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# Robust and Adaptive Mobile Ad Hoc Routing with Attractor Selection

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## Outline

- Research background
  - Routing problems in MANETs
  - Weaknesses of existing protocols
- Our protocol (MARAS)
  - Attractor selection mechanism
  - Routing with attractor selection
- Evaluation
- Conclusion

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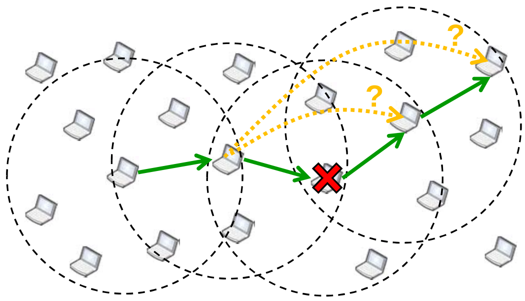
## Routing Problems in MANETs

1. Limited transmission range → multi-hop transmission
2. Limited bandwidth and lifetime → cannot afford high overhead
3. Continuous topology changes (failure, mobility, etc.)



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## Weaknesses of existing protocols

- Proactive routing protocols:
  - Wasting the energy and resources in maintaining all possible routes in the network → high overhead
- Reactive (on-demand) routing protocols:
  - Setting up the route *on-demand* → lower overhead
  - High interference from broadcast control packets
  - High delay in route discovery/recovery
- Hybrid routing protocols:
  - Complex and optimizing effort is required

On-demand robust and adaptive routing protocol with Attractor Selection

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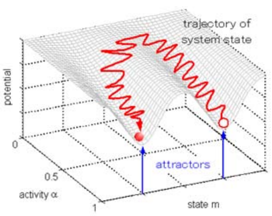
## Attractor Selection Mechanism

- Simple selection using feedback-controlled randomness
- Attractors (solution states) and two key controlling factors
  - Activity $\alpha$: feedback goodness of the current selected state
  - Noise $\eta$: randomness for discovering a better state/attractor
- Biologically-inspired mechanism
  - Adopted from the mechanism of gene expression in cell biology
  - Robust and adaptive against the external influences and noise
- Model

$$\frac{d\vec{m}}{dt} = f(\vec{m}) \times \alpha + \vec{\eta}$$

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## Routing With Attractor Selection

1. Reactive route establishment
   - AODV-like broadcast route discovery
2. Feedback-based route maintenance
   - Feedback packet per each delivered data packet
   - Activity $\alpha$ is calculated based on the travelled hop count of the feedback packet
3. Noise-driven next hop selection
   - Applying attractor selection mechanism

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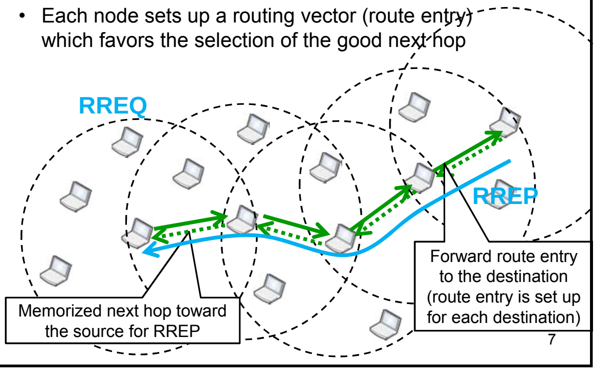
## Reactive route establishment

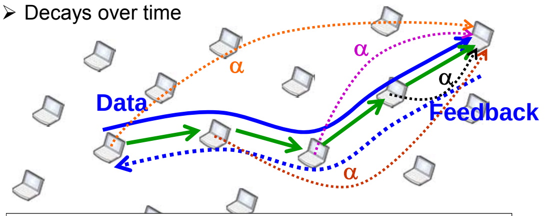
- AODV-like broadcast route discovery
- Each node sets up a routing vector (route entry) which favors the selection of the good next hop






## Feedback-based route maintenance

- Feedback packet per each delivered data packet
- Activity α is calculated based on the travelled hop count of the feedback packet → *re-calculated on feedback arrival*
  - ➢ Ratio of minimum of <u>memorized</u> values to the latest one
  - ➢ Decays over time




**Each intermediate node calculates activity α for the route to the destination via the current selected next hop**



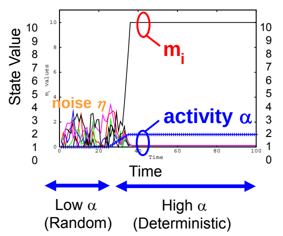
## Noise-driven next hop selection

- Applying attractor selection mechanism

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

where $m_{max} = \max_{j=1,\dots,M}(m_j)$, $d(\alpha) = \alpha$,

$s(\alpha) = \alpha[\beta\alpha^{\gamma} + \varphi^*]$, and $\varphi^* = \frac{1}{\sqrt{2}}$




| Routing vector | |
|---|---|
| $m_1$ | 0.0 |
| $m_2$ | 0.0 |
| $m_3$ | 1.0 |
| $m_4$ | 0.0 |
| $m_5$ | 0.0 |
| $m_6$ | 0.0 |
| $m_7$ | 0.0 |

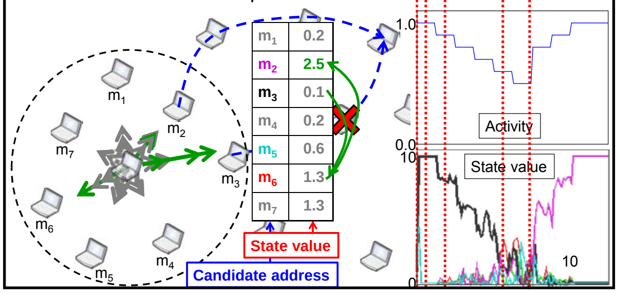
Address with max value is selected as a next hop

Candidate address | State value



## Next Hop Selection Example

- Given that the routing vector is set up by RREP.
- Assume that the link failure occurs and the activity decays. → high value decreases and effect of noise increases
- Noise-driven next hop selection



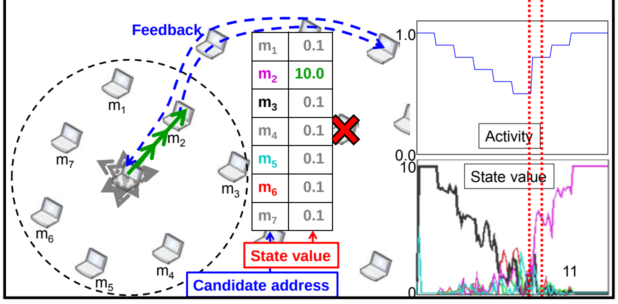

| | |
|---|---|
| $m_1$ | 0.2 |
| $m_2$ | 2.5 |
| $m_3$ | 0.1 |
| $m_4$ | 0.2 |
| $m_5$ | 0.6 |
| $m_6$ | 1.3 |
| $m_7$ | 1.3 |

State value | Candidate address



## Next Hop Selection Example (2)

- When the next hop which improves the system condition is selected, the activity increases.
- As a result, the routing becomes deterministic again.



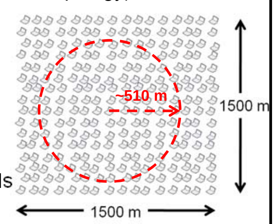

| | |
|---|---|
| $m_1$ | 0.1 |
| $m_2$ | 10.0 |
| $m_3$ | 0.1 |
| $m_4$ | 0.1 |
| $m_5$ | 0.1 |
| $m_6$ | 0.1 |
| $m_7$ | 0.1 |

State value | Candidate address



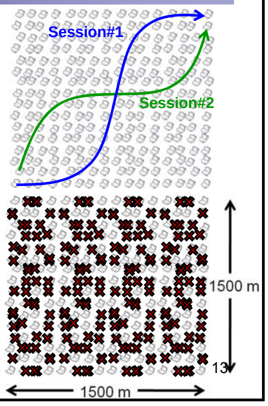
## Evaluation

- Using network simulator QualNet, average from 100 runs
- 256 nodes in 1500x1500 m² (dense topology)
- 802.11b with 2Mbps data rate
- Free-space model without propagation fading
- CBR traffic over UDP 100-byte packet 10 packets/s = 8kbps per session
- Comparison with other protocols
  - AODV: Standard AODV
  - AODV+L: Standard AODV adding local route repair
  - AODV+LI: AODV+L allowing intermediate node's reply
  - AntHocNet: ACO-based ad hoc routing



## Evaluation: Failure Scenario

- Uniform node placement
- Simulation time: 1000 s
- Traffic: 2 sessions
  - 2 pairs of sources and destinations at the corners across the diagonal
- Failure model:
  - In each fault occurrence, randomly selected 25% of all node fail
  - Failure reoccurs every certain interval
  - Fixed simulation time: shorter interval for more failure occurrences

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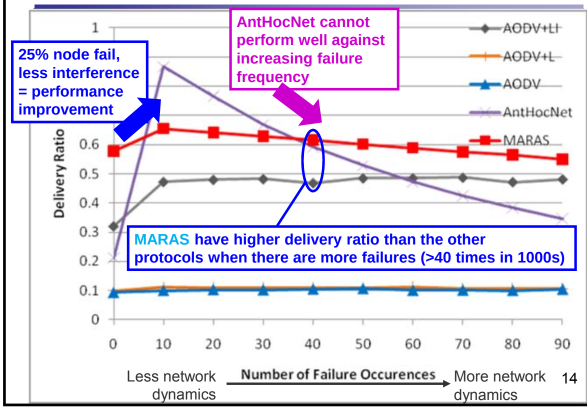
## Failure Scenario: Delivery Ratio

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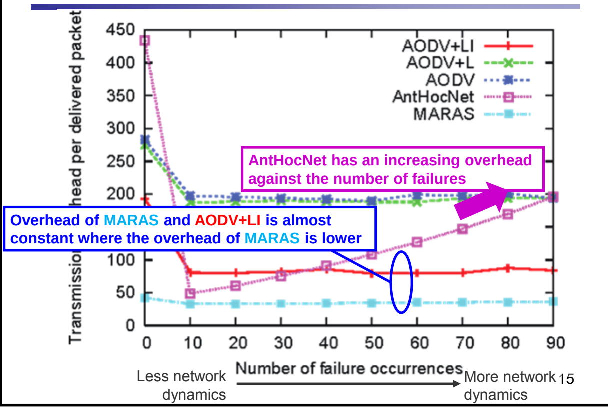
## Failure Scenario: Overhead

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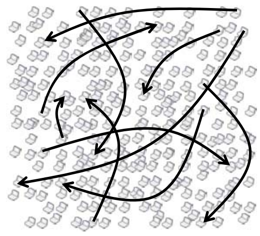
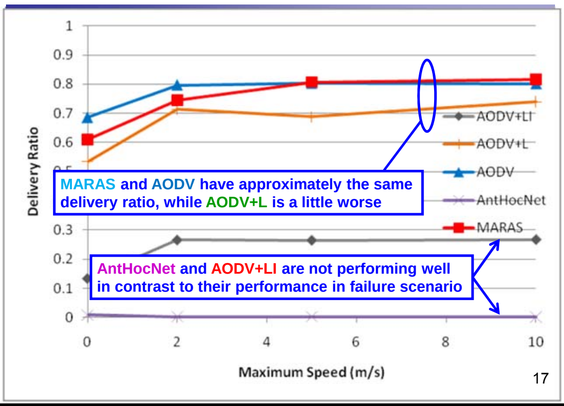
## Evaluation: Mobility Scenario

- Random node placement
- Simulation time: 1000 s
- Traffic: 10 sessions
  - Randomly selected 10 pairs of sources and destinations
- Mobility model:
  - Random waypoint model
  - Pause time: 0 second
  - Minimum speed: 0 m/s
  - Maximum speed: 2,5,10 m/s



## Mobility Scenario: Delivery Ratio

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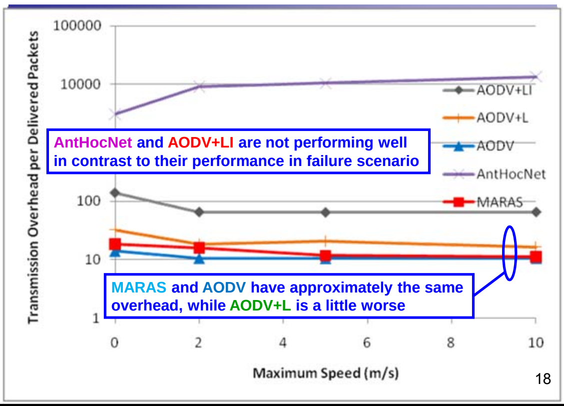
## Mobility Scenario: Overhead

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## Conclusion and Future Work

- Biologically-inspired routing protocol
- Data packet forwarding: the next hop is selected by attractor selection state value (highest value)
- Noise-driven route maintenance by attractor selection and feedback packet
- Robust against network dynamics:
  - Delivery ratio of MARAS is relatively high in both failure and mobility scenarios
- Adaptive over different scenarios:
  - MARAS can maintain a relatively high performance in both scenarios unlike AODV+LI and AntHocNet
- Future work:
  - Investigate effects of parameters



## Thank you for your attention

## Q&A