

An Ant-based Routing Protocol using Unidirectional Links for Heterogeneous Mobile Ad-Hoc Networks

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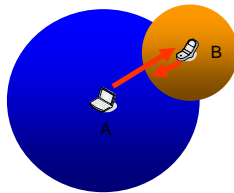
- Background
 - Heterogeneous MANET
 - AntHocNet
- Proposal
 - Detour unidirectional link
 - Detection of link failure
 - Blind retransmission
- Simulation
- Conclusion

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Heterogeneous Mobile Ad-Hoc Networks

- Heterogeneous Mobile Ad-Hoc Networks
 - Mobile ad-hoc network with heterogeneous nodes
 - Unidirectional links due to heterogeneity
- Omission of unidirectional links by Hello messages or BlackListing
 - ↓
- Path establishment fails
- Less number of paths
- Longer paths

Unidirectional Link
A can talk to B,
but A cannot hear B



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Our Proposal

- Using unidirectional links
- Ant-based
 - Higher success ratio
 - Higher robustness
 - Shorter paths
 - More scalable
 - More paths
 - More adaptive

ISSUES

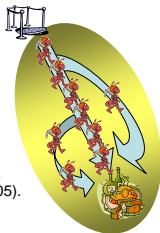
Path establishment
Detection of link failures
Transmission of packets

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AntHocNet

- A routing algorithm adopting foraging behavior of ants (Ants autonomously establish the shortest path)
 - Reactive path establishment
- + Proactive path management and improvement
 - Multi-path
 - Probabilistic packet forwarding

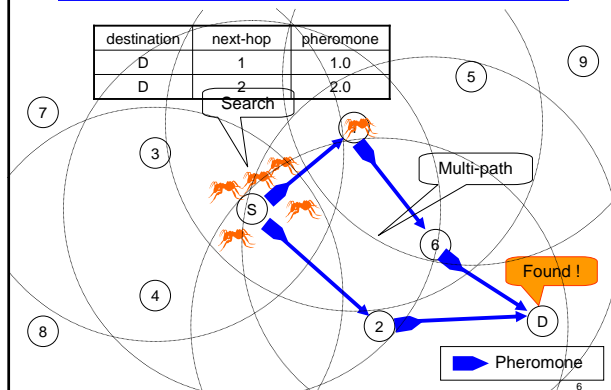
- F. Ducatelle, G. D. Caro and L. M. Gambardella, "Ant Agents for Hybrid Multipath Routing in Mobile Ad Hoc Networks," in Proceedings of the Second Annual Conference on Wireless On demand Network Systems and Services (WONS 2005), pp. 44–53 (2005).



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Basic Behavior of AntHocNet

destination	next-hop	pheromone
D	1	1.0
D	2	2.0



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Reactive Path Establishment

- Reactive Forward Ant
 - Generated by source node on application's request
 - On intermediate nodes, follows routing information if exists, otherwise broadcasts

$$P_{nd} = \frac{(T_{nd}^i)^{\beta_1}}{\sum_{j \in N_{nd}^i} (T_{nd}^j)^{\beta_1}}, \quad \beta_1 \geq 1$$

- Records intermediate nodes traversed in list P
- Discard a redundant Reactive Forward Ant which
 - Reaches predetermined TTL
 - Takes a longer path

$$n_i \leq a_1 \min_{j < i} (n_j) \& t_i \leq a_1 \min_{j < i} (t_j), \quad 0 < a_1 < 1$$

If the first hop is different, $a_1 < a_2$ is applied instead

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Reactive Path Establishment

- Backward Ant
 - Generated for a reactive forward ant at destination
 - Visits all nodes in list P in a reverse direction
 - Updates pheromone value on node $i \in P$

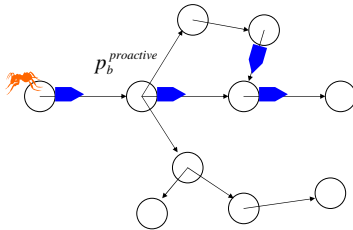
$$\tau_d^i = \left(\frac{\hat{T}_d^i + hT_{hop}}{2} \right)^{-1}$$

$$T_{nd}^i = \gamma T_{nd}^i + (1 - \gamma) \tau_d^i, \quad 0 < \gamma < 1$$

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Proactive Path Maintenance

- Proactive Forward Ant
 - Generated per $n^{proactive}$ data packets
 - Moves toward destination following pheromones
 - Broadcasts at probability to find a better path $p_b^{proactive}$ up to $n_b^{proactive}$ times



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Probabilistic Packet Forwarding

- Chooses next-hop node based on pheromones

$$P_{nd} = \frac{(T_{nd}^i)^{\beta_2}}{\sum_{j \in N_{nd}^i} (T_{nd}^j)^{\beta_2}}, \quad \beta_2 \geq \beta_1 \geq 1$$

- A path with more pheromones is likely to be chosen
- A path with less pheromones is sometimes chosen

destination	next-hop	pheromone
D	1	1.0
D	2	2.0

$$P_{1D} = \frac{1^2}{1^2 + 2^2} = 0.2, \quad P_{2D} = \frac{2^2}{1^2 + 2^2} = 0.8$$

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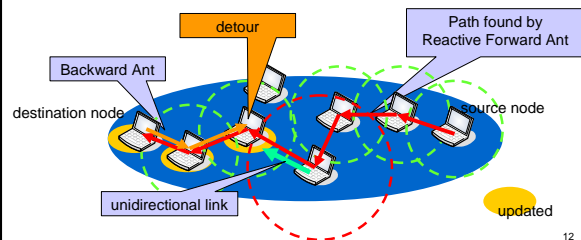
Proposed Protocol based on AntHocNet

- Establish a path with unidirectional links
 - Detour unidirectional links by Backward Ant
- Detection of link failures
 - Timeout mechanism using Proactive Forward Ant
- Packet forwarding over unidirectional links
 - Blind retransmission mechanism

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A Path with a Unidirectional Link

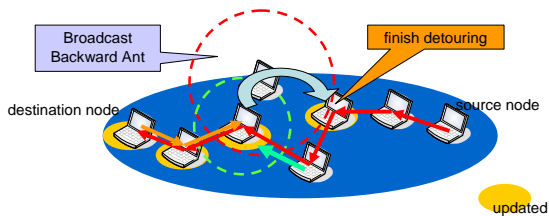
- Backward Ant cannot traverse the path in a reverse direction => **DETOUR**



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Detour a Unidirectional Link

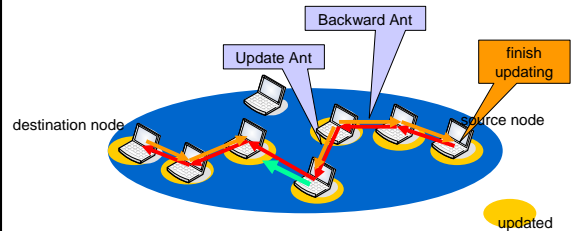
- Broadcast Backward Ant
 - Detours a unidirectional link by broadcasting up to n_b^{detour}
 - Stops broadcasting on reaching an unvisited node in list P



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Update Routing Tables

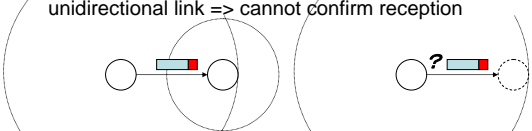
- Update Ant
 - Updates routing tables on skipped nodes
- Backward Ant
 - Continues updating nodes toward the source



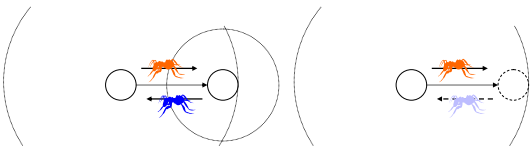
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Detection of Link Failures

- Packets are forwarded by broadcasting on a unidirectional link => cannot confirm reception



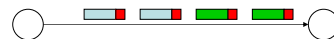
- Detects link failures by missing Backward Ant



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Blind Retransmission

- Bidirectional Link
 - Packet forwarding is confirmed by ACK
- Unidirectional Link
 - ACK cannot be received by a sender
- Blind Retransmission
 - Sends the same data packet twice blindly
 - One is discarded if both are received



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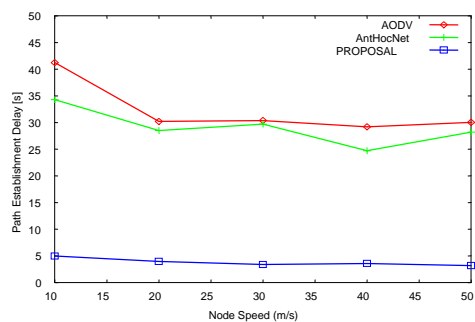
Simulation Experiments

- Area: 1800mX600m
- Nodes: 100
- Range: 300m-30nodes, 150m-40nodes, 100m-30nodes
- Random Waypoint Model
- 802.11b DCF (11Mbps)
- Traffic: CBR 64 B/s (512 b/s)
- Measures
 - Path establishment delay
 - Delivery ratio of data packets
 - End-to-end packet delay
 - Control overhead per data packet
- Comparison: AntHocNet, AODV

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Path Establishment Delay

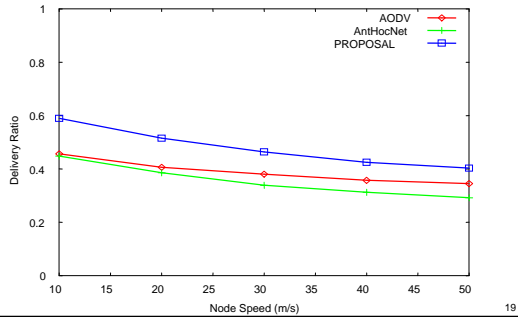
- Paths are established faster by using unidirectional links
- 1.25 paths on average



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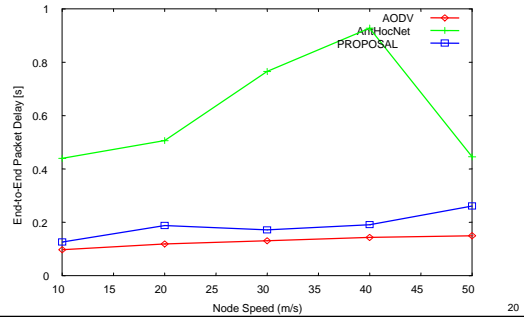
Delivery Ratio

- Higher delivery ratio due to faster path establishment



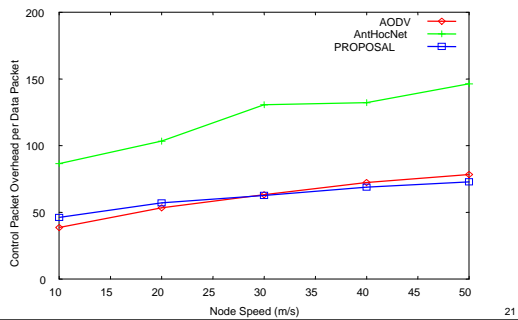
End-to-end Packet Delay

- Multi-path routing leads to slightly longer packet delay for using longer paths



Control Overhead per Data Packet

- Comparable to AODV



Conclusion

- By using unidirectional links
 - Faster path establishment
 - Higher packet delivery ratio
 - Small packet delay (as AODV)
 - Small overhead (as AODV)
- Future works
 - More efficient detouring
 - Quantitative evaluation of the protocol in terms of scalability, robustness, and adaptiveness

Questions?