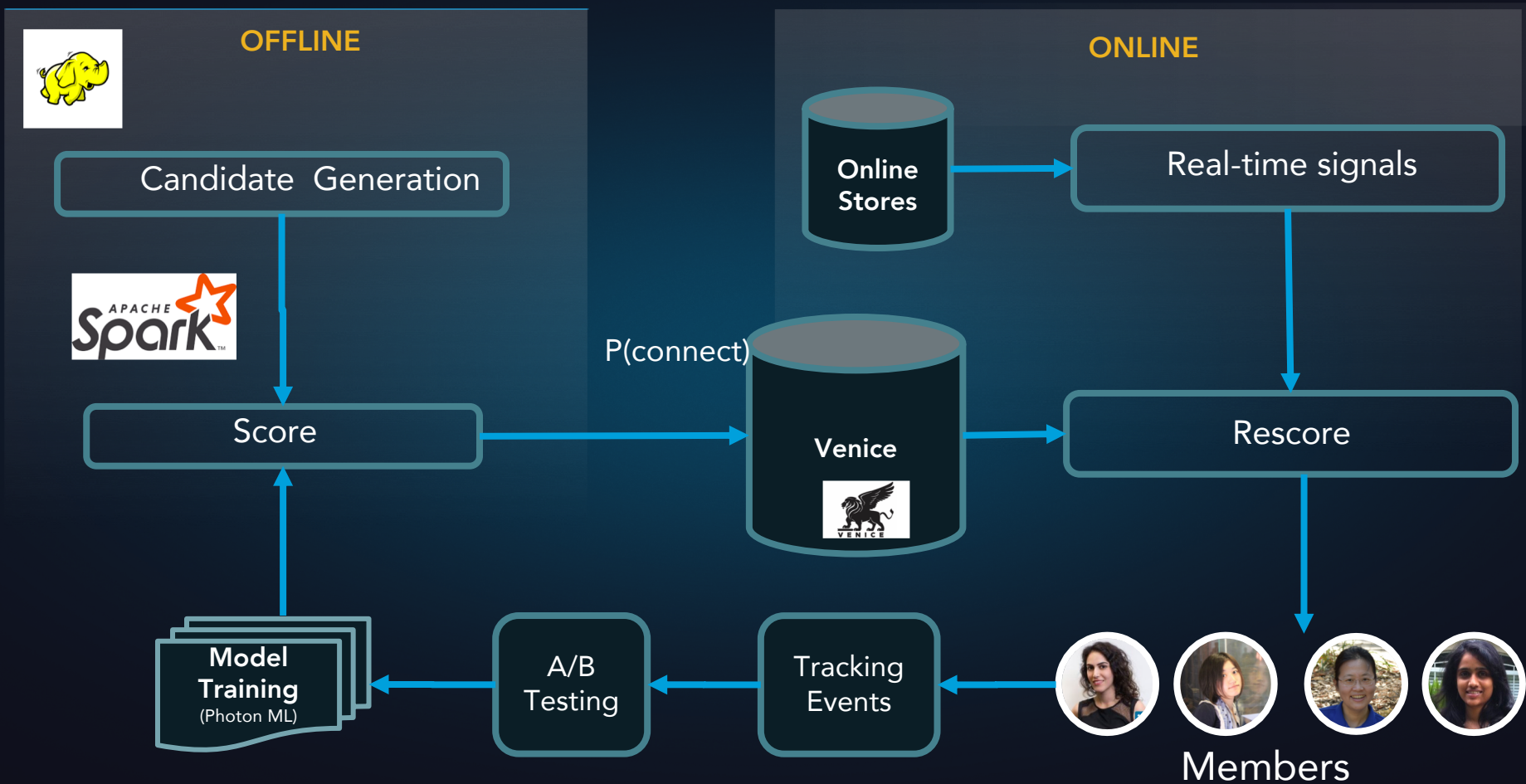
PYMK Architecture (circa 2015)



PYMK Architecture (circa 2015)

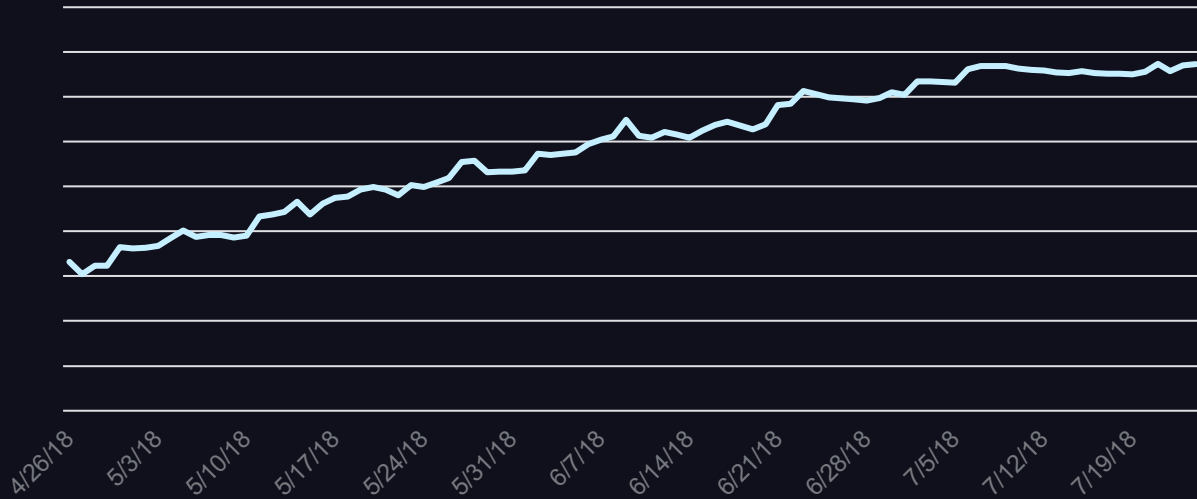


PYMK Architecture (circa 2015)



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

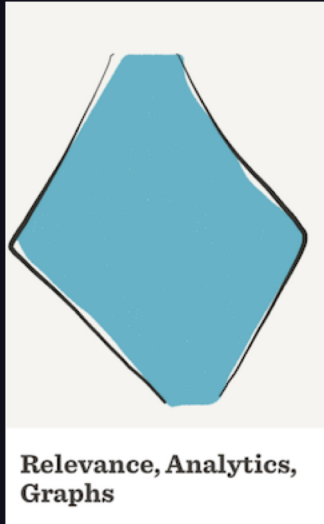
1. inter = JOIN node_features WITH pair_features table WHERE mid == source_mid
2. result = JOIN inter WITH node_features WHERE mid == dest_mid

source_mid	dest_mid	source_features	dest_features	pair_features

Wide middle

Score (result)

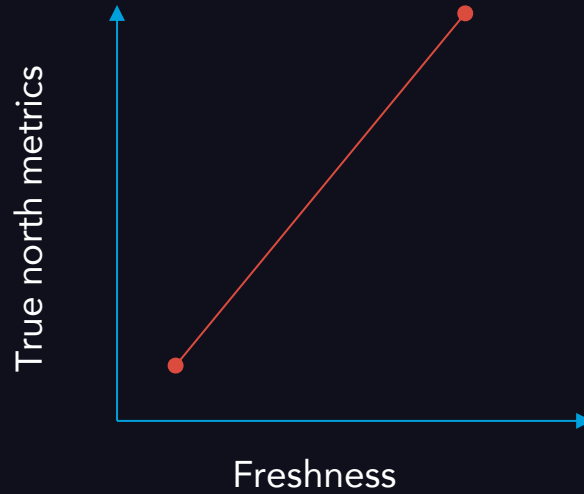
Need Smart Joins



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)

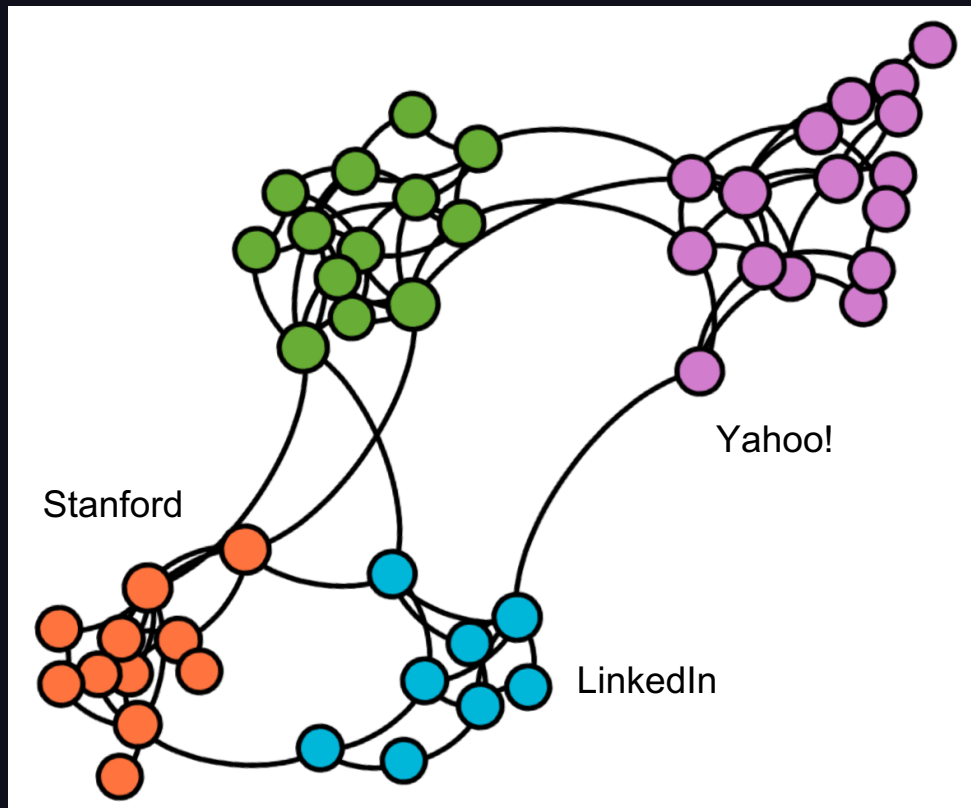
Observation: Freshness matters!



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).

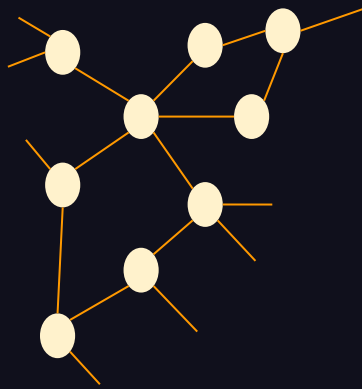


Near Realtime Recommendation Platform: GAIA

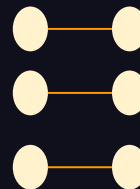
Graph algorithm code



Any kind of graph



Updates to graph



Via Kafka,
Brooklin,
etc.

Near Realtime Recommendations

One of the biggest Site-wide improvements in connections

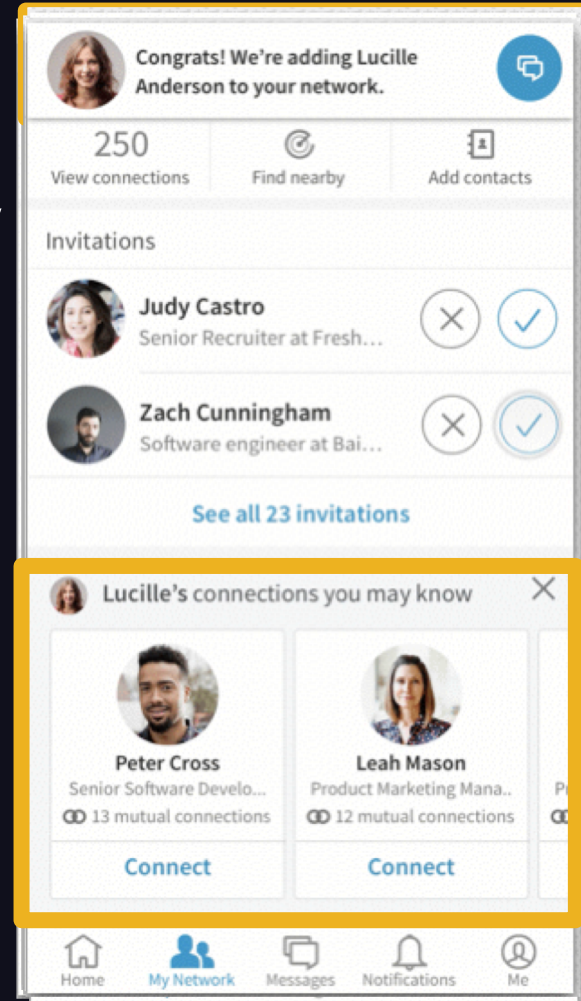
++ achieve 30 connections

++ quality signups

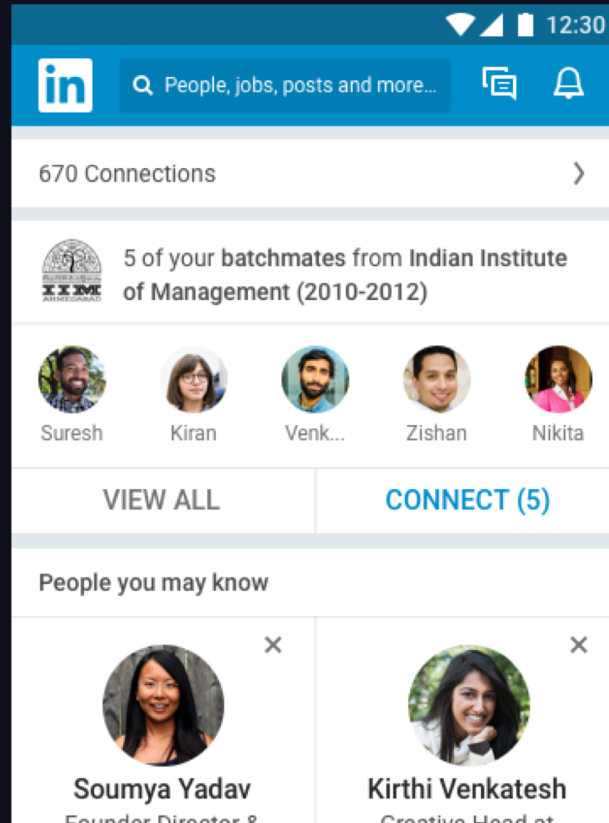
....

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

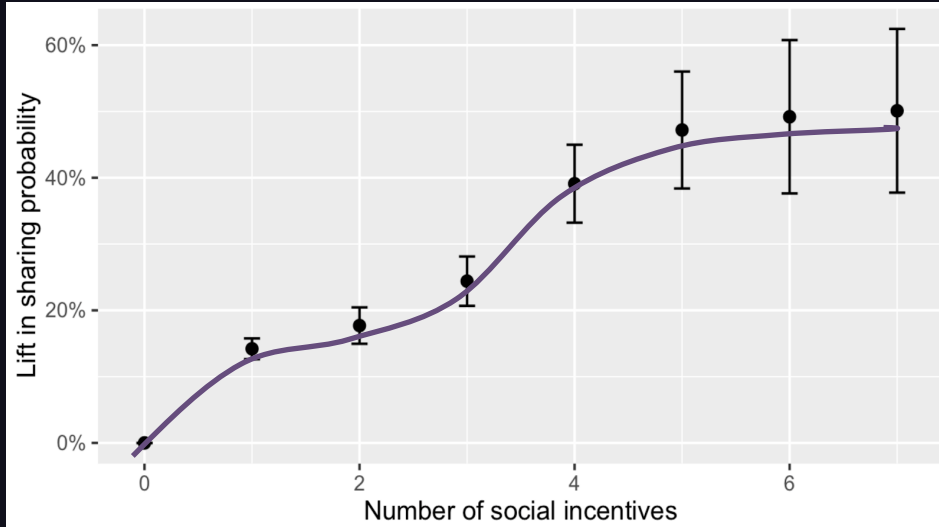


Context matters

A young woman with voluminous, curly, light-brown hair is smiling warmly while looking down at a white smartphone held in both hands. She is wearing a dark purple top under a grey button-down shirt and has a brown shoulder bag. The background is a bright, slightly blurred outdoor setting with green trees and a white building, suggesting a park or city walk. The lighting is soft and natural, with a slight lens flare effect on the right side of the image.

An active professional community can help further your career

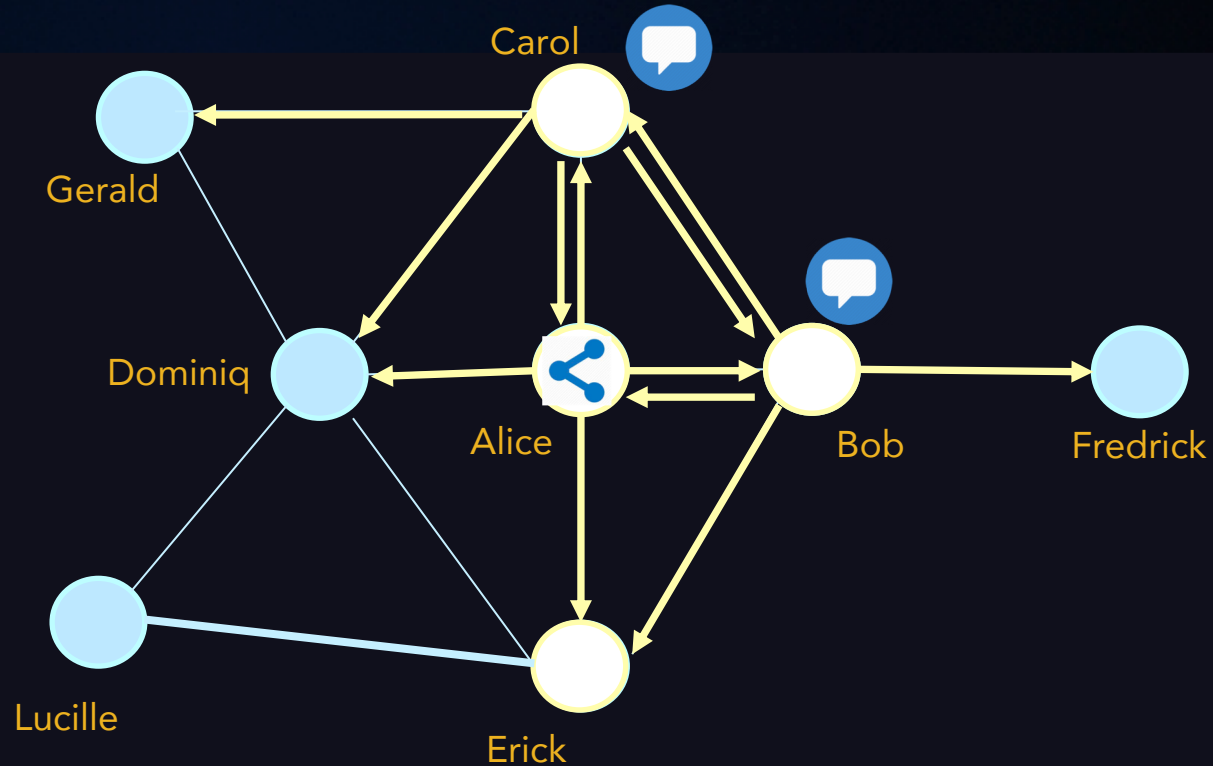
Building active communities



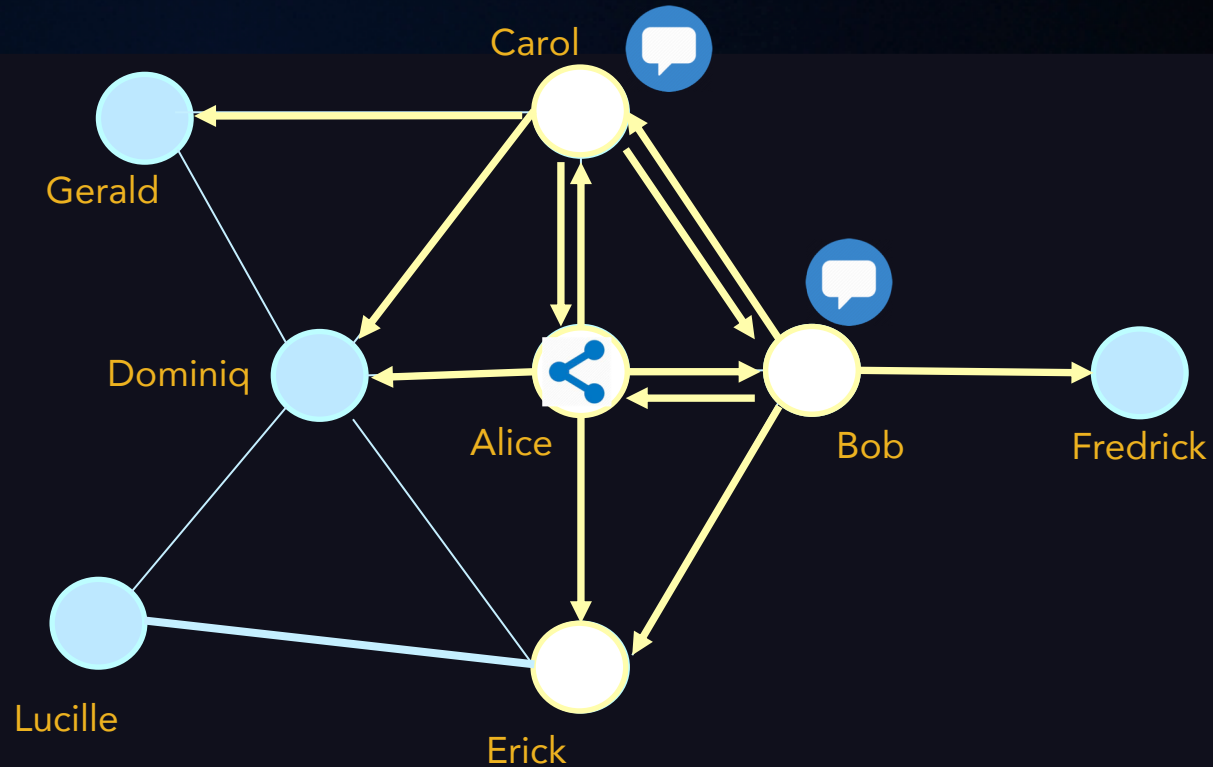
Observation:

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

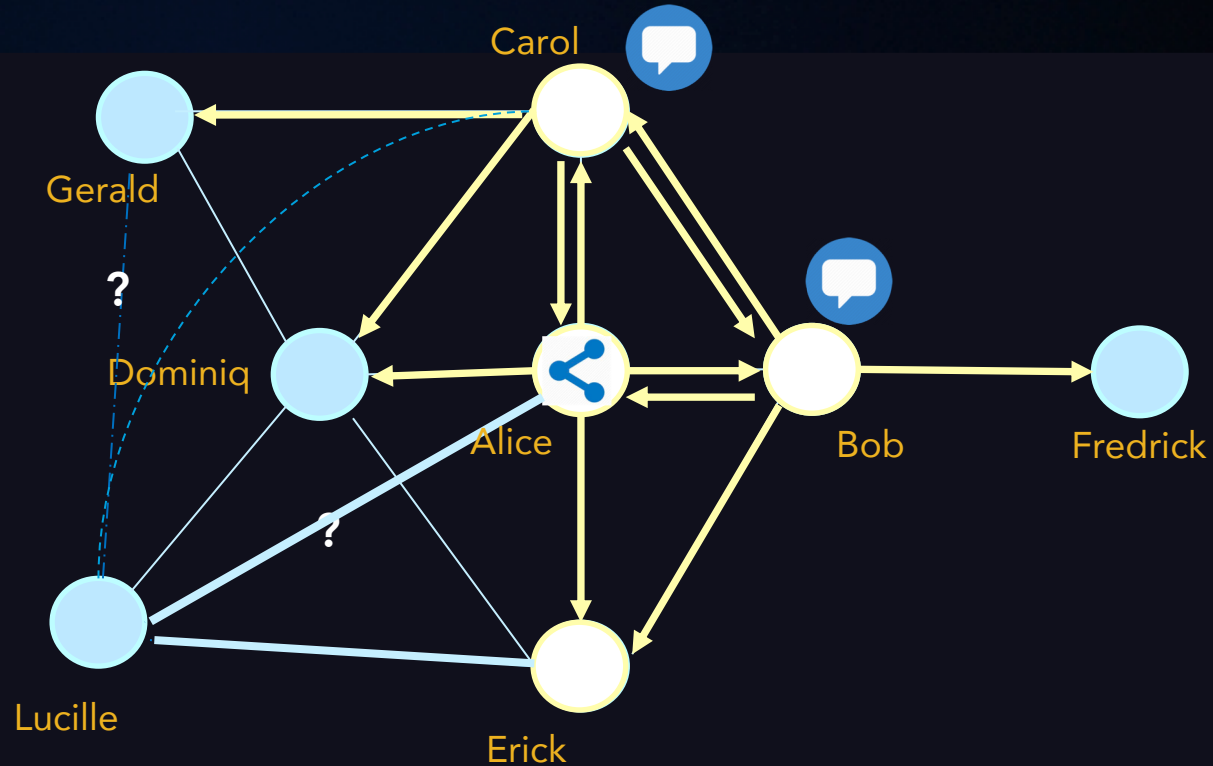
An active professional community



Biasing connection recommendations for an active community



Biasing connection recommendations for an active community



Tuning Connection Recommendations to Conversations

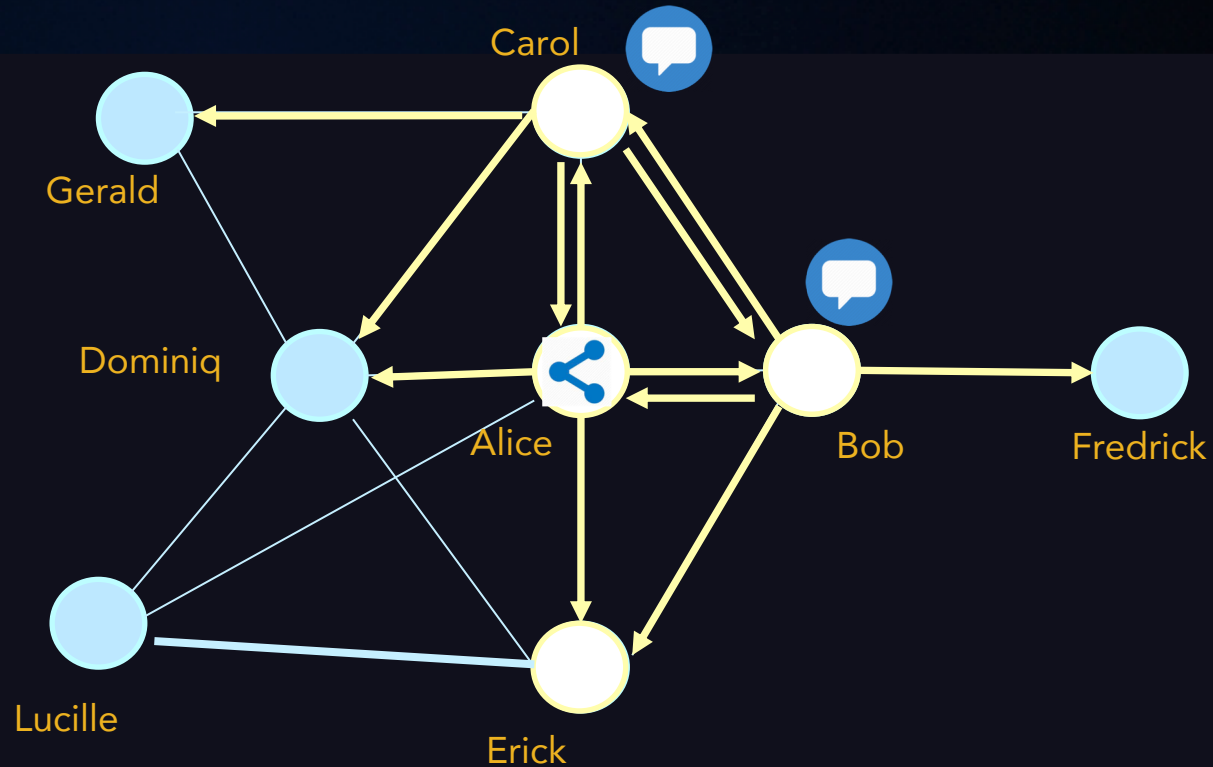
$$\text{Score}(m1, m2) = P(\text{connect} | m1, m2) (1 + \alpha P(\text{conversation} | \text{connection}_{m1, m2}))$$

Notifications

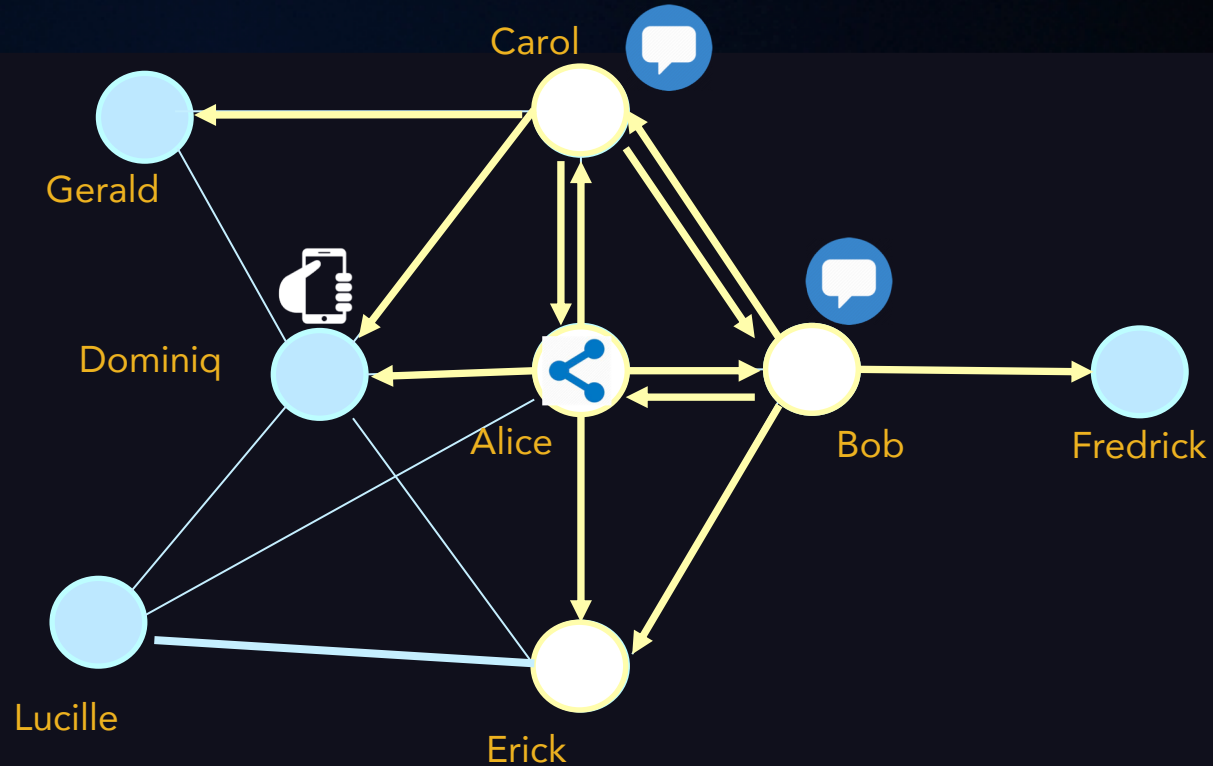


The role of notifications for active communities

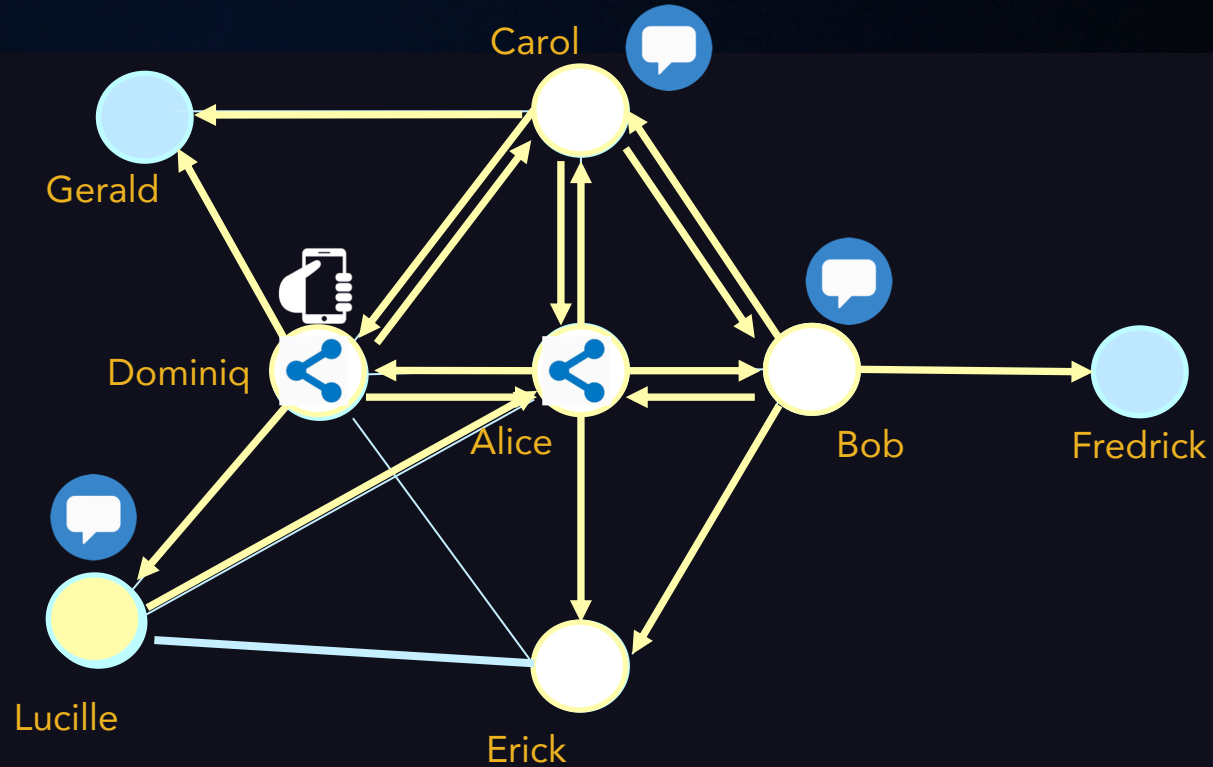
Notifications to never miss a conversation



Notifications to never miss a conversation



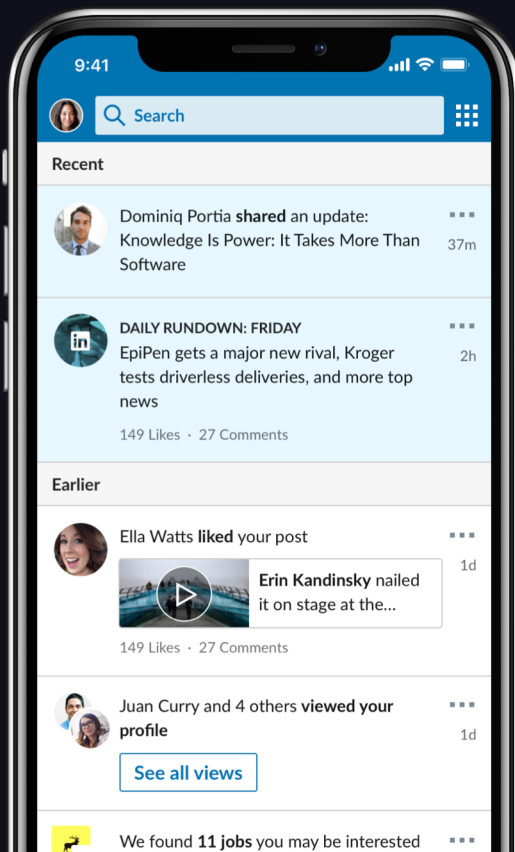
Can result in further viral actions



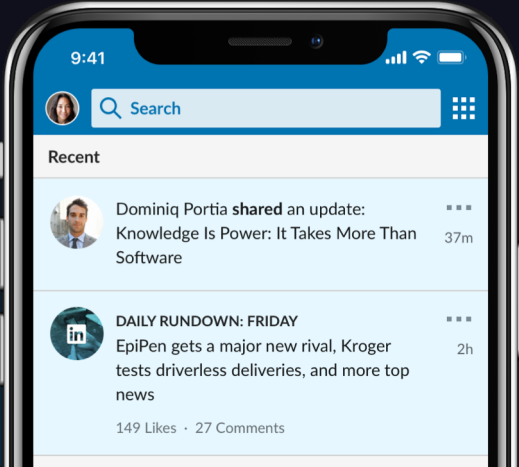
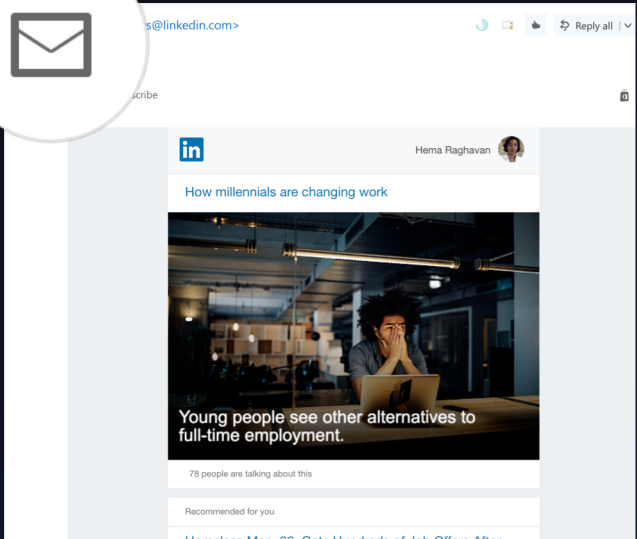
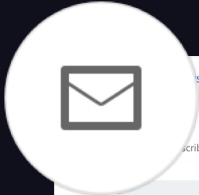
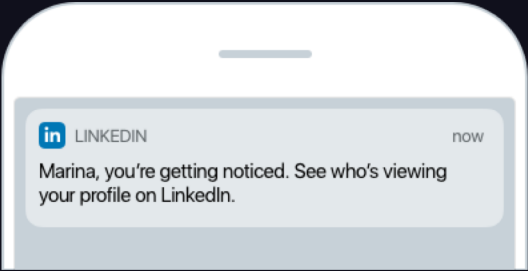
Shared by your network notification

Ensures a member does not miss out
on a conversation!

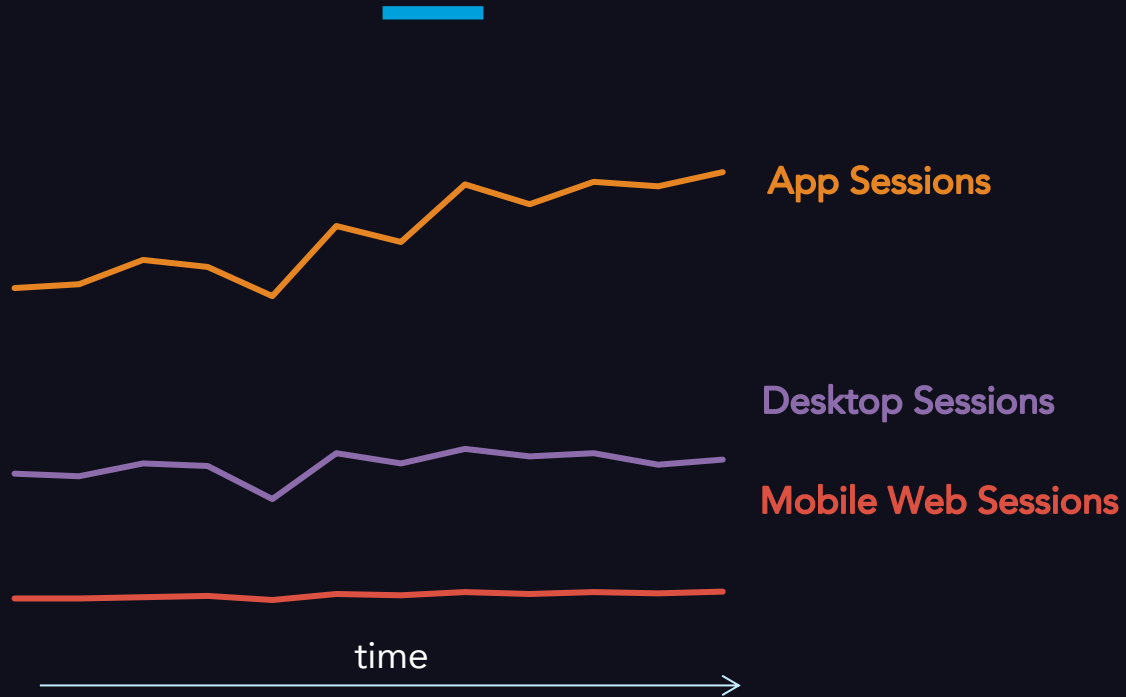
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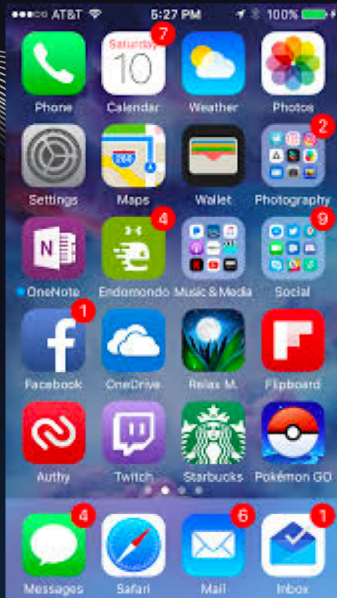
Notification Channels



Increase in number of sessions from the Mobile App



Must Avoid Notification Fatigue!



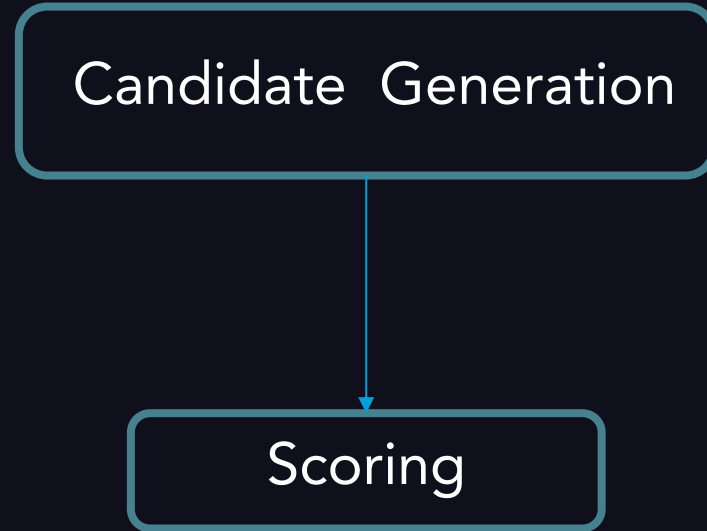
Notification Relevance Problems

- 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

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

Incremental
probability of visiting

Value of the
additional session

Notification Relevance Problems

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

Air Traffic Controller (ATC): Volume Optimization

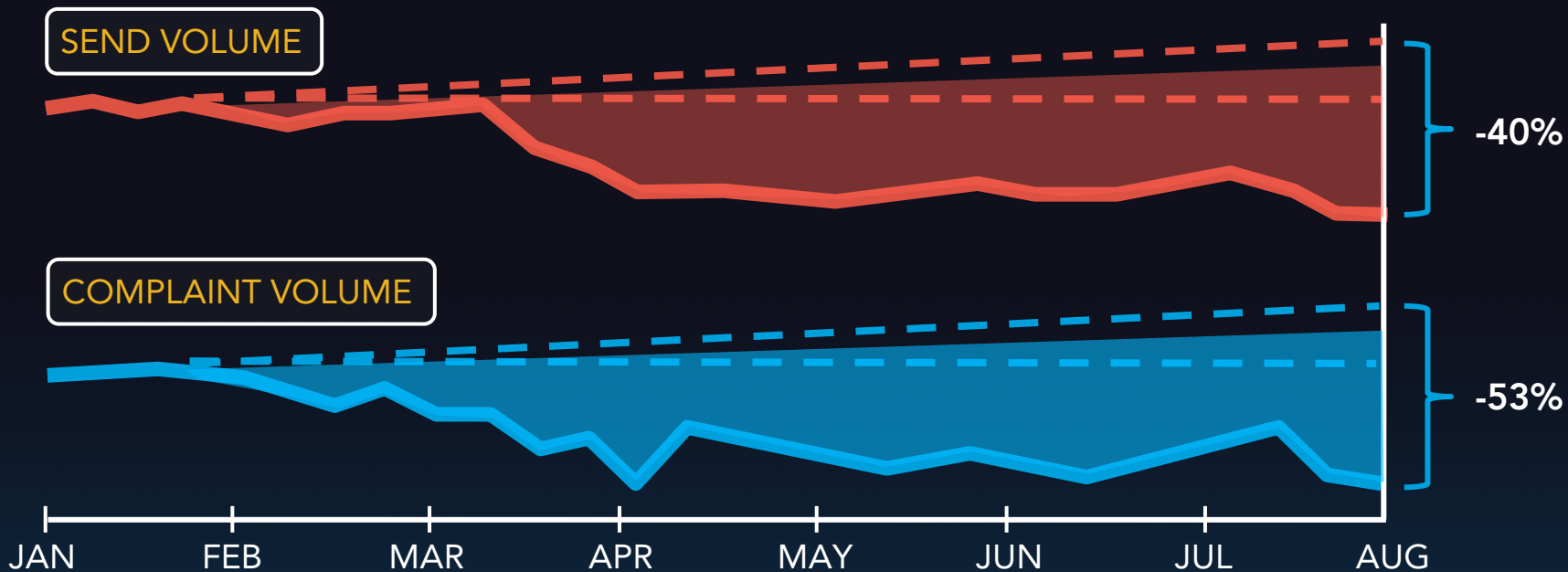
Minimize(sends)

such that

- clicks $>$ clicks_target
- conversations $>$ conversations_target
- disables $<$ disables_target

ATC: It actually works!

Actuals Projections (Organic)



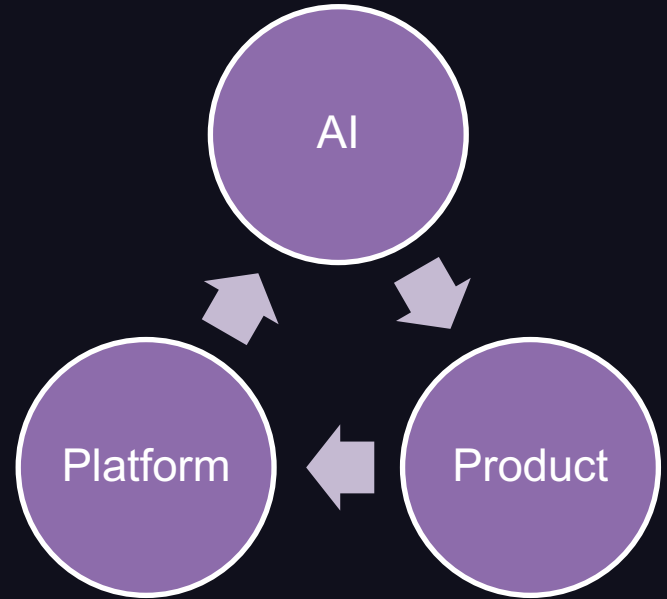
Holistic Optimization of a Product

- Avoid duplicate content on feed and notification channels

Summary

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

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





Q & A

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