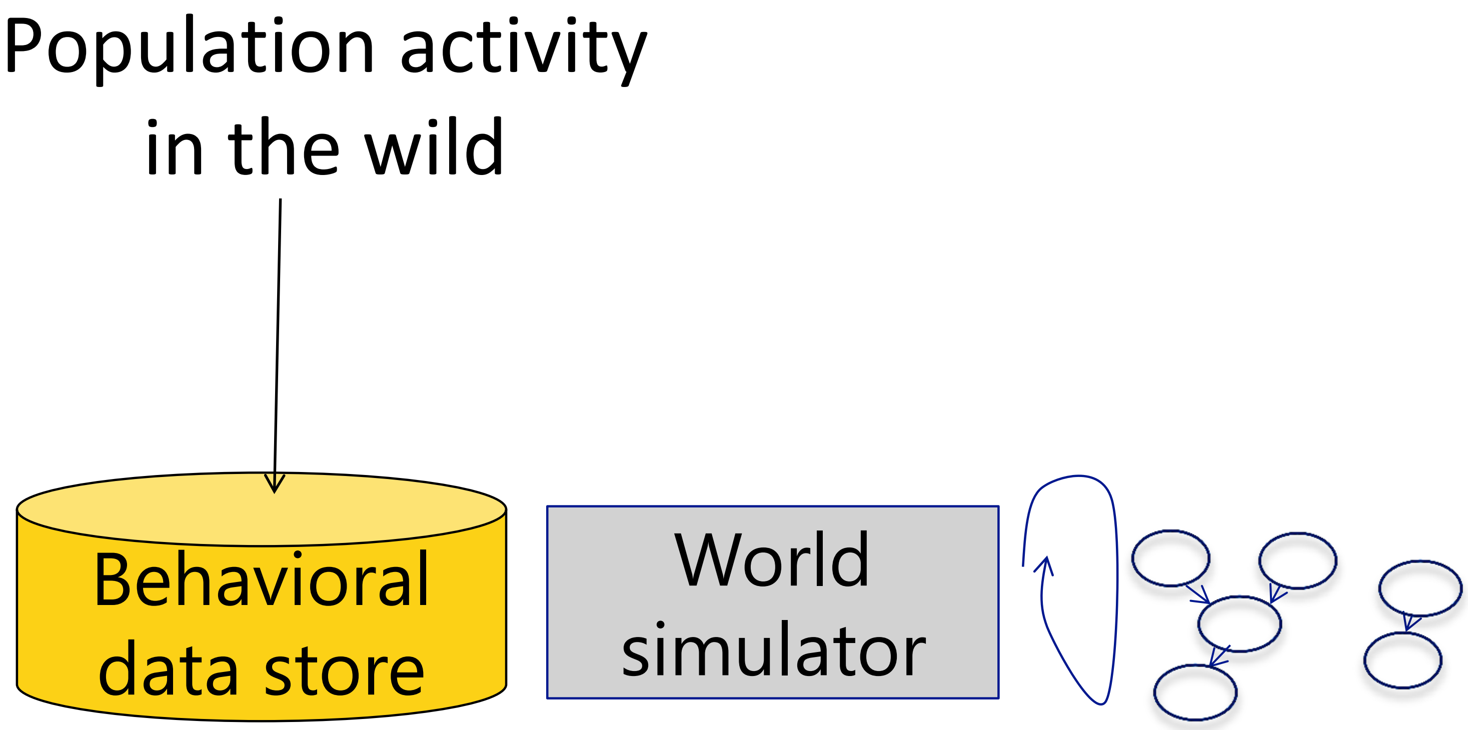
Crowd Physics: Studies of Collaborative Opportunities in Spatiotemporal Networks of People

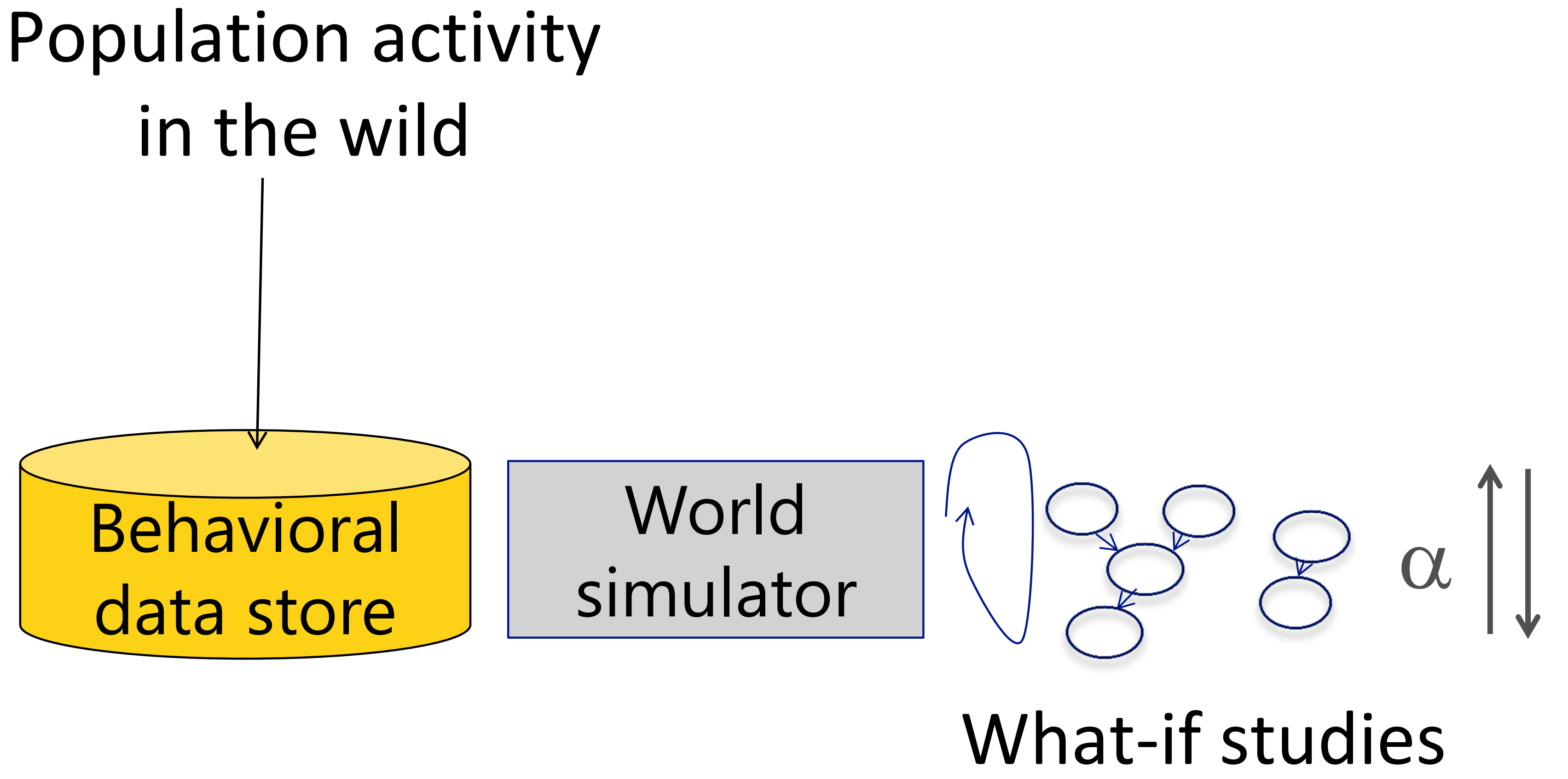
Eric Horvitz

Joint work with John Krumm and Adam Sadilek

Paradigm for Digital Experimentation



Paradigm for Digital Experimentation



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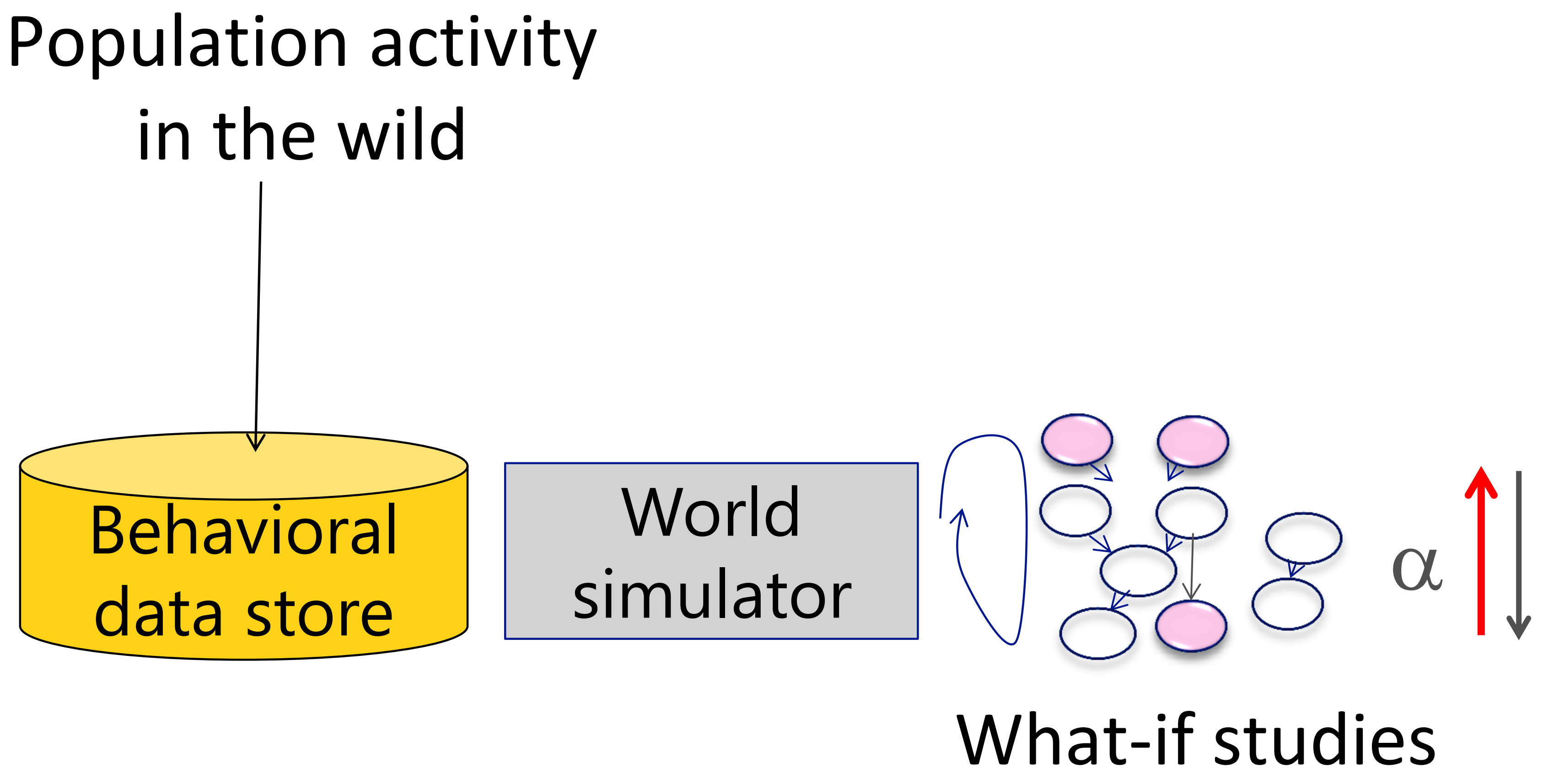

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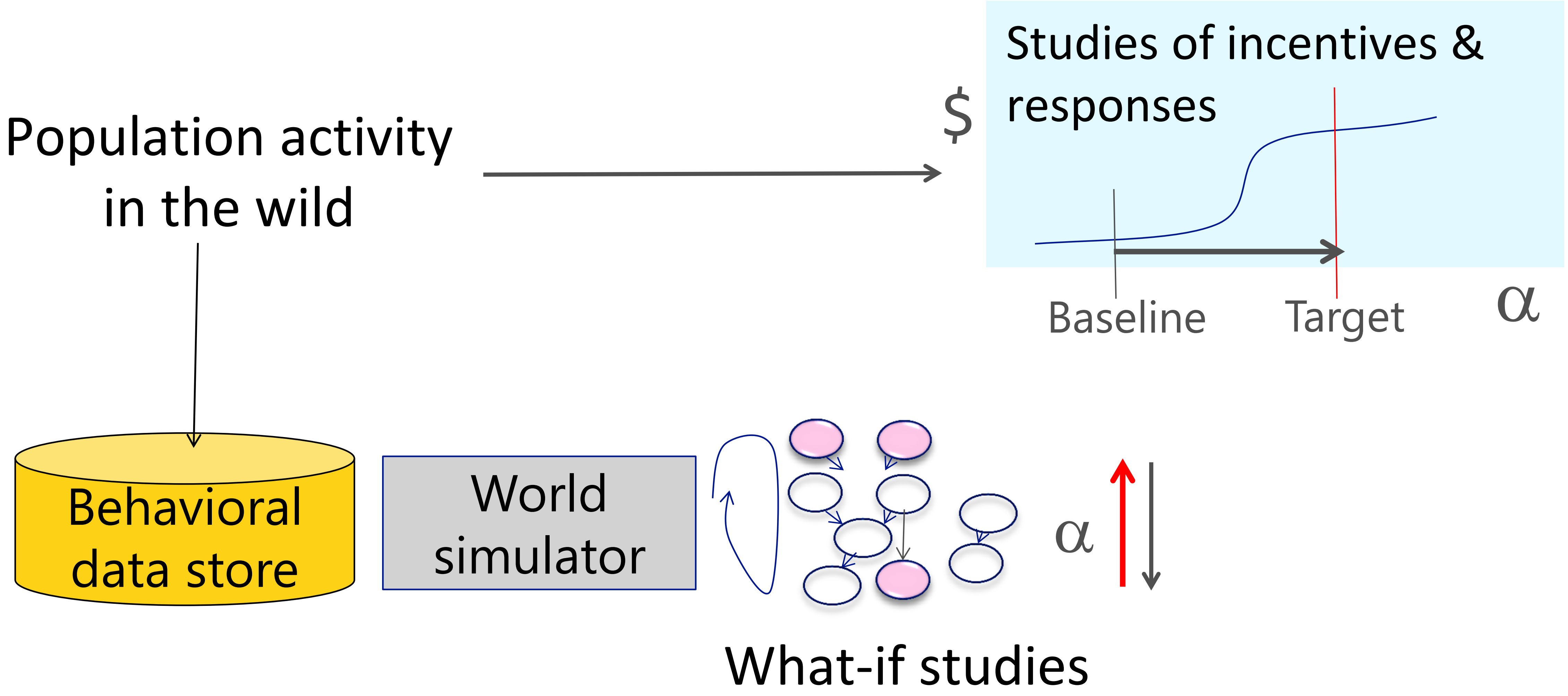

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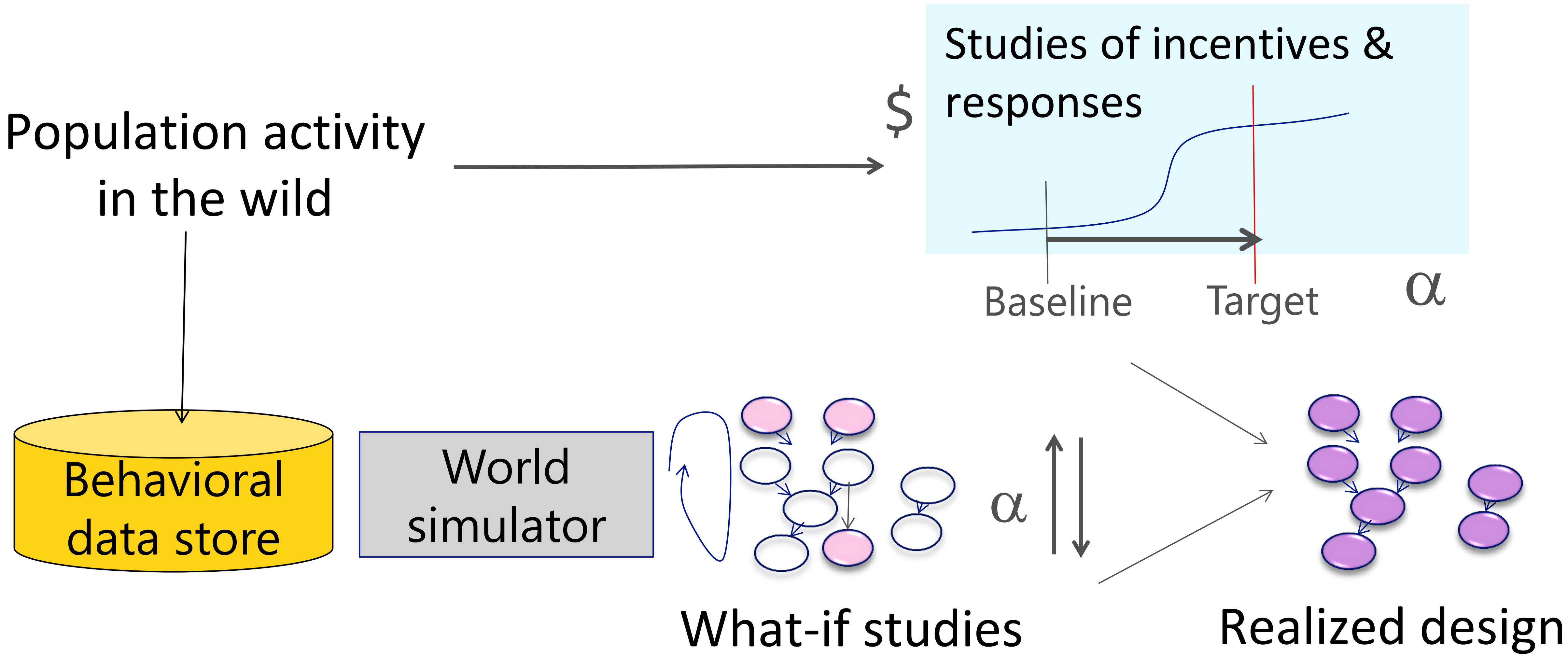
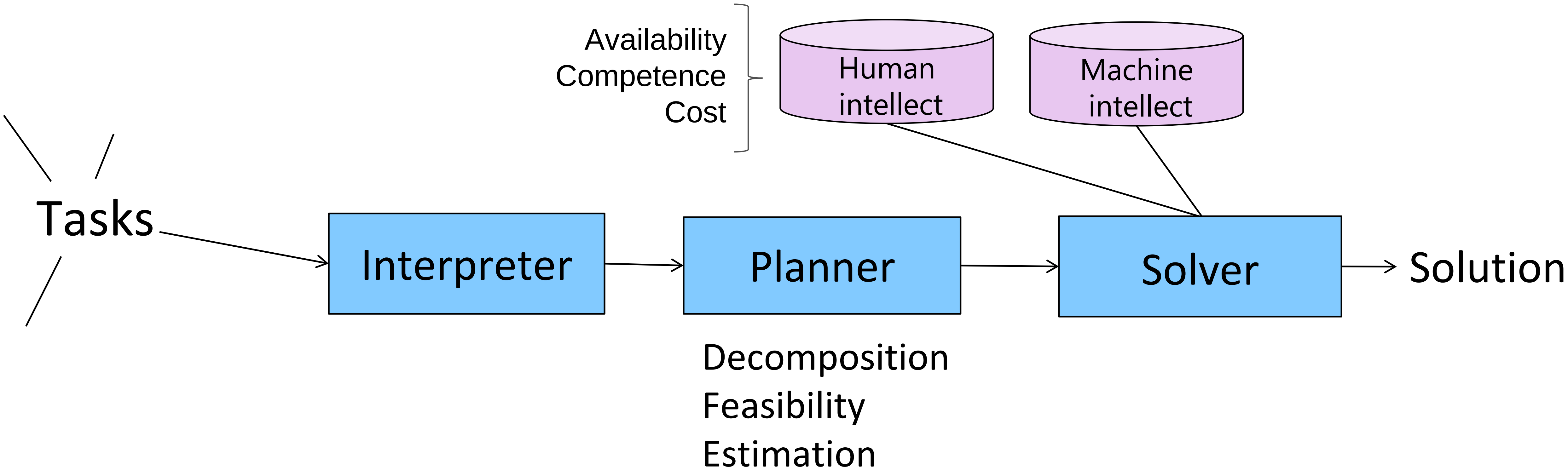


Motivation: Generalized Task Markets



E. Kamar, S. Hacker, E. Horvitz. Combining Human and Machine Intelligence in Large-scale Crowdsourcing, 2012.

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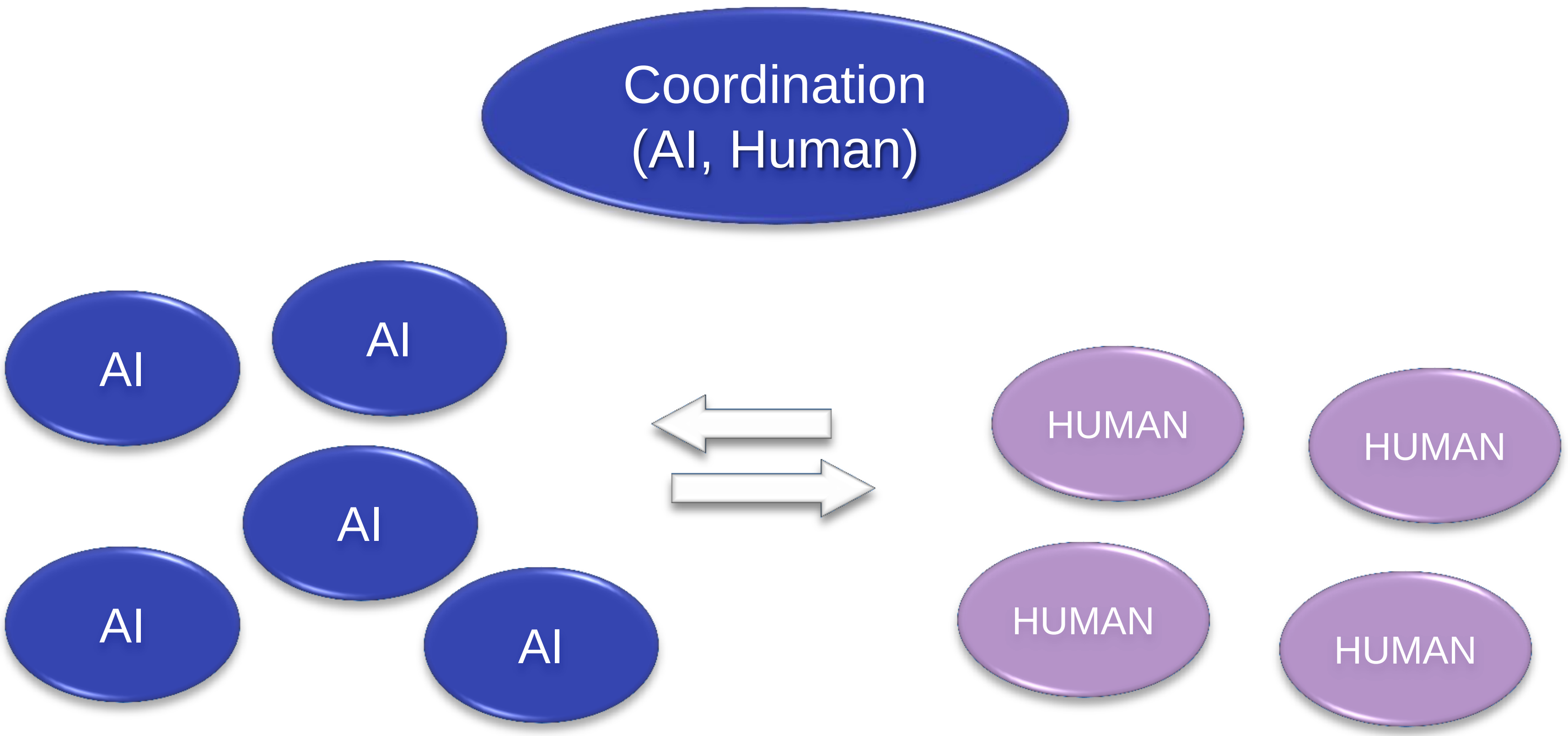
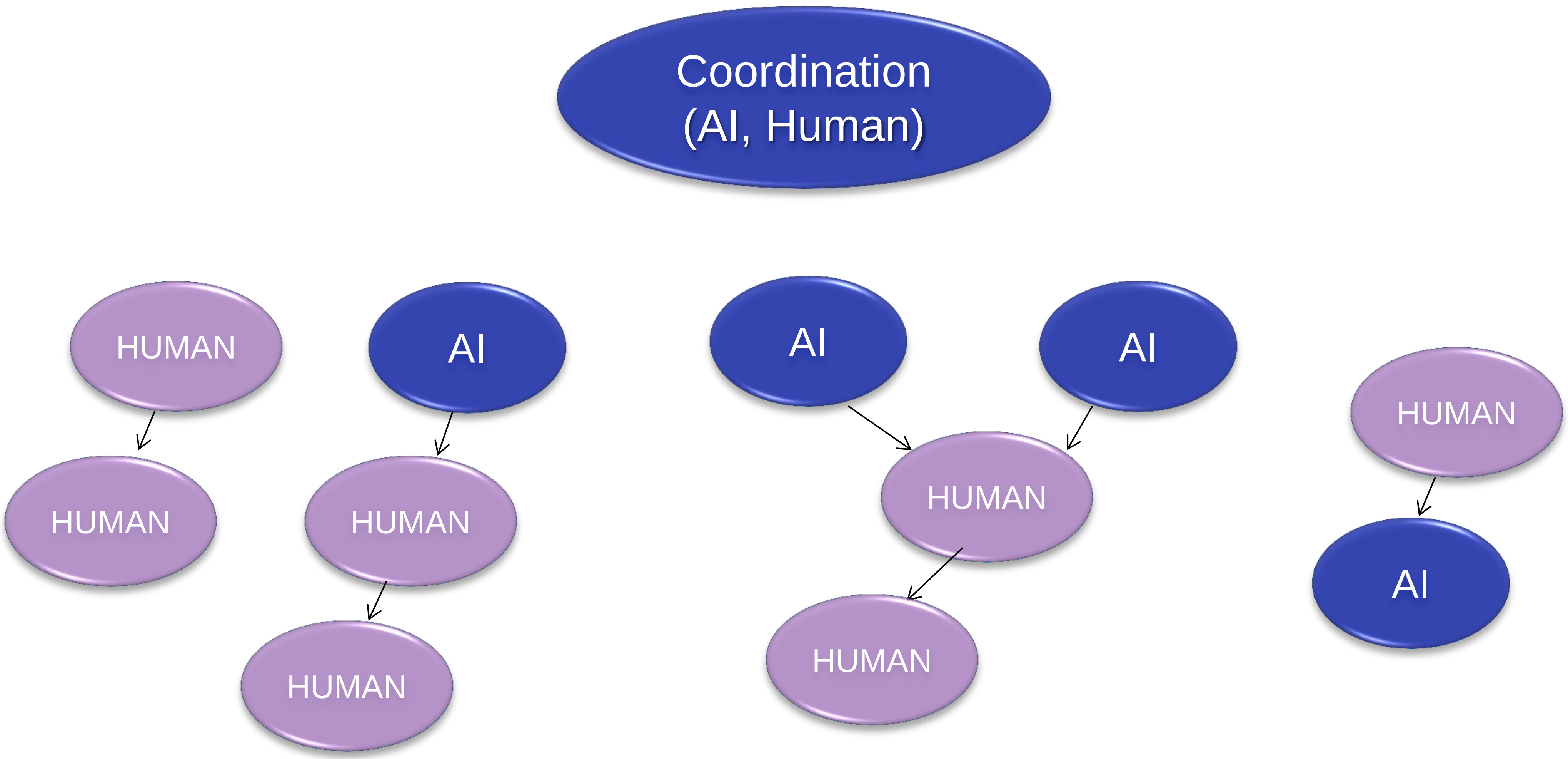


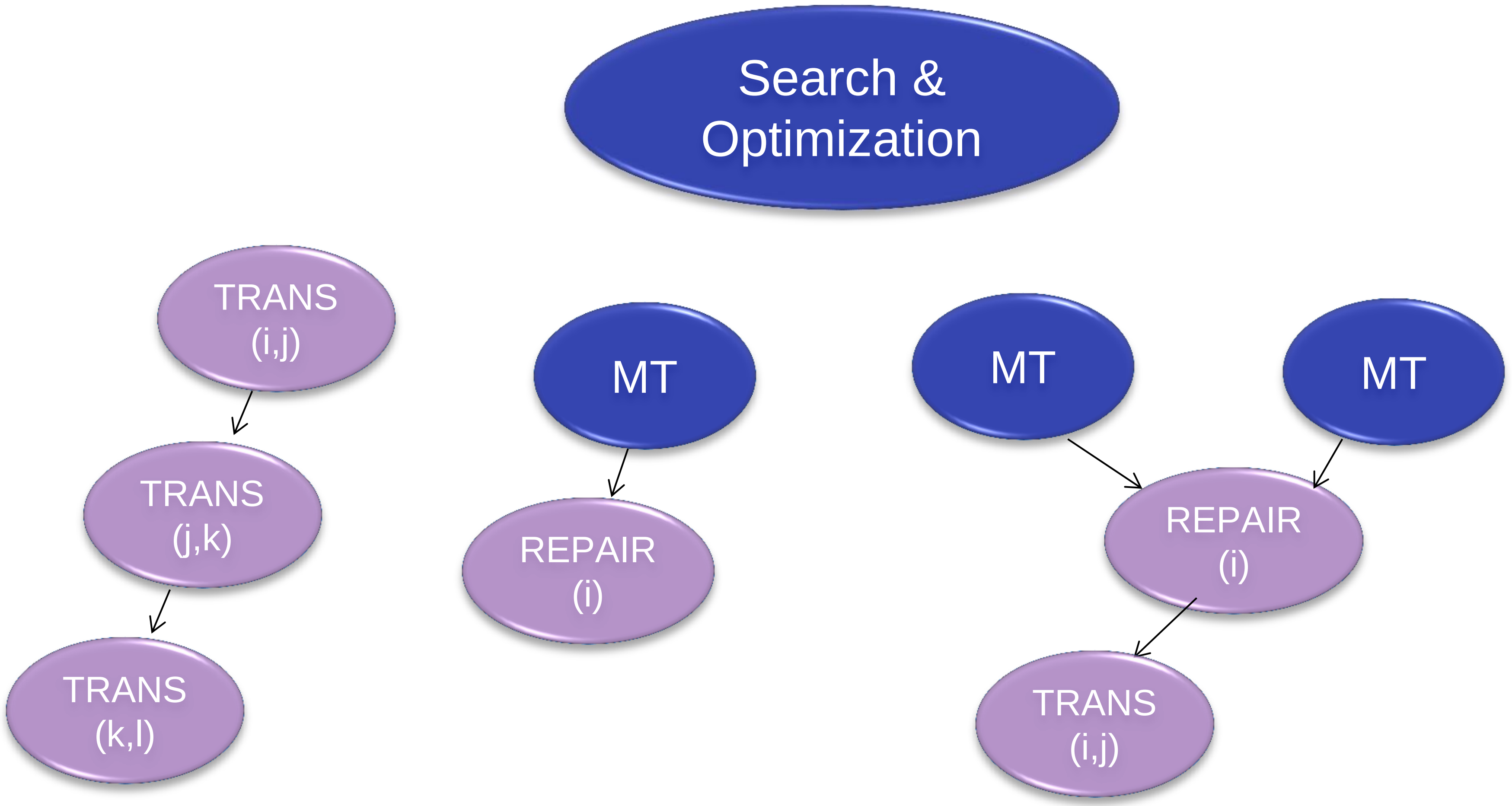
Ideal assemblies of human & machine intelligence

Workflows & Routing



Example: Lingua Mechanica

Translate languages via networks of people & machines

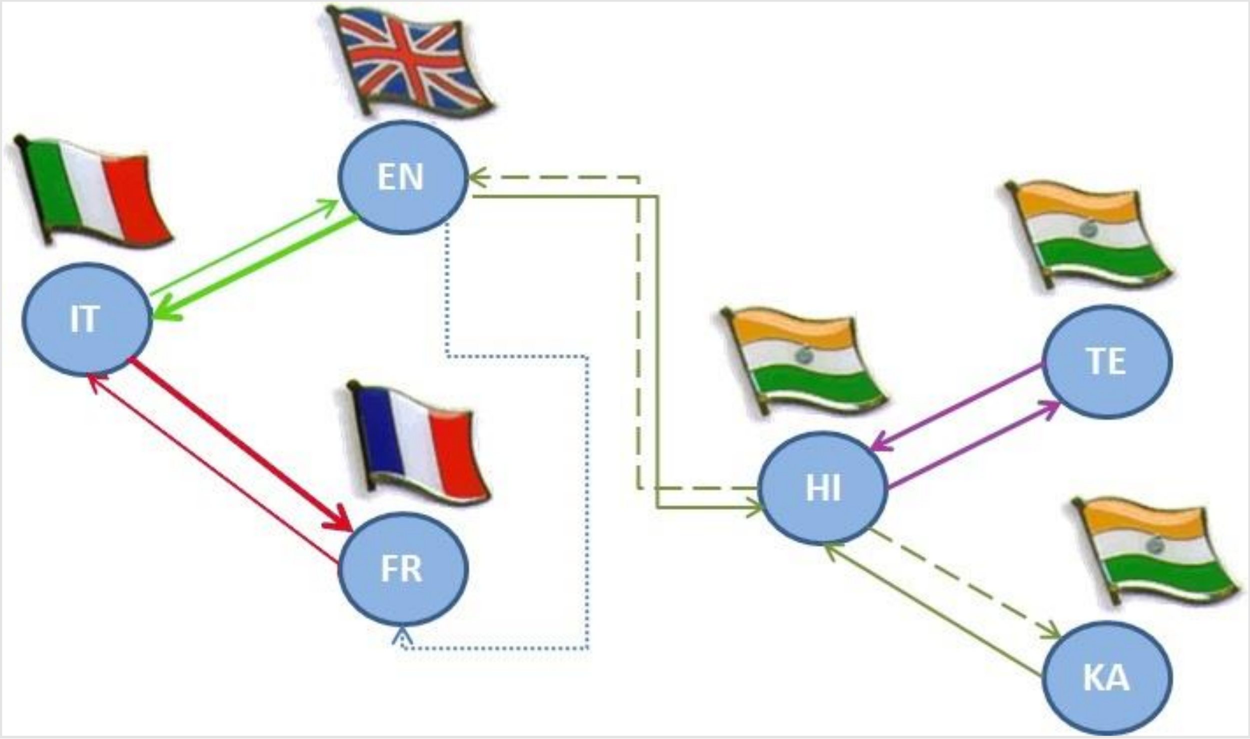


D. Shahaf, & E. Horvitz. Generalized Task Markets, AAAI 2010.

Example: Lingua Mechanica

Translate languages via networks of people & machines

Learn competencies & availabilities of crowdworkers



D. Shahaf, & E. Horvitz. Generalized Task Markets, AAAI 2010.

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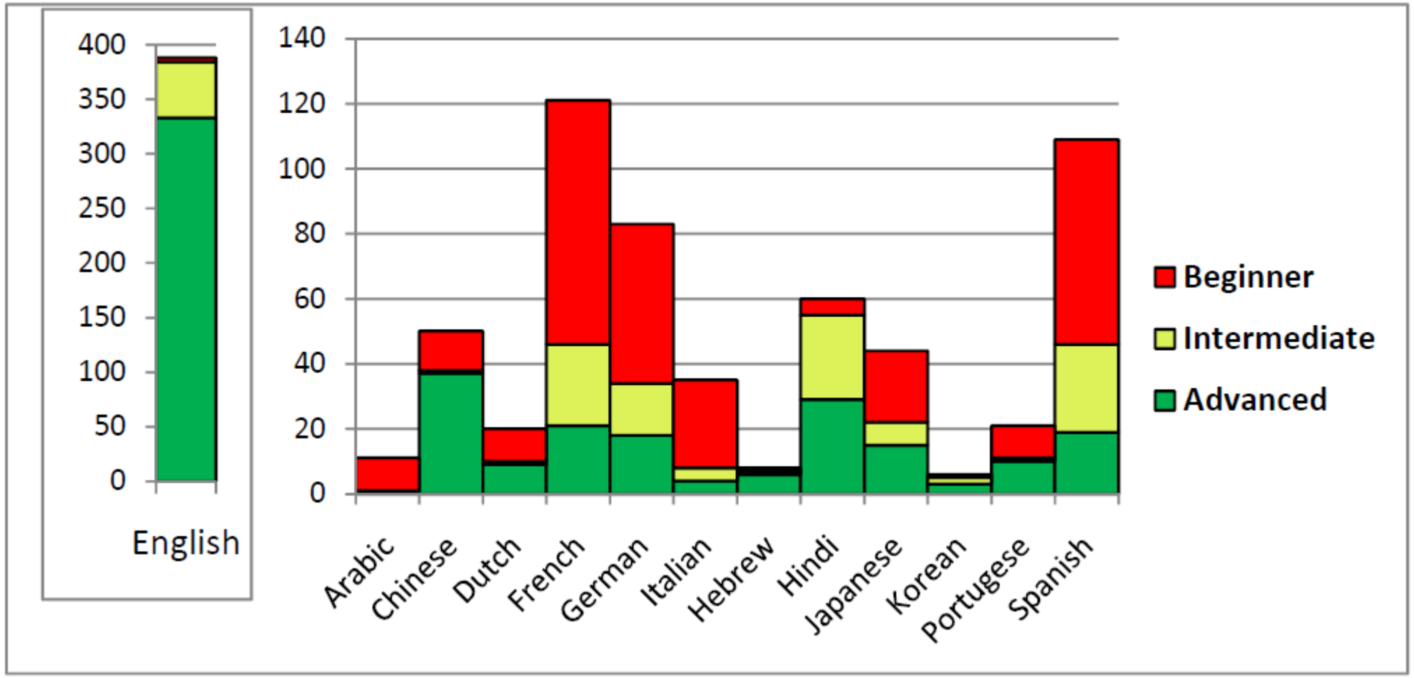
Translate languages via networks of people & machines

Learn competencies & availabilities of crowdworkers

Crowdworker translation competencies



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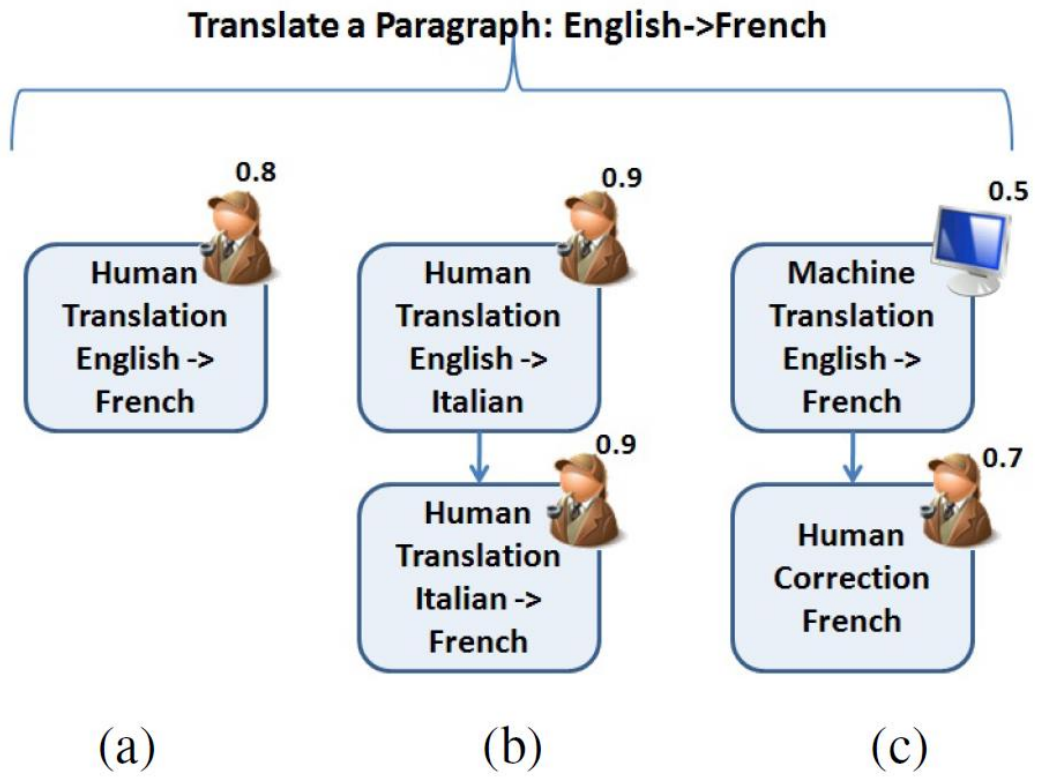
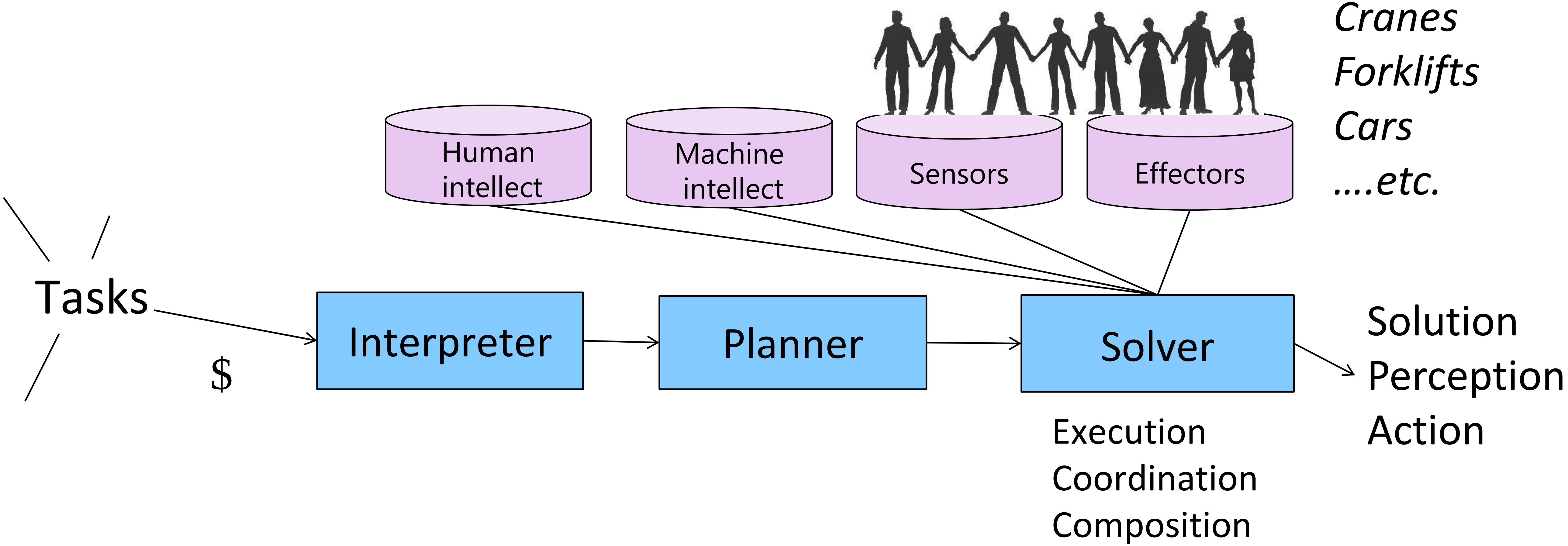


D. Shahaf, & E. Horvitz. Generalized Task Markets, AAAI 2010.

Getting Physical: Crowd Physics

People
Cameras
Cranes
Forklifts
Cars
....etc.



D. Shahaf, & E. Horvitz. Generalized Task Markets, AAAI 2010.

Crowd Physics Studies

Capture real-world data on location and mobility

Digital experimentation via parameter sweeps

Seek insights on shaping “fabric” of collaboration

Preferences, incentives and links to collaborative fabric

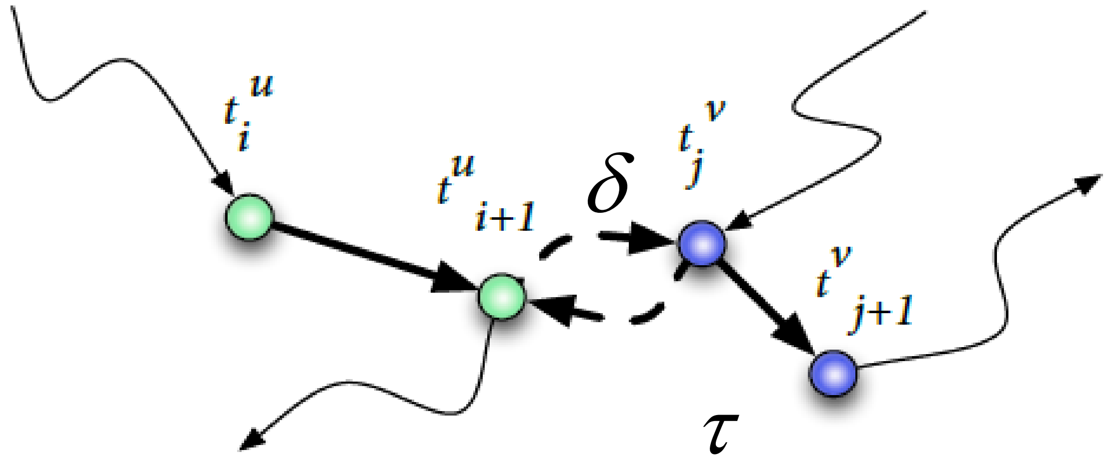
Implications & directions

A. Sadilek, J. Krumm, E. Horvitz. Crowdphysics: Planned & Opportunistic Crowdsourcing for Physical Tasks.

Canonical Crowd Physics Problem

Shaped Contact Graphs

Actively "shaped" routing graph: set proximity δ, dwell time τ



<u>Studies</u>

Locations via GPS-coded tweets

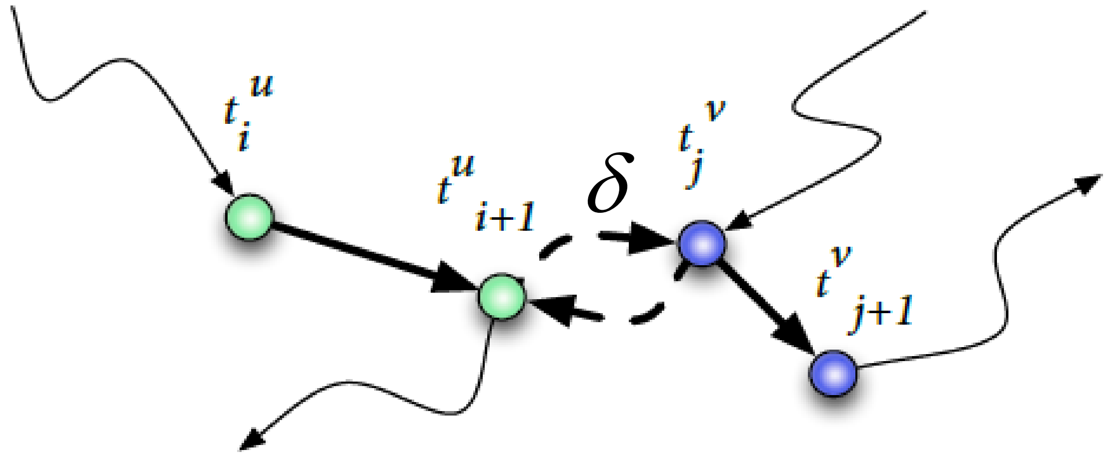
Sweep through δ, τ

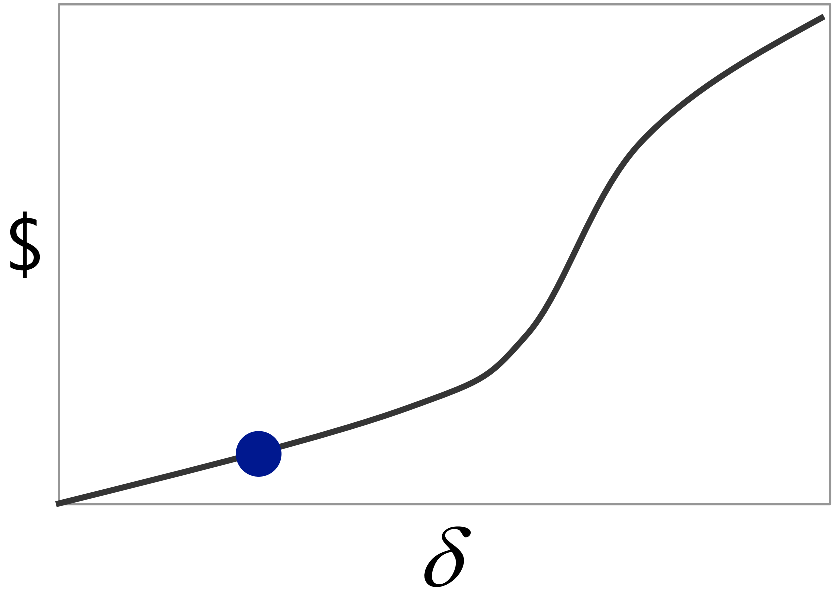
<u>A. Sadilek, J. Krumm, E. Horvitz. Crowdphysics: Planned & Opportunistic Crowdsourcing for Physical Tasks.</u>

Contact Graphs from Tweets

Shaped Contact Graphs

Actively "shaped" routing graph: set proximity δ, dwell time τ





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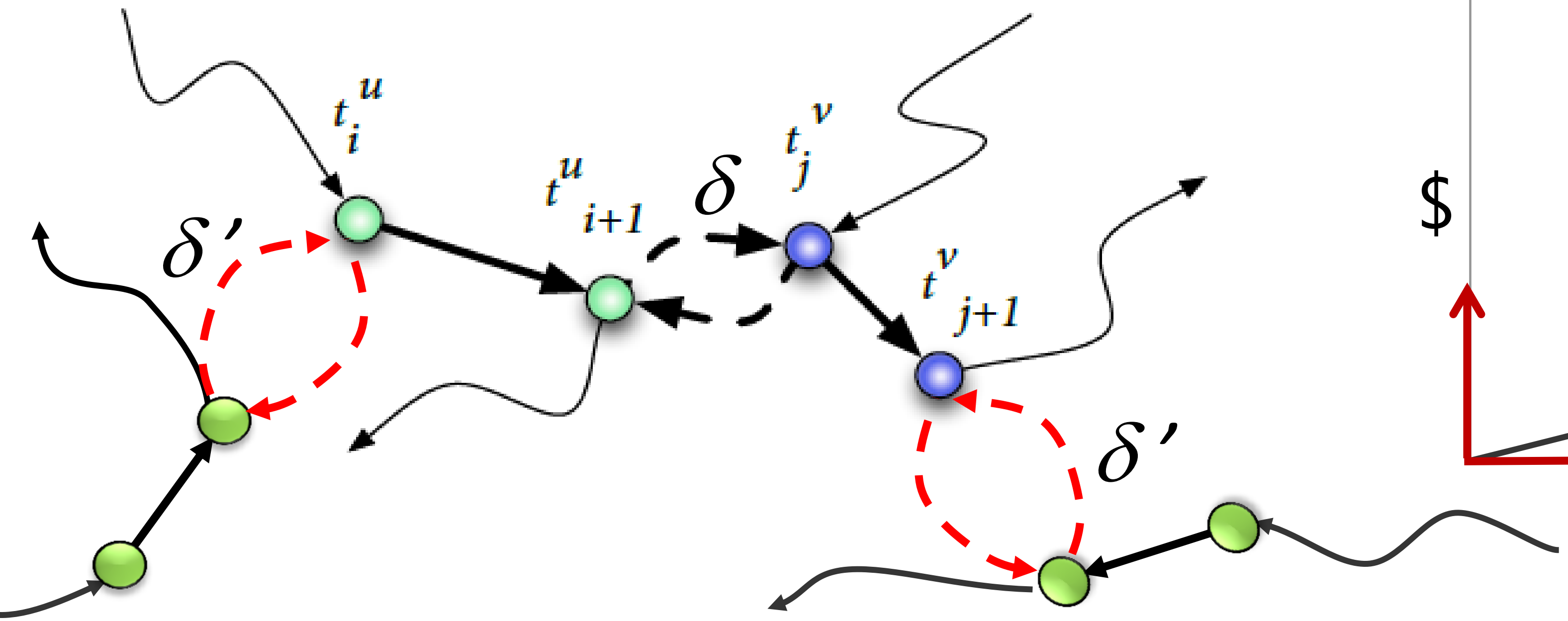
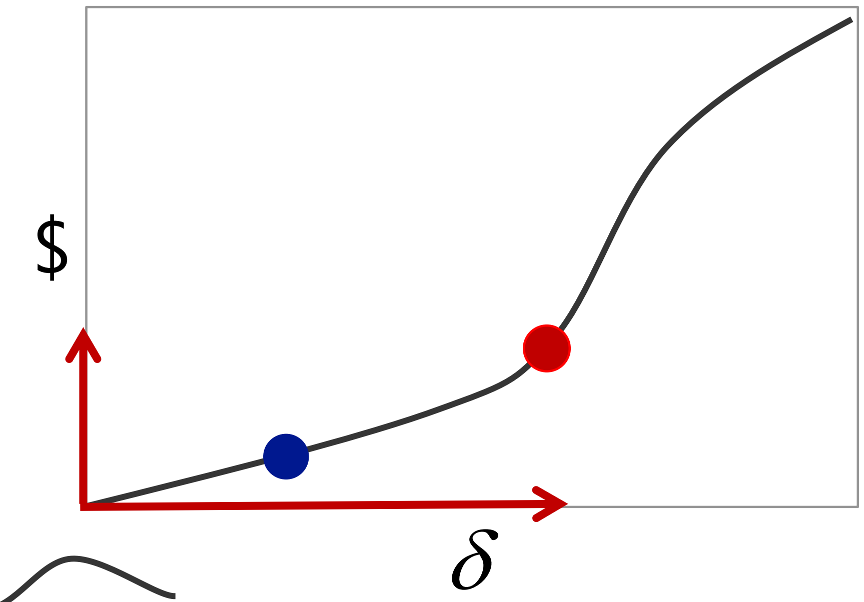




A. Sadilek, J. Krumm, E. Horvitz. Crowdphysics: Planned & Opportunistic Crowdsourcing for Physical Tasks.

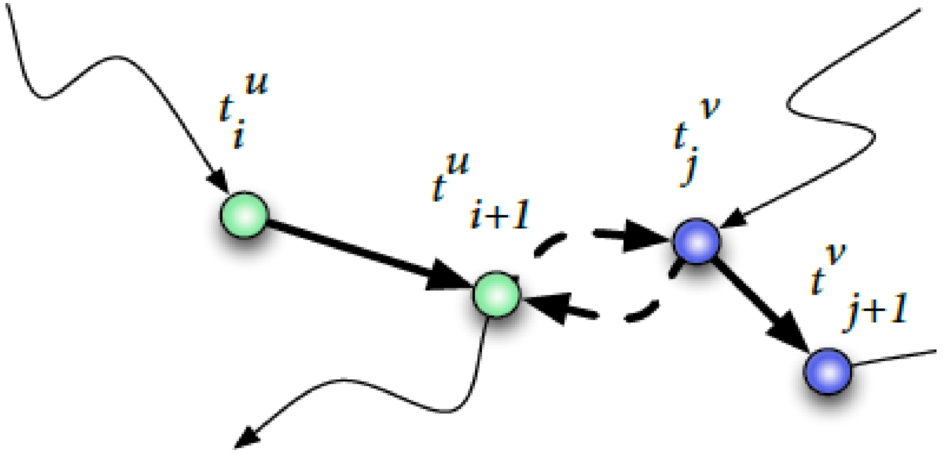
Contact Graphs from Tweets

Shaped contact graphs: Experiments with design

Actively "shaped" routing graph: set proximity δ, dwell time τ

21 days
Cities: 60x60 km

$\delta = 100$ meters
$\tau = 30$ minutes



Dataset	Days	Users	Tweets	Edges in G
NYC	21	47,713	544,606	740,489
SEA	21	10,424	125,620	140,075
US	2	371,481	3,434,898	3,931,884

A. Sadilek, J. Krumm, E. Horvitz. Crowdphysics: Planned & Opportunistic Crowdsourcing for Physical Tasks.

Canonical Task: Routing Physical Objects

Synchronization & sequencing of effort

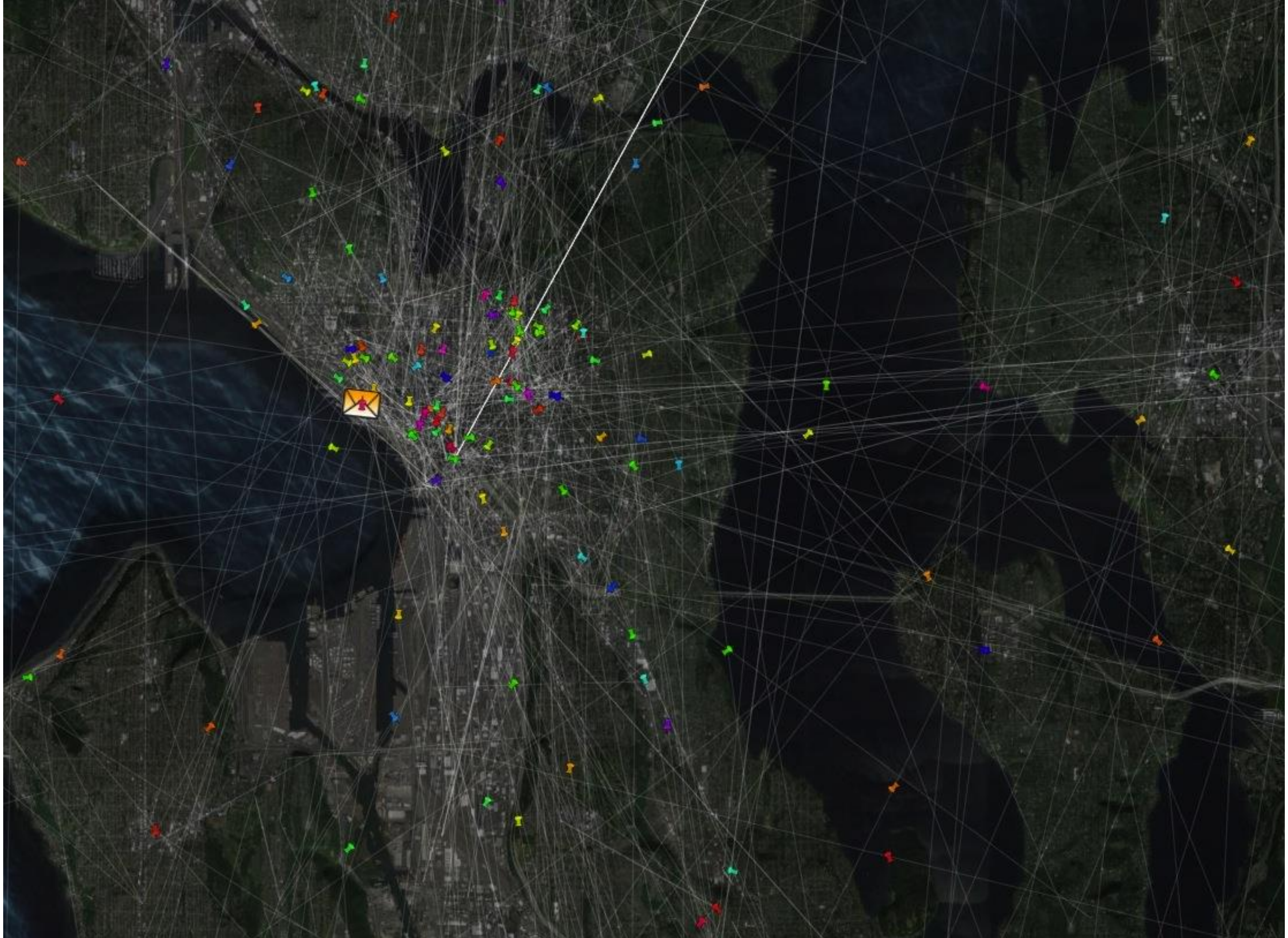
Local vs. centralized plans

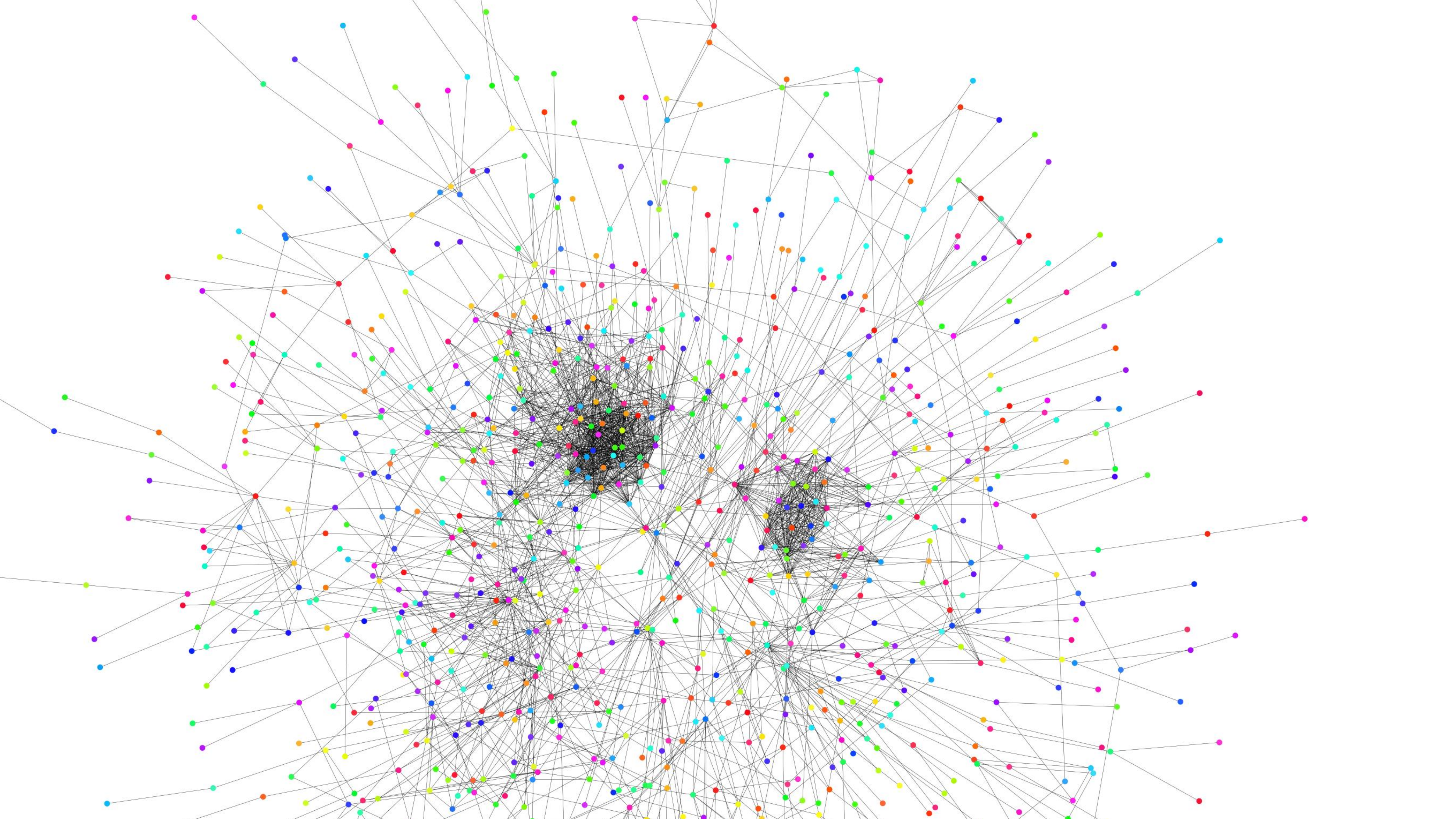
Canonical task: Route packages

- Coverage & reachability
- Efficiency (delivery time)
- Optimality of routing heuristics
- Robustness to graph ablation
- Locale sensitivity

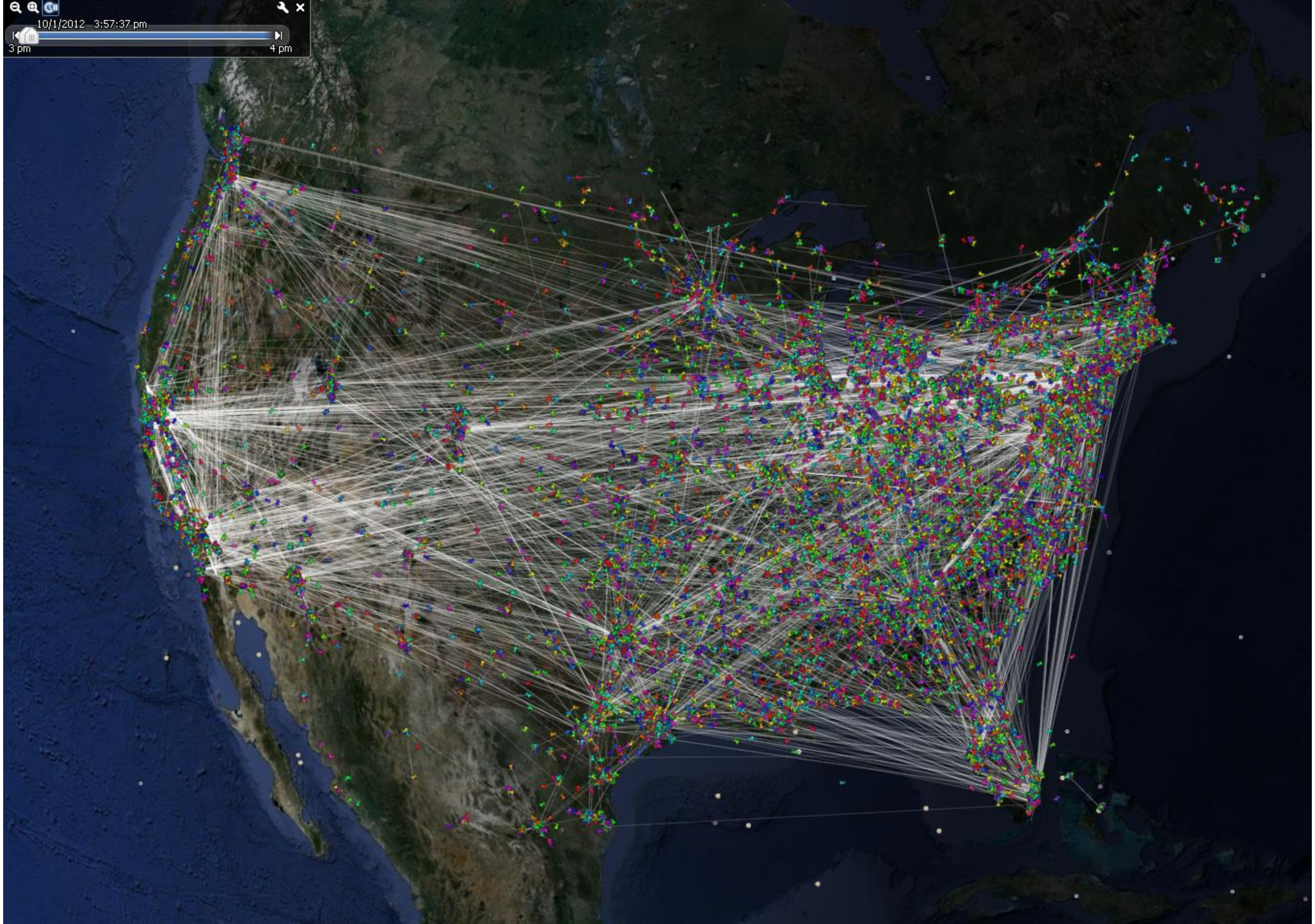
Video


Click to toggle time slider animation.
12/31/2011 4:00 pm
2/31/2011
1/2/2012
Tipping Point





Video


10/1/2012 3:57:37 pm
3 pm
4 pm

Results on Contact Graphs

Random infinite graphs

Static, homogeneous networks, repeat lattice structure

Studies: Properties of finite, real-world contact graphs

Leverage for task coordination

Properties of Constructed Graphs

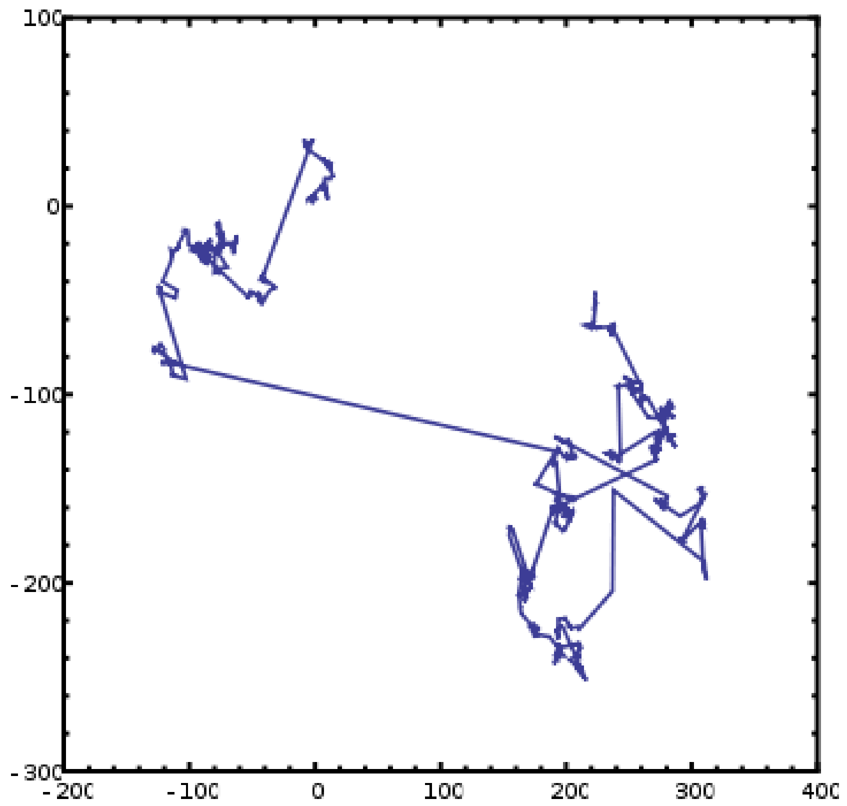
Lévy flight: random walk w/ heavy-tailed probability distribution.

Frequent short-hops, rare long jumps (Mandelbrot)

$$P(x) \propto x^{-\beta} \quad \beta = 2.2$$

Small-world phenomenon?

- Graph diameter $O(\log n)$
- Shortest path discoverable?



Studies of Routing in Contact Graphs

Global: Dijkstra, Floyd-Warshall

Assume: Complete, static knowledge

Real-time: Uncertainty about future locations

Local opportunistic routing

Use heuristics based on historical data

Routing Studies

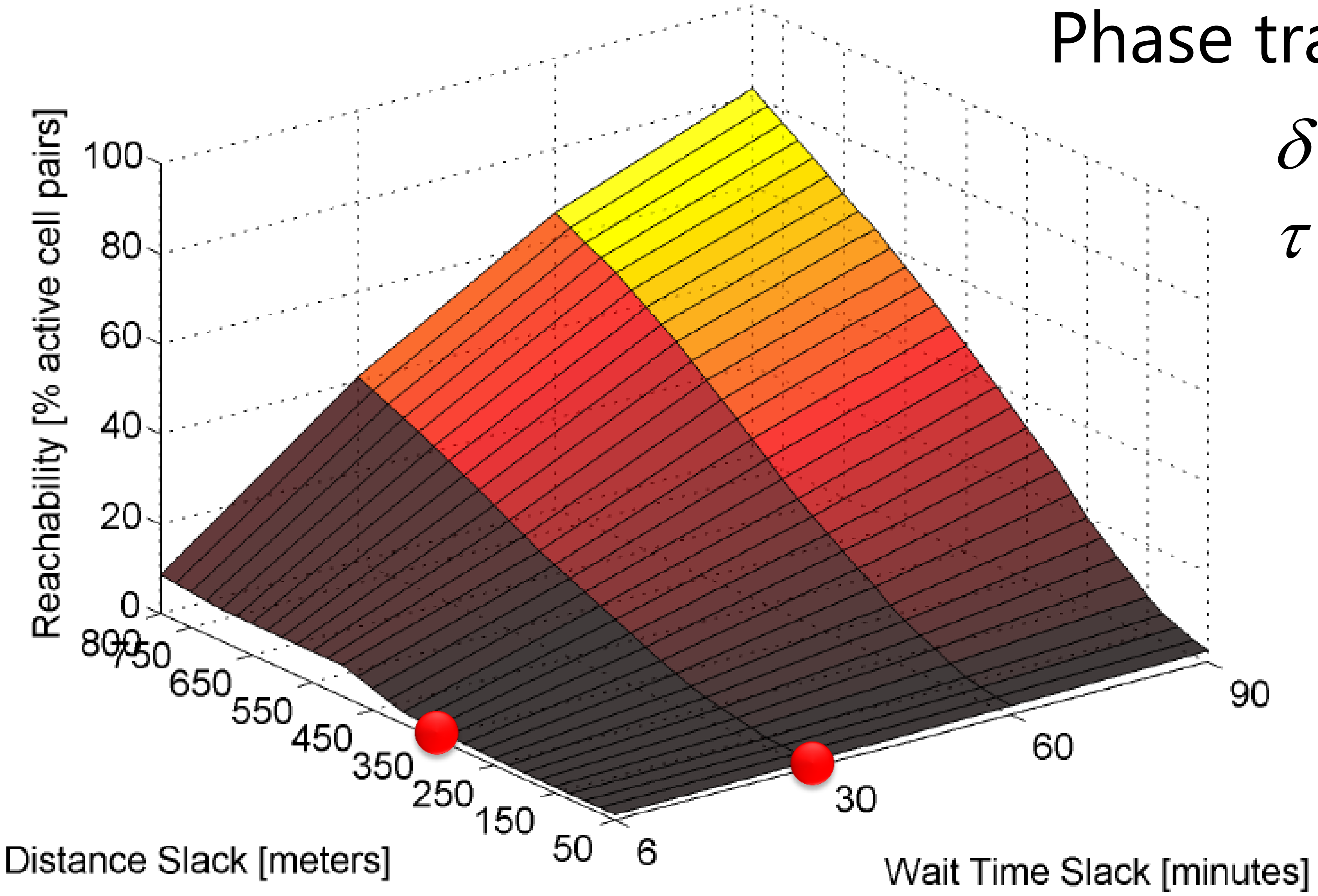
60 x 60 km bounding box around Seattle, 6 months
450 x 450 m cells, start & destination ($c_{i,}$ c_j)

Test: Final 35 hours
Train: Rest of 6 mos.

Local policy:
> For each location ℓ, consider statistics of proximity to ℓ.
> Keep package or handoff based on historical proximity

Global: Dijkstra

Phase Transition in Reachability

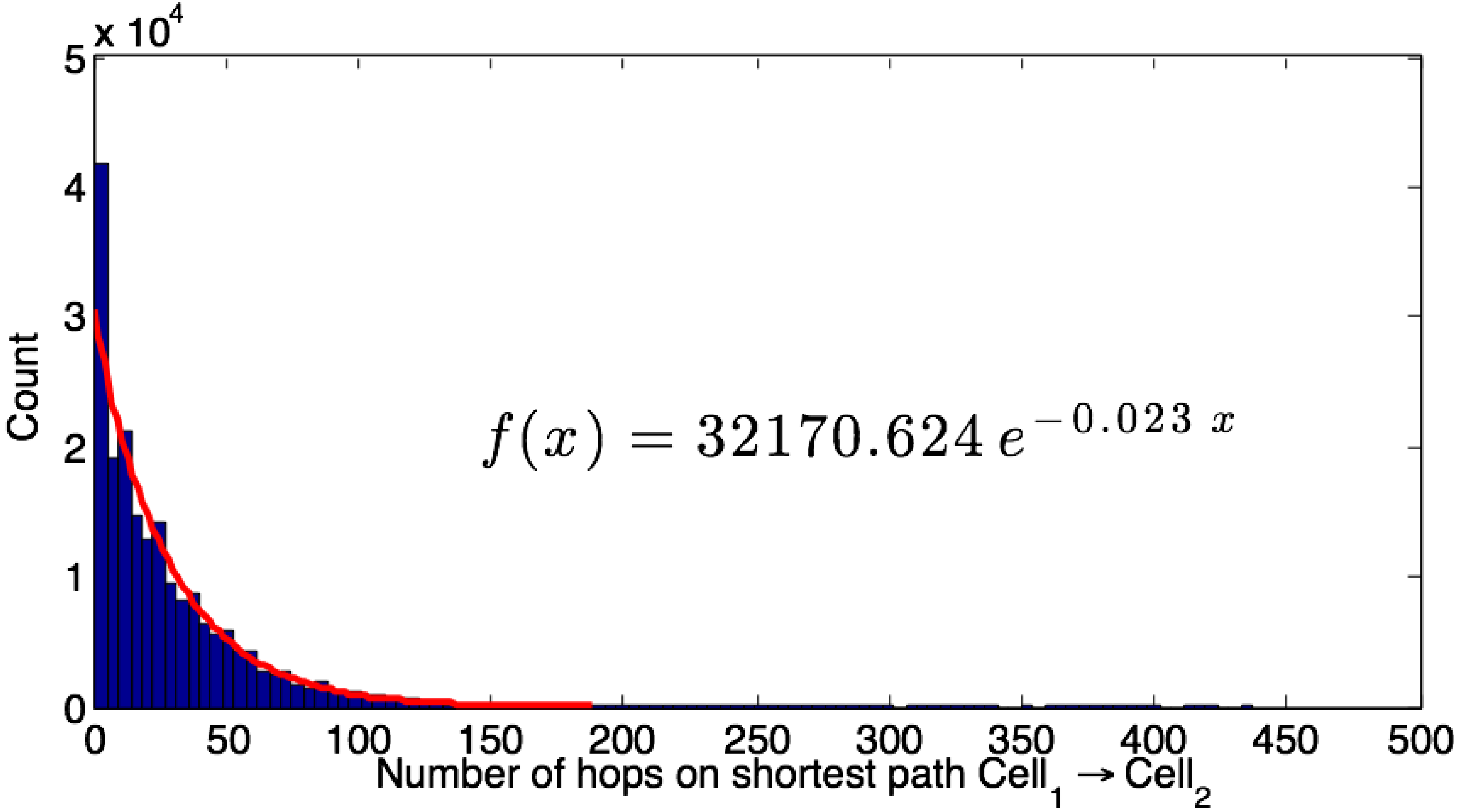


Phase transition @

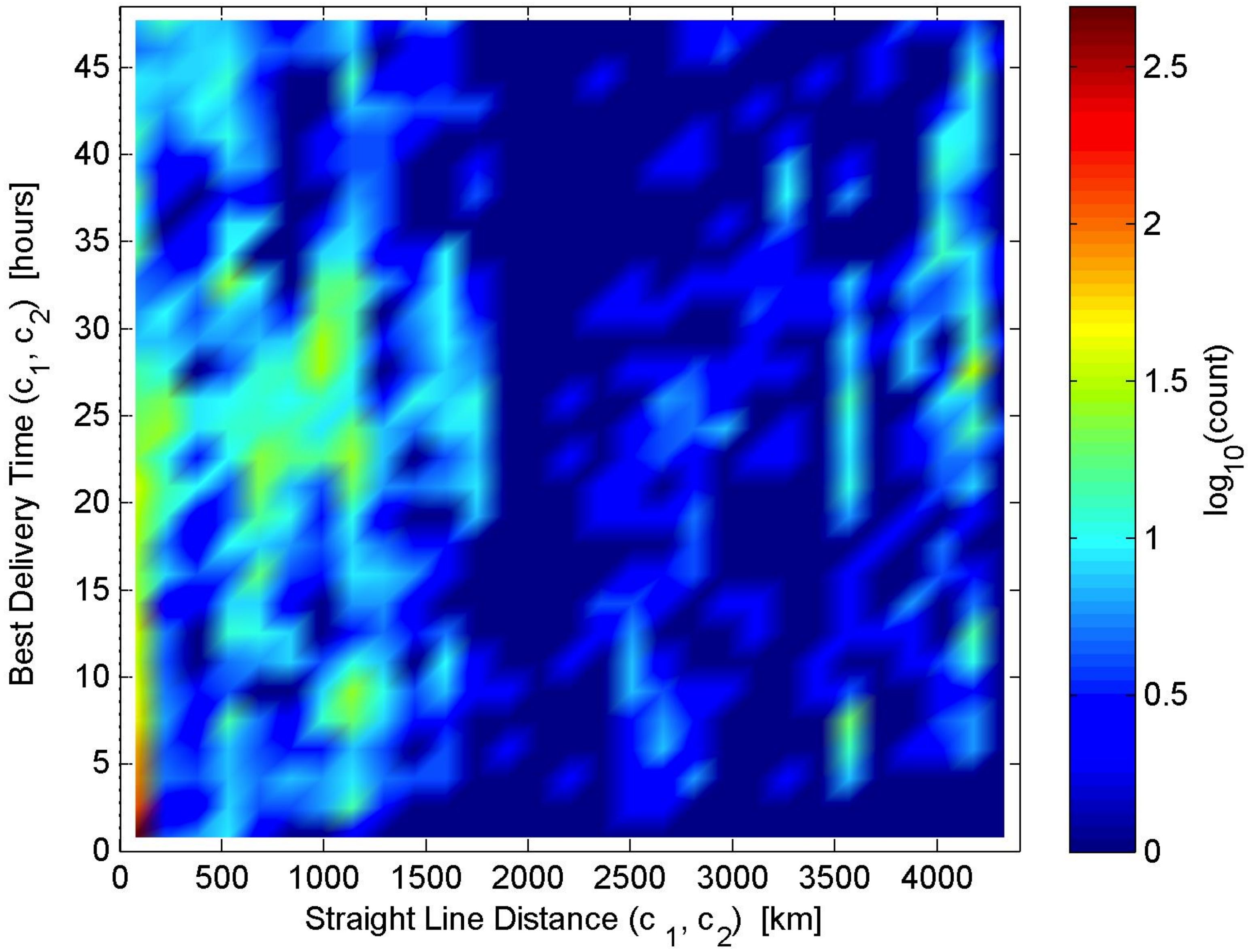
$\delta = 350$ meters

$\tau = 30$ minutes

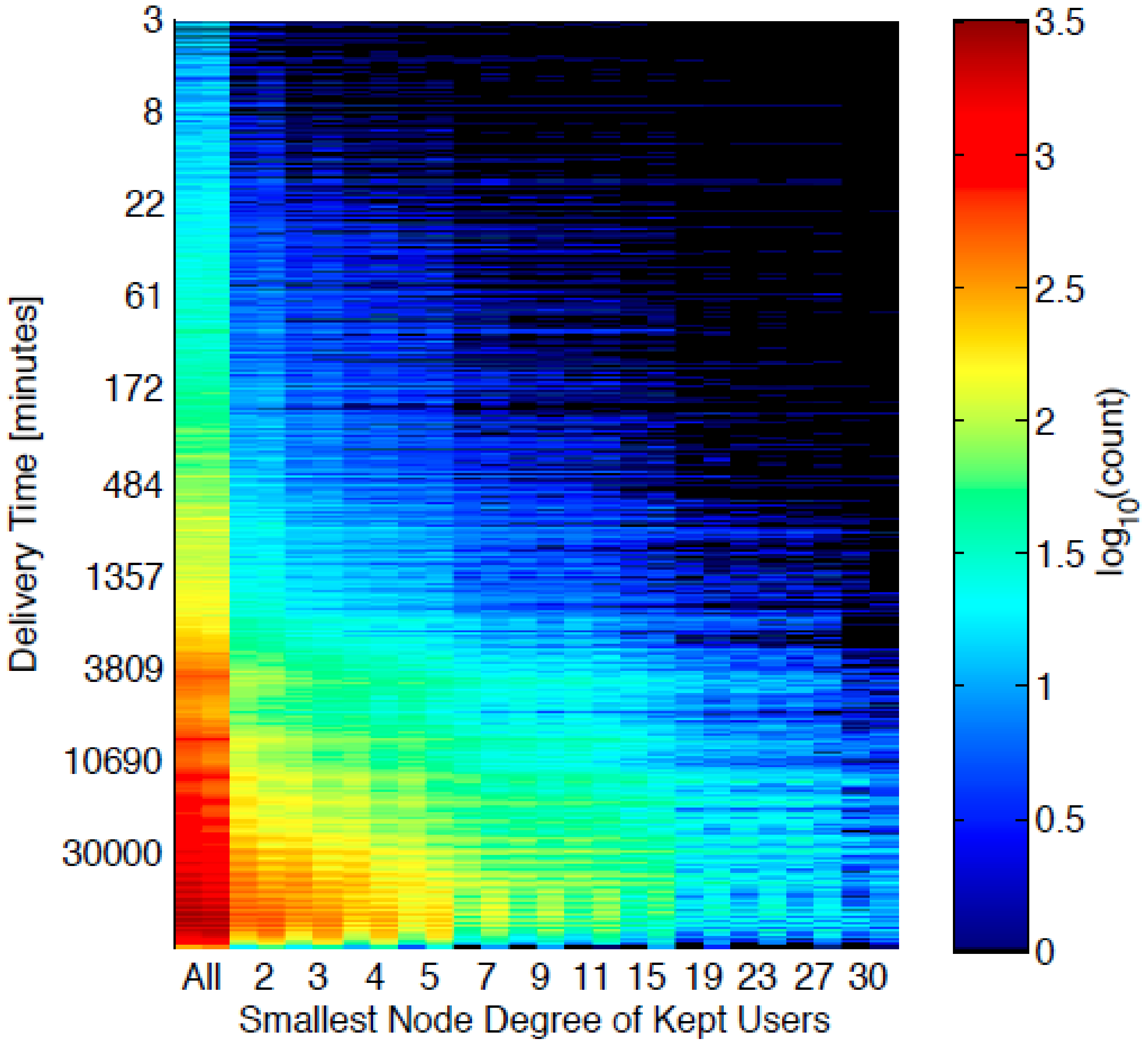
Distribution of Shortest Paths



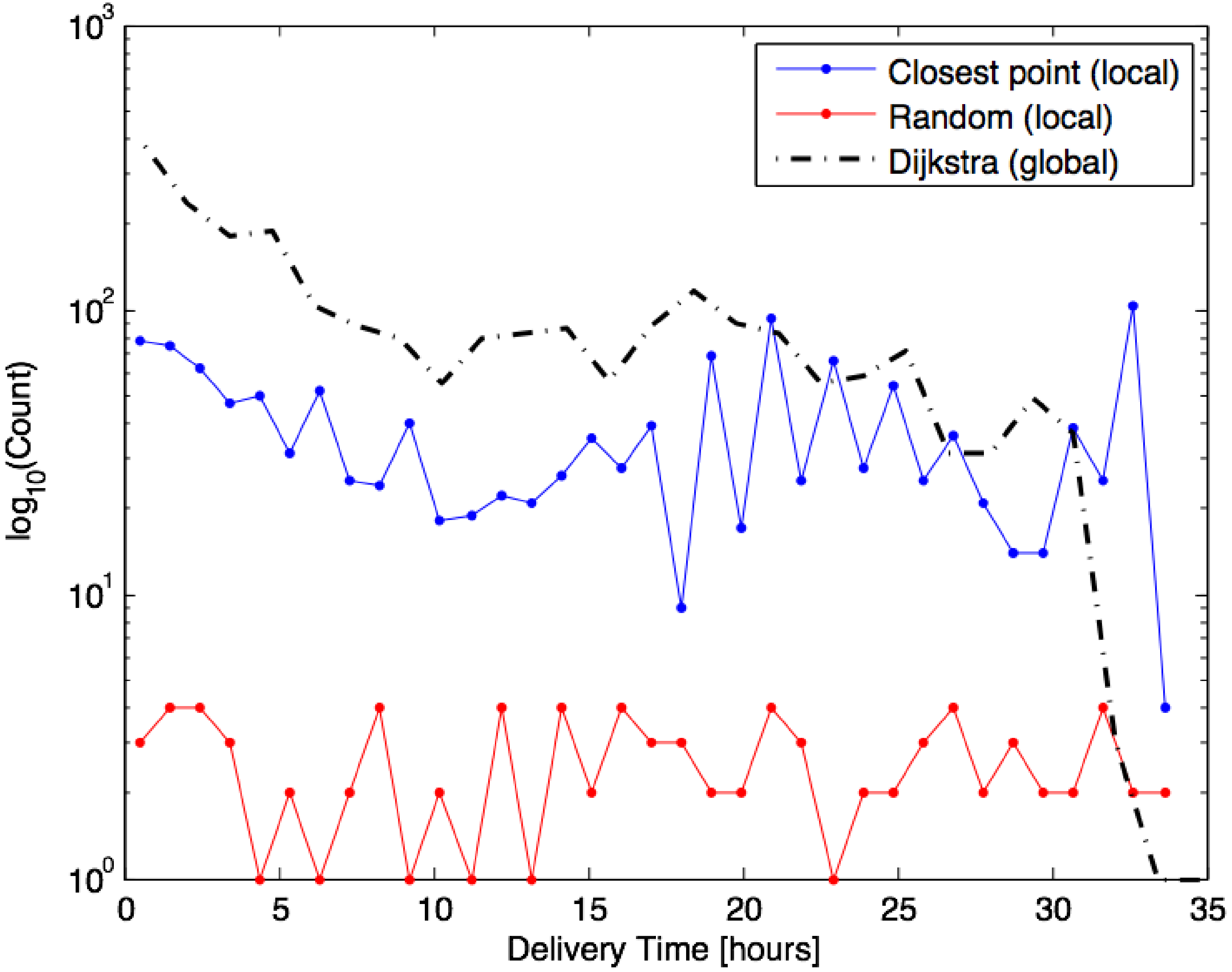
Delivery Times Across US



Studies of Robustness



Local vs. Global Planning



Understanding & Shaping Collaborative Systems

Studies of crowd physics for sensing & acting in world

Design, optimization of collaborative substrate

Rich area, multiple directions for enhancing collaboration

Opportunities include new approaches to epidemiology, e.g., where reachability & efficiency are minimized