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Biologically Inspired Adaptive Multi-Path Routing in Overlay Networks

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Outline of the Talk

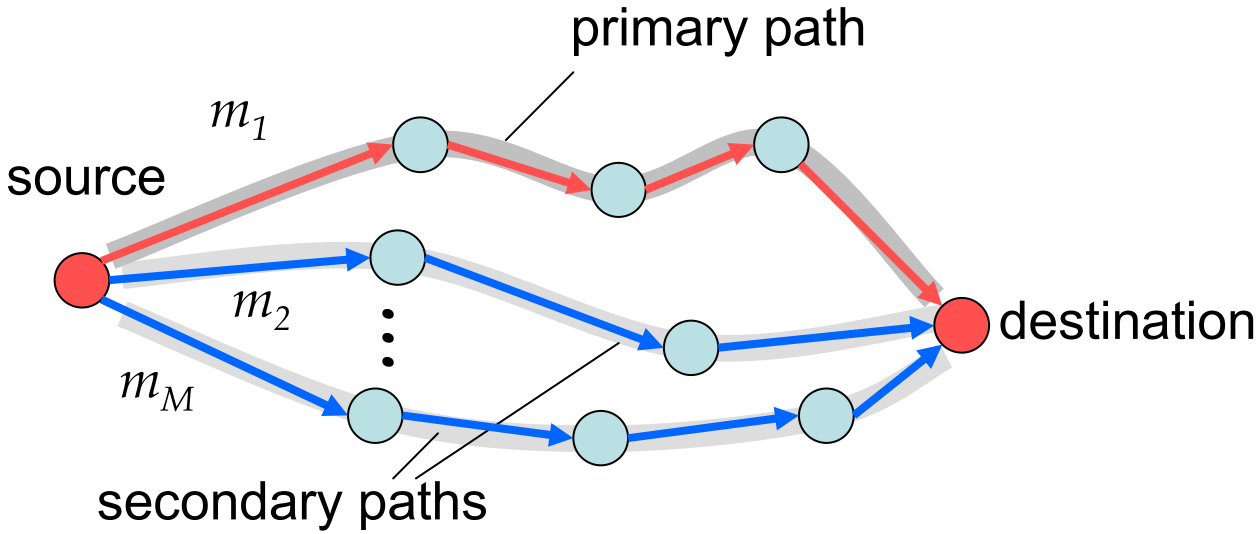
- Introduction
- Multi-Path Routing in Overlay Networks
- Biological Model
- Numerical Examples
- Conclusion and Outlook

Introduction

- Biologically-inspired models applied for telecommunication networks
- Perhaps not optimal in performance, but very robust
- Examples are *swarm intelligence*, *ant-based routing*
- This work is based on a model for *E. coli* cells to adapt to changes in the availability of a nutrient [13]

[13] A. Kashiwagi, I. Urabe, K. Kaneko, and T. Yomo, "Adaptive response of a gene network to environmental changes by attractor selection"

Multi-Path Routing



- No explicit knowledge of network topology
- *primary* and *secondary* paths with transmission rates m_i
- Inline measurement of path metrics (e.g. RTT)
- Time intervals:
  - T_M for measurements
  - T_R for routing updates

Selfish Routing

- Overlay routing is “selfish”
  - flows try to maximize their performance
  - global system stability is neglected
- Adding restraint improves performance [1], e.g.
  - randomization in path selection
  - route changes with hysteresis threshold
  - increased time between route changes

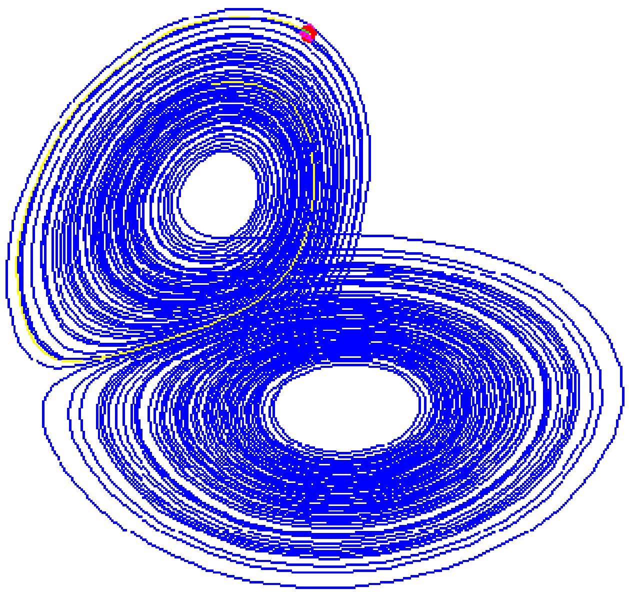
[1] M. Seshadri and R. Katz, “Dynamics of simultaneous overlay network routing”, Technical Report, UCB

Routing Algorithm Sketch

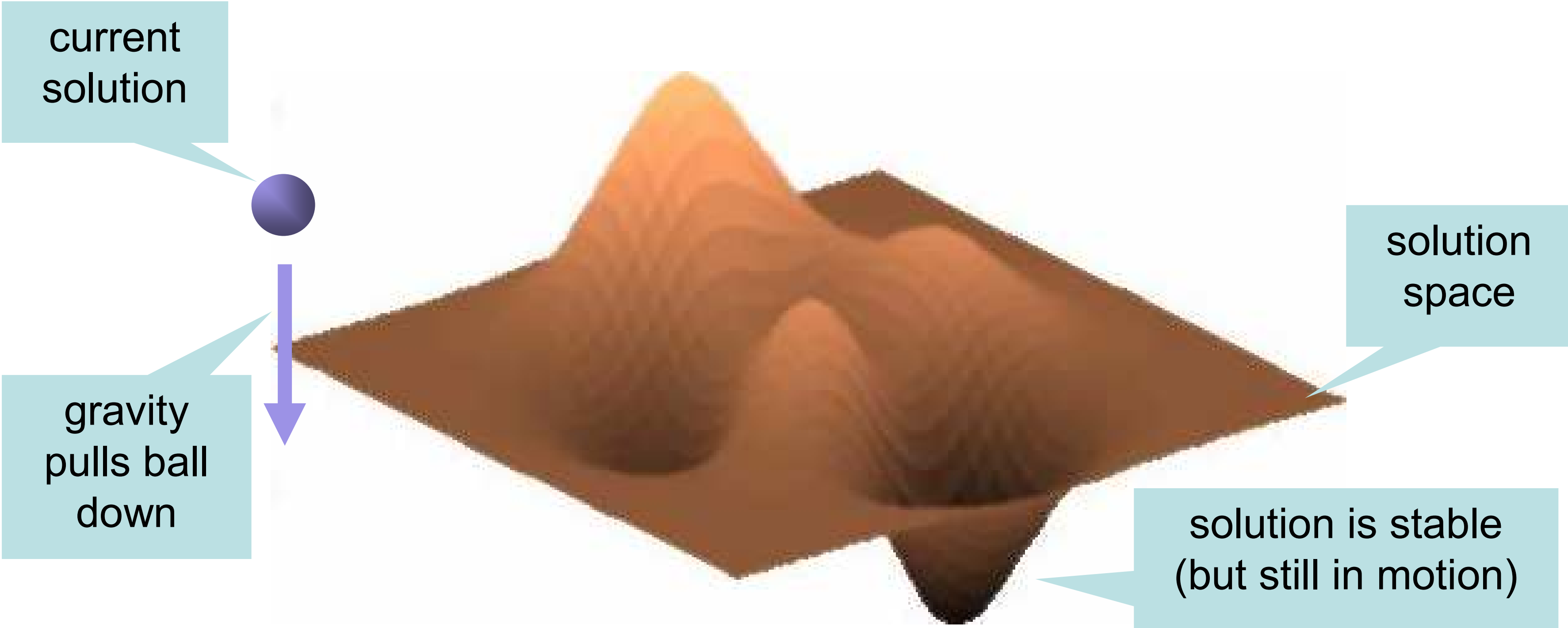
- Set up M routes, set initial m_i (output values), $i=1,\ldots,M$
- Every measurement window T_M evaluate the metrics ℓ_i (input values)
- Perform attractor-selection algorithm using m_i and ℓ_i
- After every route update window T_R, update the selection of paths i using m_i

Attractor Selection Model

- System described by its dynamic behavior
- Attractors are stable states to which system converges (e.g. Lorenz attractor)
- Transitions are noise-driven but controlled by an activity term

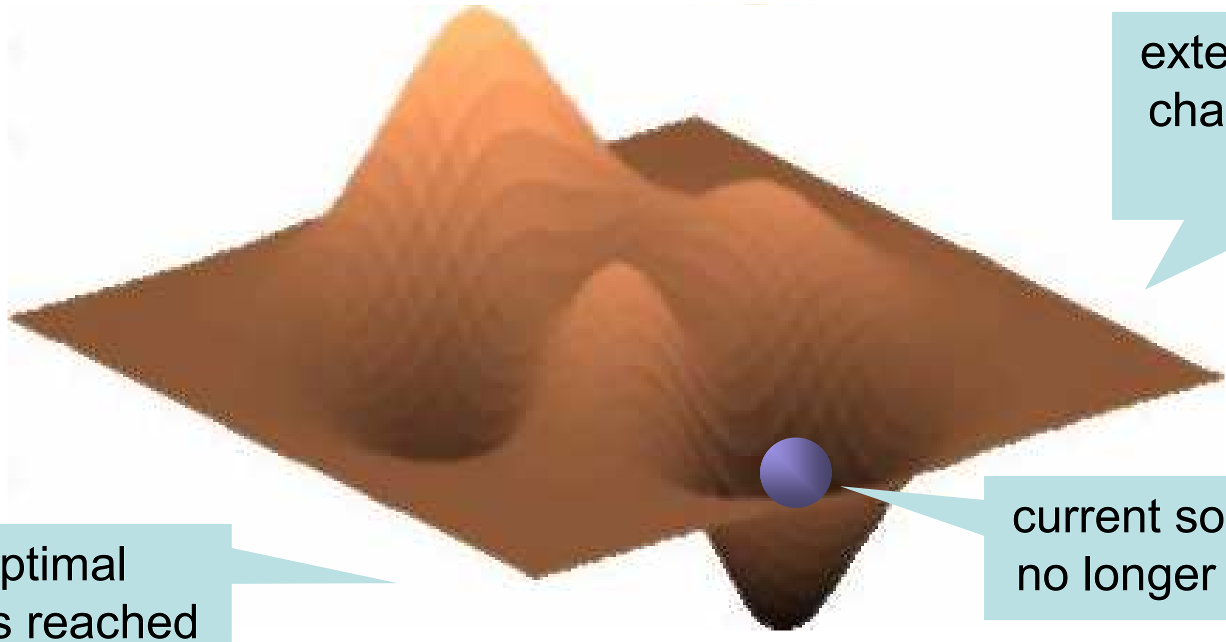


Attractor Selection Concept



- Solution = “rubber” ball permanently in motion
- “Gravity” pulls the solution downward (attraction)
- Activity influences noise (= height of jumps)

External Influence



- **Simulated Annealing**: noise is reduced over time
- **Attractor Selection**: noise is varied depending on how well the currently found solution is useful

System Definition

if activity is 0 only noise term remains

zero-mean Gaussian noise term

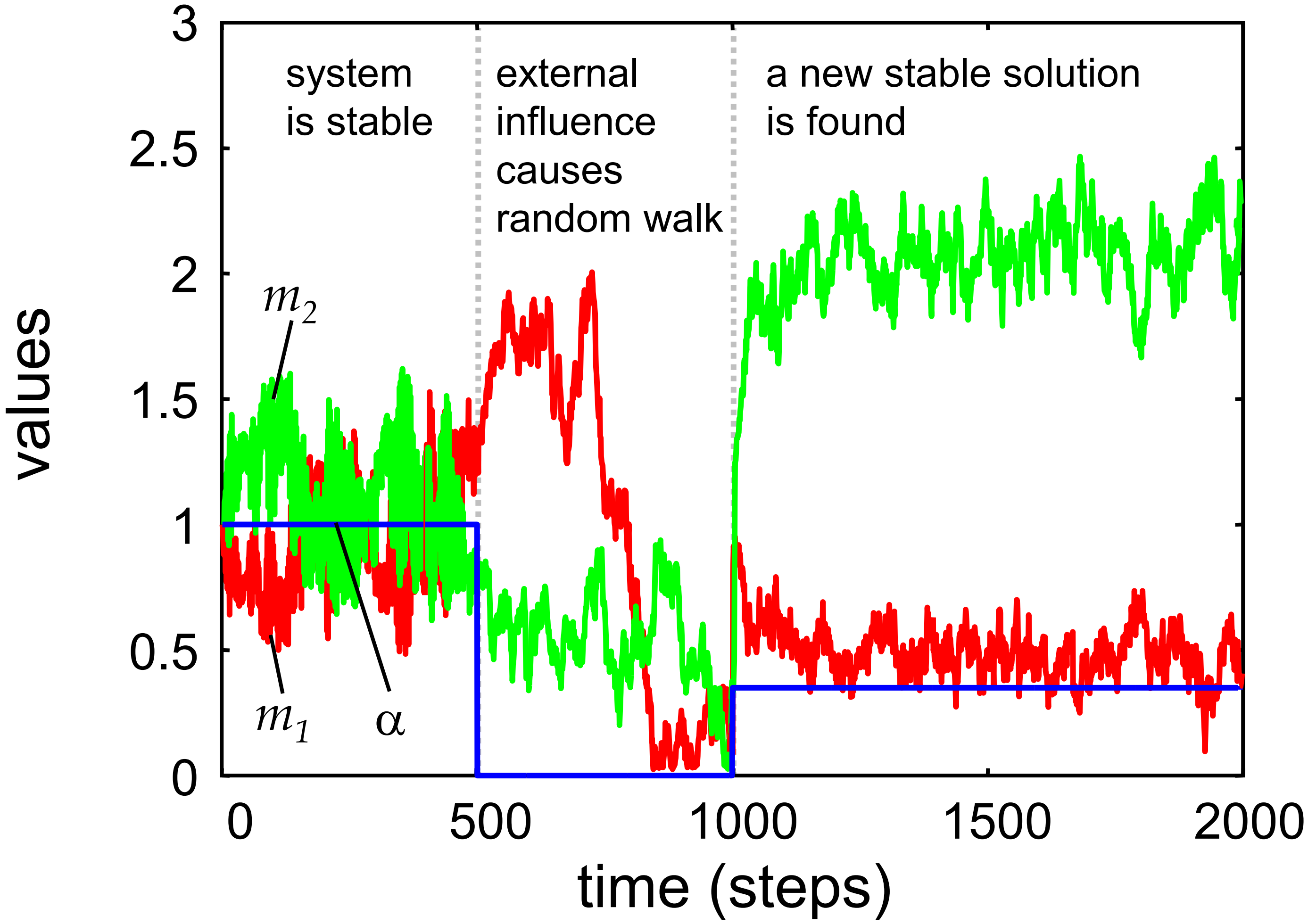
$$\frac{dm_i}{dt} = \frac{syn(\alpha)}{1+\max_j m_j^2 - m_i^2} - deg(\alpha)\, m_i + (\gamma-\alpha)^{\nu}\eta_i$$

$$\frac{d\alpha}{dt} = \sigma(\alpha^* - \alpha)$$

target value also influenced by other m_i

- Dynamic system is controlled by activity α
- If $\alpha = 0$, systems acts like random walk, otherwise it converges to attractors
- Attractor locations are entirely defined by the differential equations themselves

Principle of Attractor Selection



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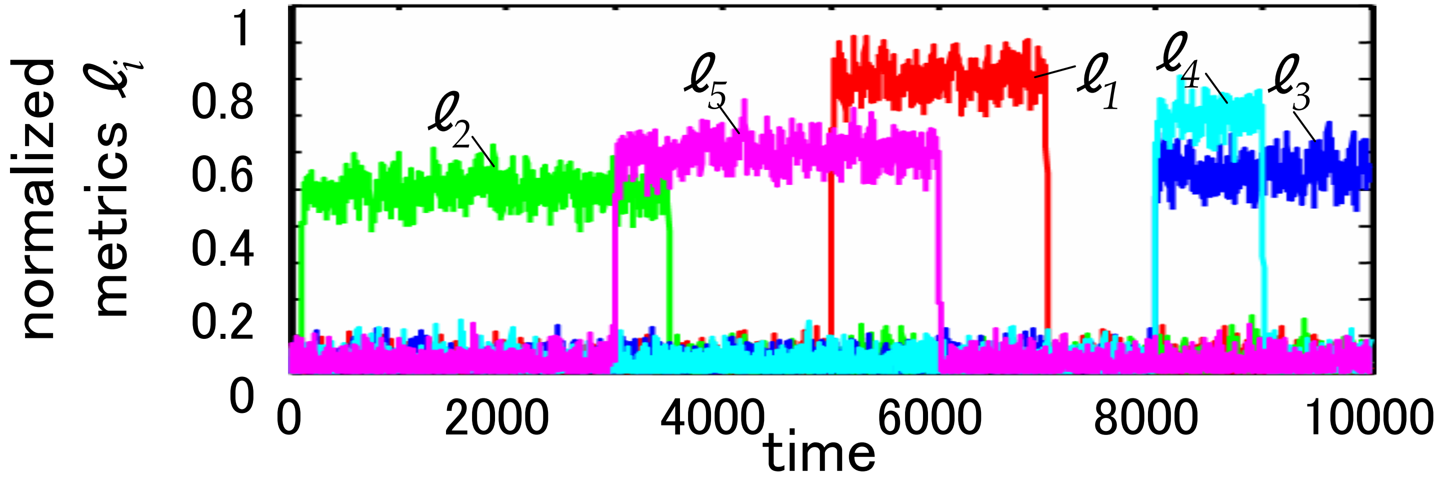
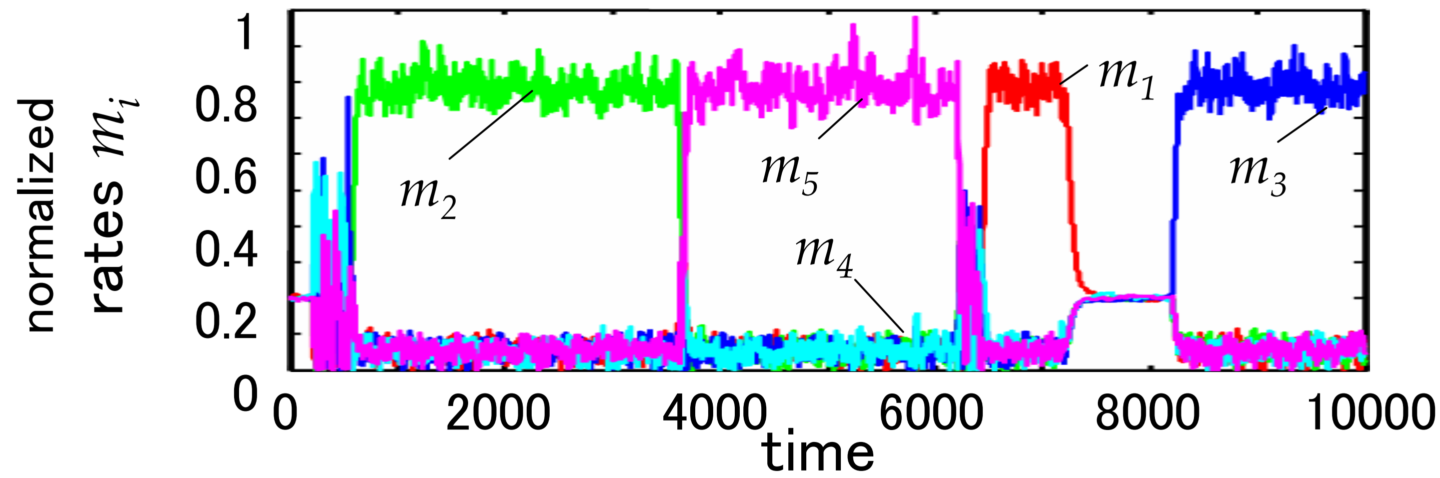
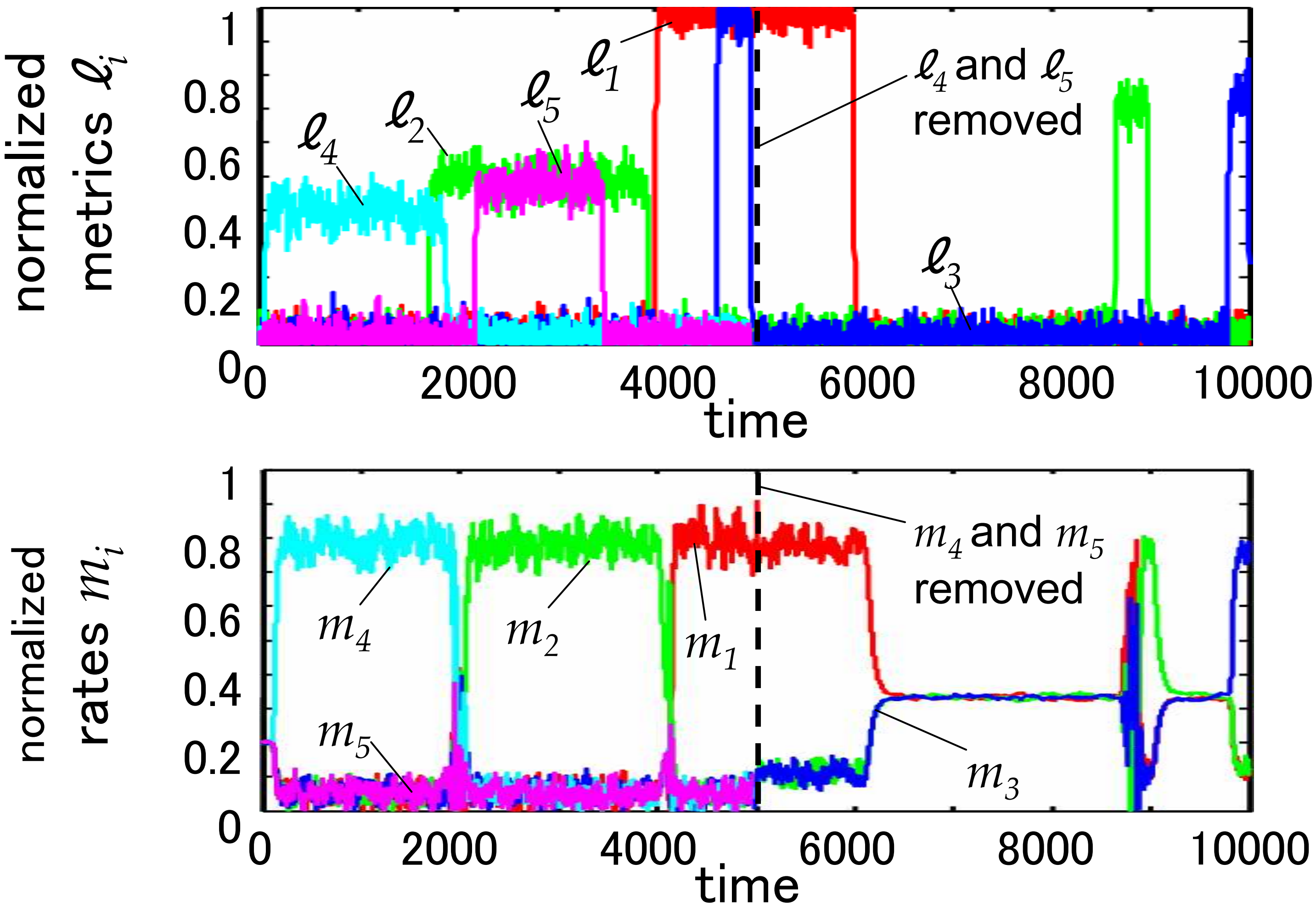
Example for Routing Scenario





Robustness against Path Removal



Conclusion and Outlook

- Path selection scheme based on biological attractor selection model
- Parameters of the model are chosen such that selfishness is reduced
- In the future:
  - different mappings of path metrics
  - symbiosis between interacting flows
  - application to ad-hoc/sensor networks