Self-Stabilizing Broadcast with O(1)-Bit Messages*

Emanuele Natale†

joint work with
Lucas Boczkowski* and Amos Korman*

* CNRS, IRIF, Institut de Recherche en Informatique Fondamentale

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4th Workshop on Biological Distributed Algorithms
(BDA)
July 25-29, 2016
Chicago, Illinois

*preprint at **goo.gl/ETNc64**

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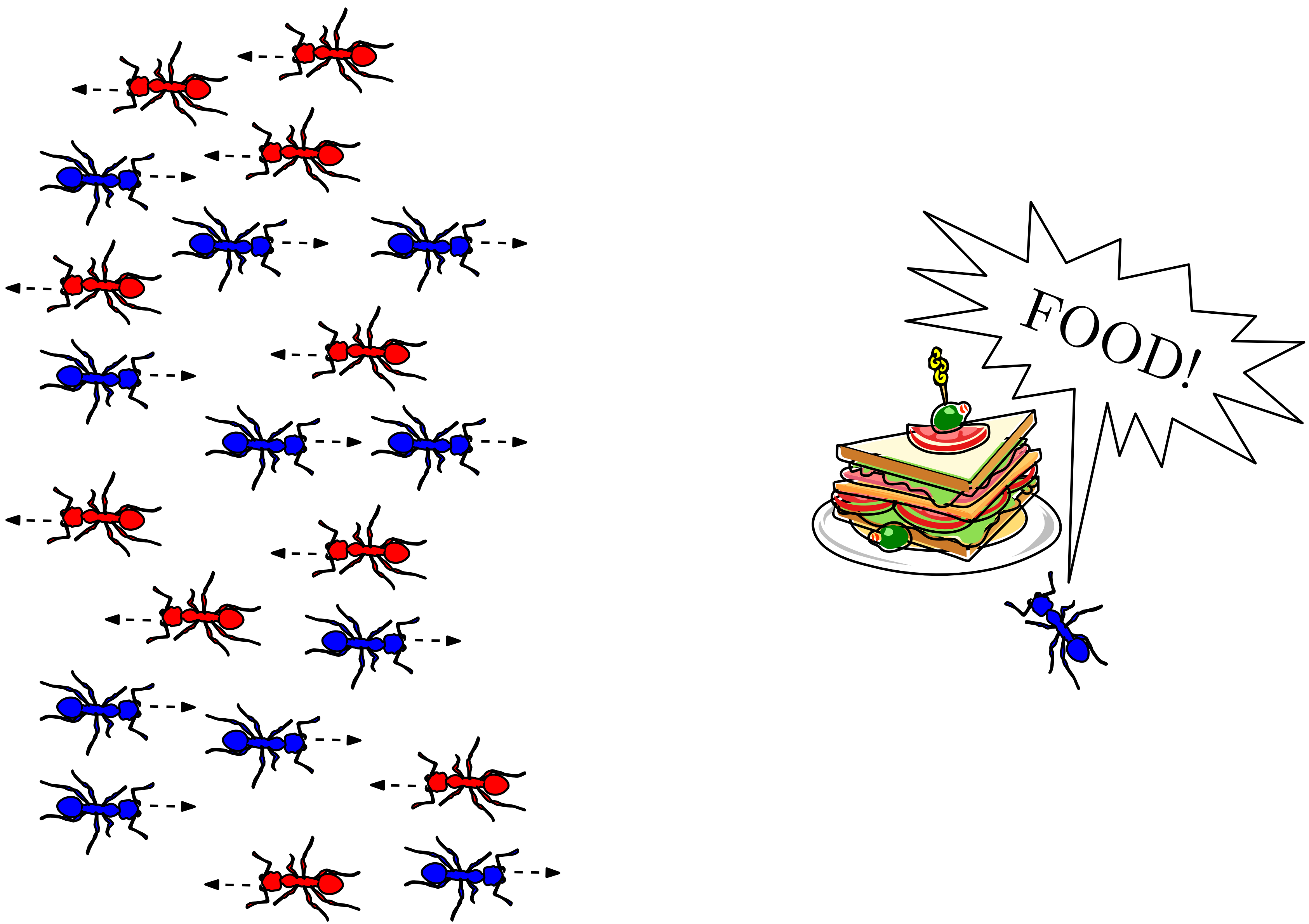

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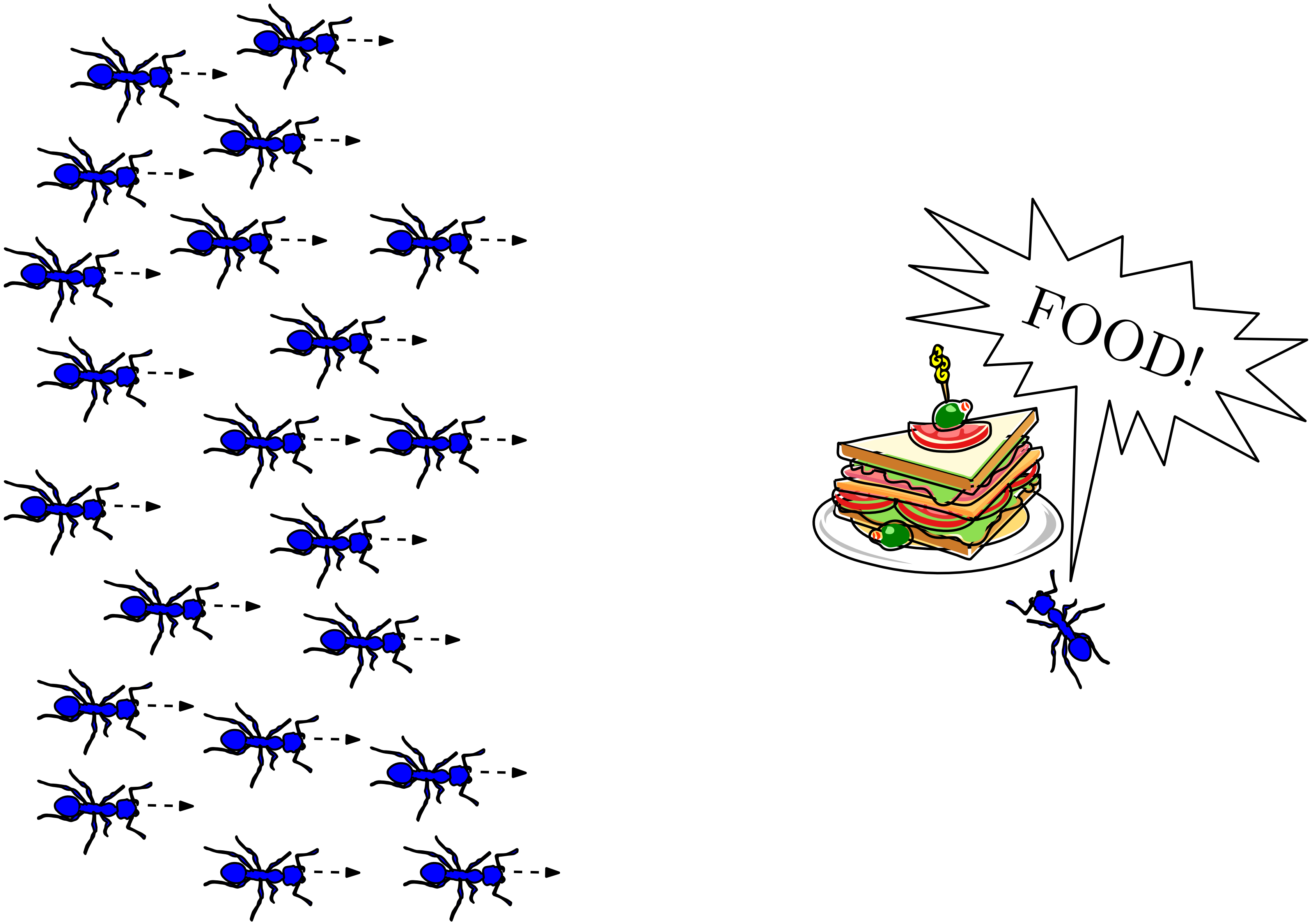

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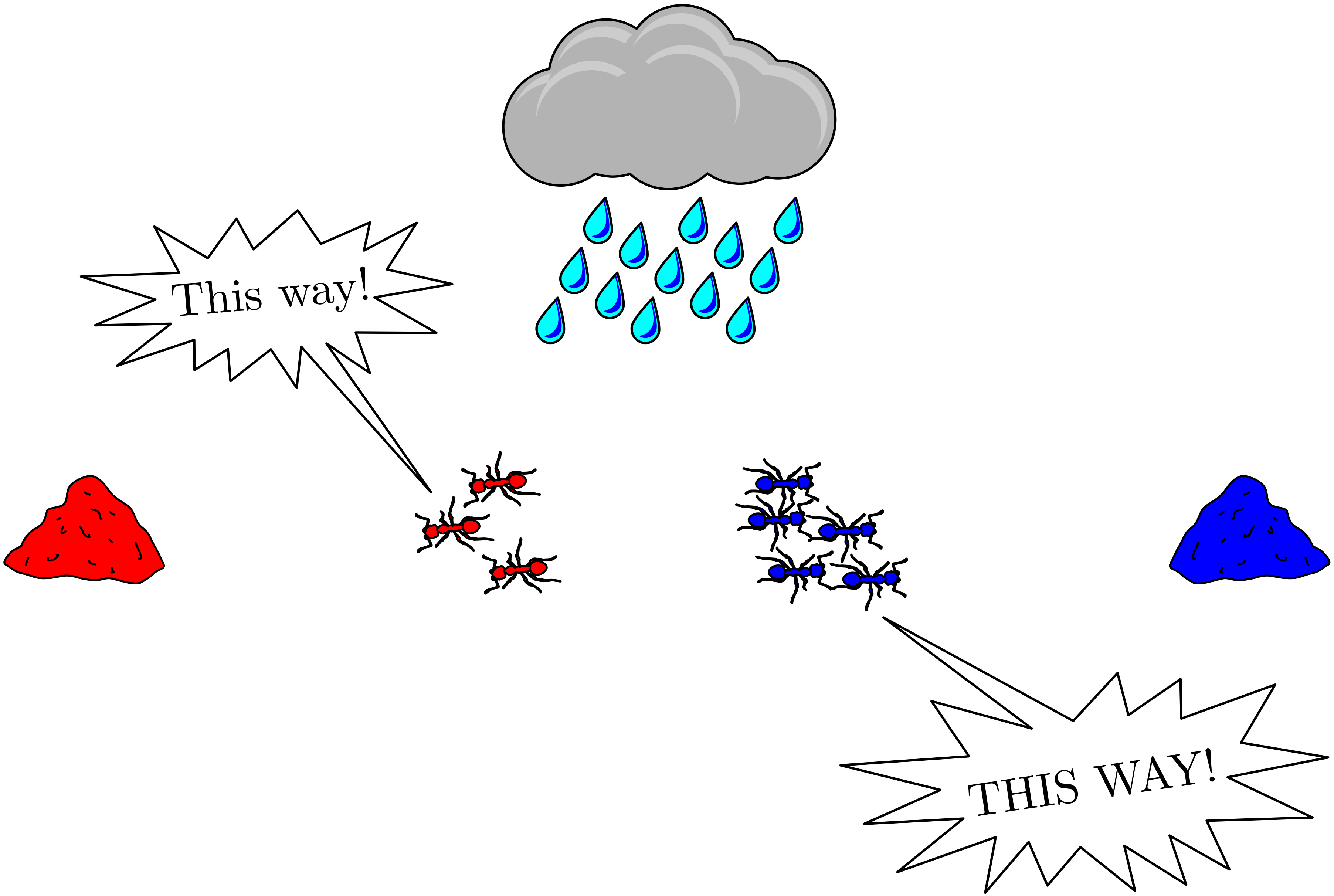

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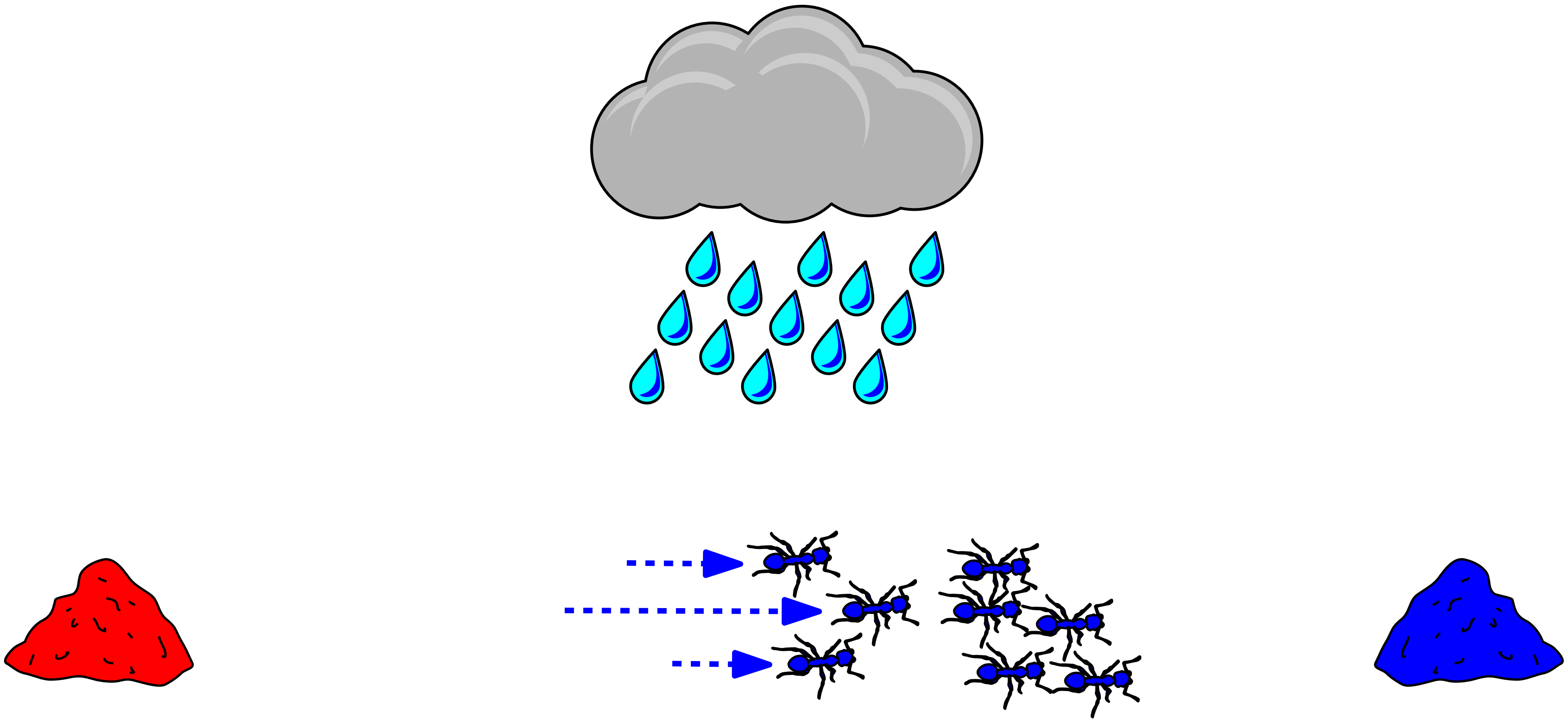

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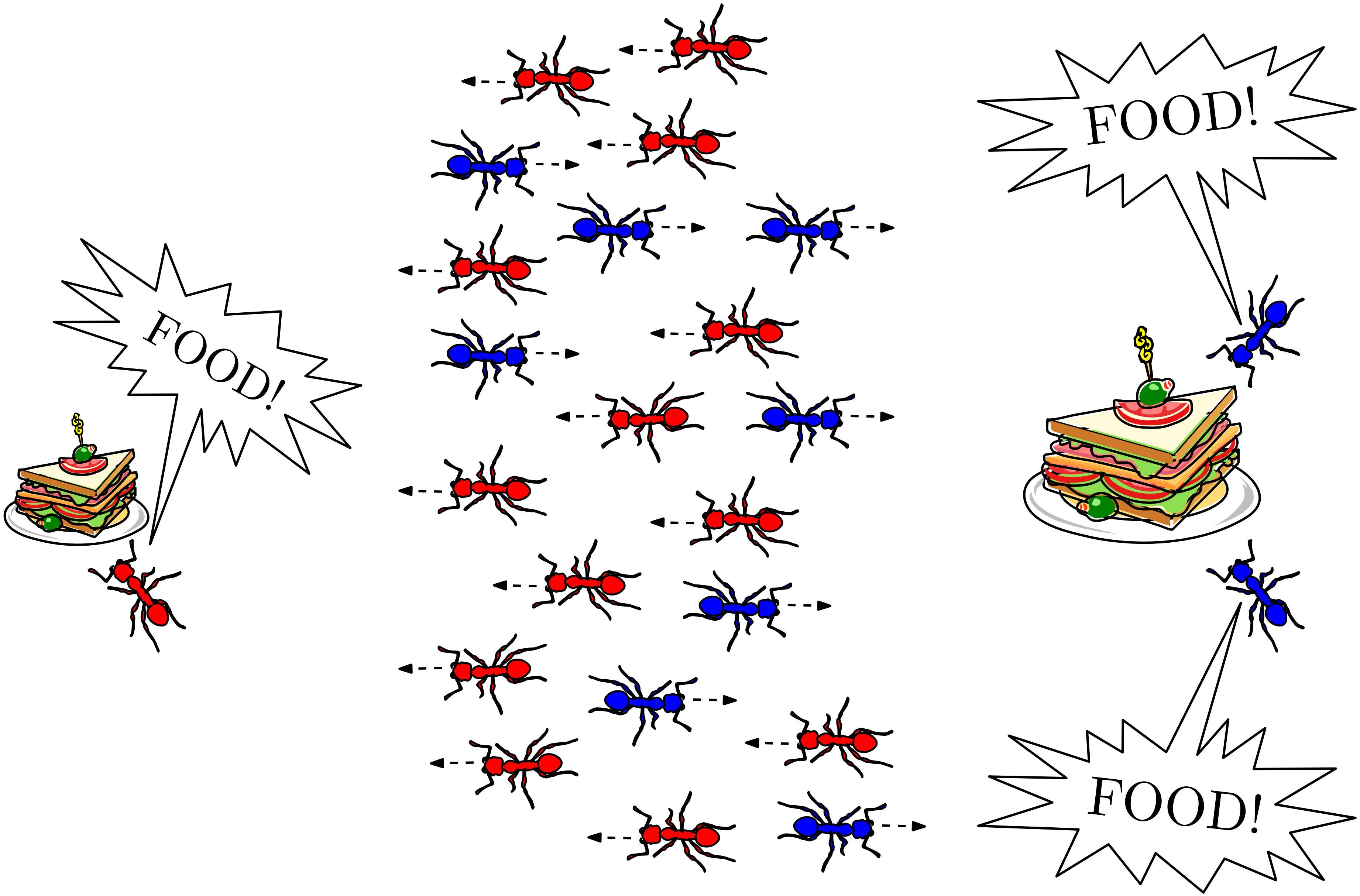

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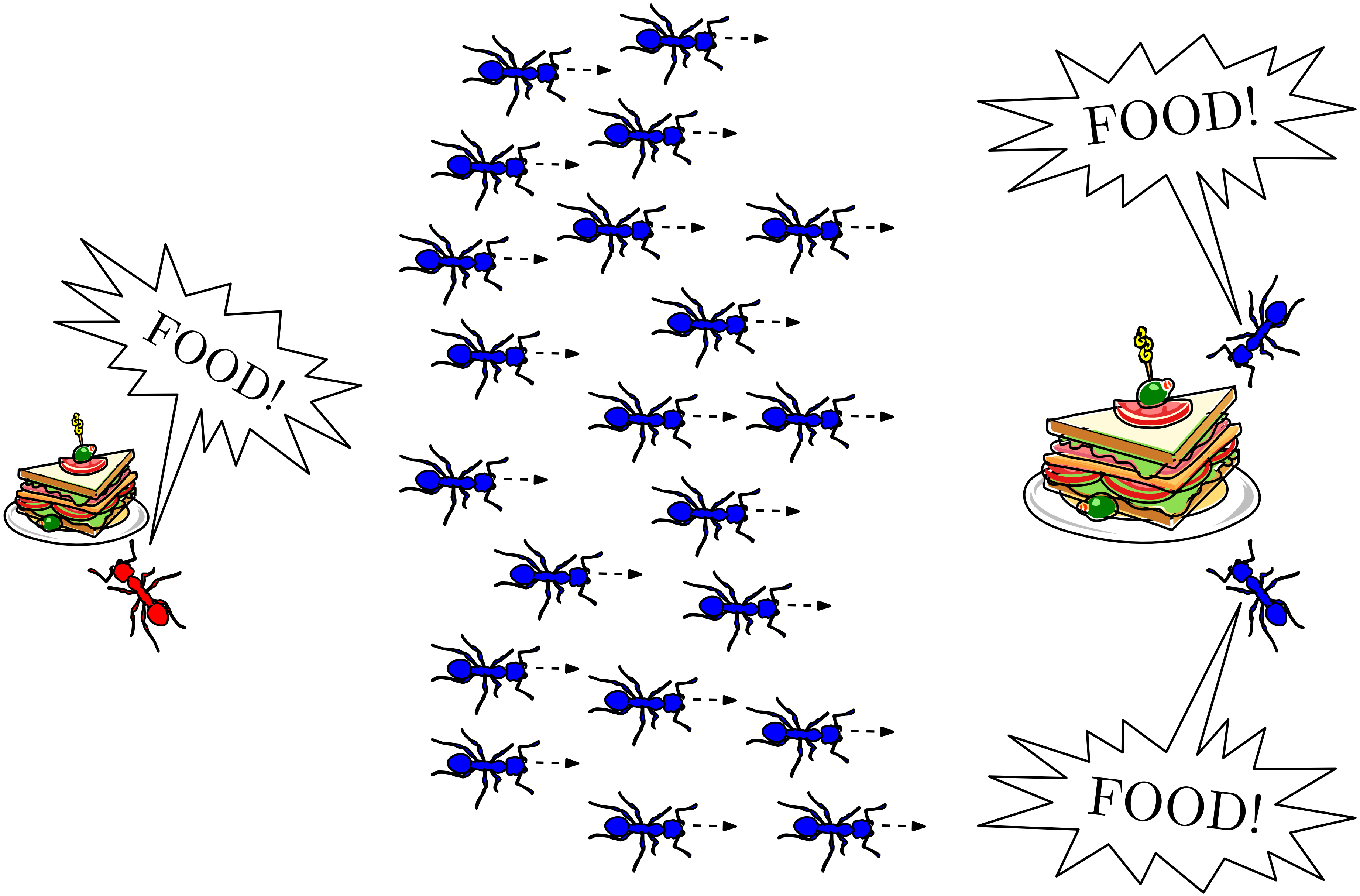

Examples

Flocks of birds
[Ben-Shahar et al. '10]

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[Franks et al. '02]

Communication Model

Animal communication:

- Chaotic
- Anonymous
- Parsimonious
- Uni-directional (Passive/Active)
- Noisy

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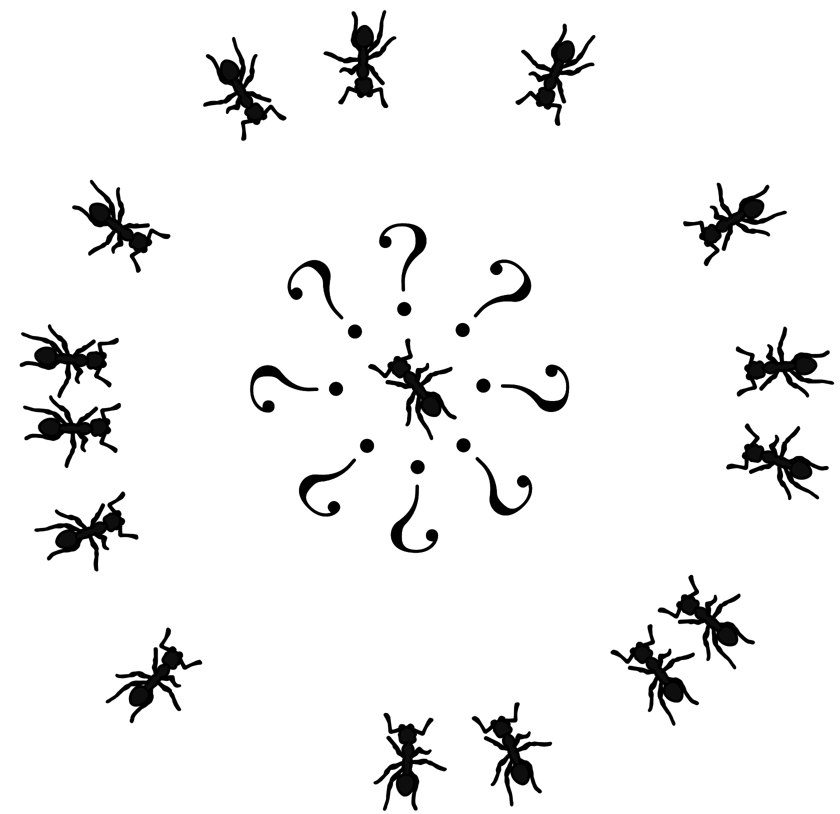
$\mathcal{PUSH}(h, \ell)$ **model** **[Demers '88]**: at each round each agent can *send a ℓ-bit message* to h other agents chosen independently and uniformly at random.



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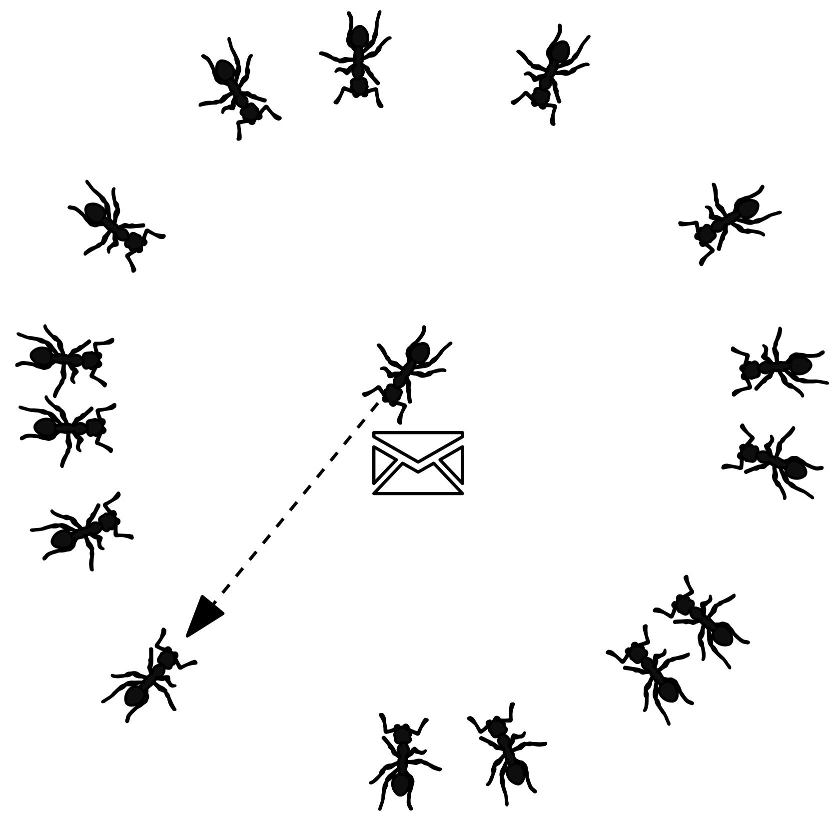

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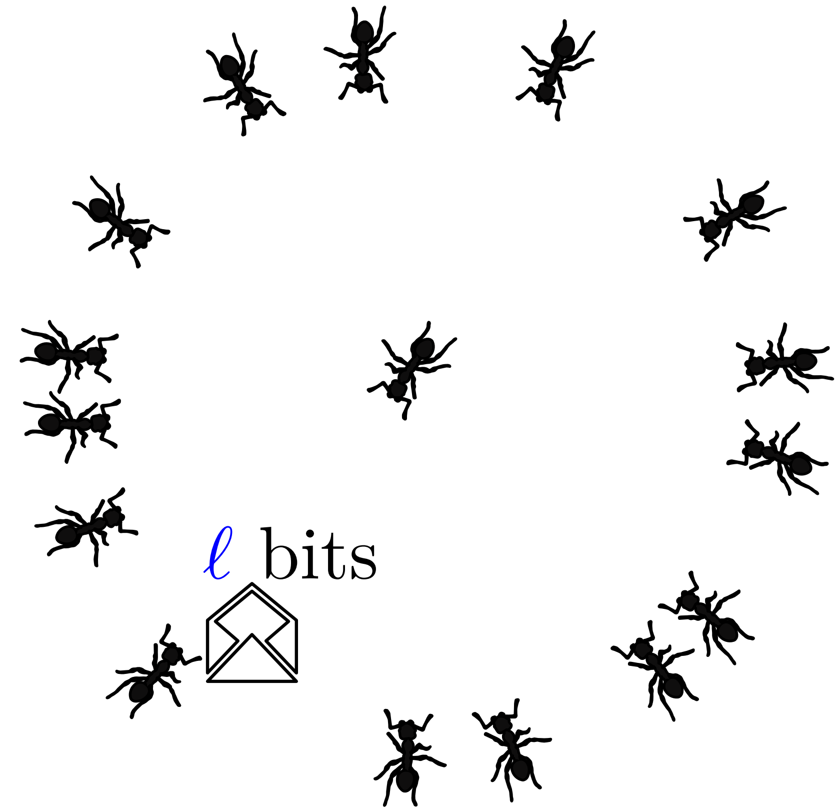

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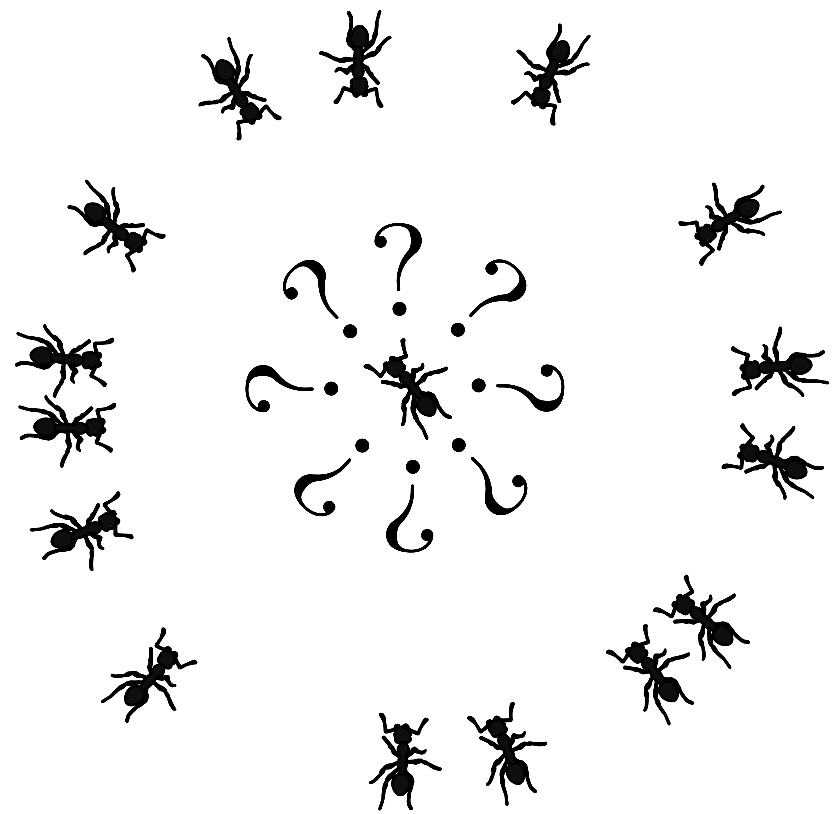

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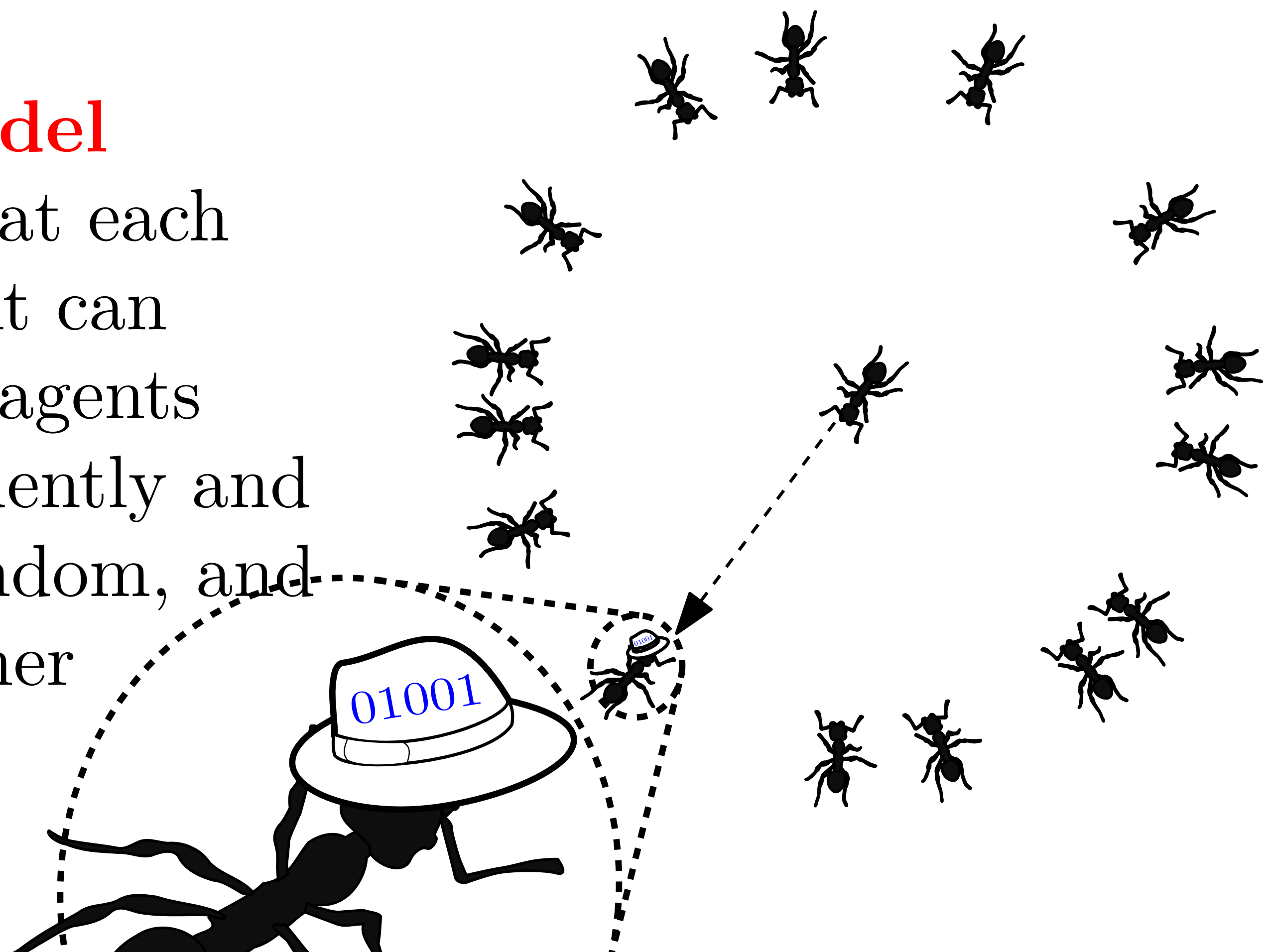
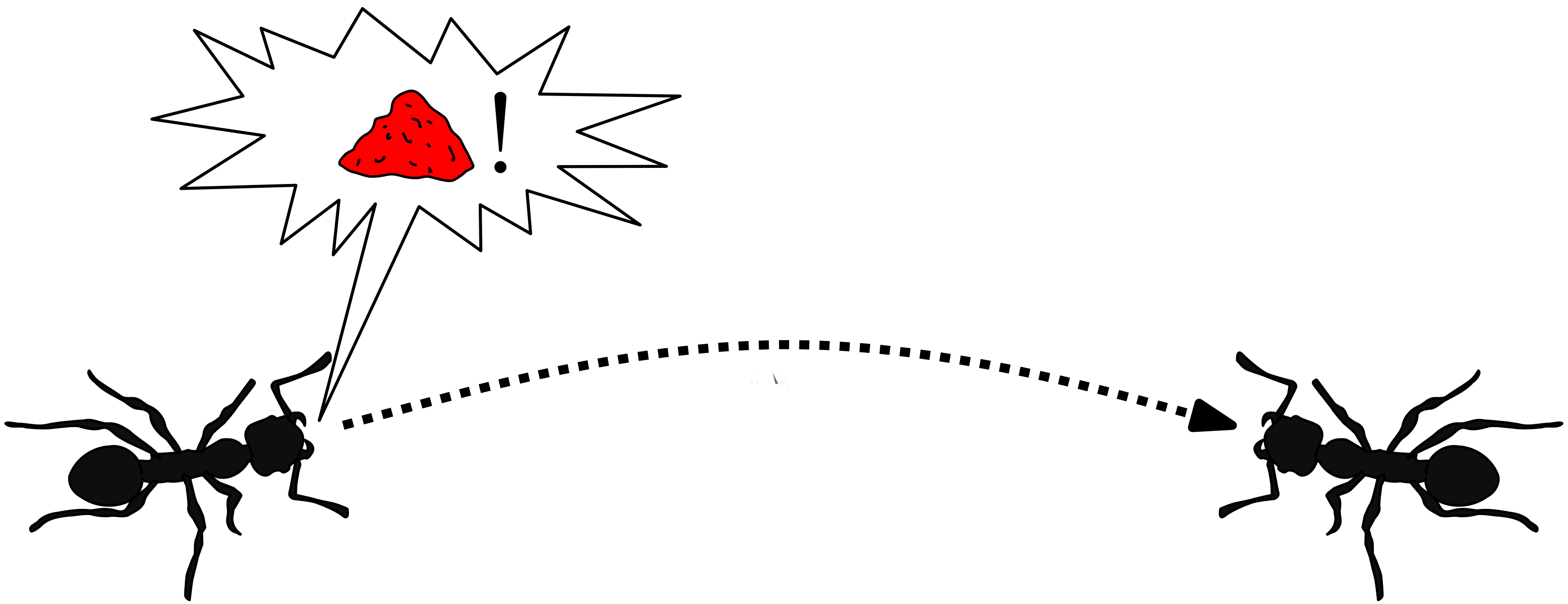


Related Work: MBD despite Noise

$\mathcal{PUSH}$ Model with *noise*: before being received, each bit is flipped with probability $1/2 - \epsilon$.



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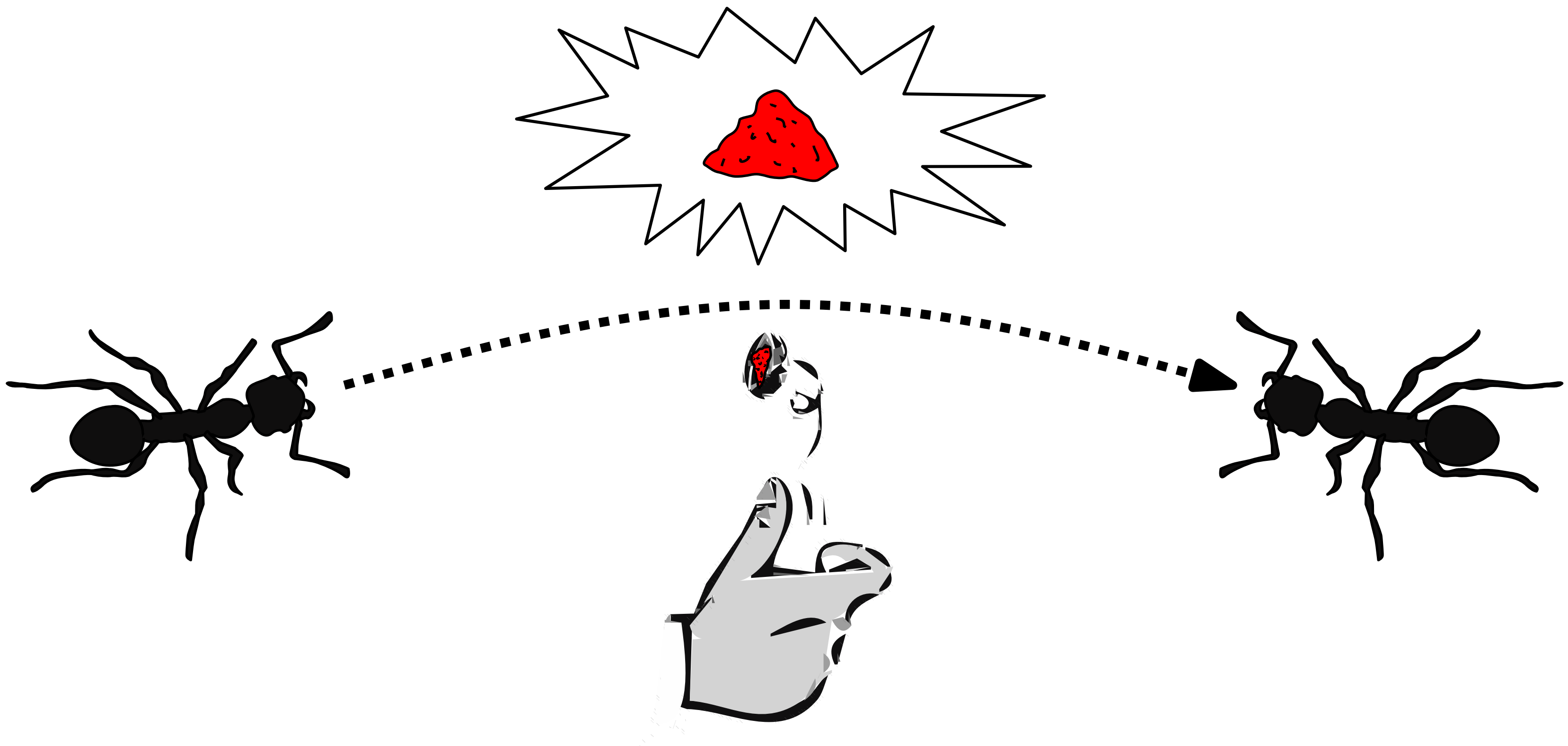

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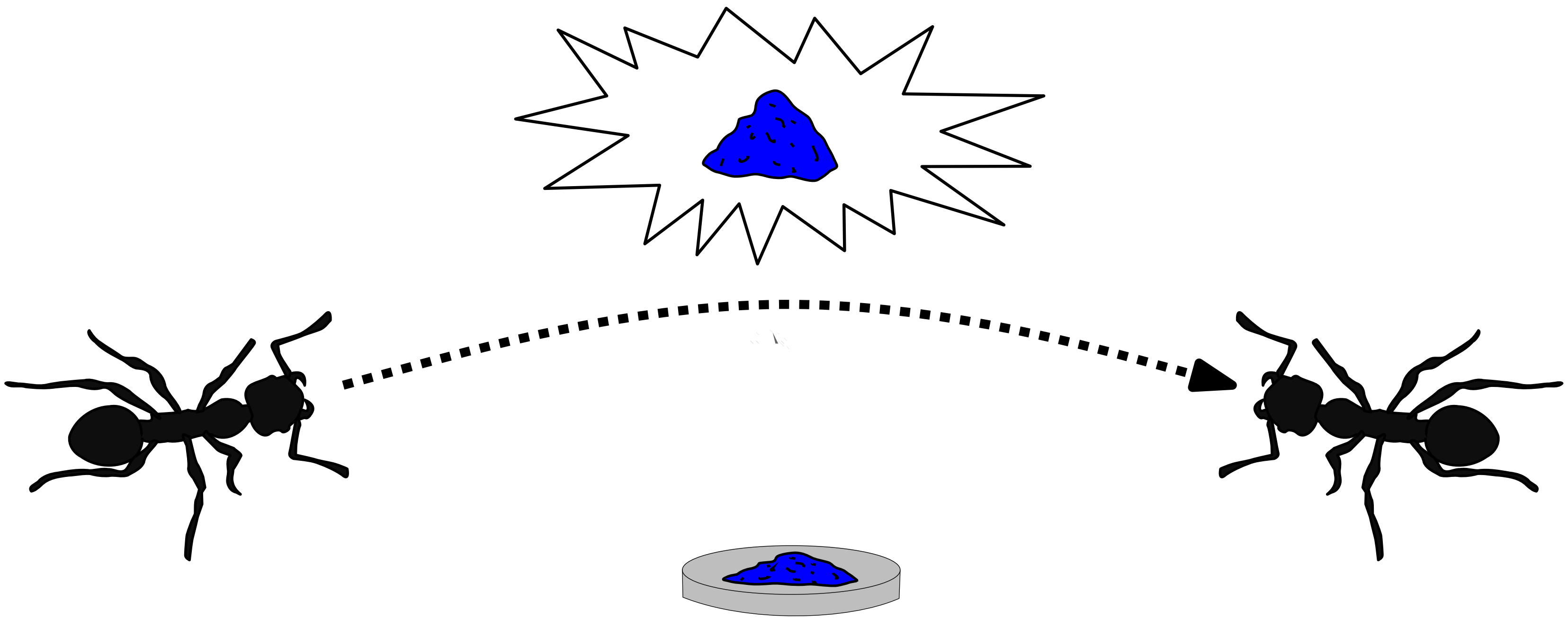

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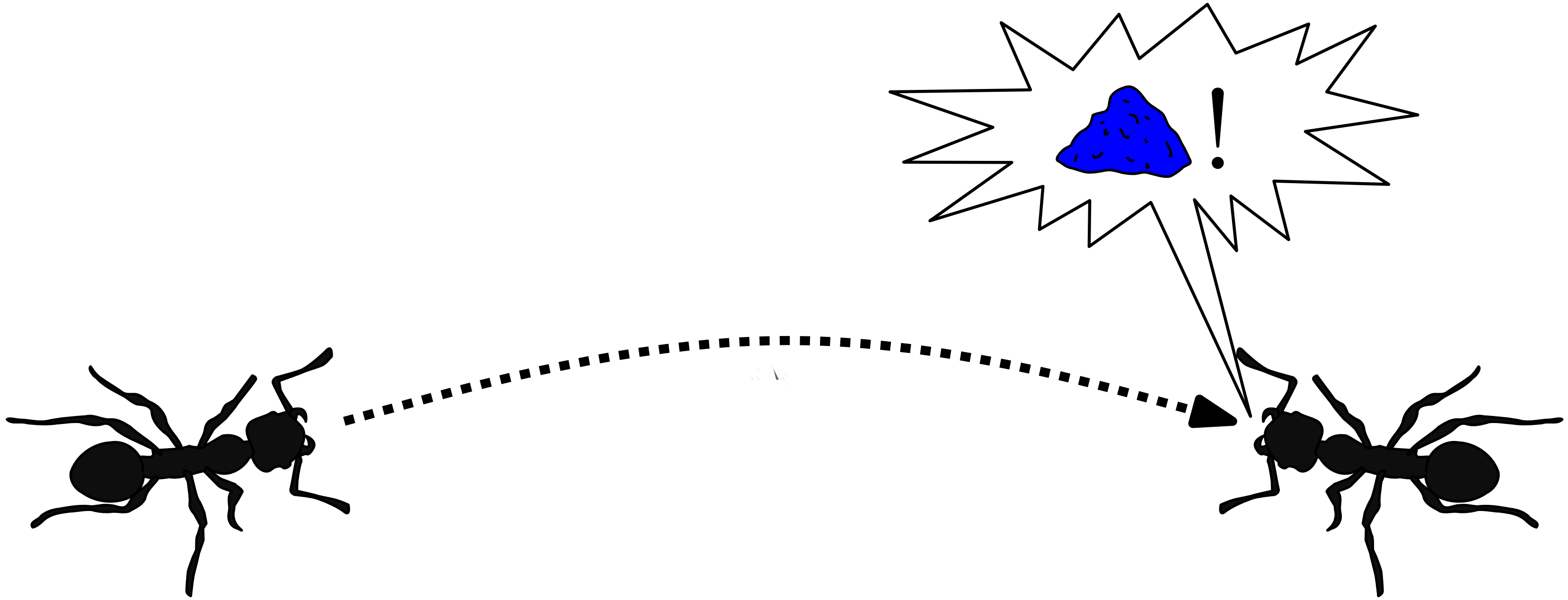

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O. Feinerman, B. Haeupler and A. Korman. *Breathe before speaking: efficient information dissemination despite noisy, limited and anonymous communication.* (PODC '14)

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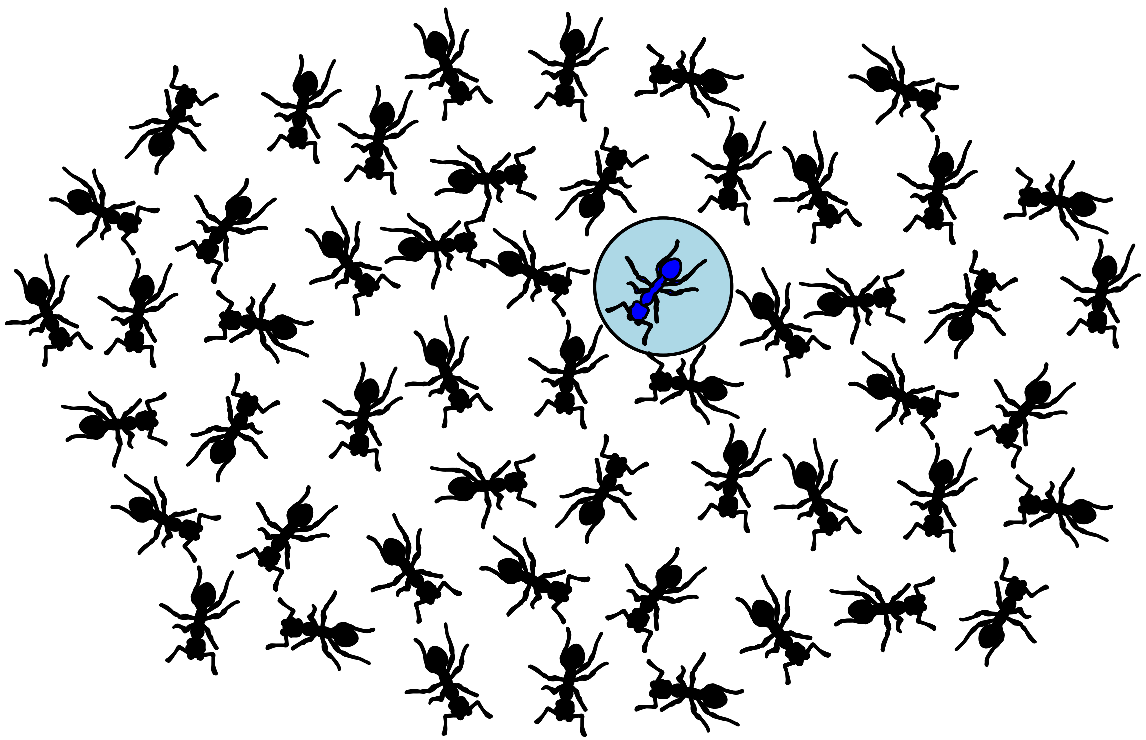
P. Fraigniaud, E. Natale.
Noisy Rumor-Spreading and Plurality Consensus. (*BDA '15*, PODC '16)

$\Longrightarrow$ Simple rules efficiently solve *multivalued* Plurality Opinion Dissemination despite noise.

(Probabilistic) Self-Stabilization

Sources' bits (and other agents' states) may change in response to *external environment*



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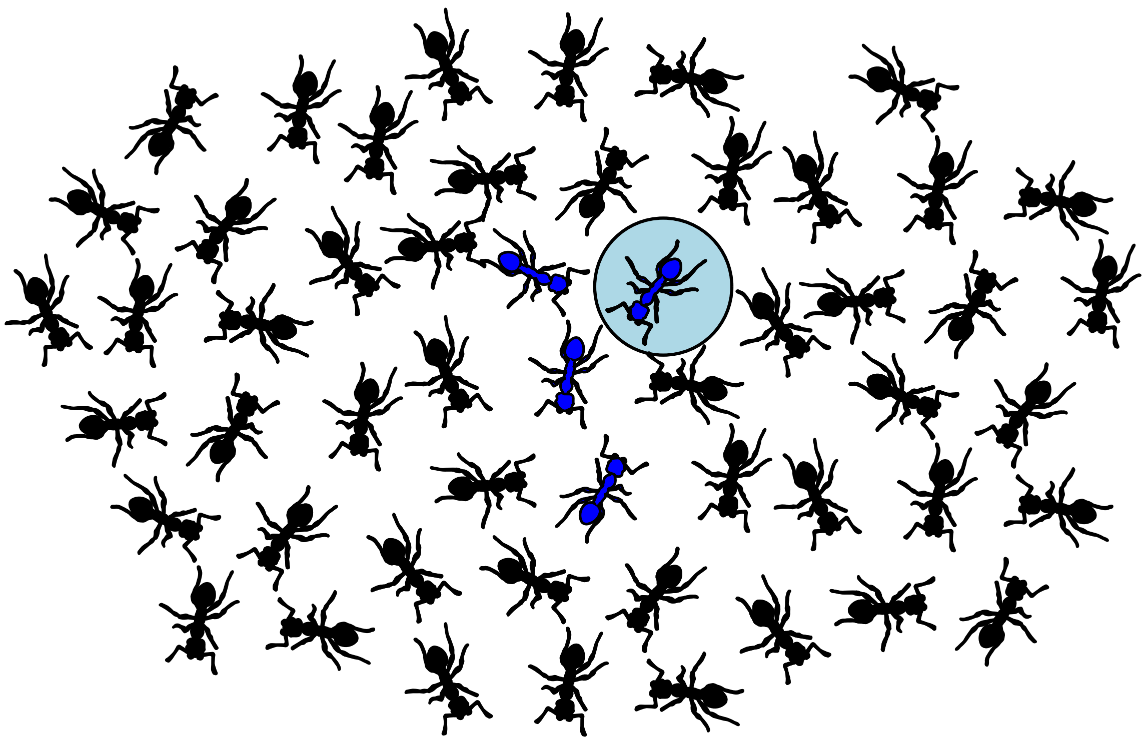

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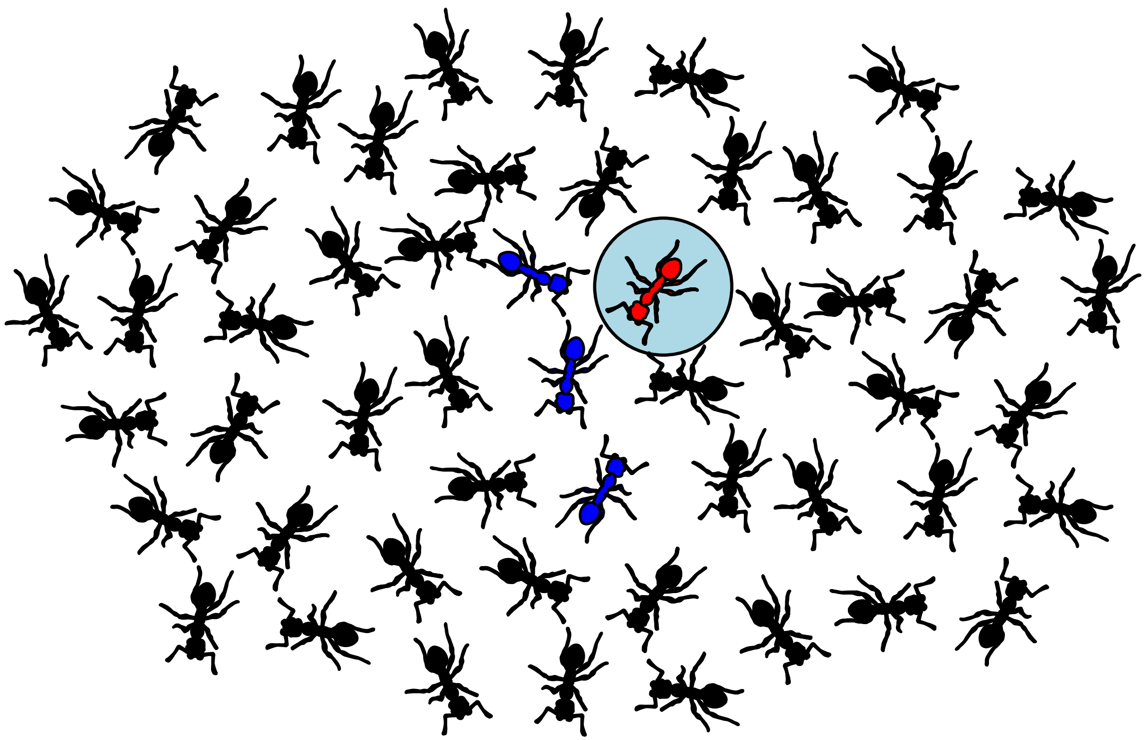

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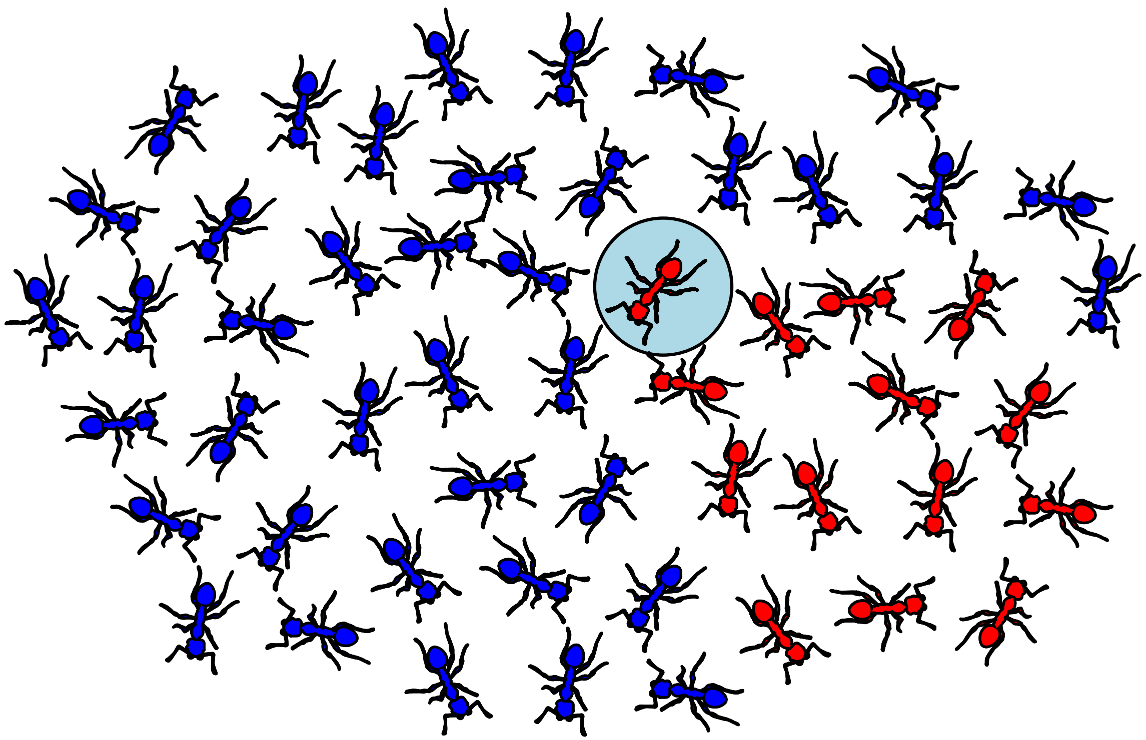
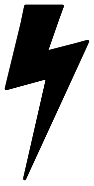


blue vs red:
$39/14 \approx 2.8$



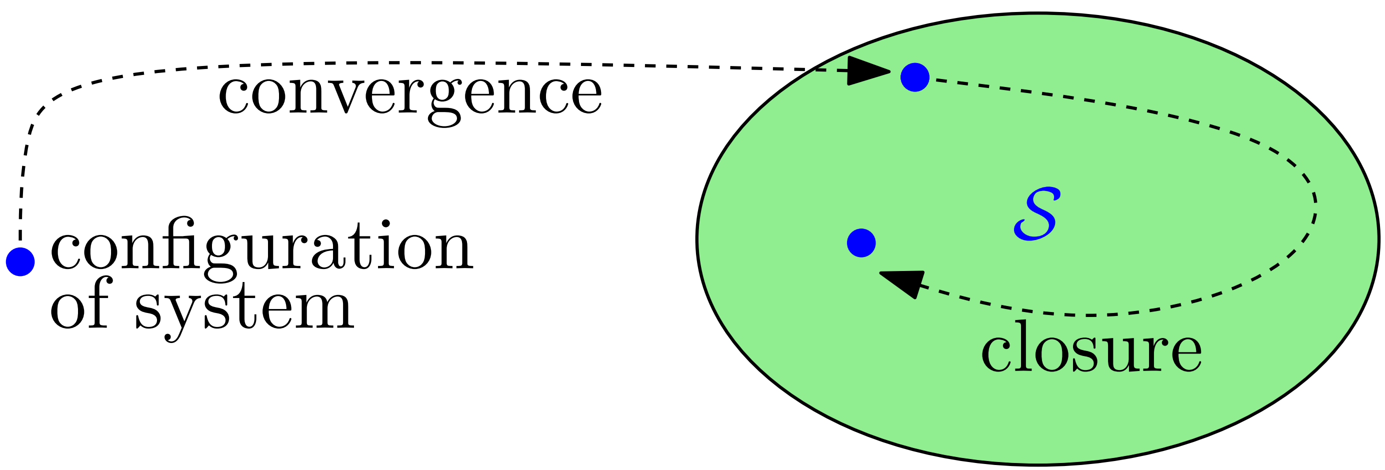
(Probabilistic) Self-Stabilization

(Probabilistic) self-stabilization:

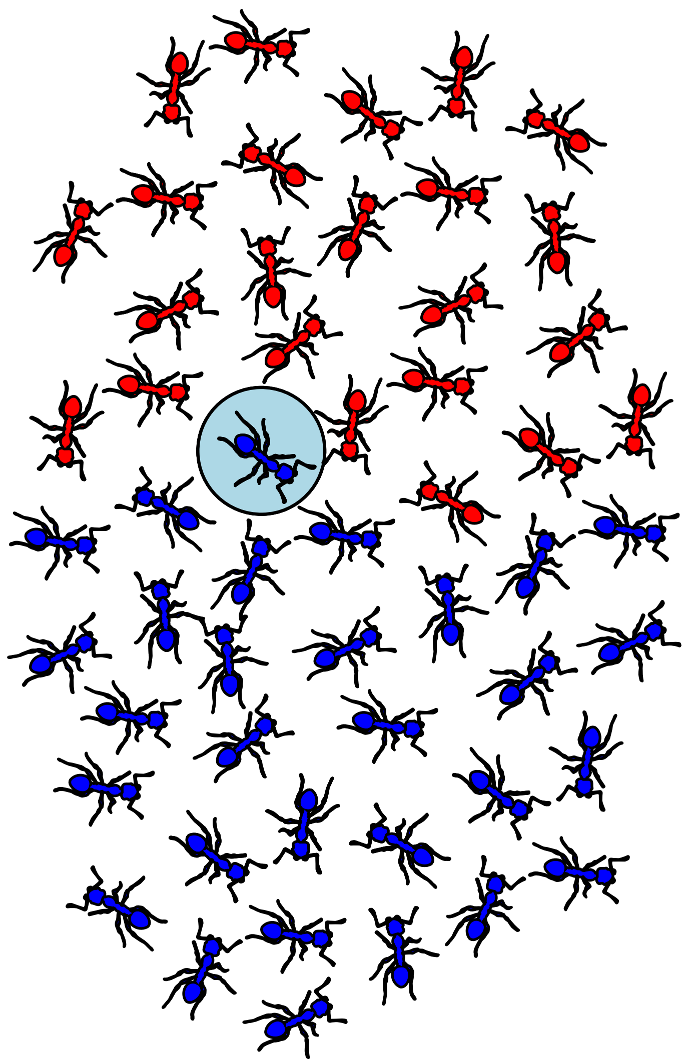
$\mathcal{S}$:= {"correct configurations of the system" }
(= consensus on source's bit)

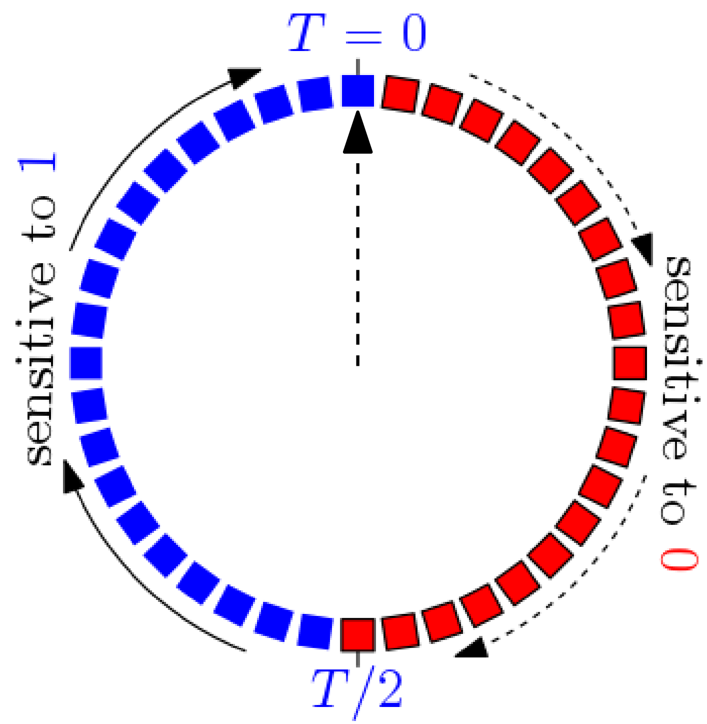
- **Convergence.** From *any* initial configuration, the system reaches $\mathcal{S}$ (w.h.p.)
- **Closure**. If in $\mathcal{S}$, the system stays in $\mathcal{S}$ (w.h.p.)

(Probabilistic) Self-stabilizing algorithm:
guarantees *convergence* and *closure* w.r.t. $\mathcal{S}$ *(w.h.p.)*



(Self-Stab.) Bit Dissemination vs Synchronization





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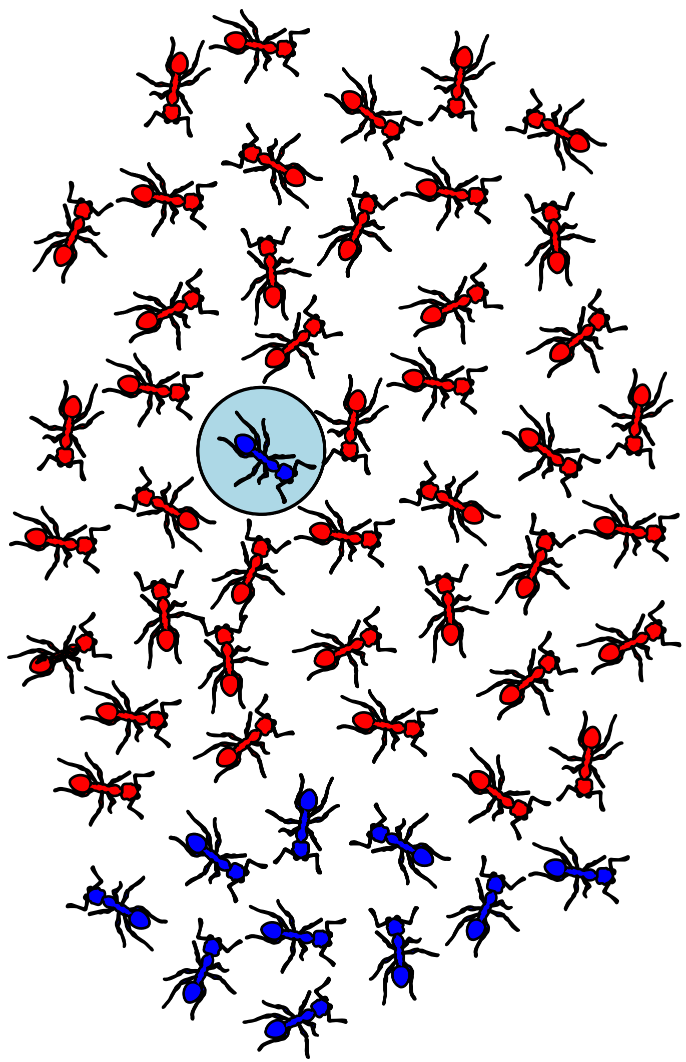

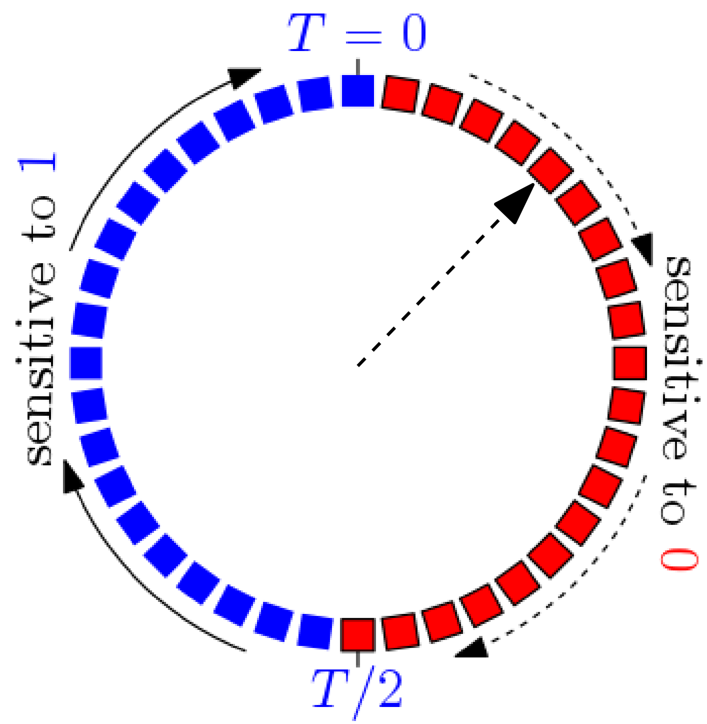

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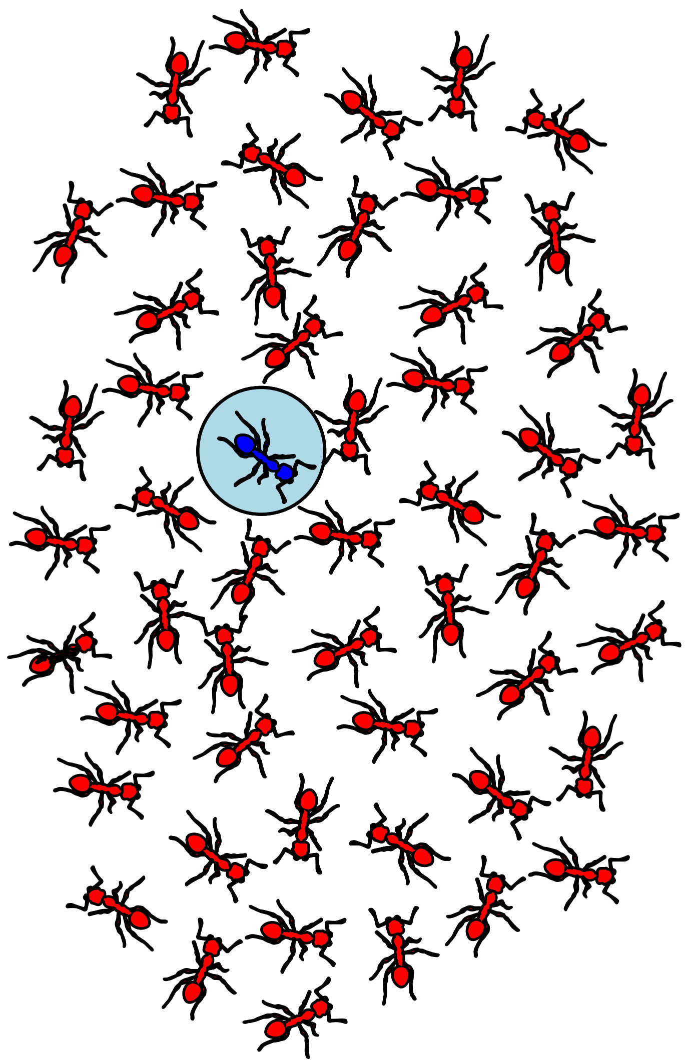

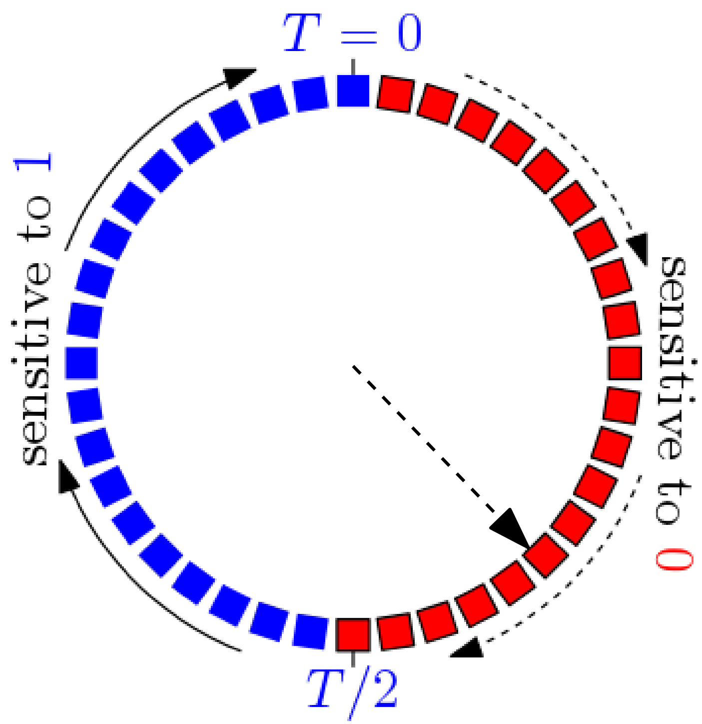

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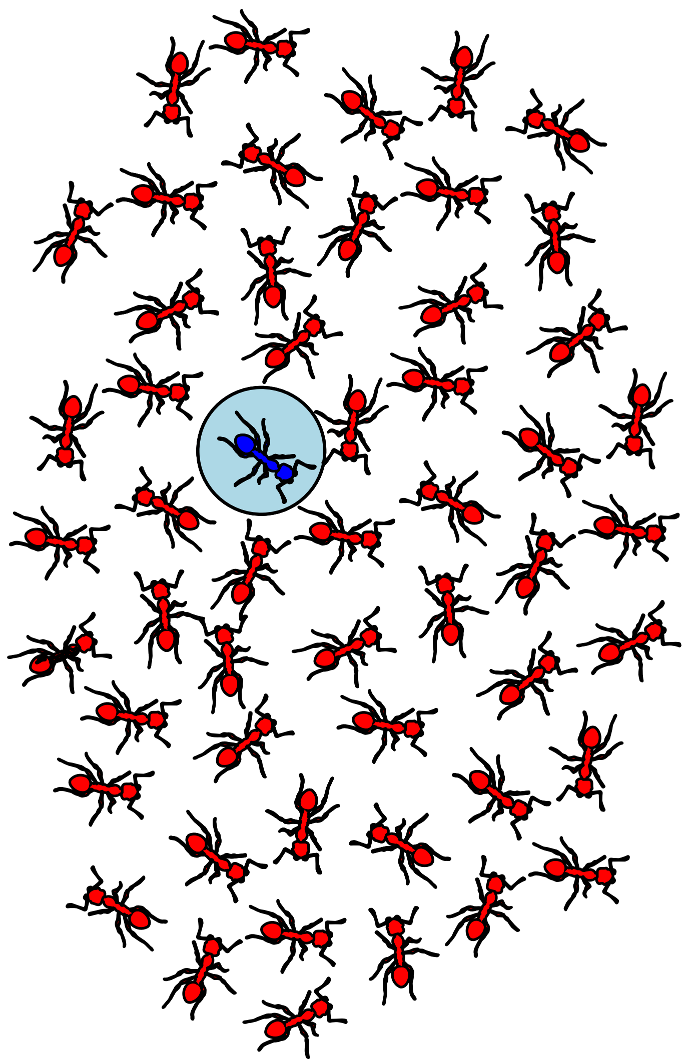

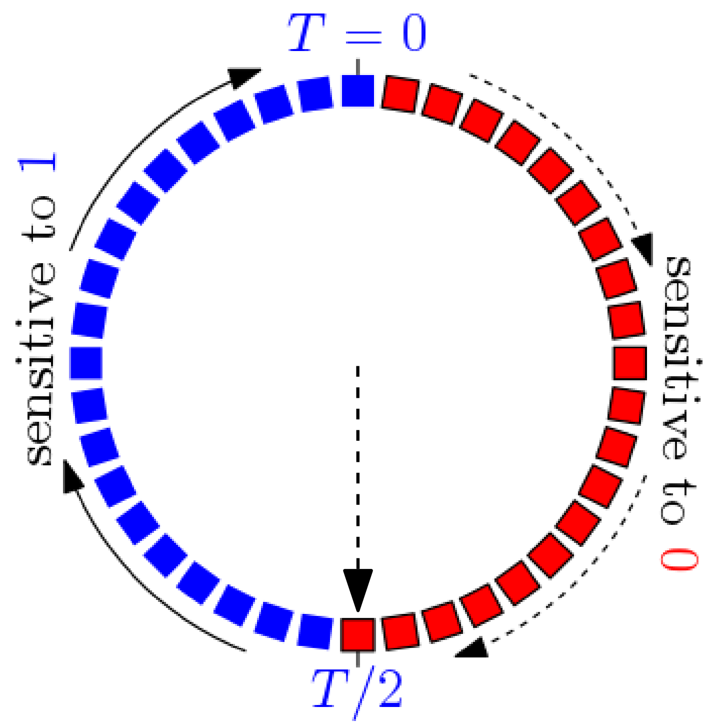

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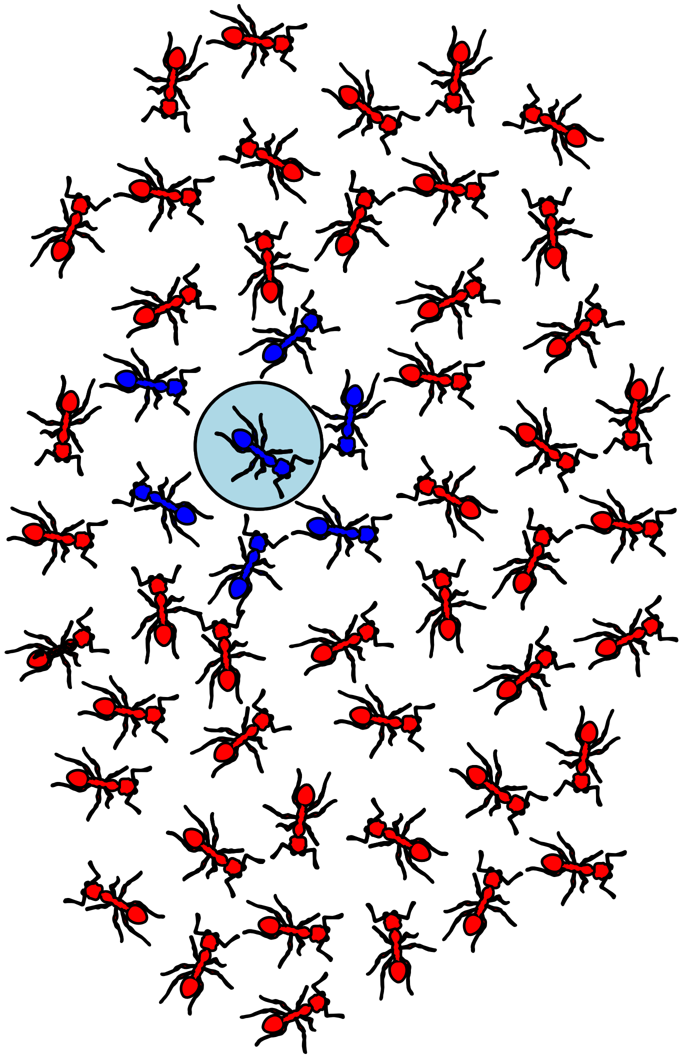

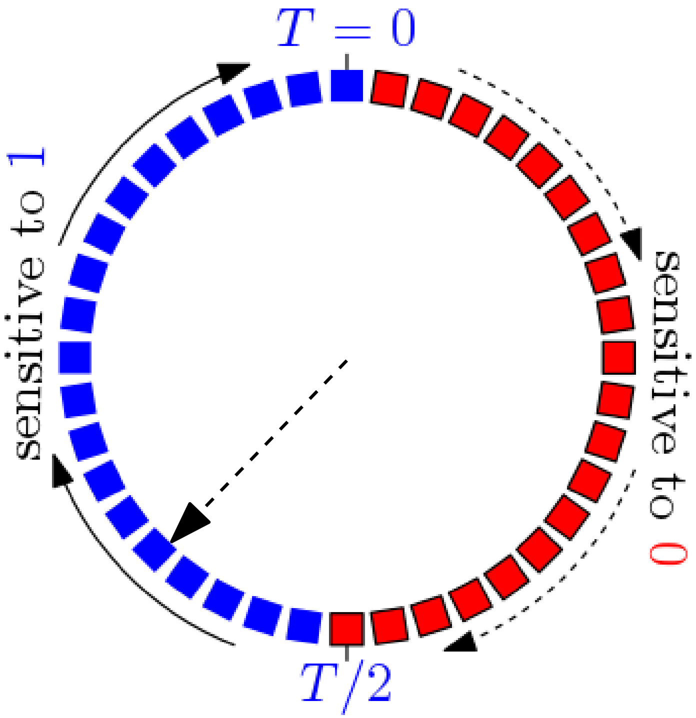

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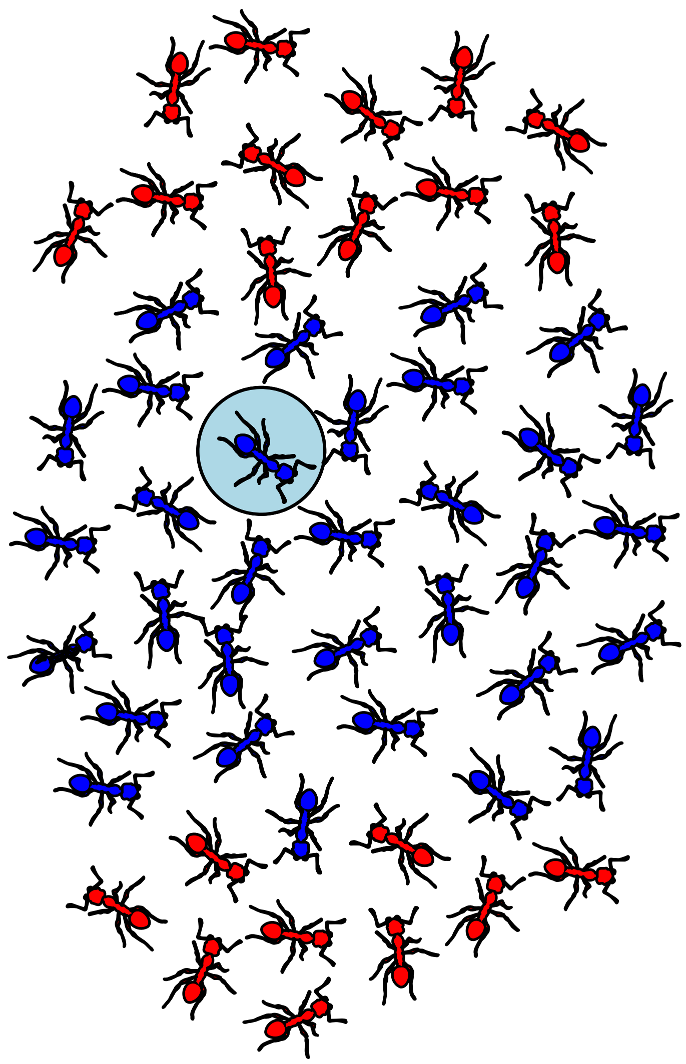

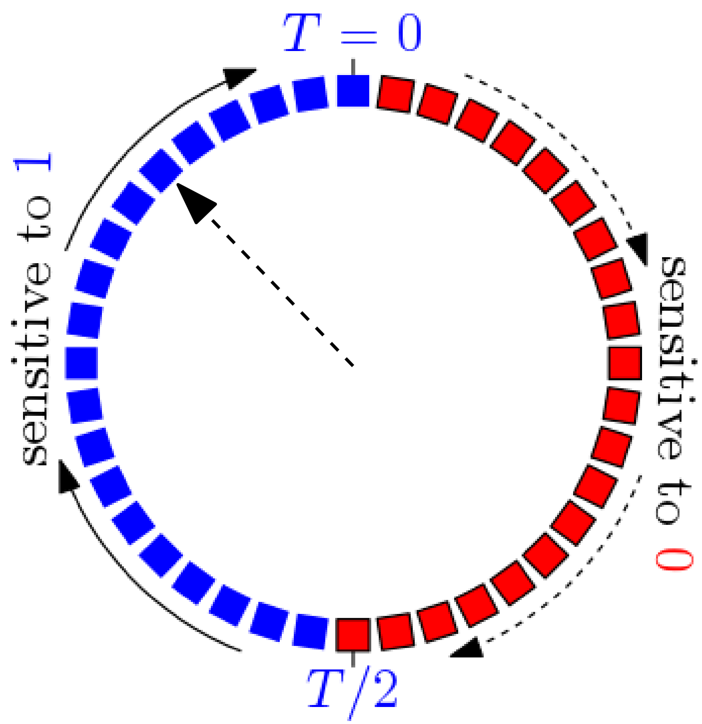

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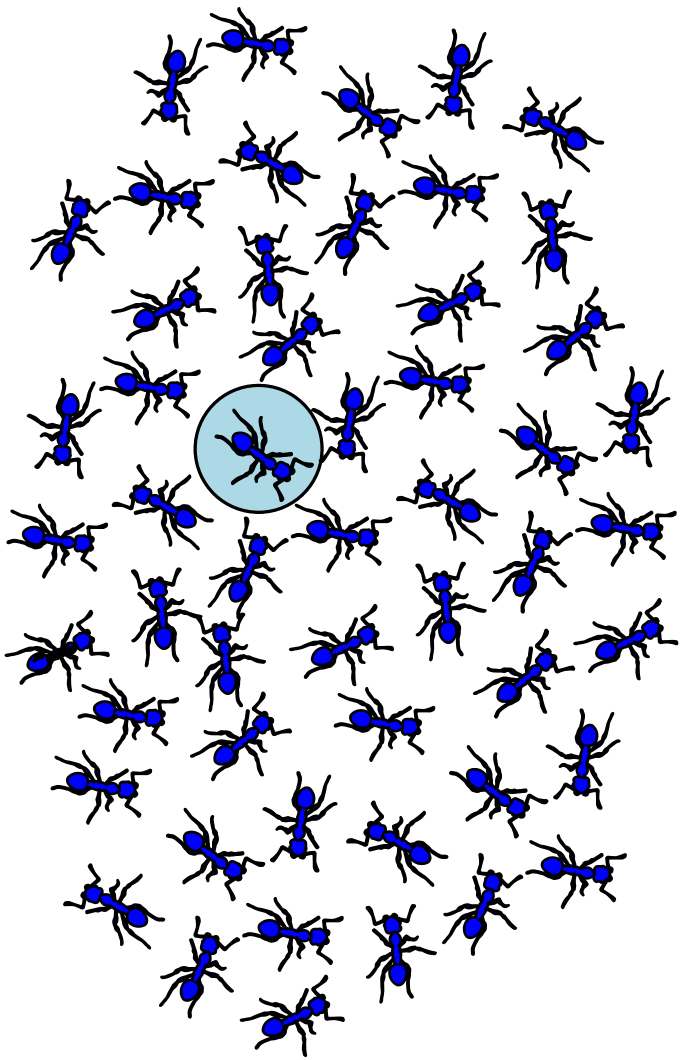
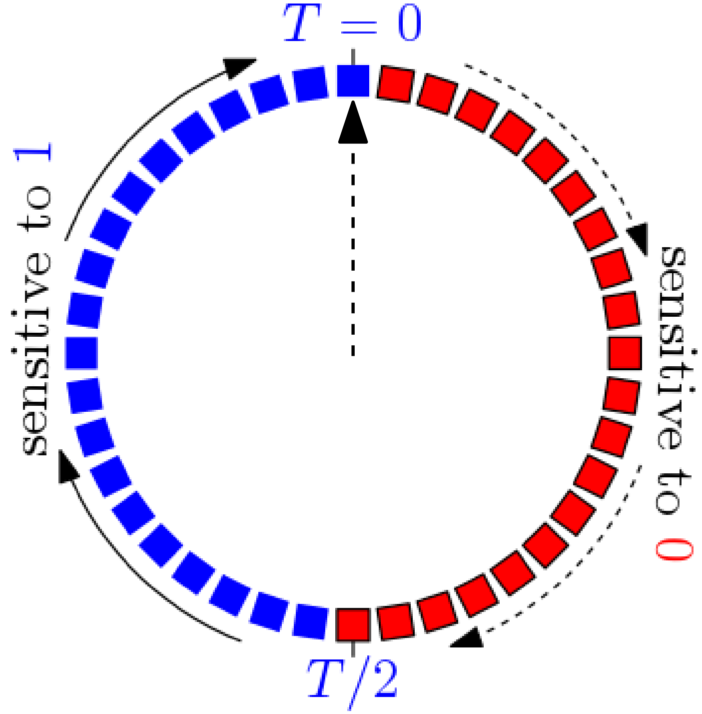
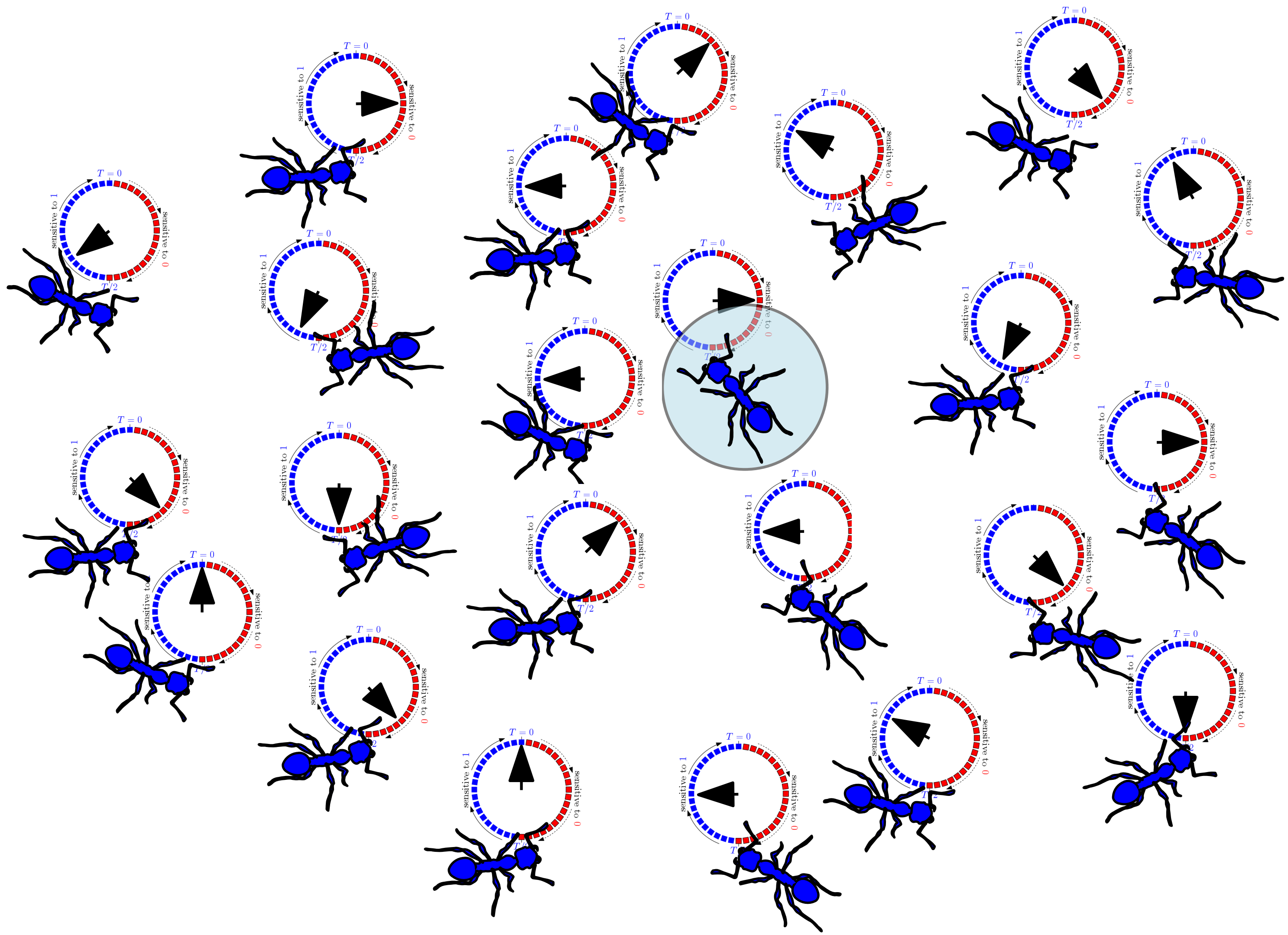


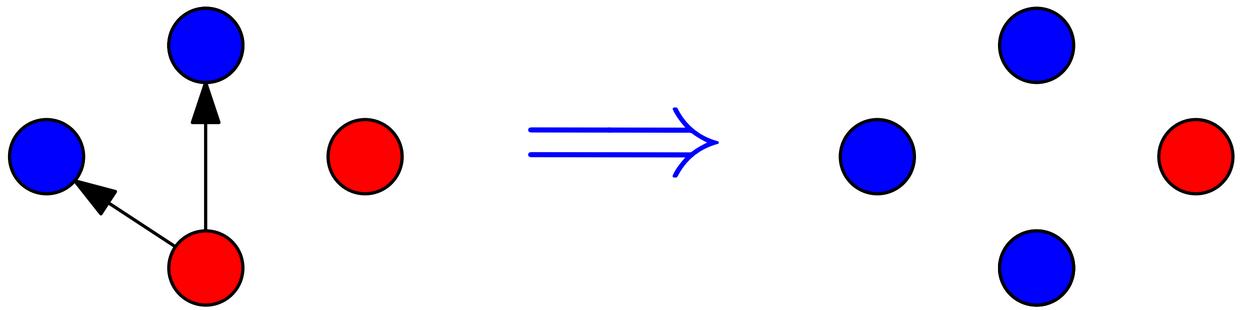


(Self-Stab.) Bit Dissemination vs Synchronization

Self-stablizing algorithms converge from
any initial configuration



Self-Stabilizing Clock Sync. in the $\mathcal{PULL}$ Model



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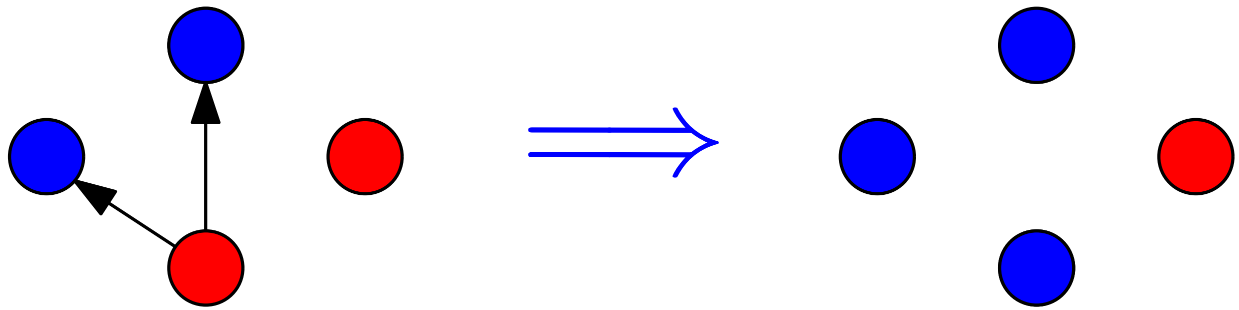

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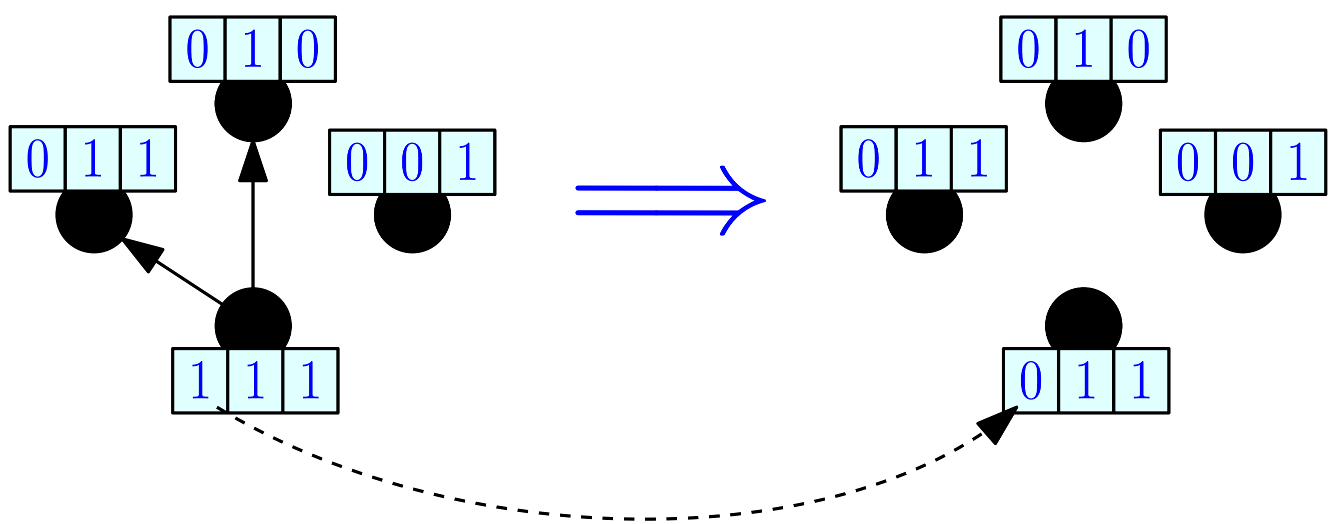

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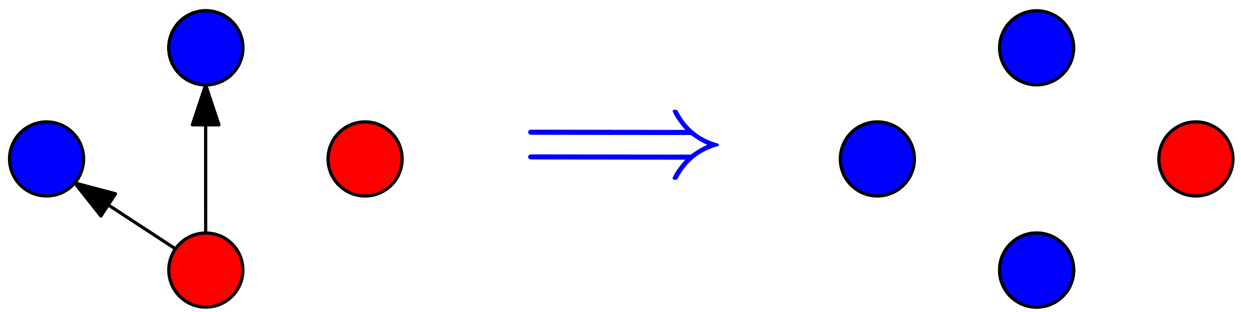

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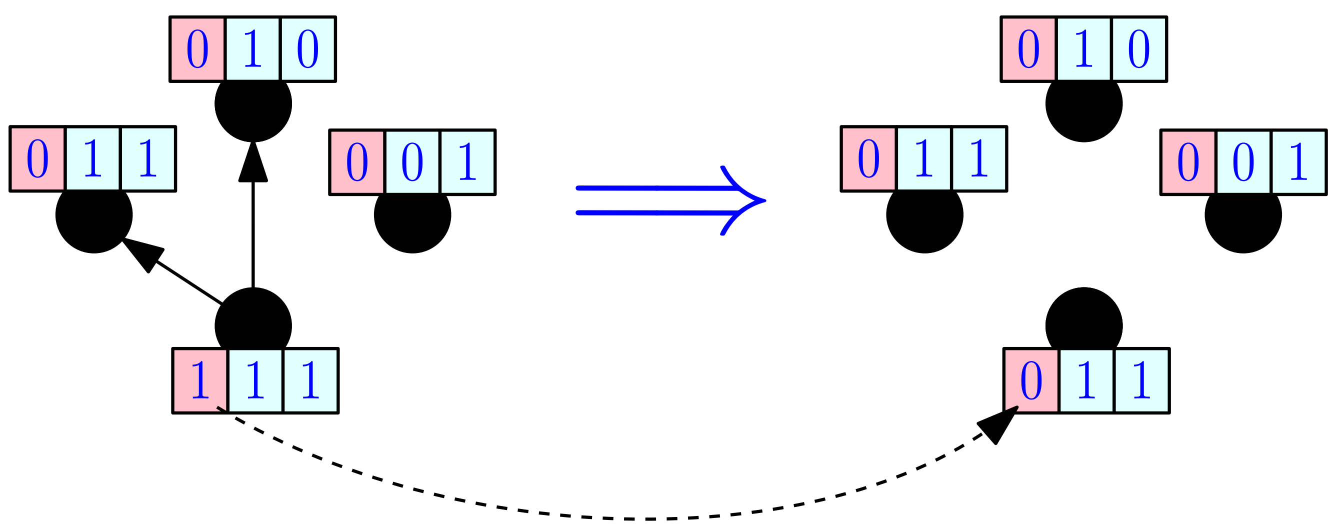

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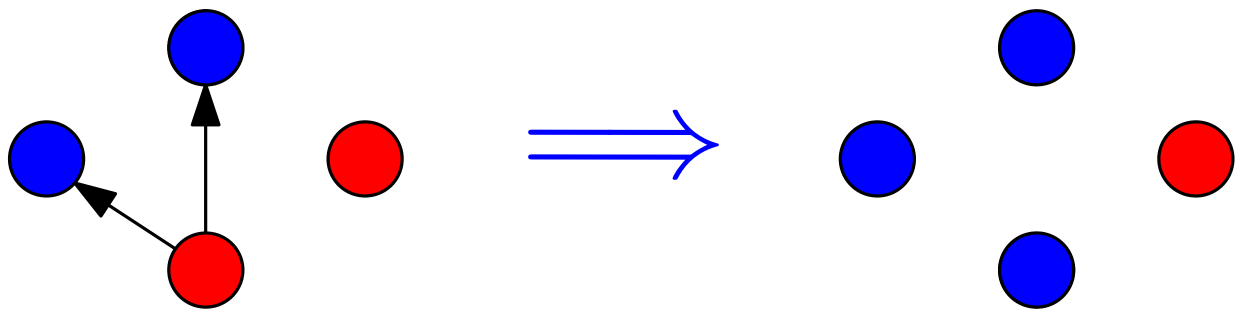

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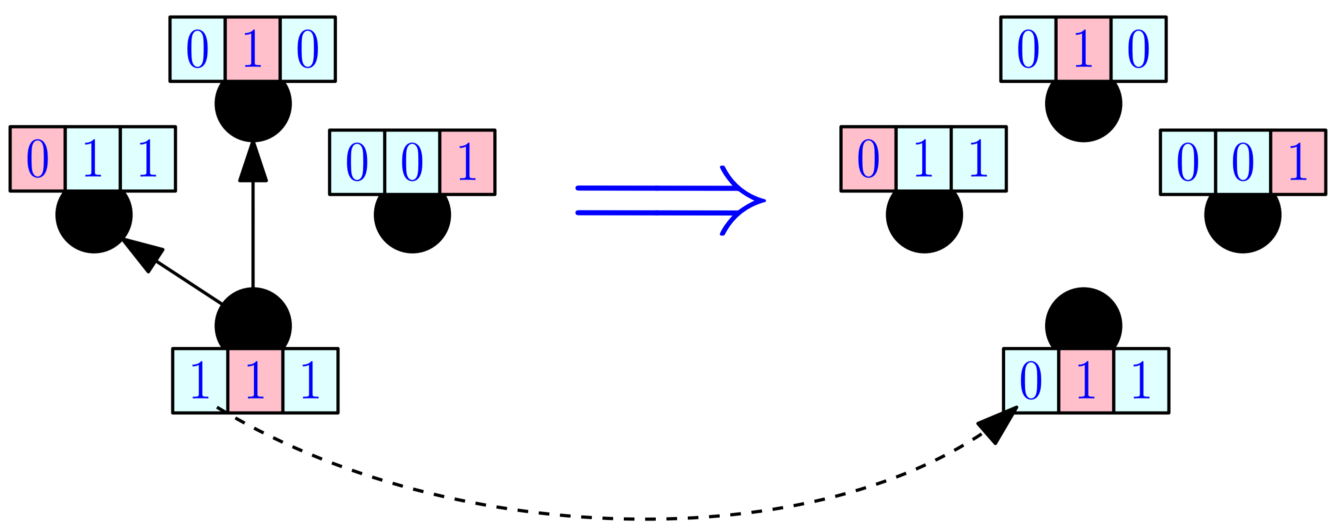

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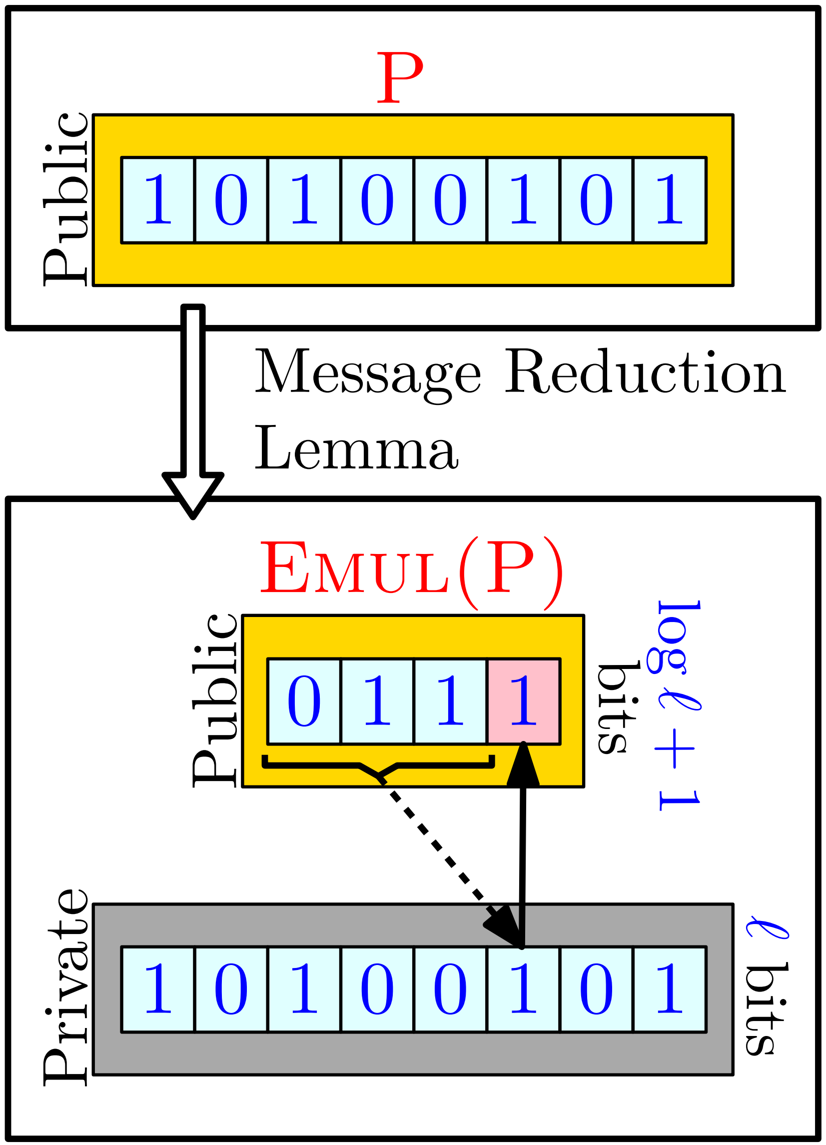

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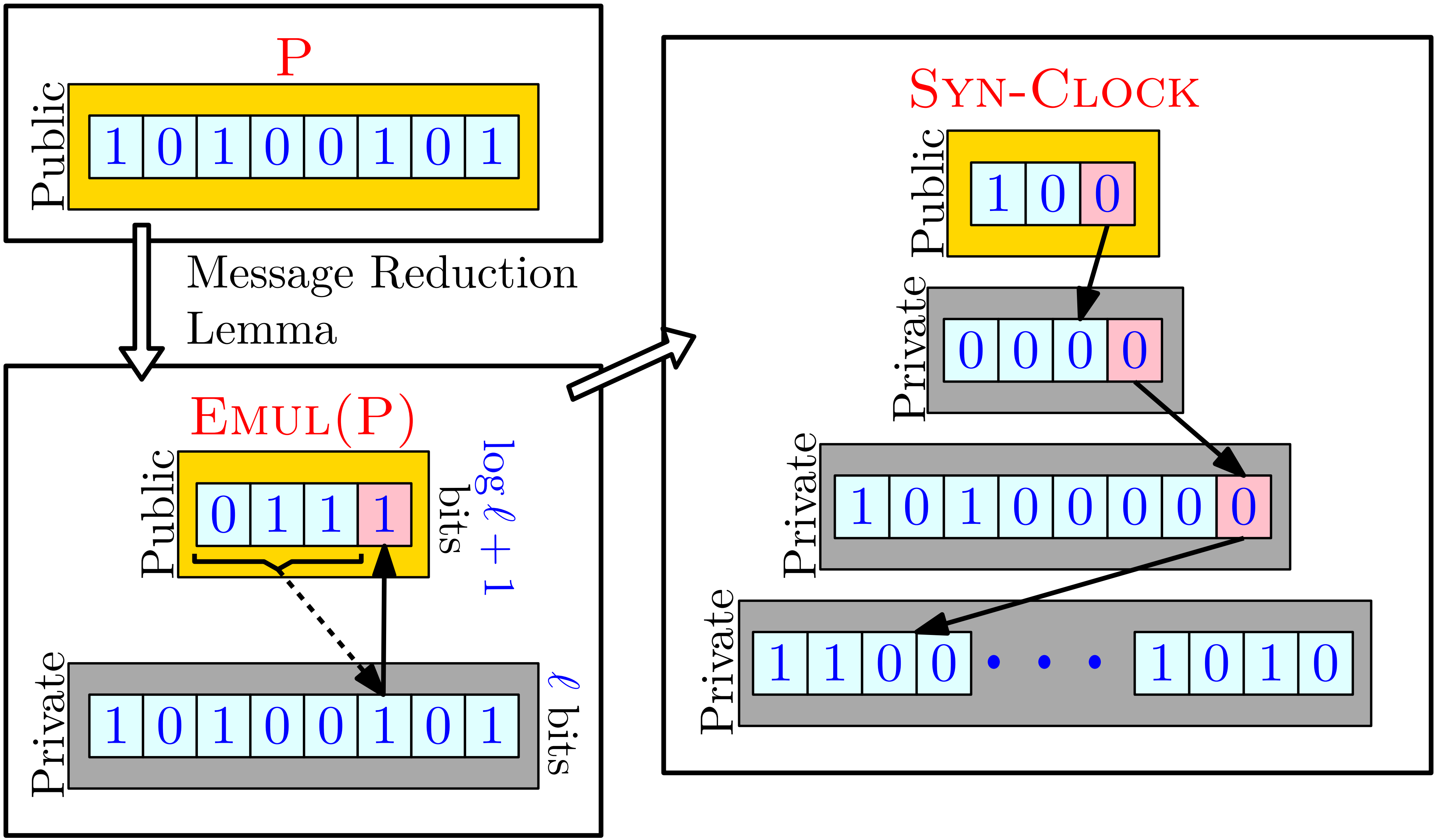
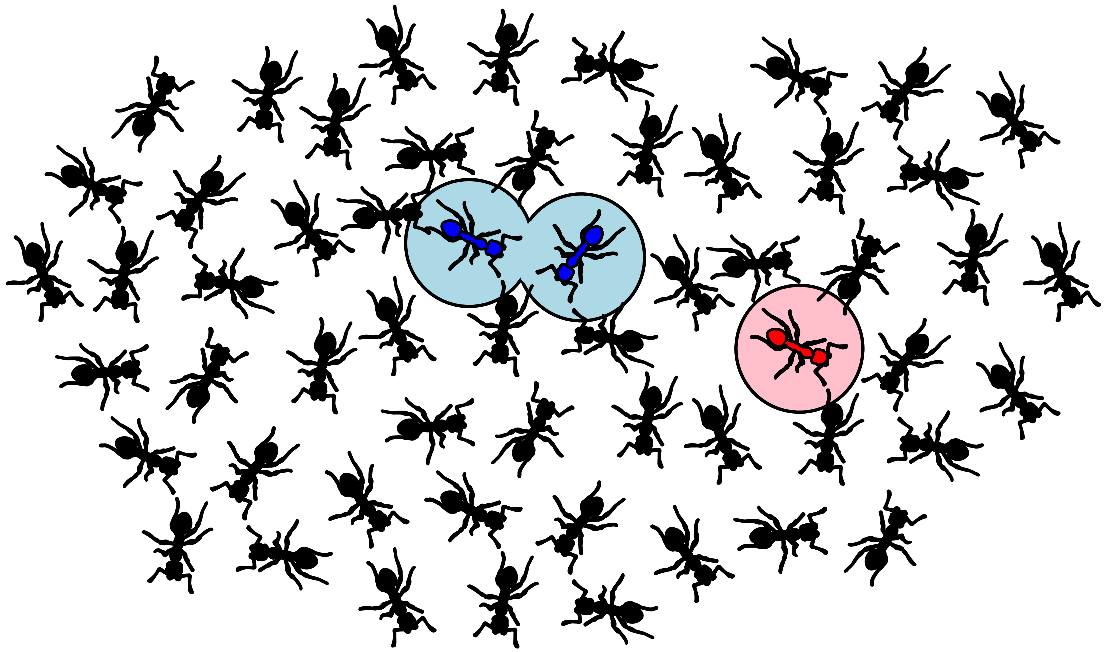


Syn-Phase-Spread



Spreading Phases
(Core idea: FHK'14)

blue vs red:
2/1

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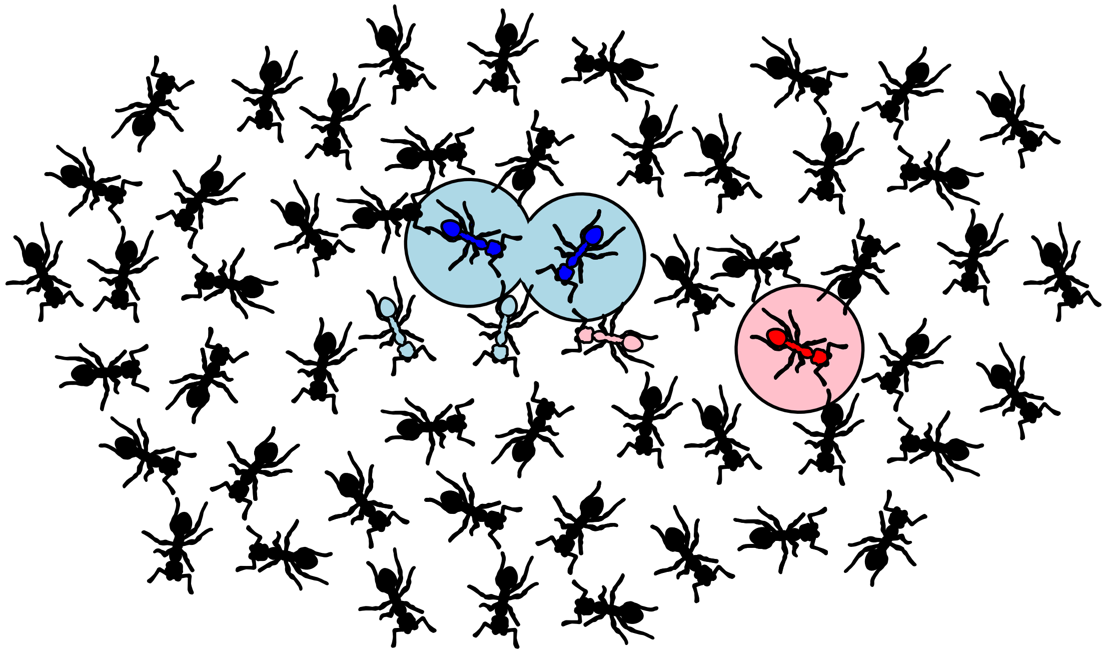

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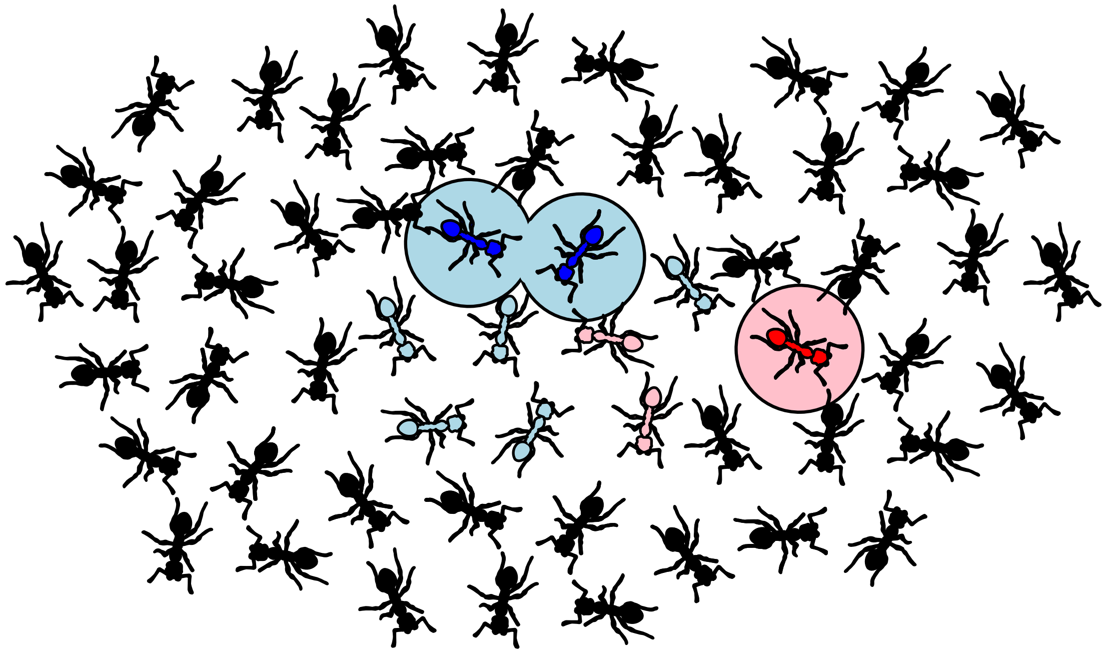

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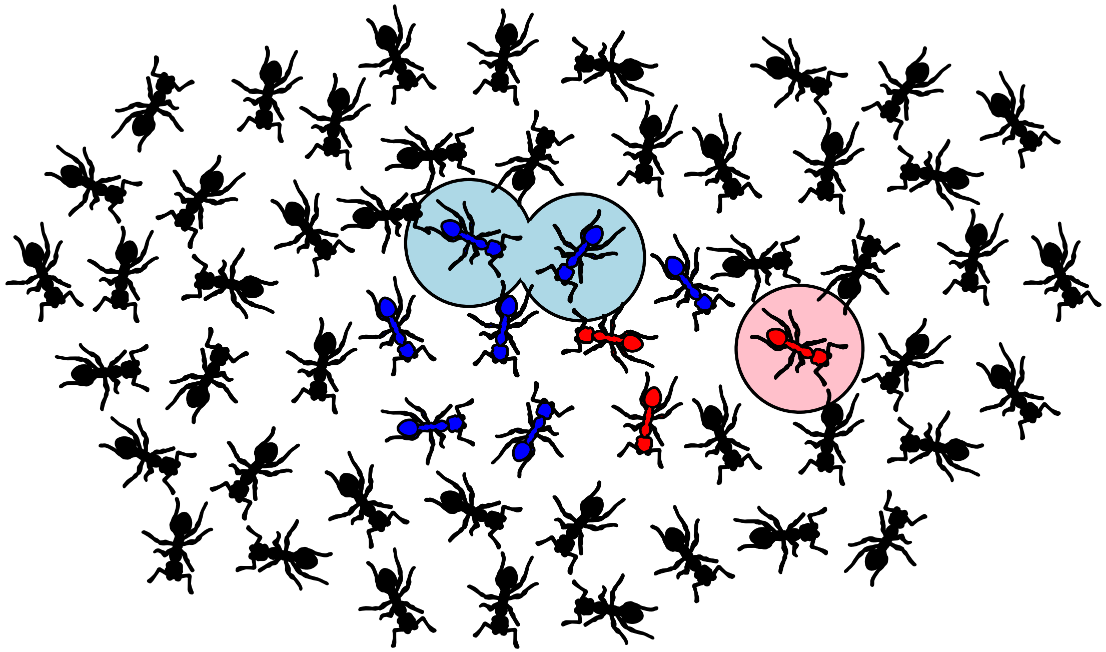

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8/4

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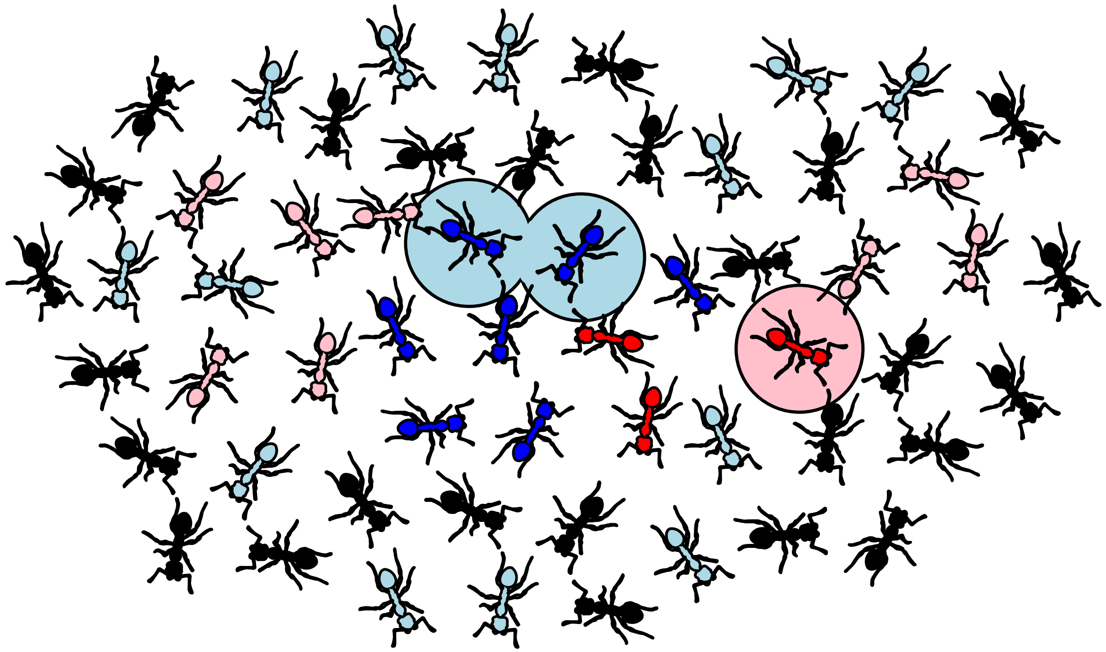

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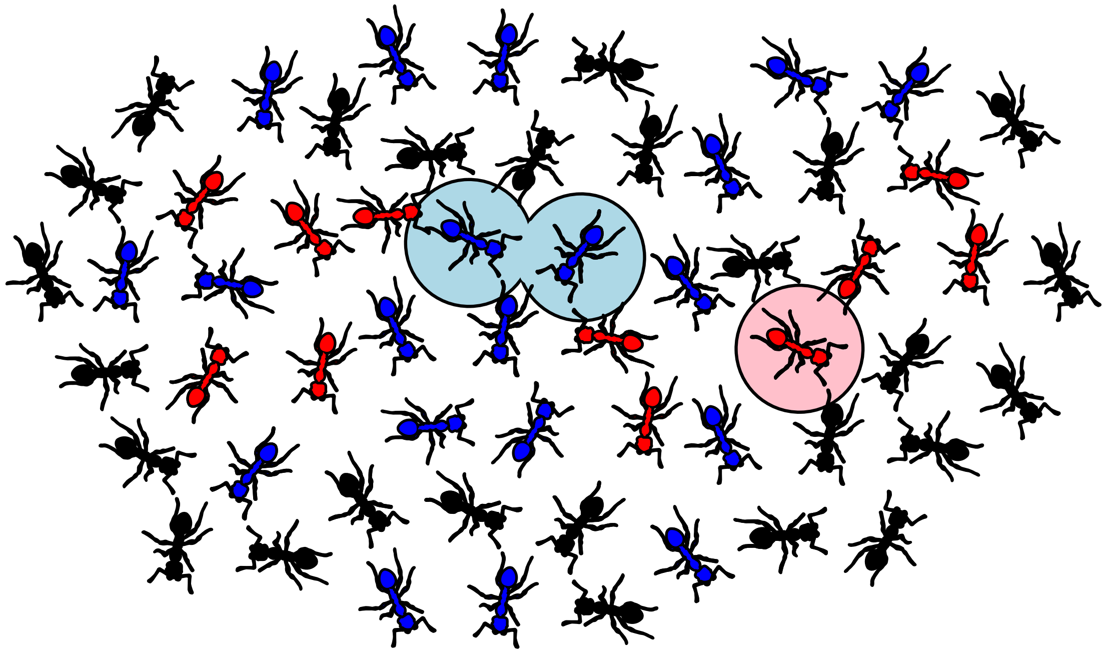

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blue vs red:
$20/11 \approx 1.85$

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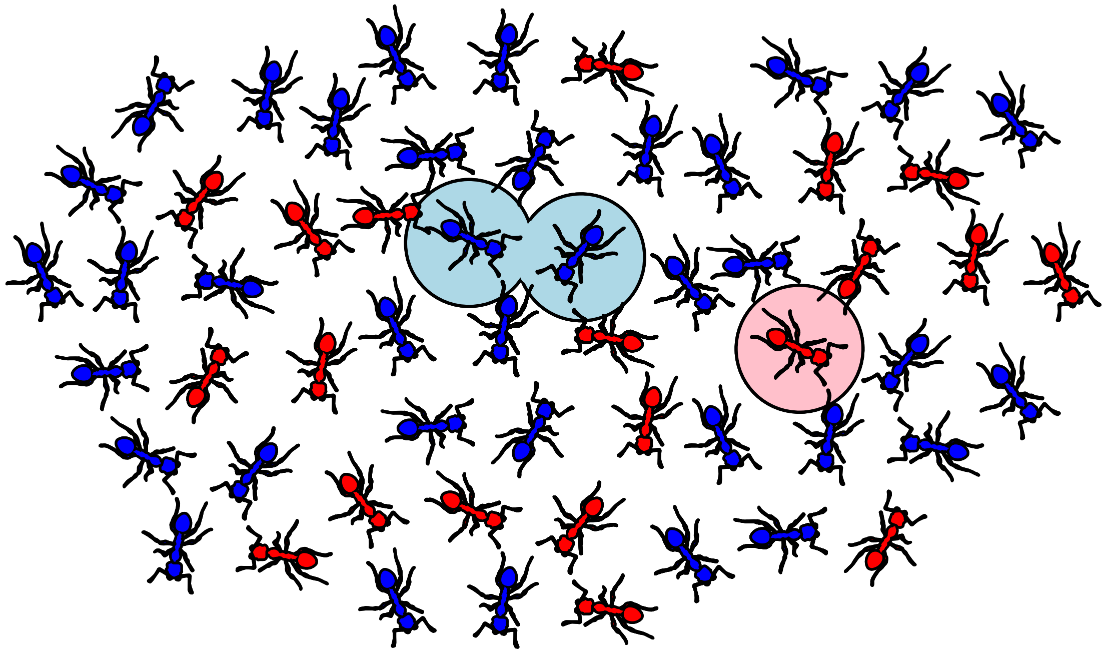

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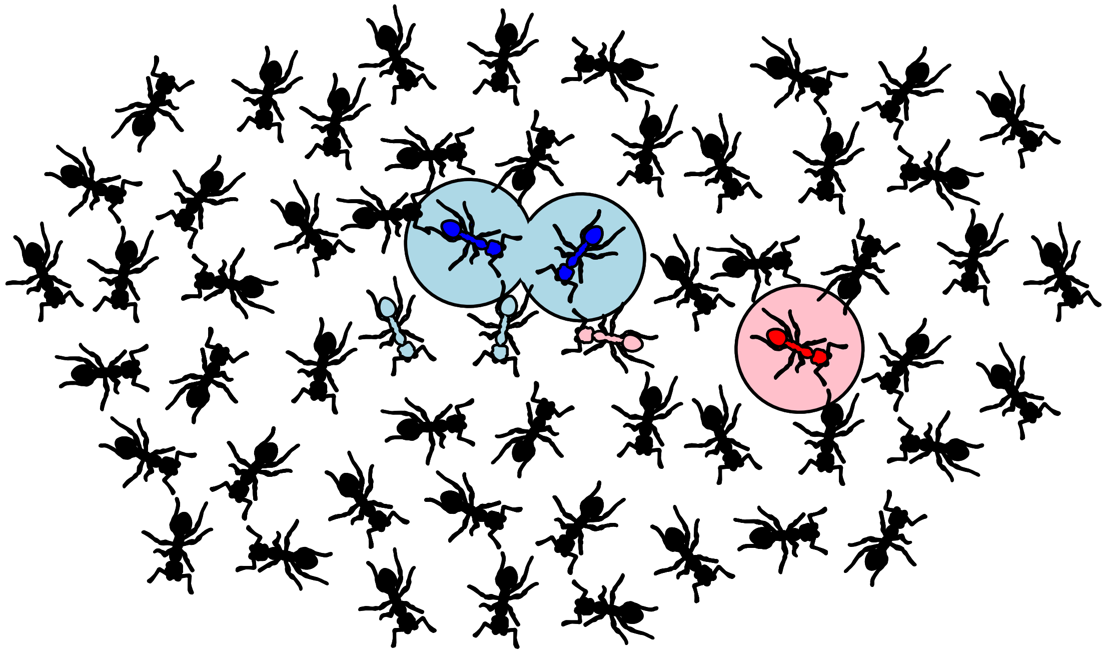
Syn-Phase-Spread



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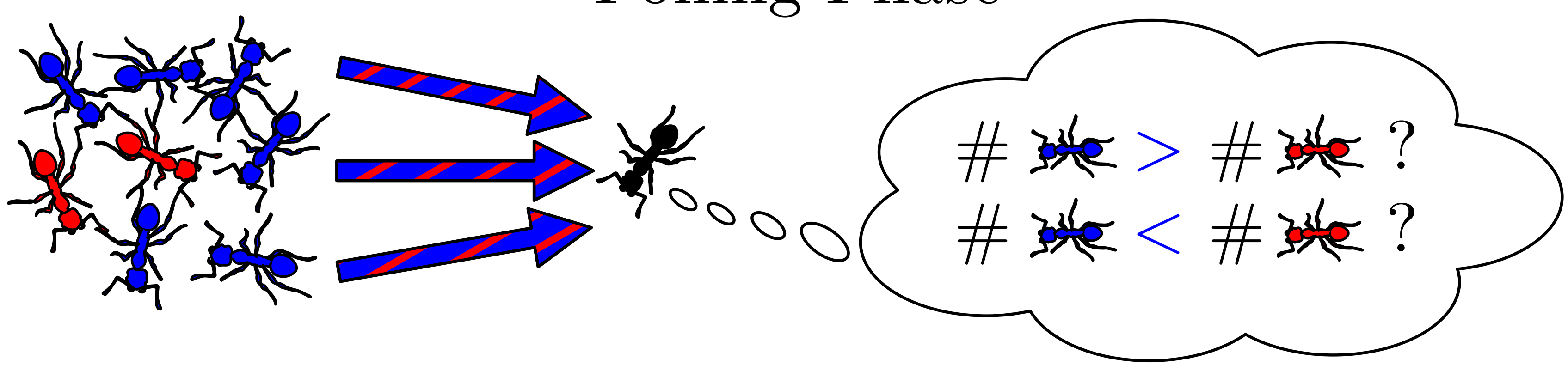
Polling Phase



Results

Theorem (Clock Syncronization). SYN-CLOCK is a *self-stabilizing* clock synchronization protocol which synchronizes a clock modulo T in $\tilde{O}(\log n \log T)$ rounds w.h.p. using 3-bit messages.

Theorem (Majority Bit Dissemination). SYN-PHASE-SPREAD is a *self-stabilizing* Majority Bit Dissemination protocol which converges in $\tilde{O}(\log n)$ rounds w.h.p using 3-bit messages, provided majority is supported by $(\frac{1}{2} + \epsilon)$-fraction of source agents.

Self-Stab. Bit Diss. with 1 bit: a Candidate

BFS(f, s). Agents can *boosting*, 1/0-*frozen* or 1/0-*sensitive*.

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- c-*sensitive*: Turn into c-*frozen* if see value c.
- c-*frozen* keep value c for f rounds before becoming *boosting*.

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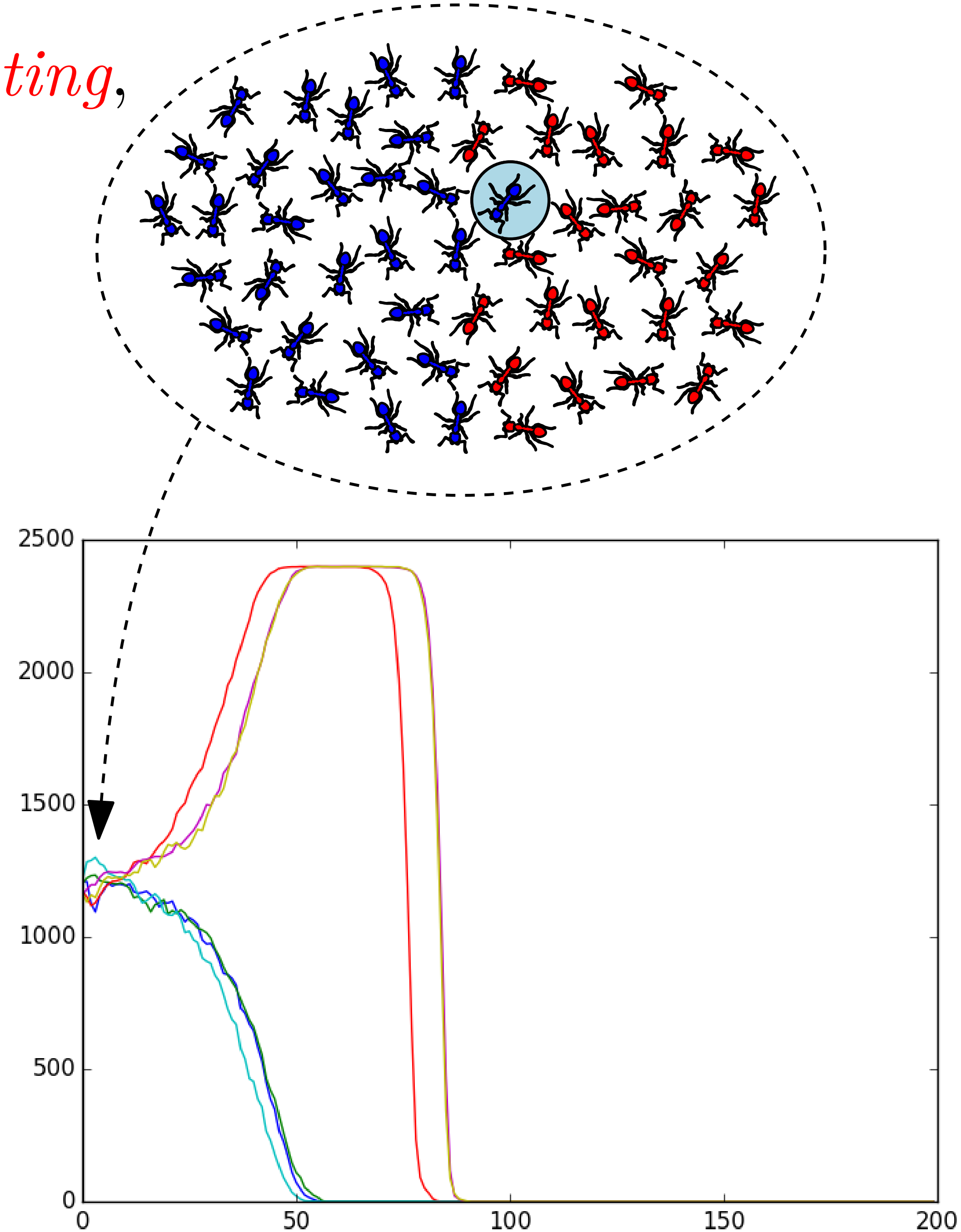

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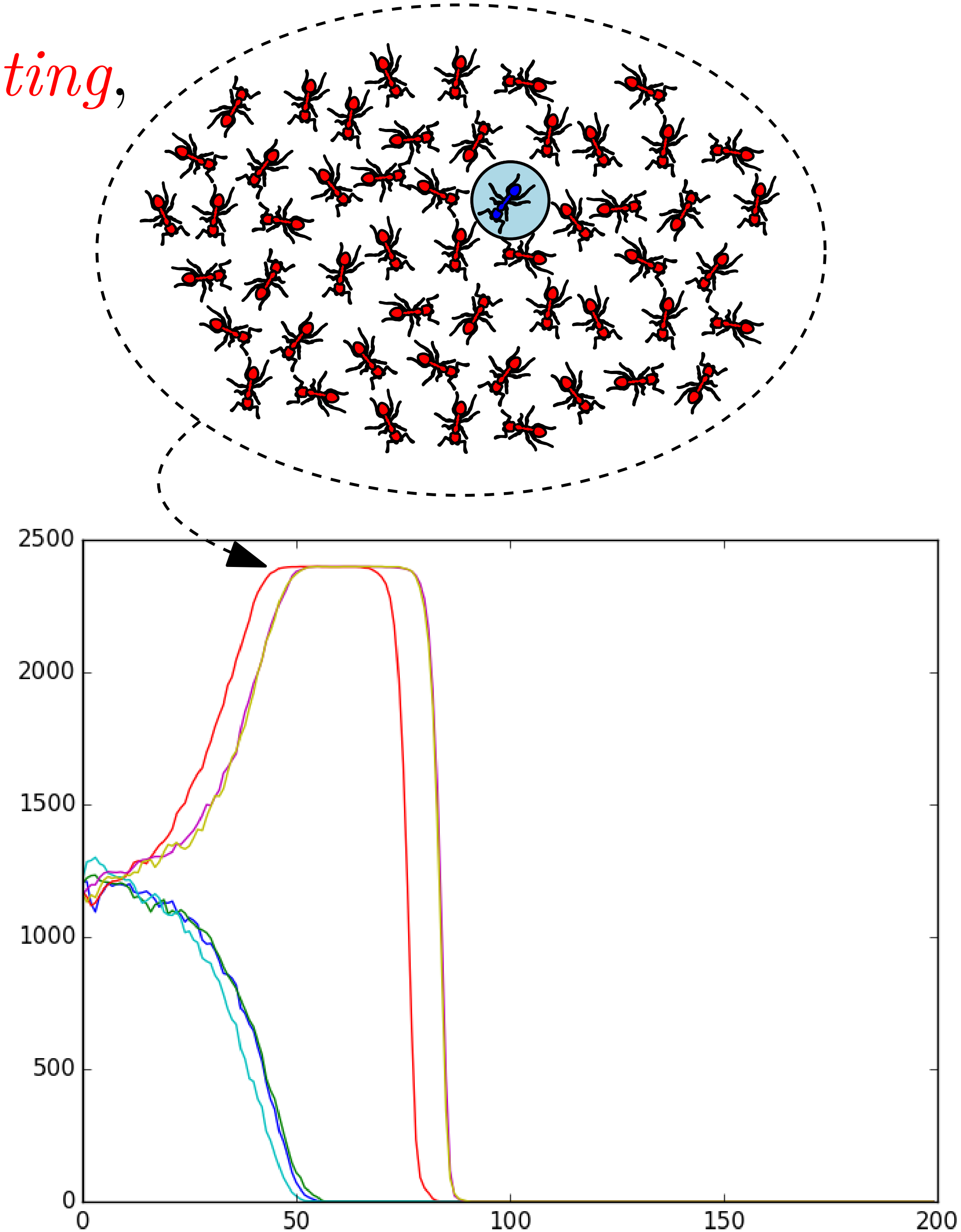

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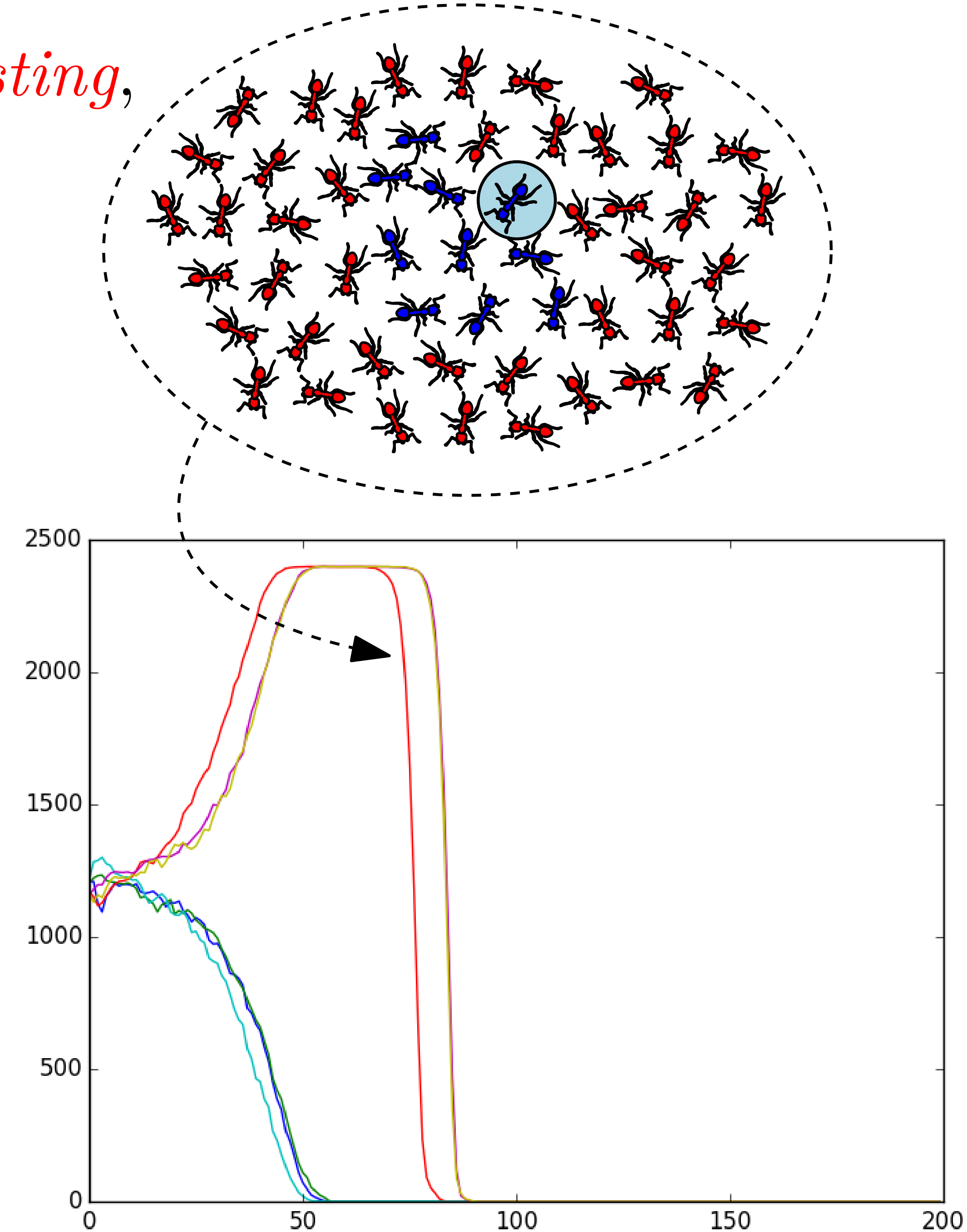

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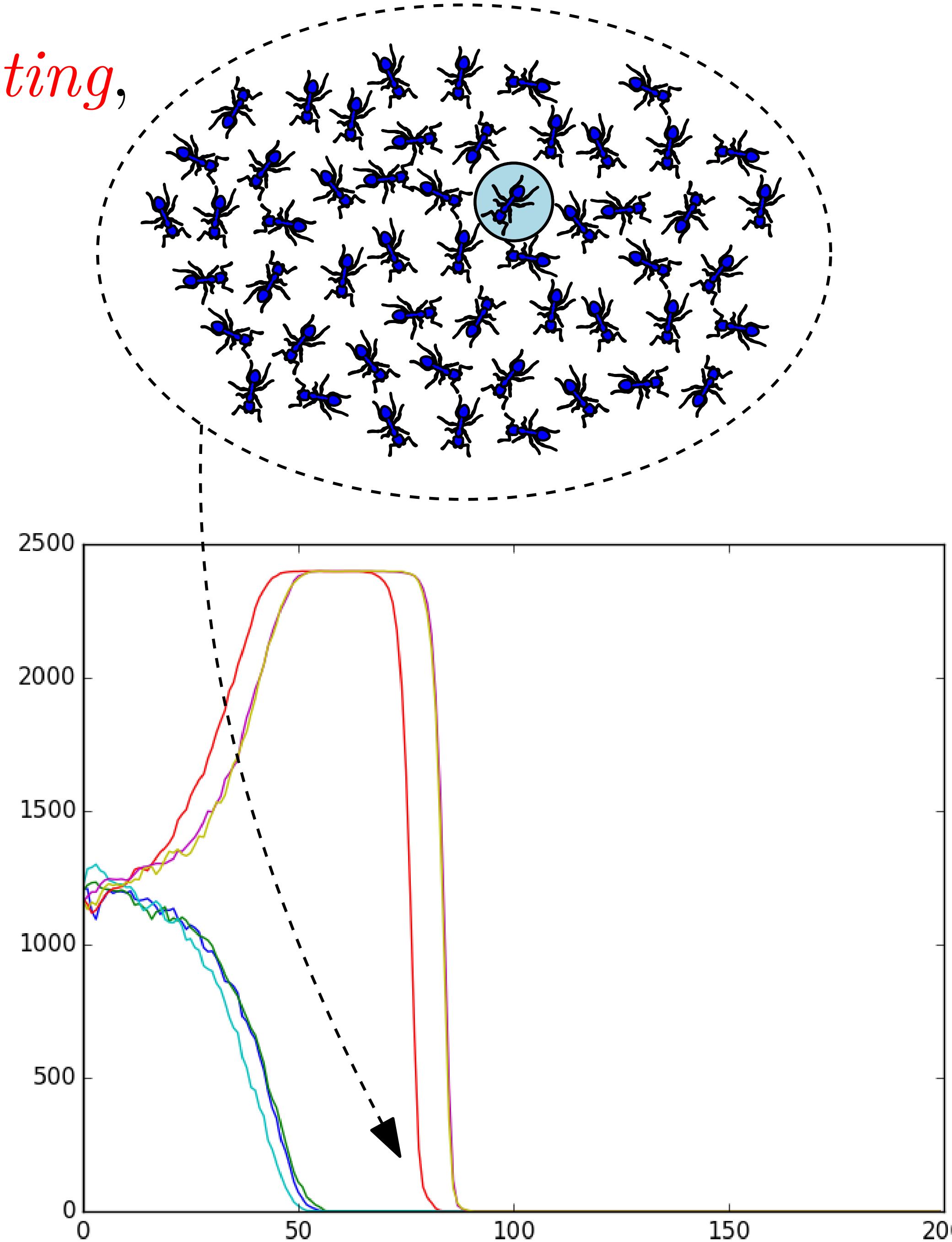

Thank
You!