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A Biologically-inspired Approach for Self-Adaptive Ad-Hoc Network Routing

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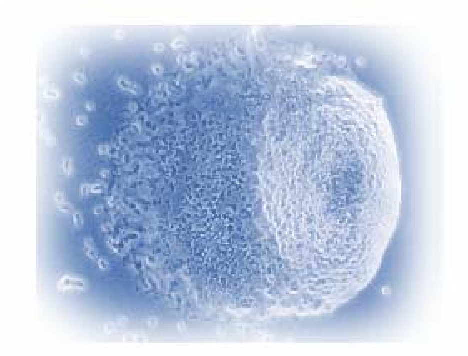
Outline of the Talk

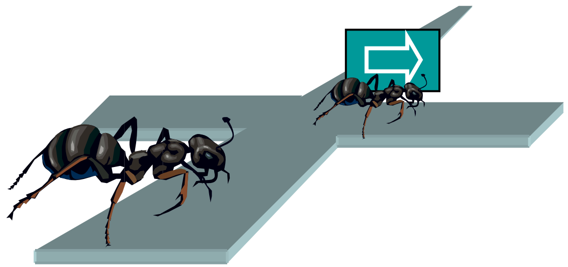
- Introduction
- Adaptive response by attractor selection (ARAS)
- Application to ad-hoc routing
- Simple numerical examples
- Conclusion and outlook



21st Century COE Program
New Information Technologies for Building a Networked Symbiosis Environment

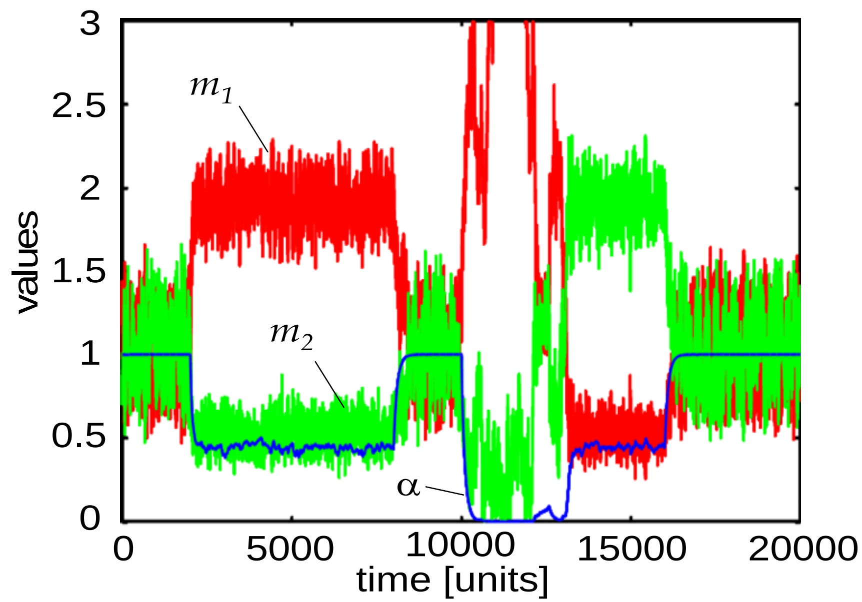
Introduction

- Biologically-inspired models applied to telecommunication networks:
  - sub-optimal performance is often acceptable
  - learning algorithms require target patterns
  - desired features: self-adaptive, robust
  - examples:
    - swarm intelligence
    - ant-based routing



Adaptive Response by Attractor Selection

- Original model for E. coli cells to adapt to changes in the availability of a nutrient
- Activity term indicates environmental changes and the “goodness” of the system state
- Concept of attractors is often used in chaos theory



Mathematical Model

$$\frac{dm_i}{dt} = \frac{syn(\alpha)}{1 + m_{\max}^2 - m_i^2} - deg(\alpha) m_i + \eta_i$$

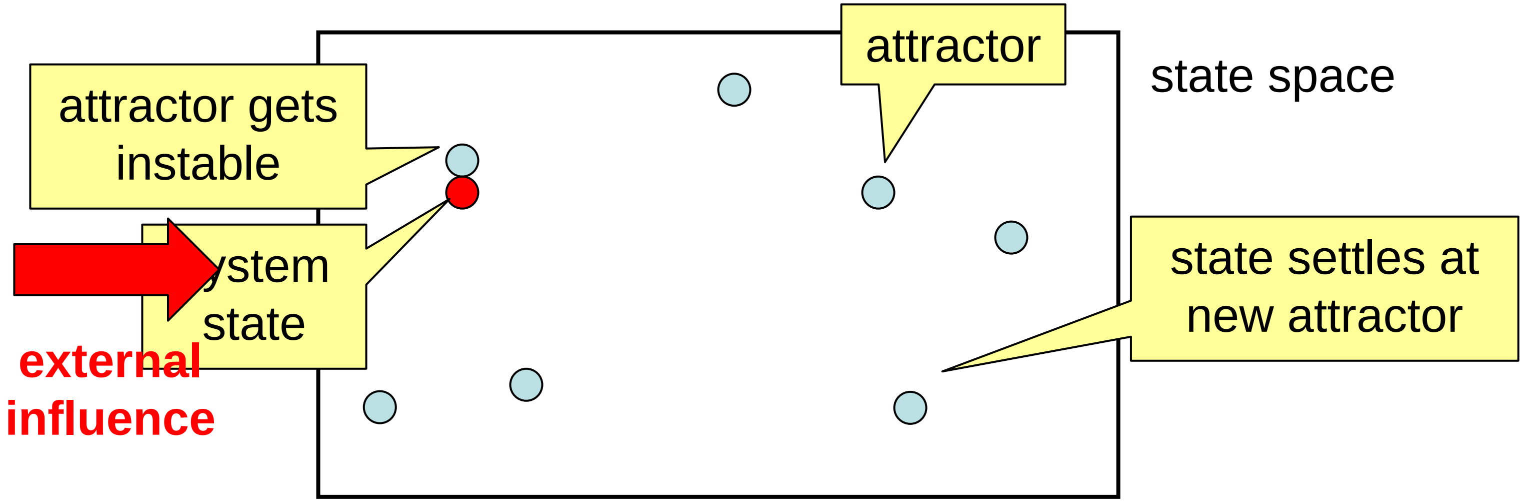
zero-mean Gaussian noise term

target value also influenced by other m_i

activity reduces equation to noise term

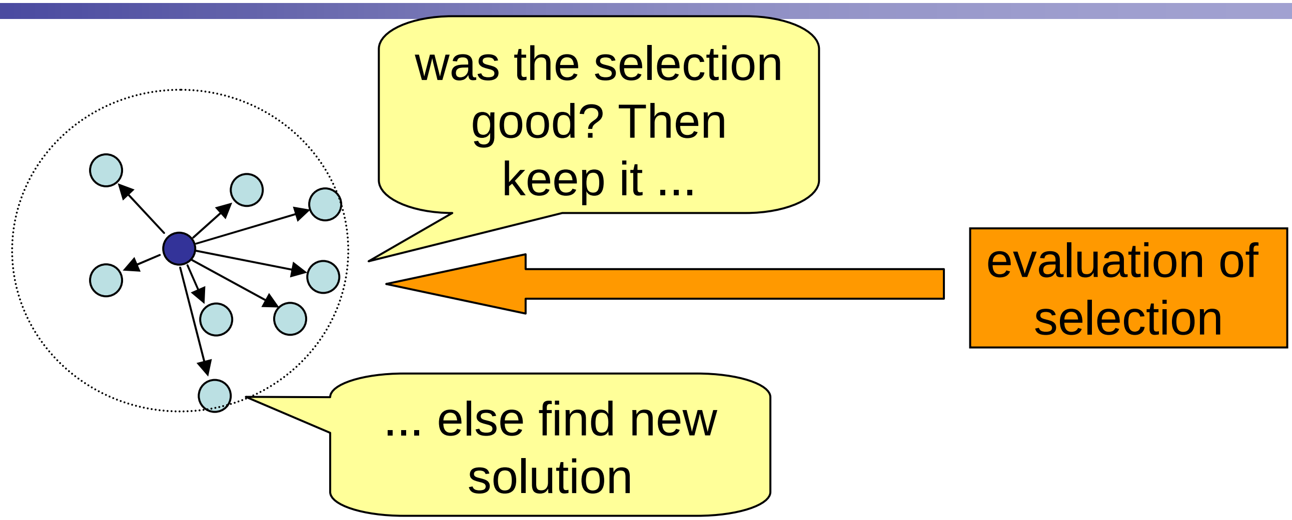
- Formulation as (stochastic) differential equation system with mutual influence
- Activity α makes the first two terms become zero ➔ system behaves like a random walk
- Attractor locations are entirely defined by the differential equations

Attractor Selection Concept



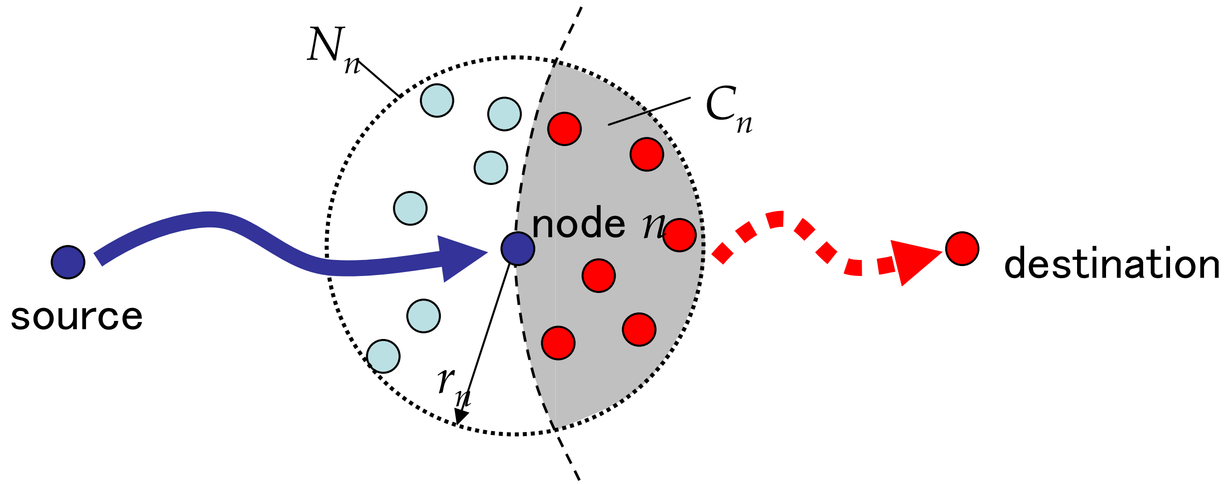
- Basic mechanism:
  - consider state space with magnets (= equilibrium solutions)
  - solution is a metal ball which is constantly in motion but stays locked at an attractor
  - activity influences which magnet is activated and the strength of the noise influence
- ARAS can be seen as a mapping of an input space (*environment*) to a set of discrete points (*attractors*)

Basic Concept of MARAS



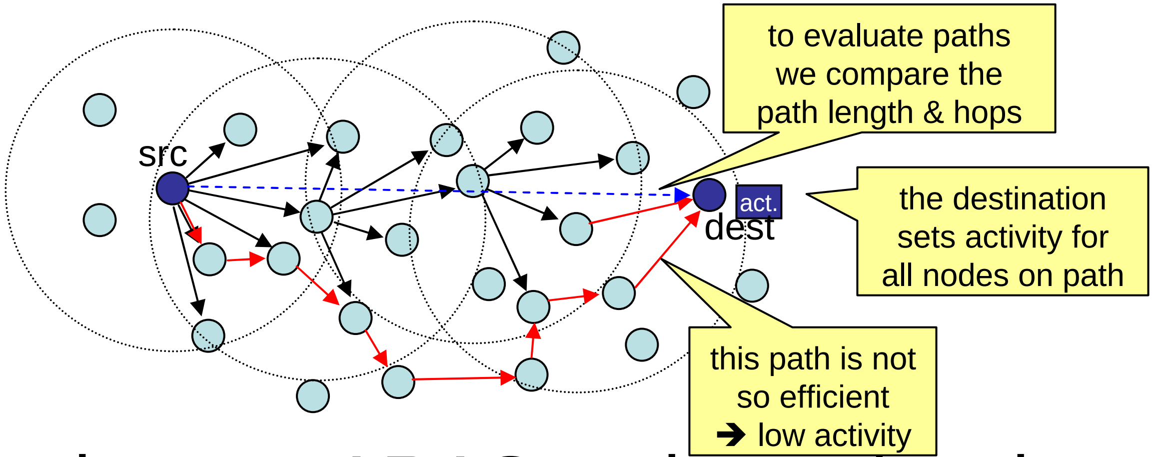
- MARAS: Mobile Ad-Hoc Routing with Attractor Selection
- Node has several possible next hops
- If it has no information, selection is randomly
- Otherwise the selection is evaluated for the next hop based on the "goodness" of the previous choice

Neighbor Set Maintenance



- Assumption of location estimation (e.g. GPS)
- Each node only uses local information by querying the distances to the destination
- Distinction in 2 sets:
  - Neighbor set N_n
  - Candidate set C_n
- Next hop is selected randomly ➔ reduction of selfishness

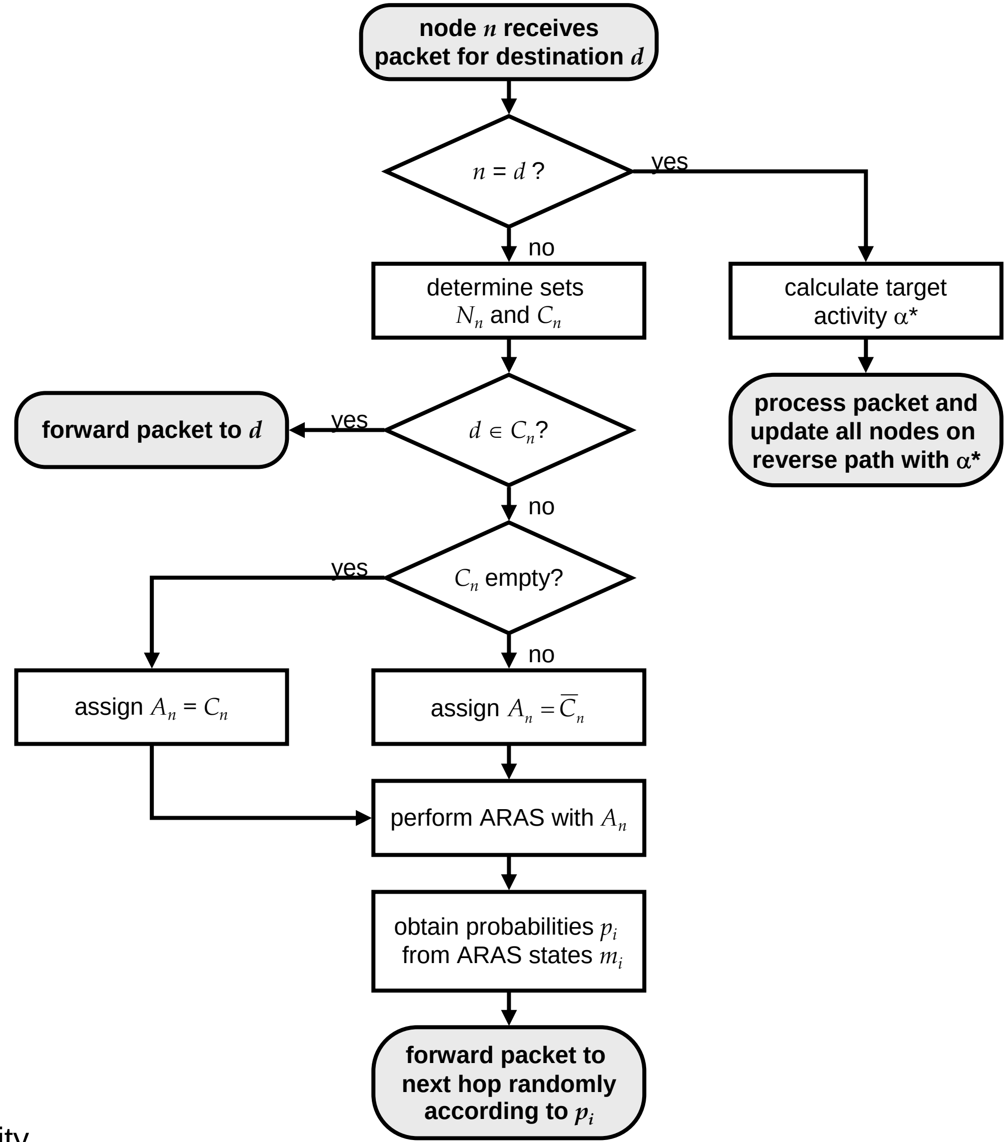
MARAS Algorithm



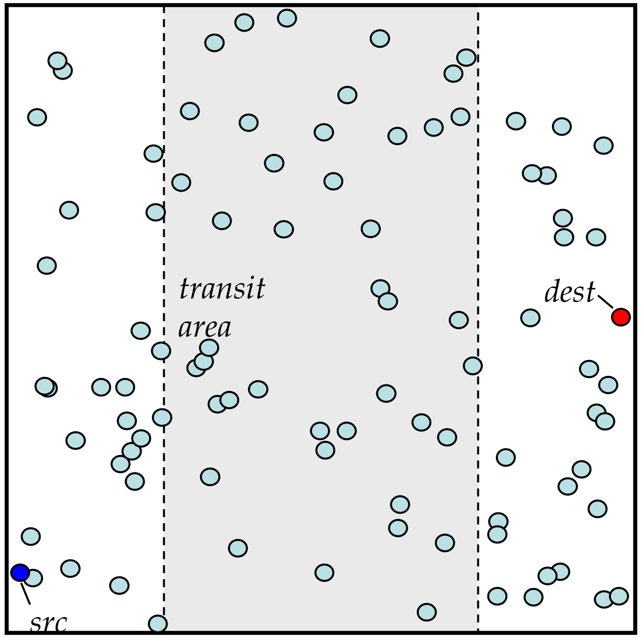
- Each node uses ARAS to determine the next hop
- "Goodness" of selection:
  - number of hops
  - distance-path length ratio

$$\frac{d\alpha}{dt} = \delta(\alpha^* - \alpha) \quad \text{with} \quad \alpha^* = 1 - (1-\rho)\left(1 - \frac{h_{min}}{h}\right)$$

Summary of Algorithm

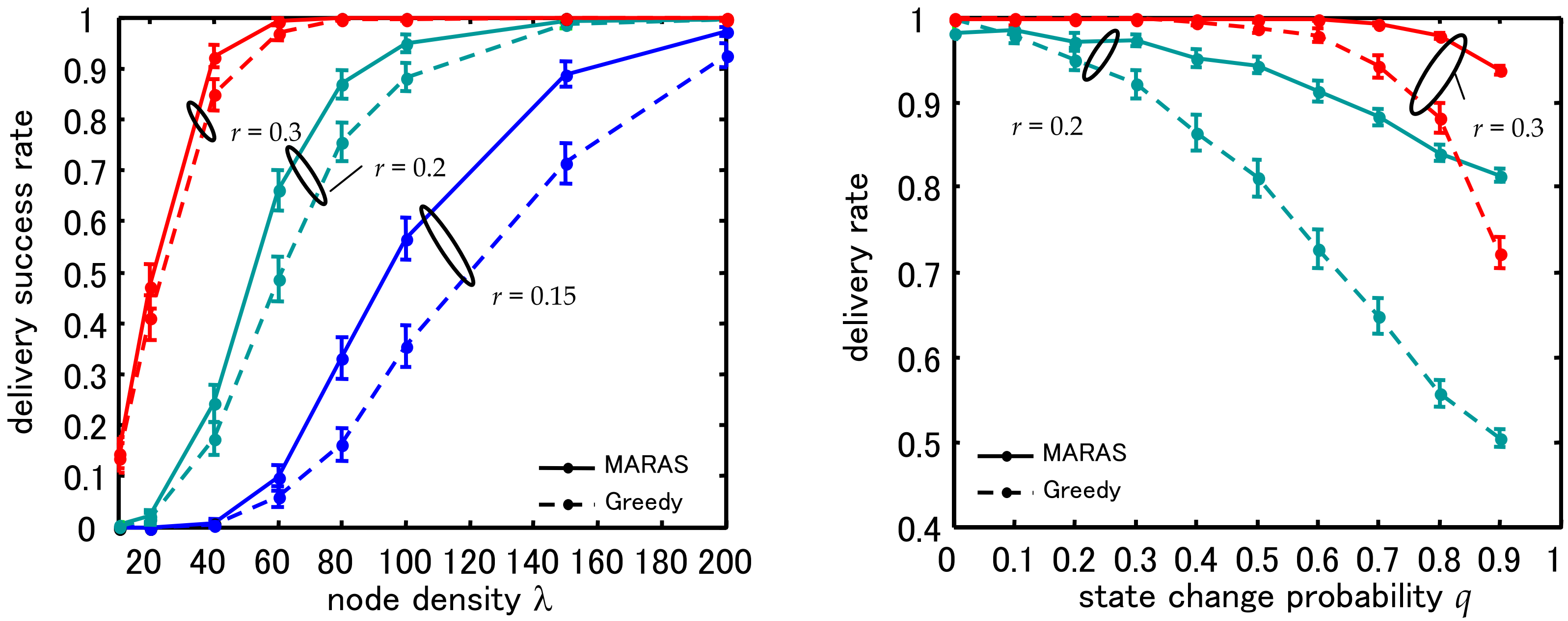


Simulation Scenario



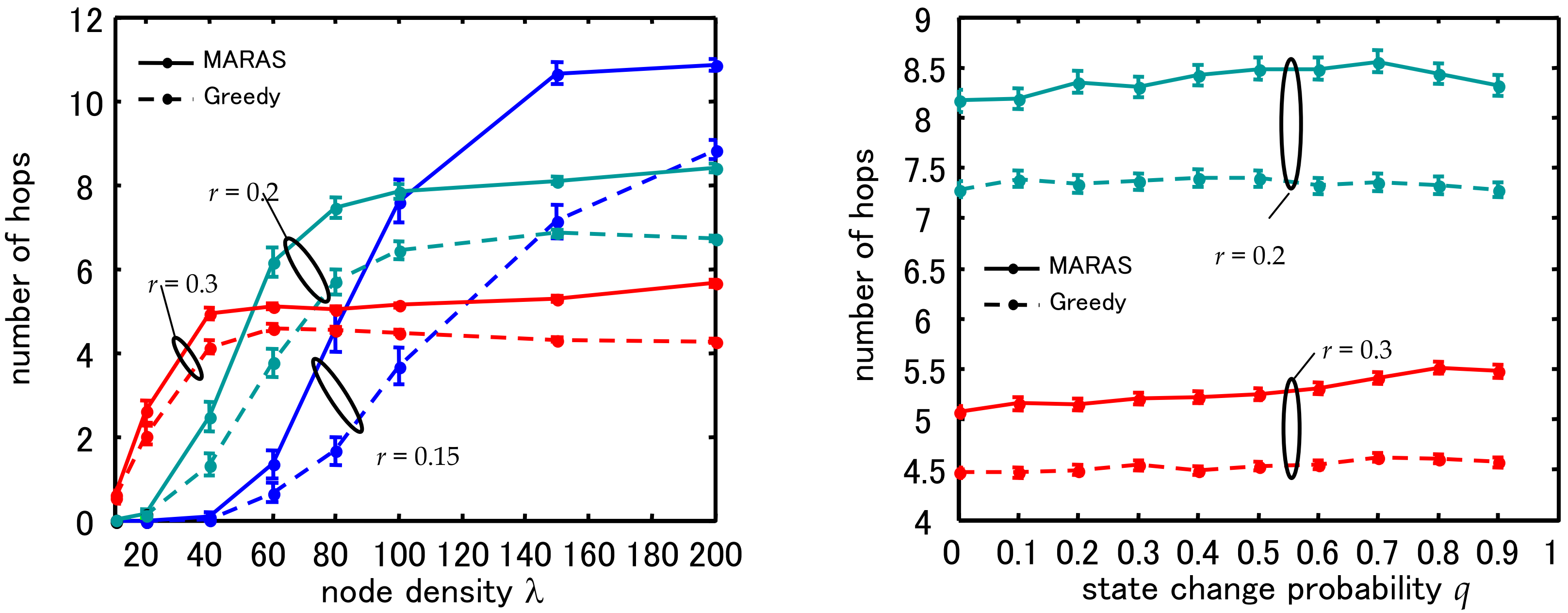
- Nodes are randomly distributed with density λ
- *src* is left-most, *dest* is right-most node
- Comparison to Greedy routing method (next hop is the one nearest to *dest*)
- Nodes in the transit area may fail with a certain probability *q*
- Performance metrics: *delivery rate*, *number of hops*

Delivery Rate



- MARAS has better delivery performance than Greedy, especially when radius is small
- Small node densities and transmission radius reduce the delivery rate (connectivity problems!)

Number of Hops



- If greedy method finds solution it has less hops (since it deterministically uses best next hop)
- Number of hops is nearly unaffected by state change probability q

Conclusion

- MARAS: Bio-inspired and self-adaptive ad-hoc routing scheme
- Different metrics can be used: hop count, distance ratio, energy consumption, ...
- MARAS can adapt easily to changes in topology with high delivery rate
- Future work:
  - consider different path metrics
  - more thorough comparison to other methods