Proposal and Evaluation of Ant-based Routing with Prediction

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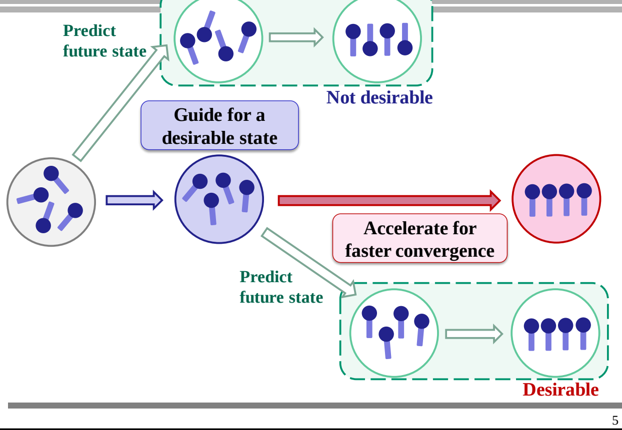
Research background

- Rapid growth of networks in scale and complexity
  - Control overhead for collecting and maintaining information of the entire system will drastically increase
  - Conventional central control or distributed control with global information suffers from the considerable overhead
- Self-organization
  - High adaptability and robustness with low overhead
  - **Long time is needed for emergence of a global pattern**
  - **Global optimality is not guaranteed**

Controlled self-organization

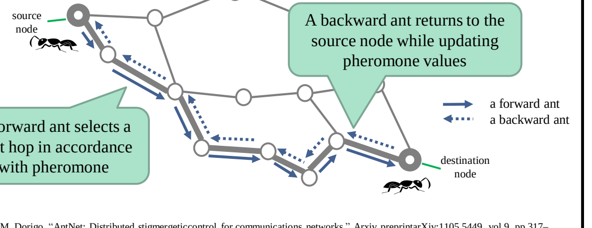
- Our goal : **Show self-organization can be accelerated by moderate control without sacrificing benefits of self-organization**
- Take AntNet as a test case
- Reduce the path convergence time with a predictive mechanism

Predictive mechanism



AntNet [3]

- A routing mechanism inspired by the foraging behavior of ants
  - Pheromones accumulated on a path indicate its goodness



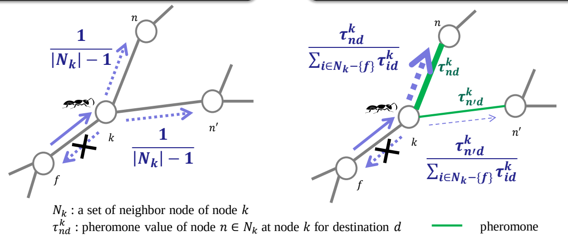
[3] G. Di Caro and M. Dorigo, "AntNet: Distributed stigmergeticcontrol for communications networks," Arxiv preprintarXiv:1105.5449, vol.9, pp.317–365, Dec. 1998.

Forward ants

- Select a next hop node stochastically in accordance with pheromones

If pheromones do not exist, a forward ant selects a next hop at random

If pheromones exist, a forward ant would select a neighbor node with more pheromones than others

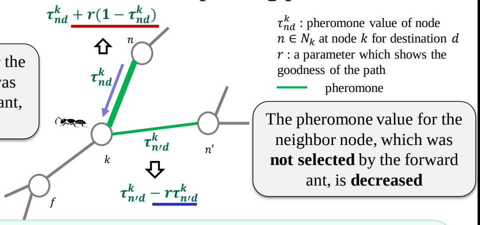


Backward ants

- Return to a source node while updating pheromone values

The pheromone value for the neighbor node, which was **selected** by the forward ant, is **increased**

The pheromone value for the neighbor node, which was **not selected** by the forward ant, is **decreased**



In AntNet, the time required for converge depends on the length of the path

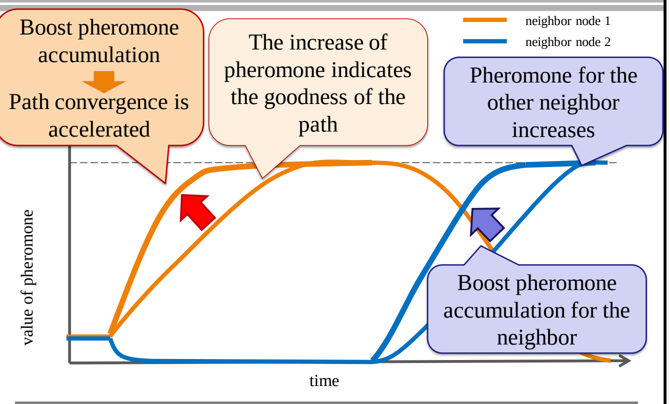
Accelerate path convergence with a predictive mechanism

Approach (1/2)

- In ant-base routing mechanism, the path is established by pheromone accumulation
  - A shorter path collects more pheromones
  - A path with more pheromones attracts more ants, which further deposit pheromones on the path (reinforcement)
  - **The increase of pheromone implicitly indicates the goodness of the path**

Boost pheromone accumulation on the path where pheromone is increasing for faster convergence

Approach (2/2)

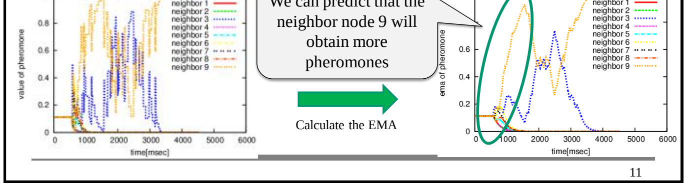


Pheromone accumulation

- A node predicts a neighbor which will obtain the highest pheromone value from pheromone accumulation
  - Exponential Moving Average (EMA) of pheromone
    - β : a parameter which shows the weight of the latest data
    - β is determined by a parameter H ($\beta = 2/(H+1)$)

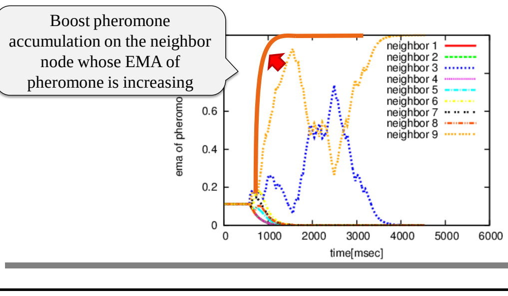
$$\overline{\tau^k_{nd}}(t) = (1-\beta)\overline{\tau^k_{nd}}(t-1) + \beta\tau^k_{nd}(t)$$

the previous EMA of pheromone — the latest pheromone value



Control

- Accelerate the path convergence by leaving more pheromone on the neighbor node whose EMA of pheromone is increasing

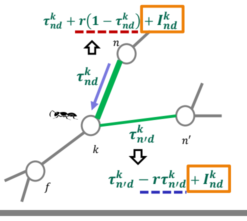


Boost pheromone accumulation

- Boost pheromone accumulation on the predicted path
- I_{nd}^k : an additional pheromone

$$I_{nd}^k = \begin{cases} \alpha \dfrac{\overline{d\tau_{nd}^k}}{\sum_{n' \in \{x \in N_k | \overline{d\tau_{xd}^k} > 0\}} \overline{d\tau_{n'd}^k}}, & \text{if } \overline{d\tau_{nd}^k} > 0 \\ 0, & \text{otherwise} \end{cases}$$

$\overline{d\tau_{nd}^k}$: increase rate of $\overline{\tau_{nd}^k}$
($\overline{d\tau_{nd}^k} = \overline{\tau_{nd}^k}(t) - \overline{\tau_{nd}^k}(t-1)$)
α : weight of predictive control



Boost pheromone accumulation on the neighbor node whose EMA of pheromone is increasing

r : a parameter which shows the goodness of the path

pheromone

Simulation experiment

- Scenario
  1. Establish the initial path using AntNet
  2. Remove one node randomly from the initial path
  3. Reestablish the path using our proposal or AntNet
- Measures
  - Convergence time
  - Path delay

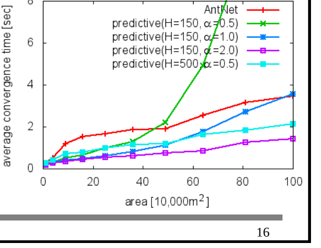
Simulation setting

- Change the size of network from $scale = 1$ (100 m x 100 m) ~ 10 (1,000 m x 1,000 m) while keeping node density
  - At $scale = 2$, 150 nodes are distributed at random in the area of 200 m x 200 m
- Communication range : 30 m
- One-hop delay : $1 + \frac{|(u,v)|}{15}$ msec
  - $|(u,v)|$: the Euclidean distance from node u to node v
- Interval of ant emissions : 10 msec

Convergence time

- Path convergence can be accelerated by our proposal when H is high or α is high
  - Higher H suppress influence of changes of pheromone values on predictive control and oscillation rarely happens
  - Higher α reinforces predictive control and the path establishment converge faster

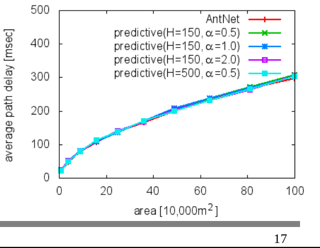
Parameters
H : **weight of the latest pheromone** in EMA
(The weight of the latest pheromone is larger with lower H)
α : **weight of the predictive control**



Path delay

- The path delay of our proposal is approximately equal to that of AntNet
  - Pheromones already exist on the network due to the establishment of the initial path by AntNet

Parameters
H : **weight of the latest pheromone** in EMA
(The weight of the latest pheromone is larger with lower H)
α : **weight of the predictive control**



Conclusion and future work

- Conclusion
  - Moderate control with prediction accelerates path establishment of ant-based routing
- Future work
  - Evaluation of influence of frequent environmental changes (adaptability and robustness of prediction)