Termite

Swarm Intelligence Routing

Authors

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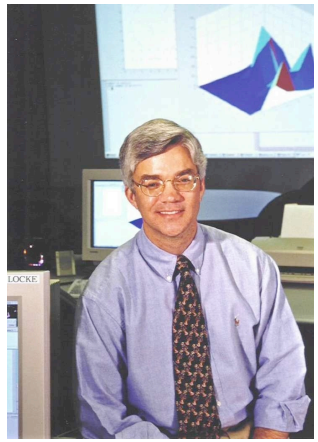
Emergent systems



Stephen Wicker

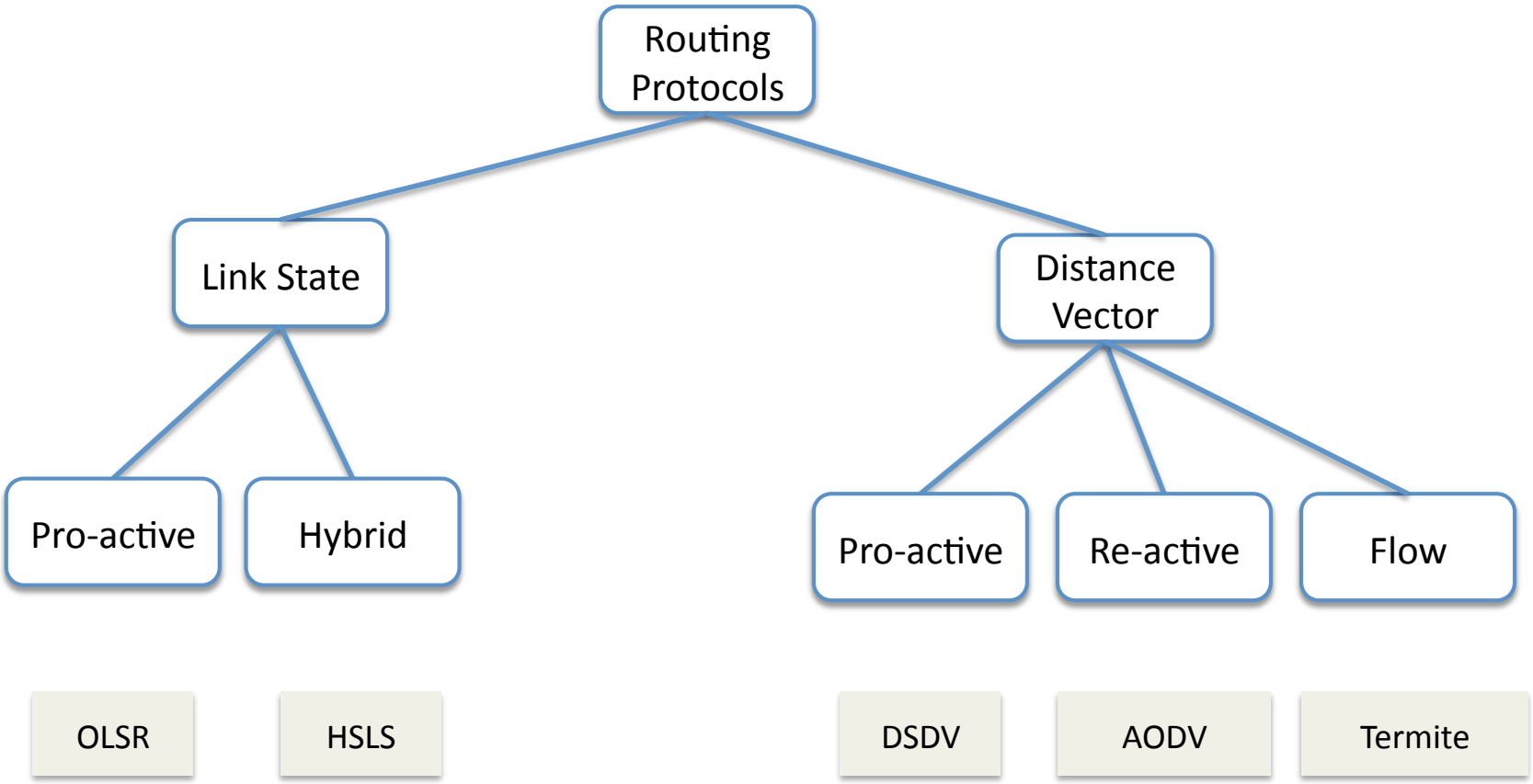
Professor at cornell/ny

Phd supervisor

Motivation

- Swarm Intelligence
- Successful in complex environments
- E.g. factory scheduling
- UAVs
- Networks!

Classification

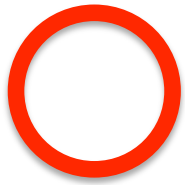


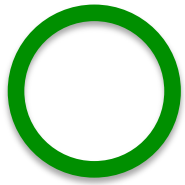
Distance Vector Visualisation

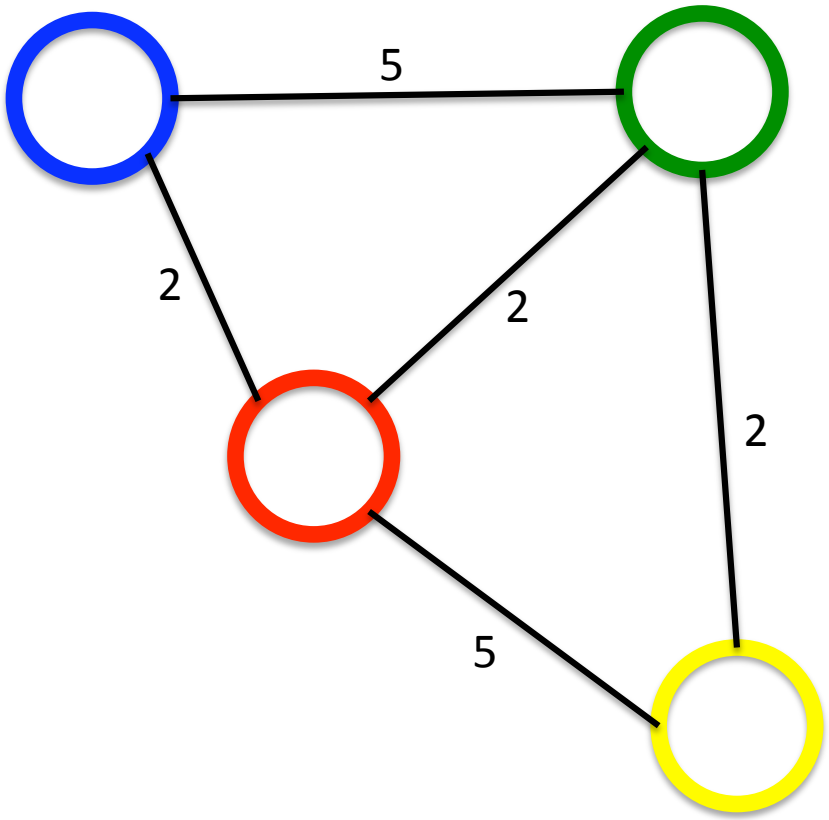
	a	b
red	2	-
green	-	5
yellow	-	-

	a	b
red	2	-
green	4	5
yellow	7	-

	a	b
red	2	7
green	4	5
yellow	7 (6)	7







. . .

Termites

- Perfect properties for MANETs:

- Decentralised planning
- Very simple agents
- Very robust community, recoverable after almost any setback

Termite Algorithm

- biologically inspired algorithm, resembling the beaviour of Termites

- Pheromone Trails
- Probabilistic Walk
- No Control Traffic
- Piggybacking information

Pheromone Trails (1/3)

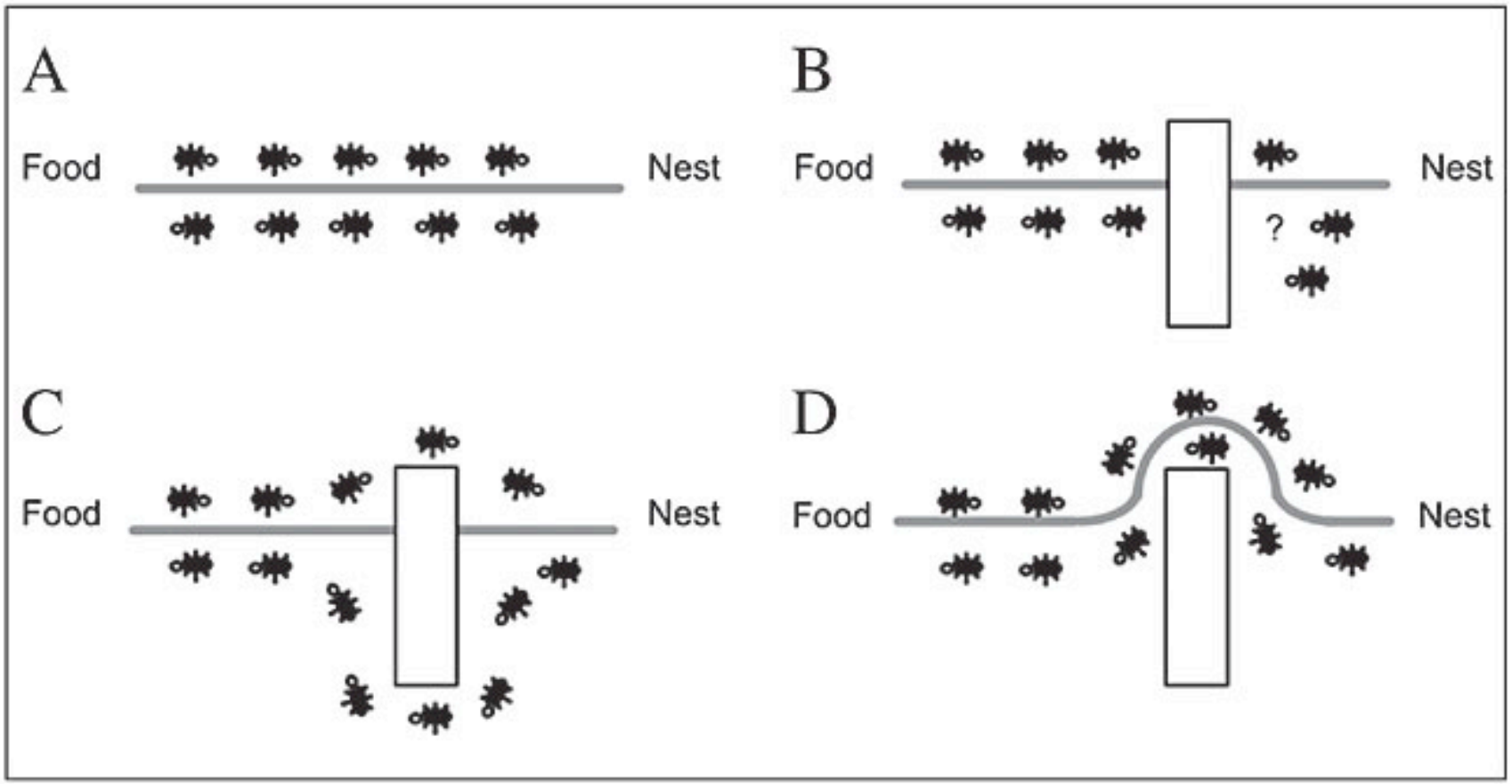
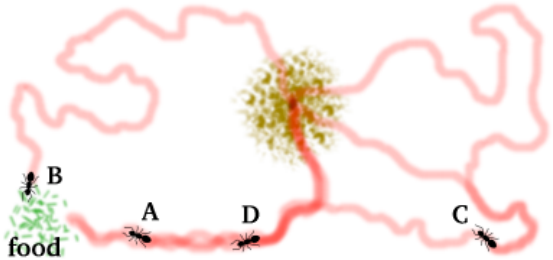


Figure 2. A. Ants in a pheromone trail between nest and food; **B.** an obstacle interrupts the trail; **C.** ants find two paths to go around the obstacle; **D.** a new pheromone trail is formed along the shorter path.

http://www.funpecrp.com.br/gmr/year2005/vol3-4/wob09_full_text.htm

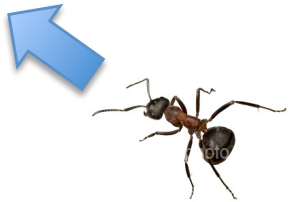
Pheromone Trails (2/3)

- node-specific pheromone
- Travelling packets drop source pheromone
- Pheromone decays over time



Pheromone Trails (3/3)

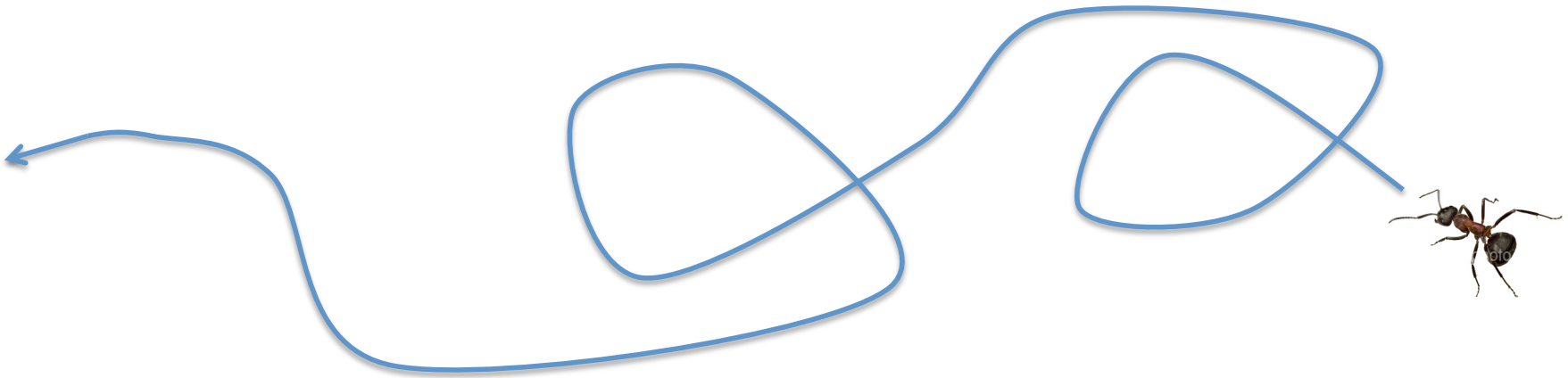
- Pull towards destination pheromone



- Push away from source pheromone

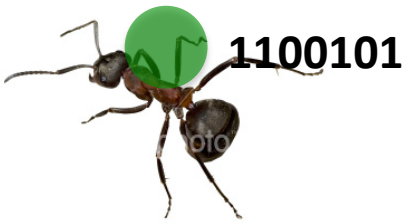
Probabilistic Walk

- Continouus network exploration
- Load balancing



Piggybacked Information

- Routing information piggybacked on data packets
- (almost) no special control traffic



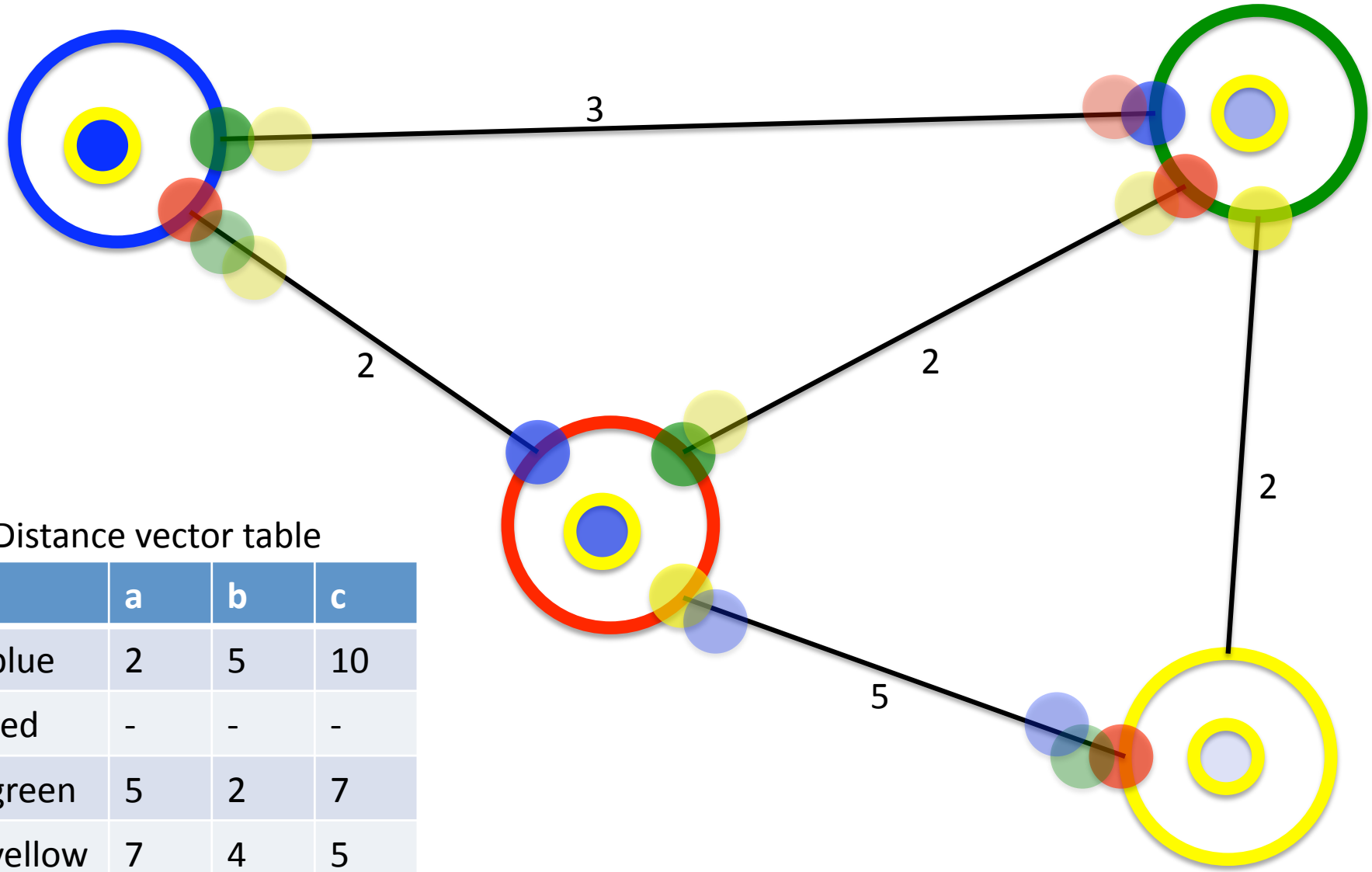
Eavesdropping

- Nodes eavesdrop on all in-range communications

- Performance increase

  (traffic is there anyway)

Termite Visualisation



Distance vector table

	a	b	c
blue	2	5	10
red	-	-	-
green	5	2	7
yellow	7	4	5

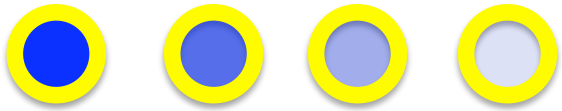
3 problems

1. Pheromone decay on the agents
2. Pheromone decay on the links
3. Routing decision on the nodes

Pheromone decay on the agents

- y is the agent's pheromone
- c is the cost from the previous to the current node

$$\gamma \leftarrow (\gamma^{-1} + c_{r,n})^{-1} \leftarrow \frac{\gamma}{1 + \gamma c_{r,n}}$$



Pheromone decay on the links

- P is the pheromone
  on current node n
  from neighbor node r
  from source node s

$$P_{r,s}^{n}$$

$$\leftarrow P_{r,s}^{n} e^{-(t-t_{r,s}^{n})\tau} + \gamma$$

$$\leftarrow \frac{P_{r,s}^{n}}{e^{-(t-t_{r,s}^{n})\tau}} + \gamma$$

- y is the agent's pheromone

- Listen to all traffic
  (update and drop)

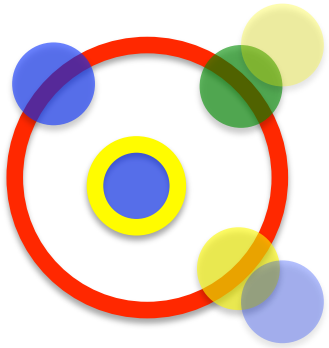
$$\frac{old.pher.}{age} + new.pher.$$

Routing decisions (1/3)

Destination pheromone distribution

- Time-based pheromone-aging
- normalization

$$p_{i,d}^{n} = \frac{\left[P_{i,d}^{n} e^{-(t-t_{i,d}^{n})\tau} + K \right]^{F}}{\sum_{j \in N} \left[P_{j,d}^{n} e^{-(t-t_{j,d}^{n})\tau} + K \right]^{F}}$$



$$dest.distr. = \frac{\frac{dest.pher.}{age}}{\sum}$$

Routing decisions (2/3)

Source pheromone distribution

- Pheromone decay rate:
  tau (=2.0, 1.0?h)

$$p_{i,s}^{n} = \frac{\left[P_{i,s}^{n} e^{-(t - t_{i,s}^{n})\tau} + K \right]^{F}}{\sum_{j \in N} \left[P_{j,s}^{n} e^{-(t - t_{j,s}^{n})\tau} + K \right]^{F}}$$

- Pheromone threshold:
  K (=1/32)

- Pheromone sensivity:
  F (=10.0)

$$src.distr. = \frac{\frac{src.pher.}{age}}{\sum}$$

Routing decisions (3/3)

Total probability

- Source aversion sensivity:
  A (=0.5)

$$\hat{p}_{i,d}^{n} = \frac{p_{i,d}^{n}(p_{i,s}^{n})^{-A}}{\sum_{j \in N} p_{j,d}^{n}(p_{j,s}^{n})^{-A}}$$

- Periodic updates vs. live calculation

$$tot.distr. = \frac{dest.distr.}{src.distr.}$$

$$\sum$$

Route Requests

- No destination pheromone on node

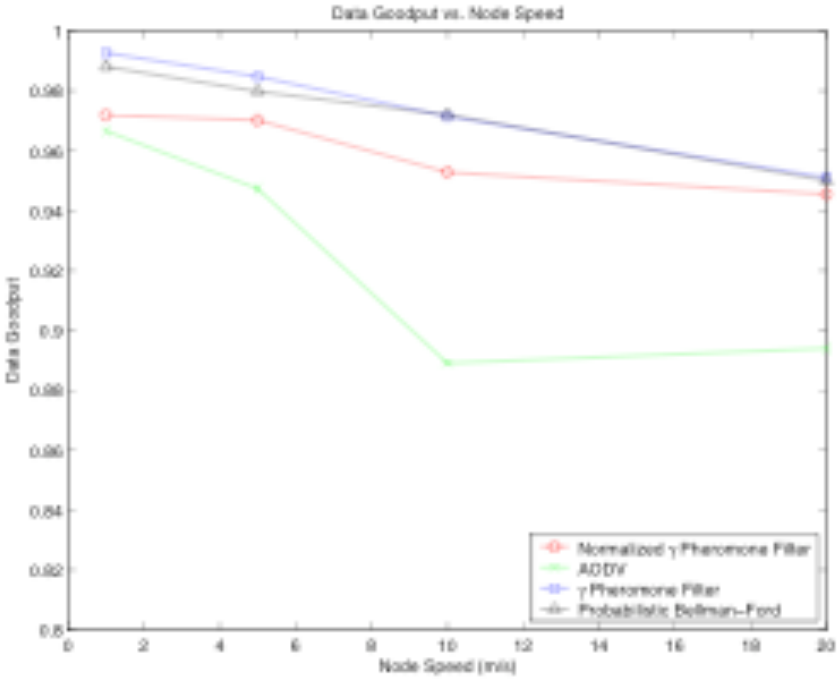
-> RREQ broadcasts

- Node has required pheromone

-> RREP

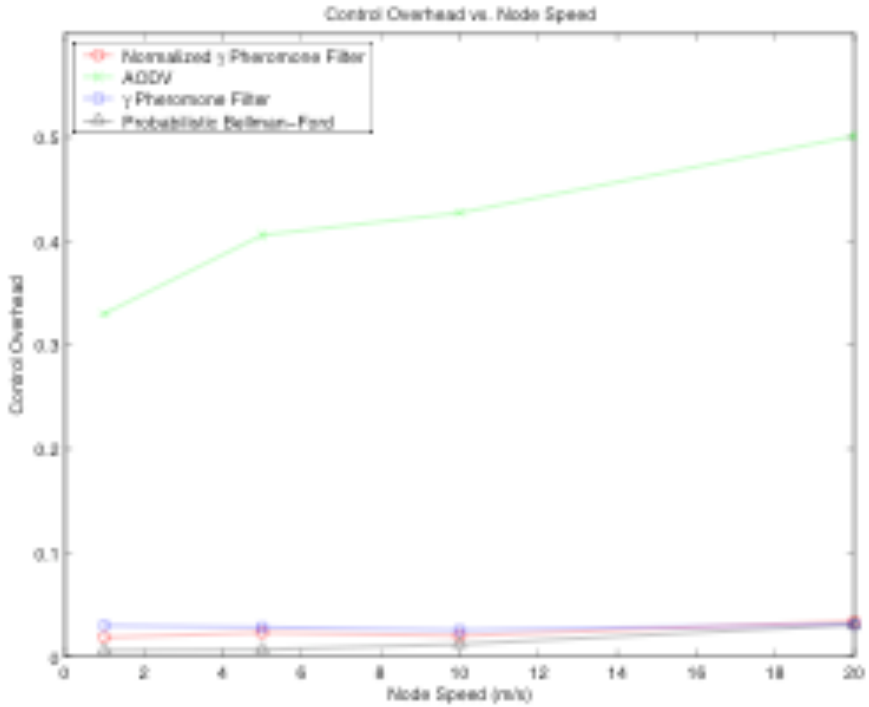
Data Goodput

- Delivered data packets / total data packets
- Termite wins by 2% - 5%
- Big advantage with fast moving nodes



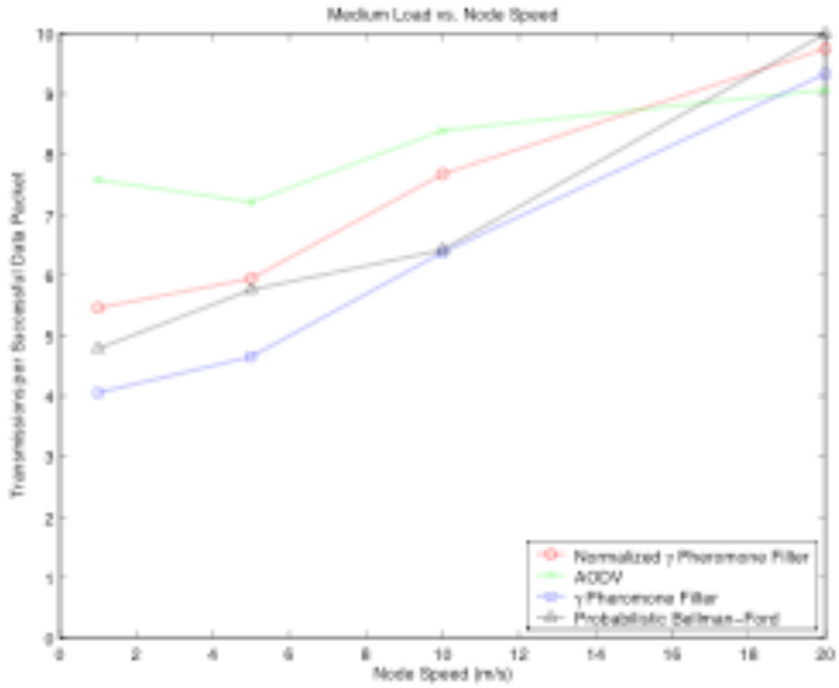
Control Overhead

- Control packets / total packets
- Termite uses virtually no control traffic



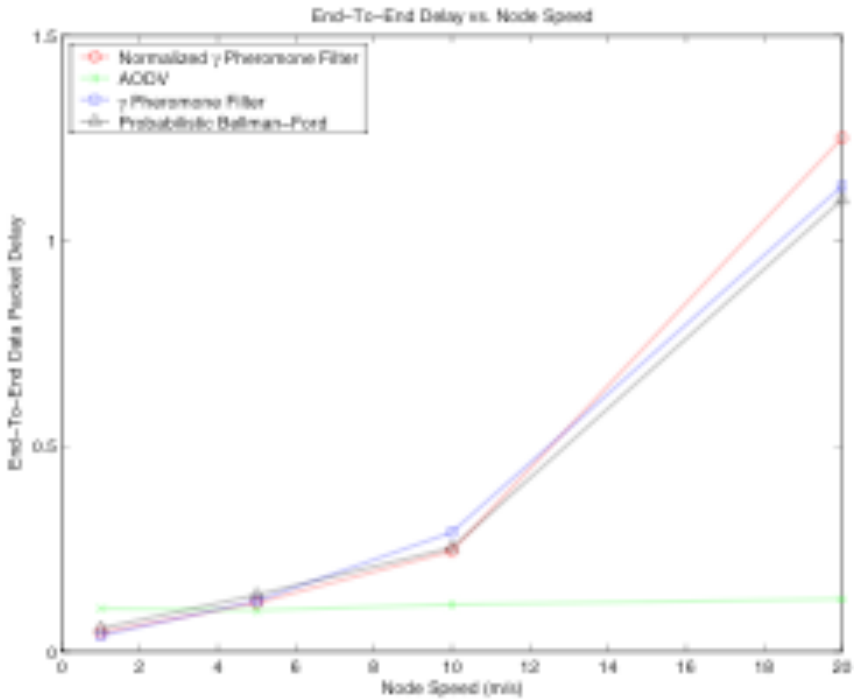
Medium Load

- Transmissions / successful data packet
- 4/1 for Termite
- 8/1 for AODV



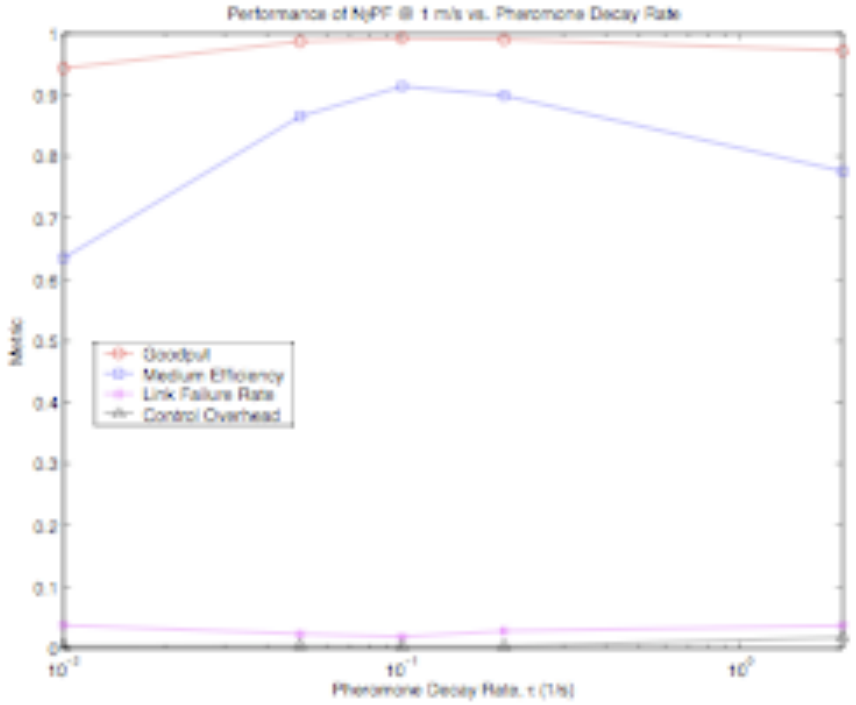
End to End Delay

- Huge advantage here by aodv
- Dropping slowest 5%, results are coming close again



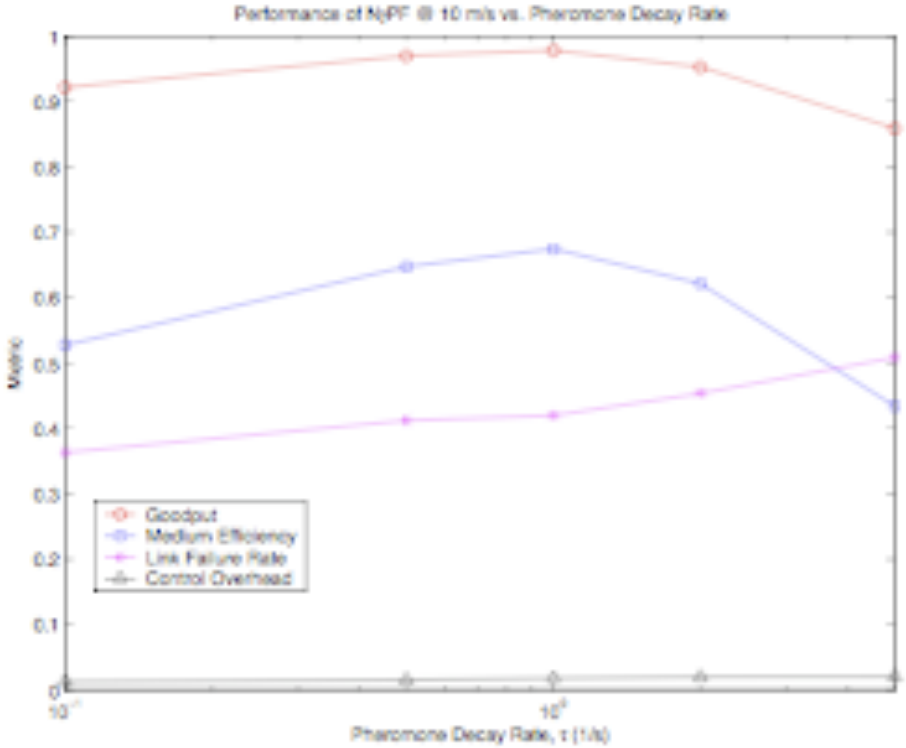
Pheromone Decay Heuristic

- node speed 1m/s
- Decay rate vs metric
- Best at tau=0.1



Pheromone Decay Heuristic

- node speed 10m/s
- Decay rate vs metric
- Best at tau=1.0



Summary

- Efficient and adaptable routing based on swarm intelligence
- Piggybacked routing information
- Pheromone pull and push
- Probabilistic routing decisions

Criticism

- Complexity vs. Efficiency
- Network behaviour on low traffic
- Simulation environment

Outlook

- Ajust algorithm parameters (tau,K,F,A) on a real-time, per node, per link basis
- This could result in a superior algorithm and detailed understanding of network internals

Comparison

- AntColonyOptimization (ACO) (1992):
  first ant-algorithm and base for all others

- Ants and Reinforcement Learning (1997):
  backward dest. to src. exploration

- Ant-AODV (2002):
  n random walking route-ants drop pheromone

- AntBasedRouting (2002) & AntHocNet (2004):
  FANTs & BANTs connect graph. Proactive updates

$$p_{n,d}^{i} = \frac{\left[\tau_{n,d}^{i}\right]^{\beta}}{\sum_{j \in N}\left[\tau_{j,d}^{i}\right]^{\beta}}$$

Thank you for your attention

Any questions?