Integrating DTN and MANET Routing

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(slides from ACM CHANTS workshop)

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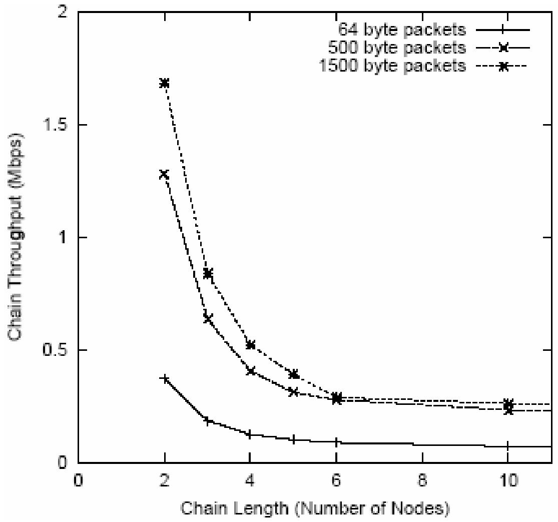
Motivation: Ad-hoc Networking for Human Users

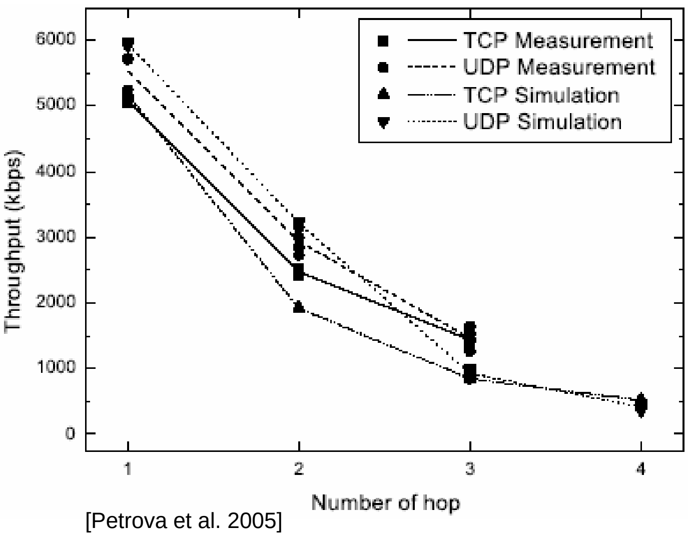
- Target field: interpersonal communication and Internet access
- Node density in environments without controlled deployment will often be sparse
  - Heterogeneity of consumer devices: different brands, versions, capabilities
  - Also: users may not want to cooperate
  - An end-to-end path may exist—but often will not
  - Calls for asynchronous communications: DTN
- User experience benefits from immediate end-to-end interactions
  - Users have grown expectations over time
  - Application protocols designed in this way anyway
  - Anything but end-to-end may only be second best
  - Yet better than not communicating at all

Motivation: Limitations in End-to-End Performance

- Communication performance degrades with increasing number of wireless hops in ad-hoc networks



[Li et al. 2001]



[Petrova et al. 2005]

- Path stability decreases with distance depending on mobility

Approach: Integrating DTN and AODV

- Let the application (and ultimately the user) decide
- Provide an interface to learn about the ad-hoc environment
  - Rather than completely abstracting from (i.e., hiding) it

- Combine AODV route search with DTN node location
  - Return available end-to-end route + path length
  - Return available DTN nodes in the vicinity + path lengths

- Application then chooses whether to use synchronous end-to-end or asynchronous hop-by-hop (DTN) communication
  - Example: Simply use DTN as fallback if end-to-end fails
  - Example: Path length, expected performance and stability vs. data volume

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  - Example: Simply use DTN as fallback if end-to-end fails
  - Example: Path length, expected performance and stability vs. data volume

<u>Applicability Statement:</u>

No, this does not work with existing applications

<u>But:</u>

Existing applications don’t work well with mobility anyway.

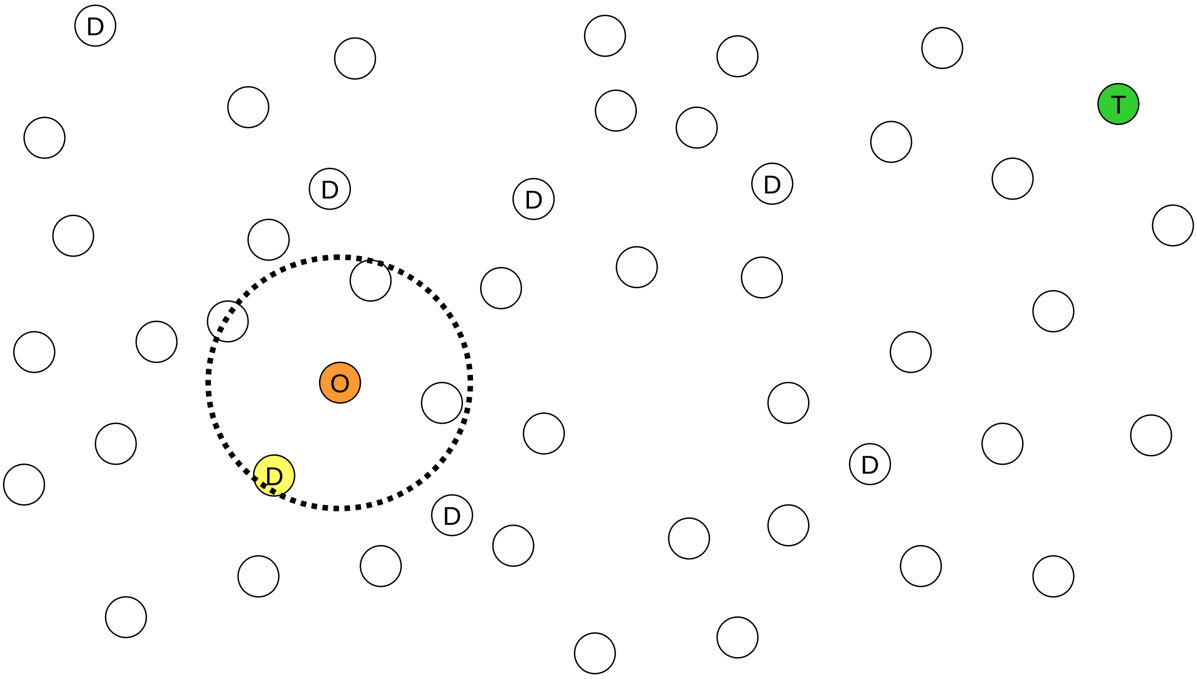
<u>Solutions:</u>

Short-term: use proxies as interim means for migration.

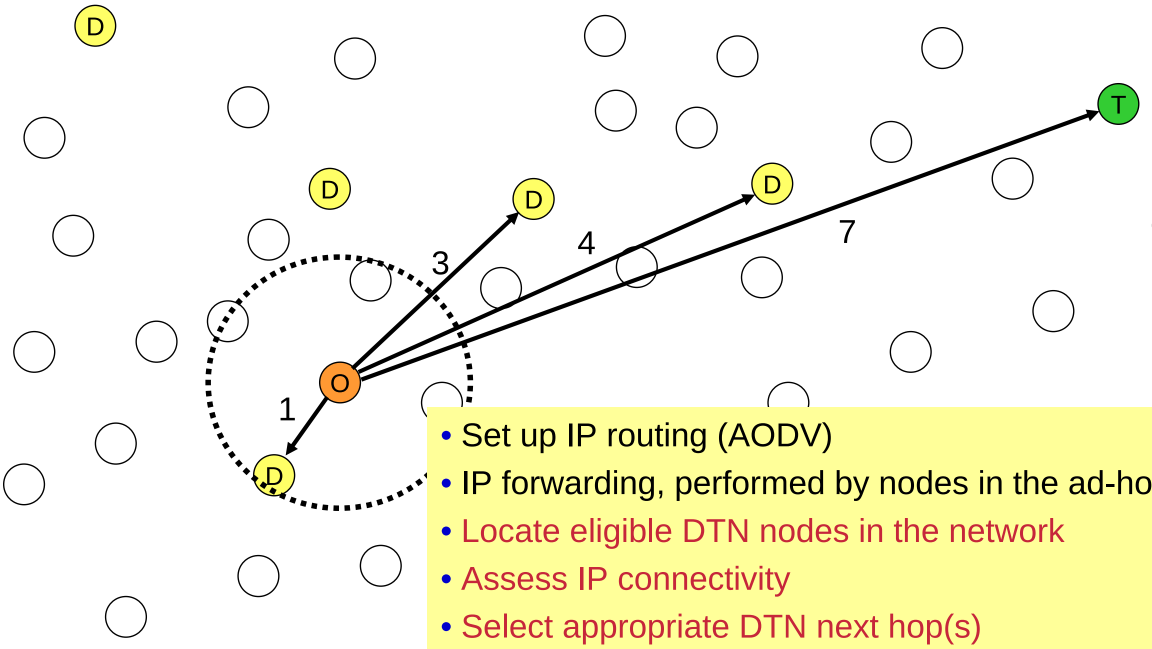
Long-term: design application protocols in a more suitable way.

Special Application: DTN routers

Required Functions



Required Functions



- Set up IP routing (AODV)
- IP forwarding, performed by nodes in the ad-hoc network
- Locate eligible DTN nodes in the network
- Assess IP connectivity
- Select appropriate DTN next hop(s)
- General DTN routing
- DTN forwarding

AODV Extensions

- Additional attributes in RREQ and RREP packets
  - Indicate extension support
  - Report DTN node contact info
- Optional
  - Convey source, target EID
  - Include routing metrics
- Modified processing and timer handling rules
- Workable with plain AODV nodes

a) DTN router info + optional metric

<table>
<tr><th colspan="2">0 7</th><th colspan="2">8 15</th><th colspan="2">16 31</th></tr>
<tr><td colspan="2">Type = 29</td><td colspan="2">Length</td><td colspan="2">DTN router port</td></tr>
<tr><td colspan="6">DTN router IP address</td></tr>
<tr><td>T</td><td>Hop count</td><td colspan="2">Option EID</td><td>EID len</td><td></td></tr>
<tr><td colspan="6">DTN router EID</td></tr>
<tr><td colspan="2">Option Metric</td><td>D</td><td>Metric len</td><td colspan="2"></td></tr>
<tr><td colspan="6">DTN Routing Metric</td></tr>
</table>

b) Optional DTN EID

<table>
<tr><th>0 7</th><th>8 15</th><th>16 31</th></tr>
<tr><td>Type = 30/31</td><td>Length</td><td></td></tr>
<tr><td colspan="3">DTN source or target EID</td></tr>
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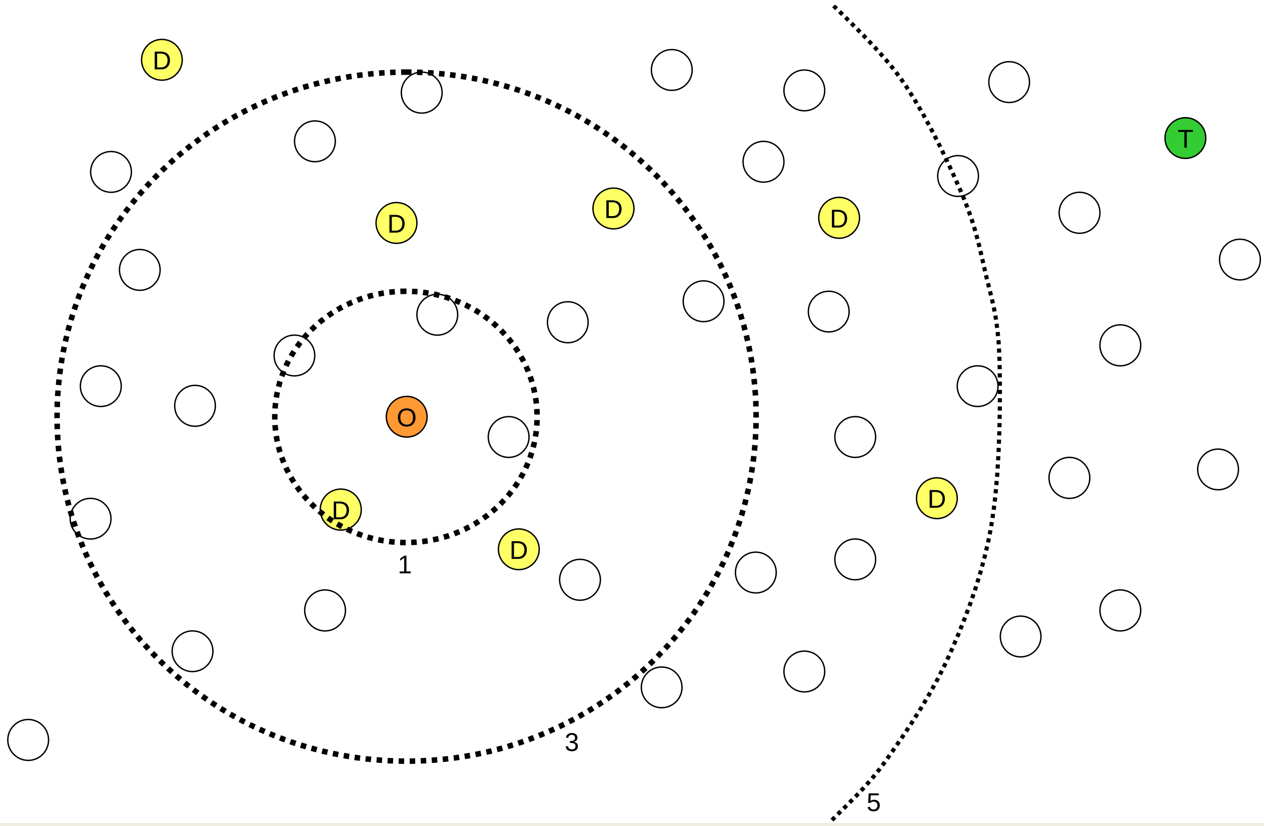
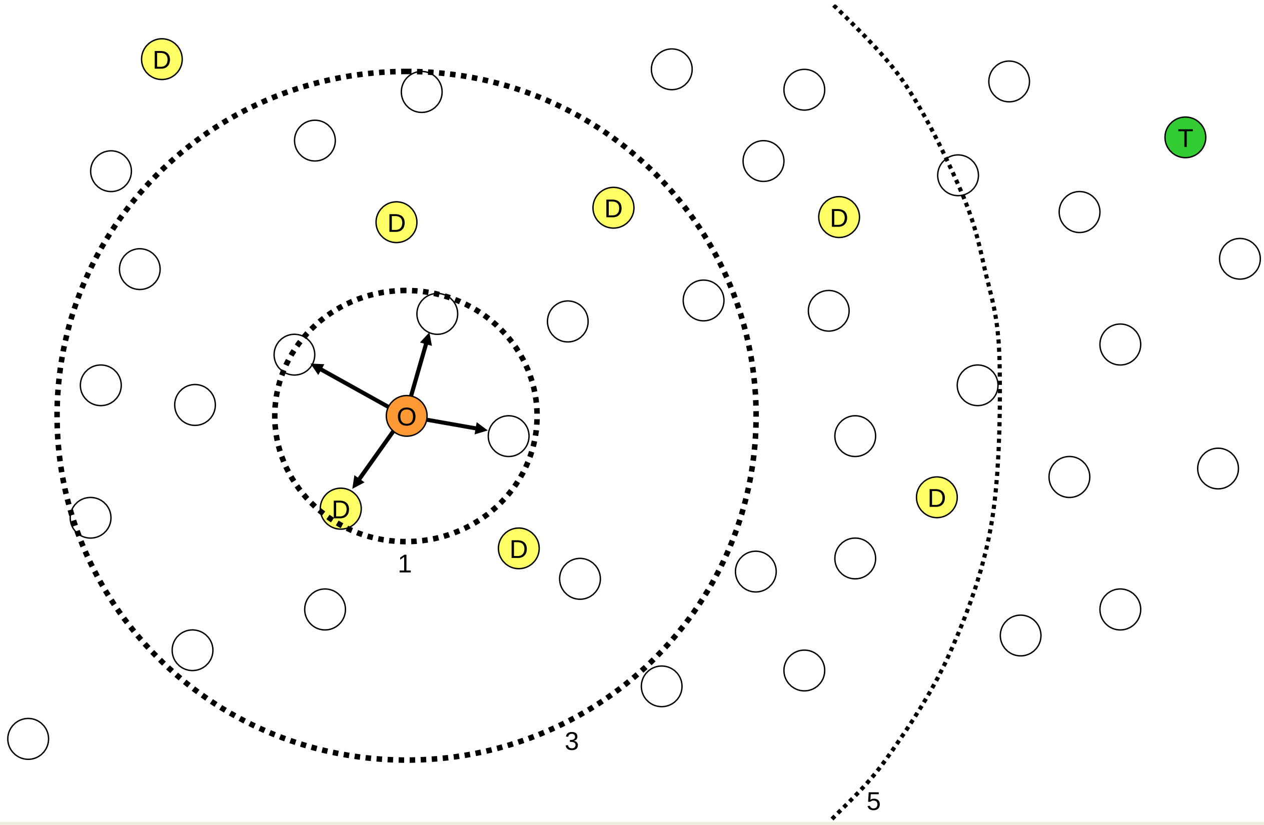
Extended AODV Operation



Extended AODV Operation (TTL 1)



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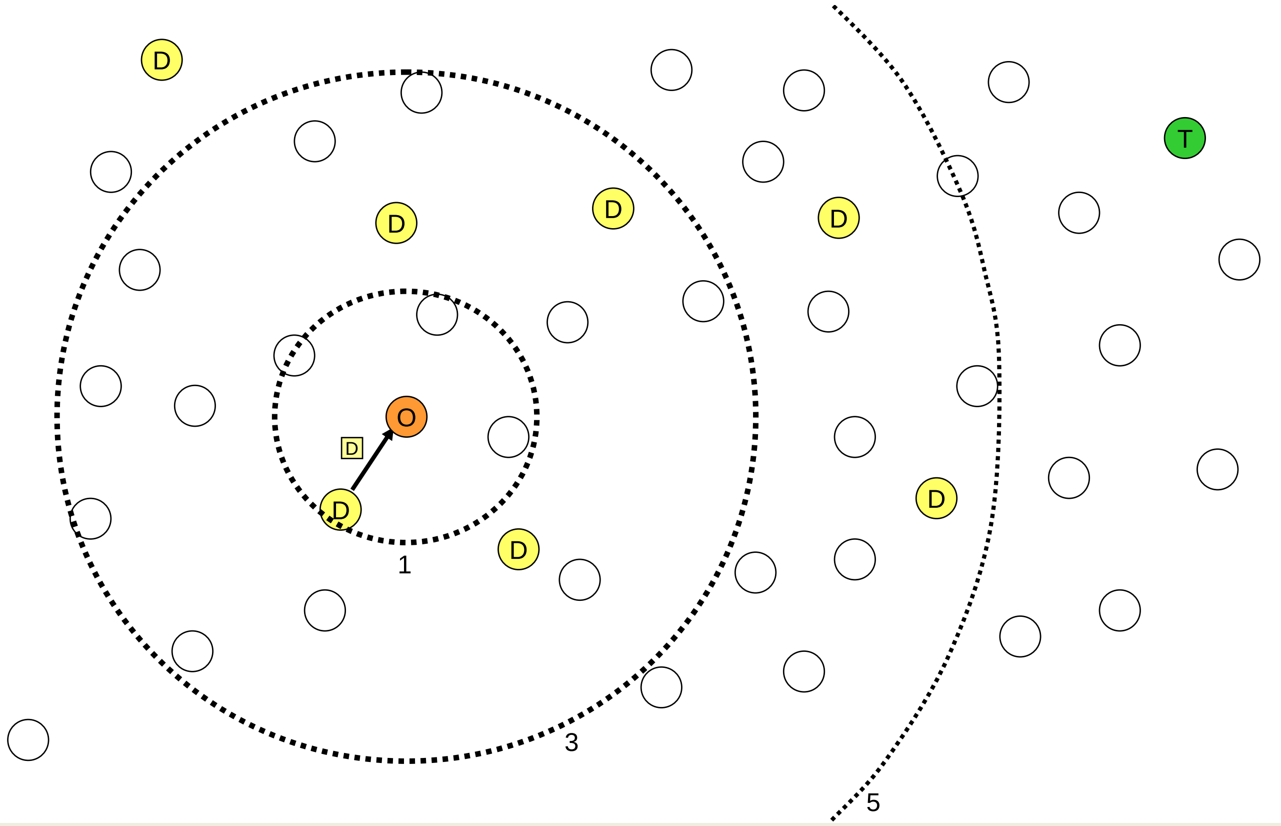
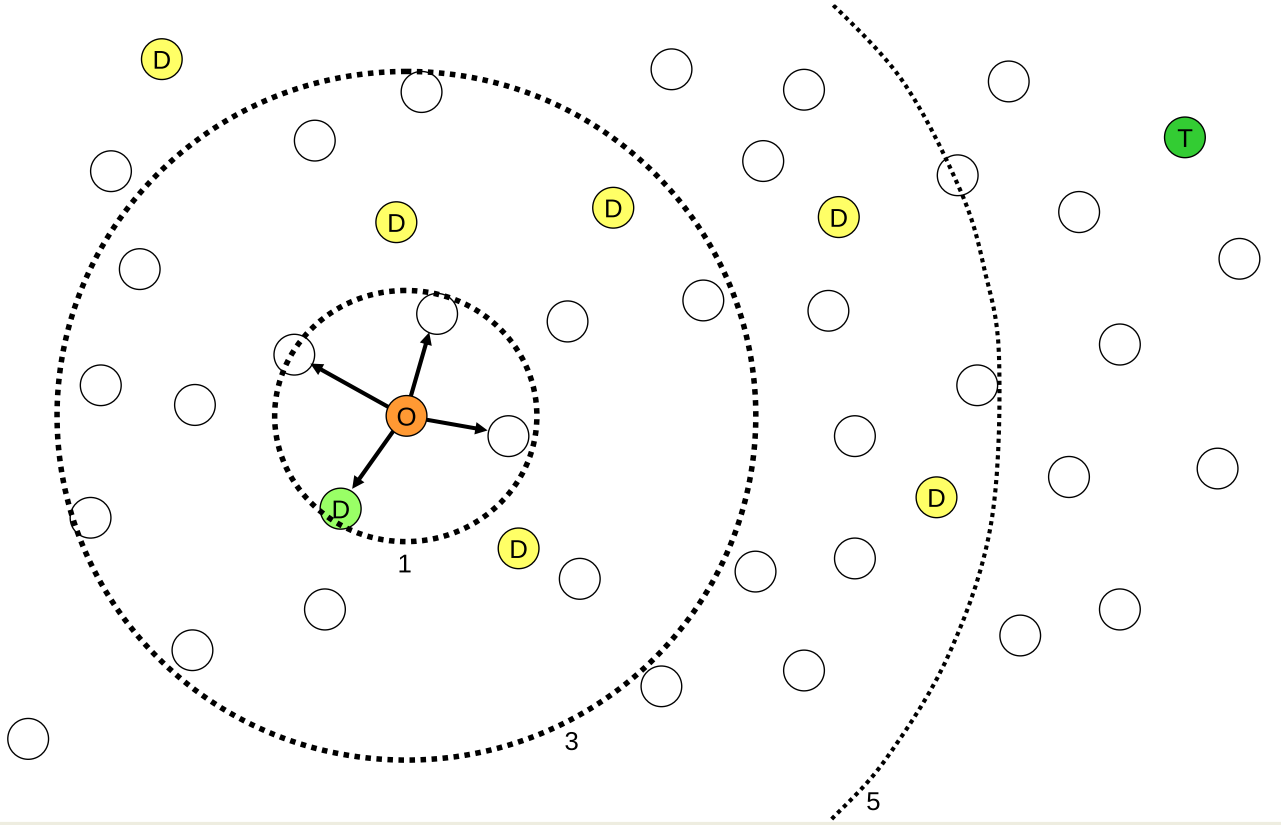


Extended AODV Operation (TTL 3)



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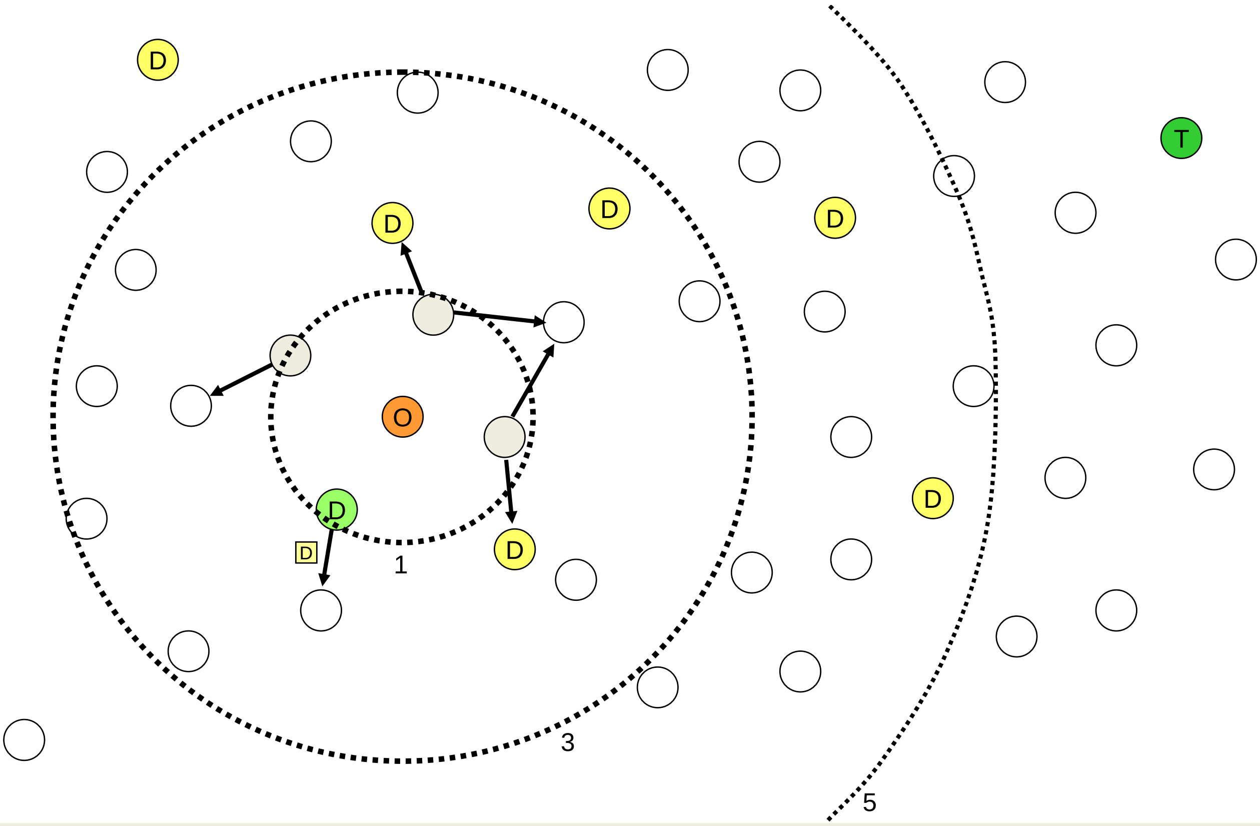

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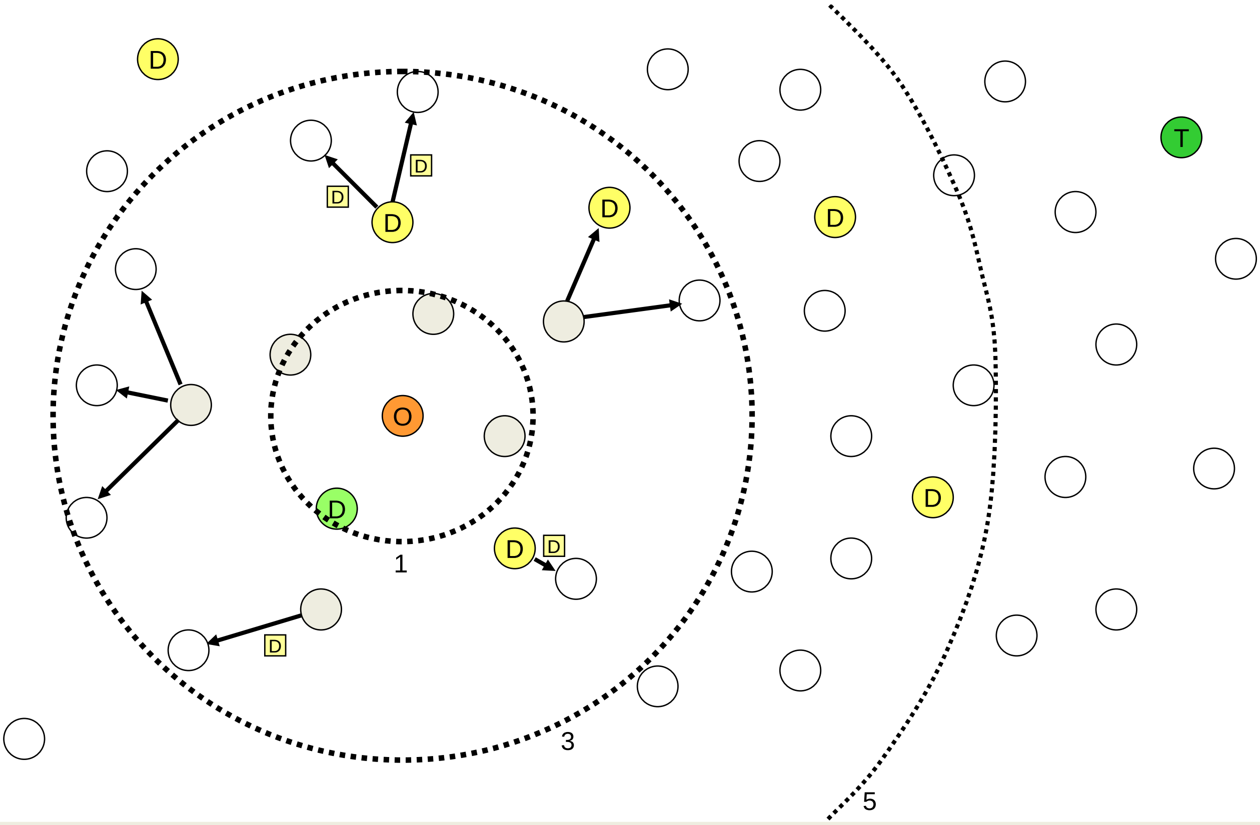

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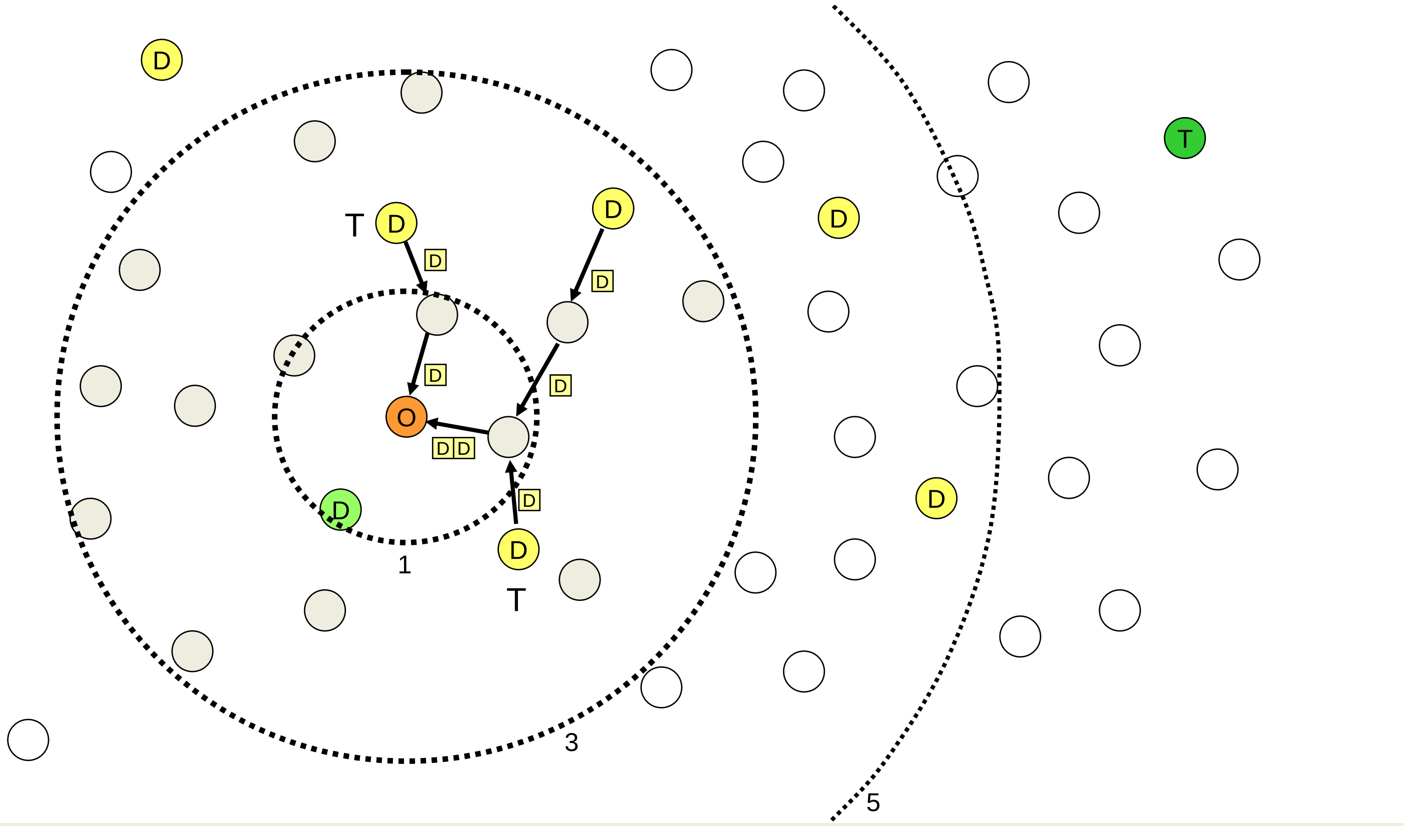

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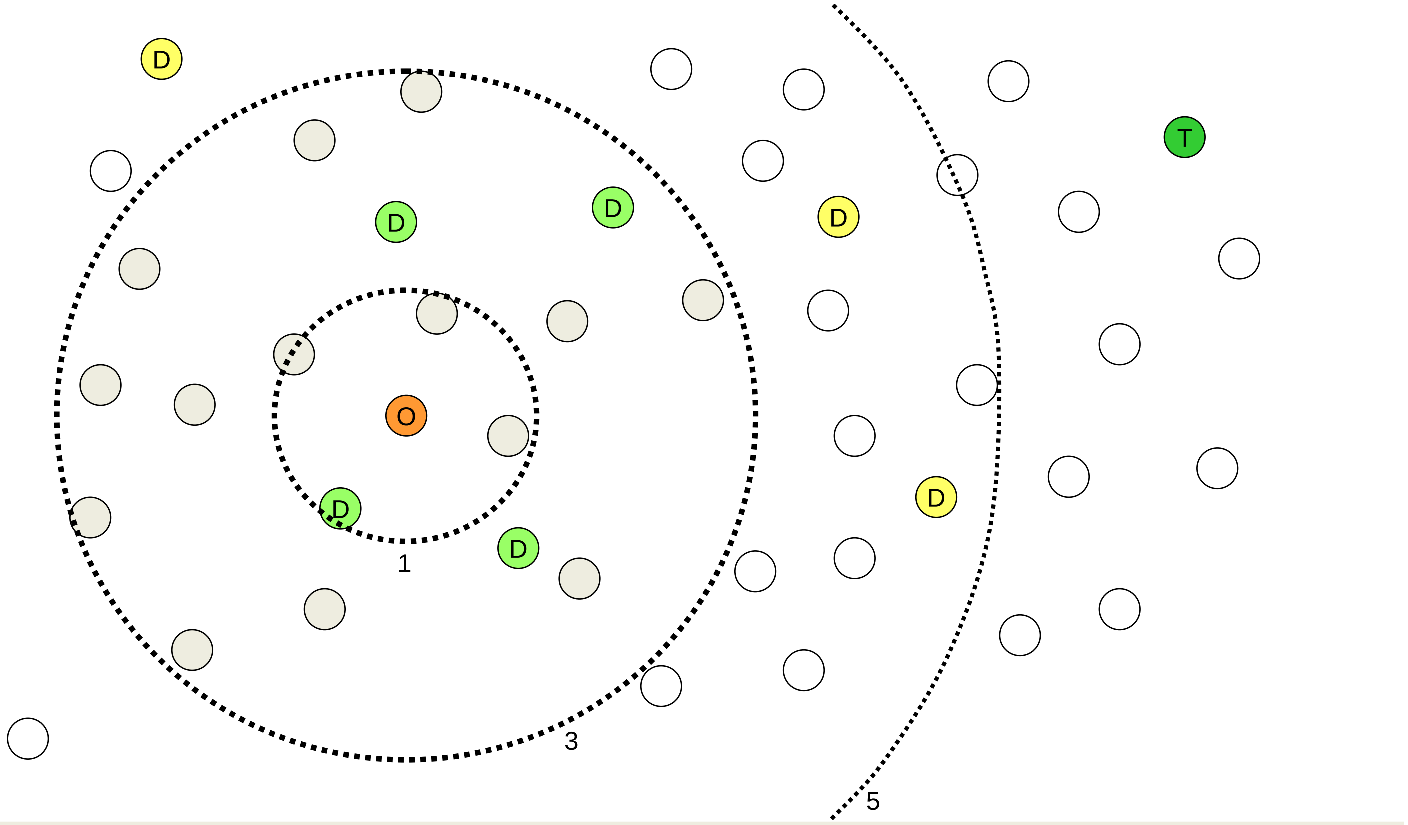
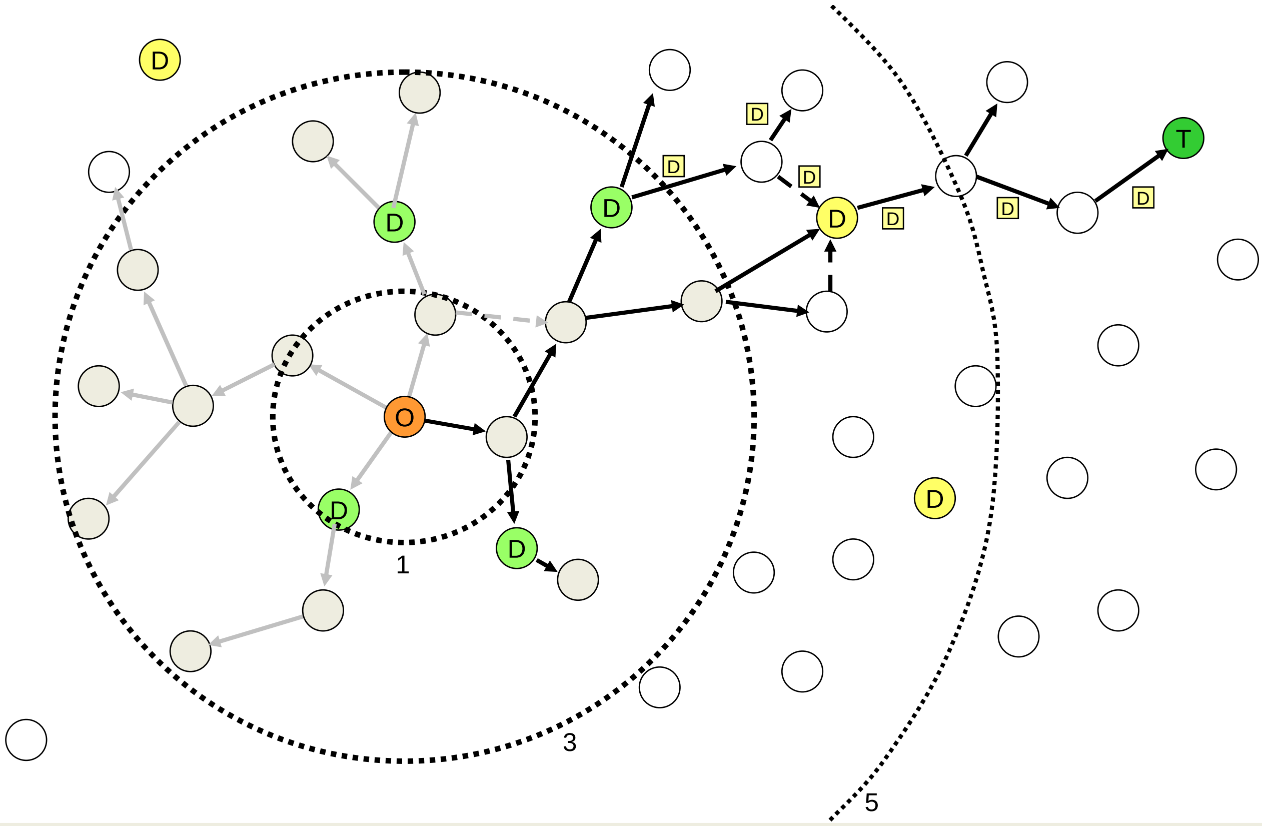


Extended AODV Operation (TTL 7)



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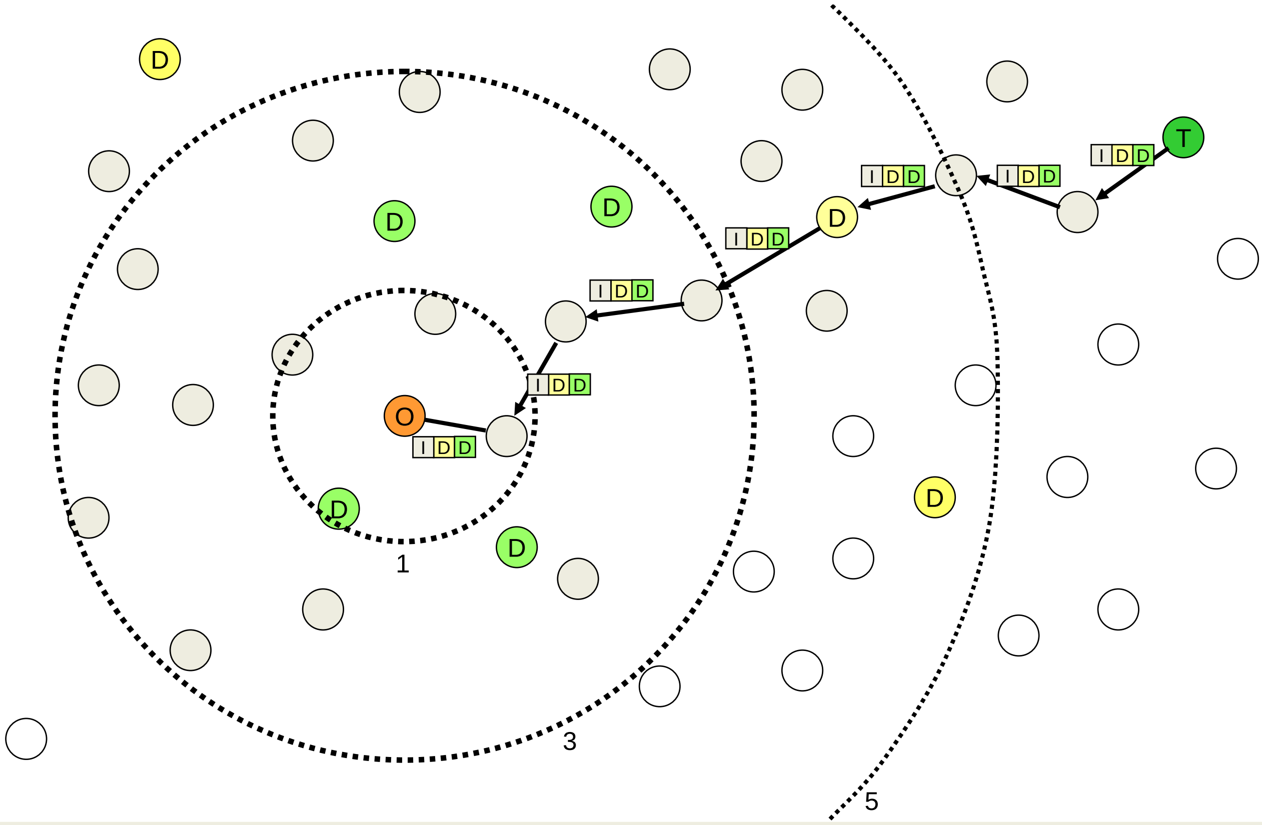

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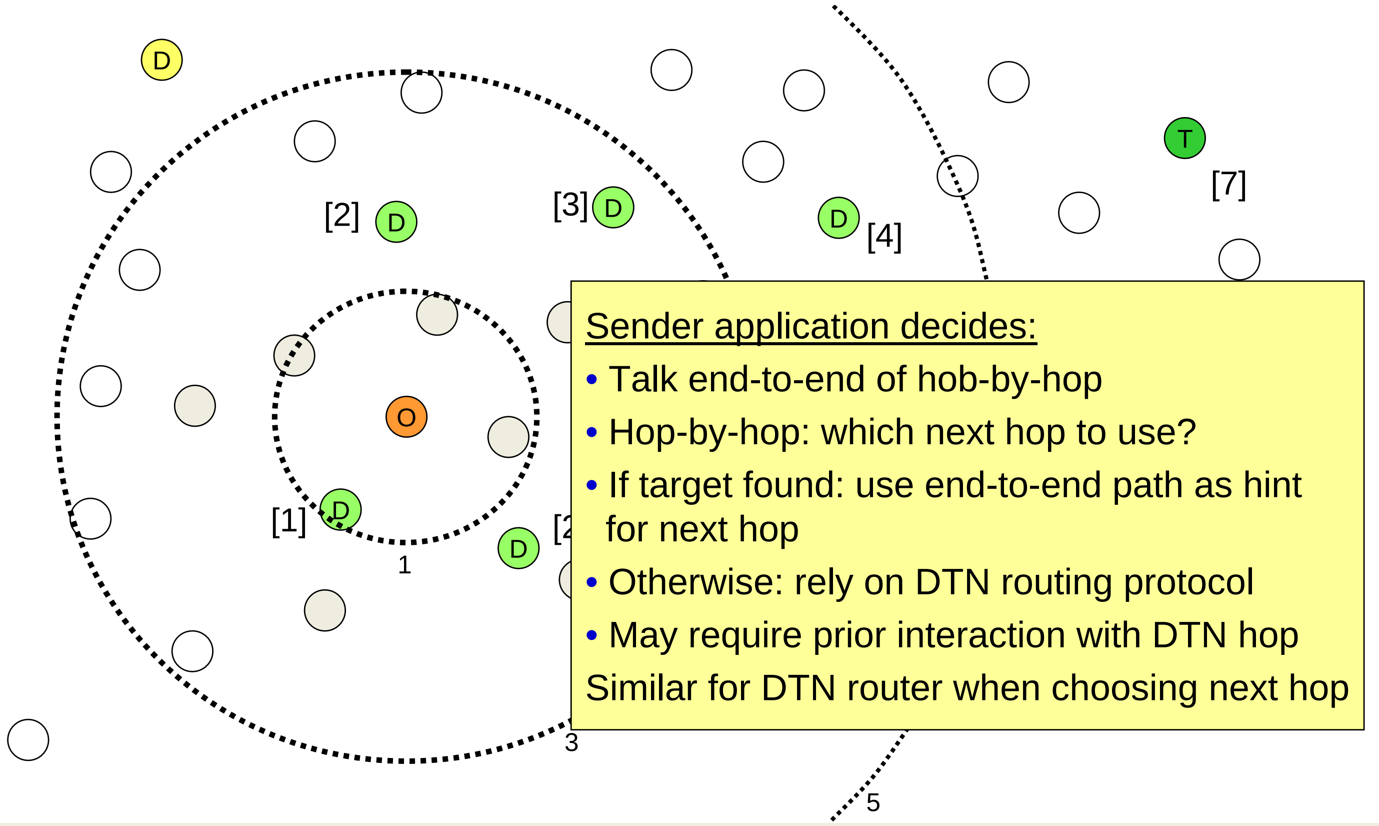


<u>Sender application decides:</u>

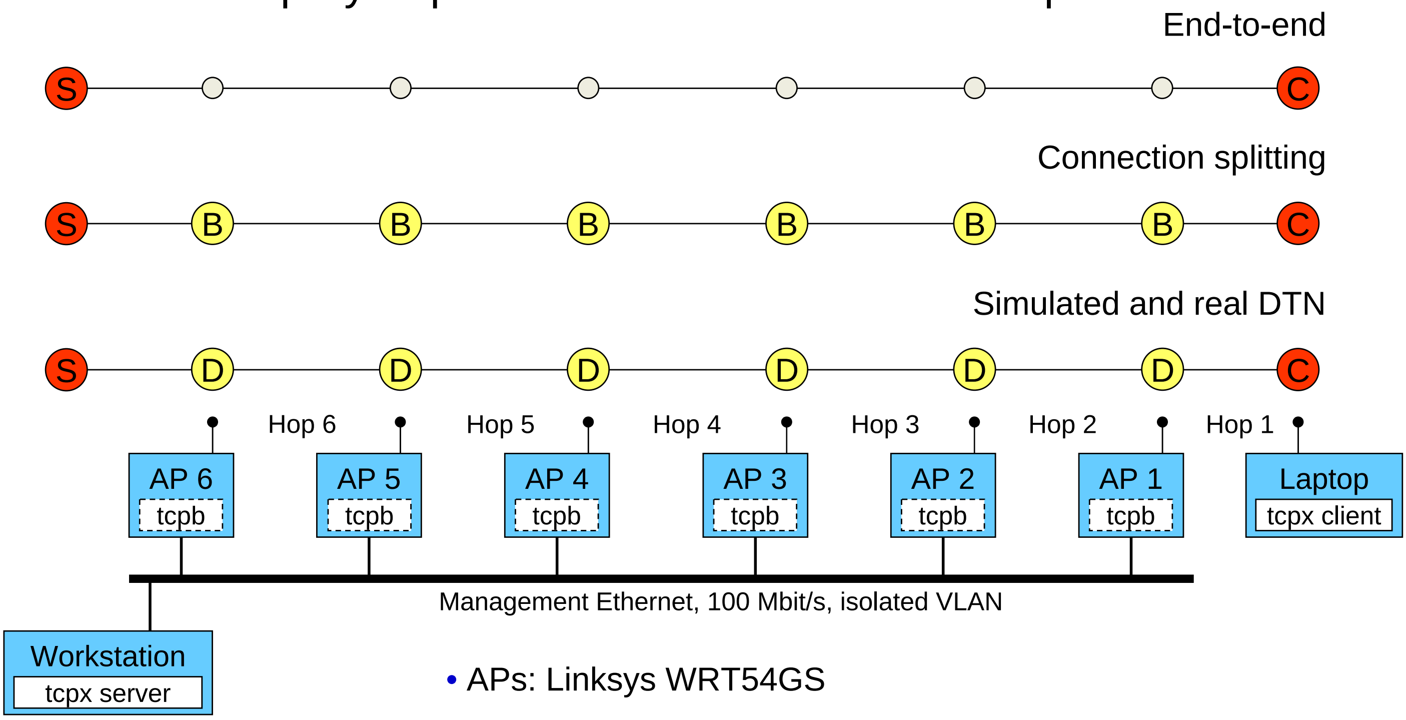
- Talk end-to-end of hob-by-hop
- Hop-by-hop: which next hop to use?
- If target found: use end-to-end path as hint for next hop
- Otherwise: rely on DTN routing protocol
- May require prior interaction with DTN hop

Similar for DTN router when choosing next hop

Performance Observations

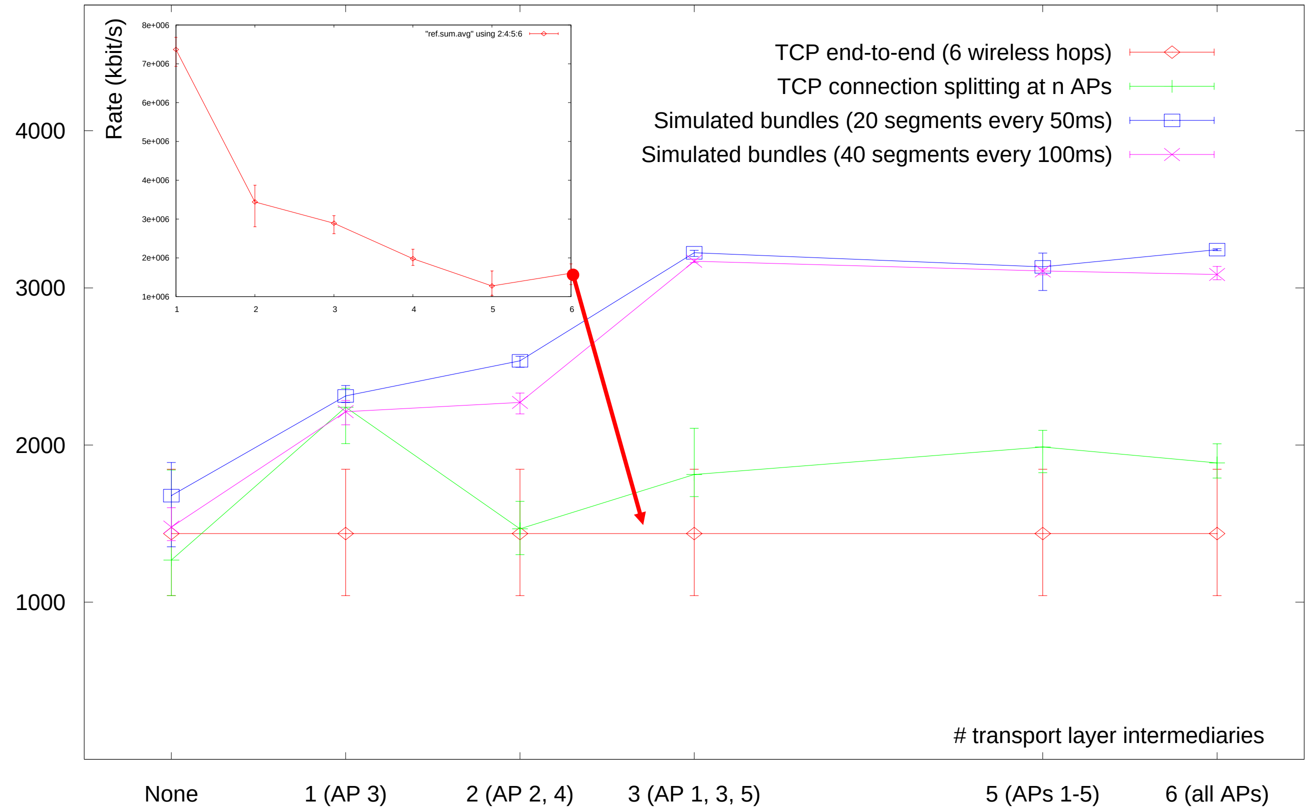
Measurements (1)

- Part 1: Hop-by-hop vs. end-to-end in a static setup

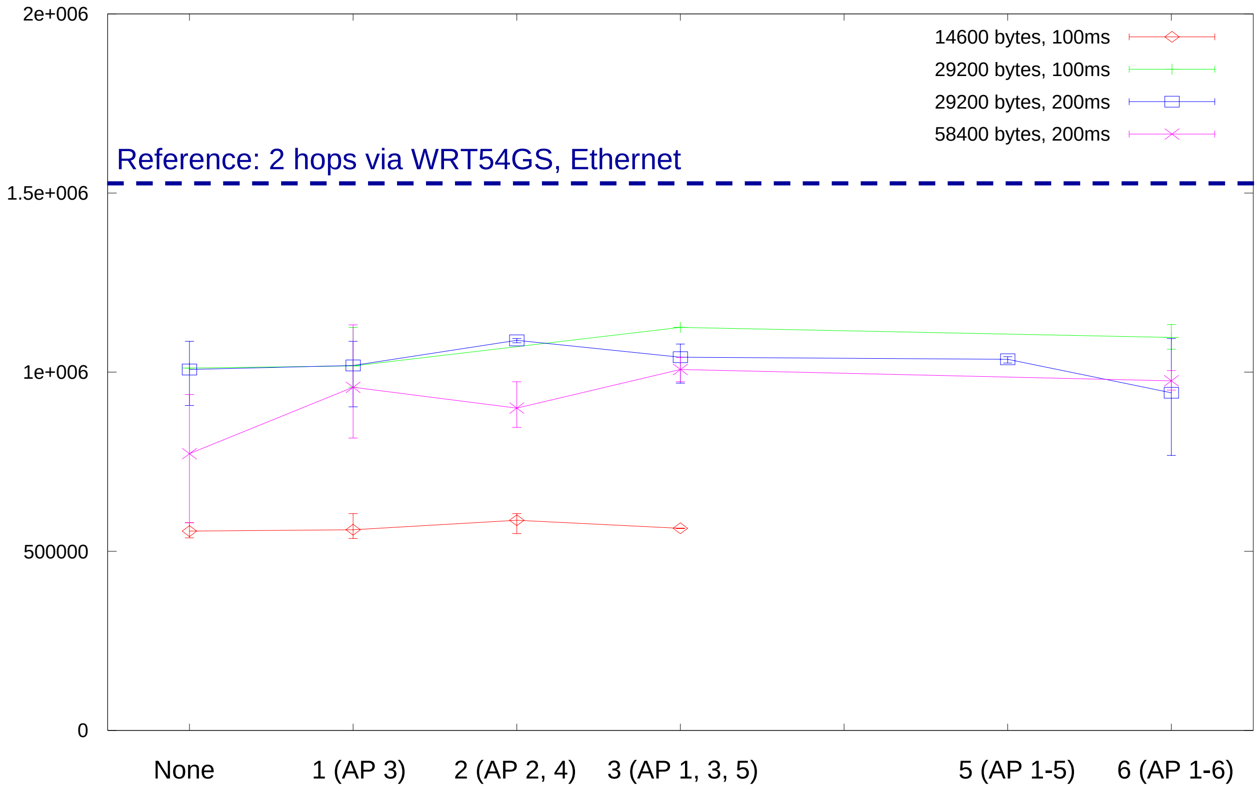


- APs: Linksys WRT54GS

Results (1.1)



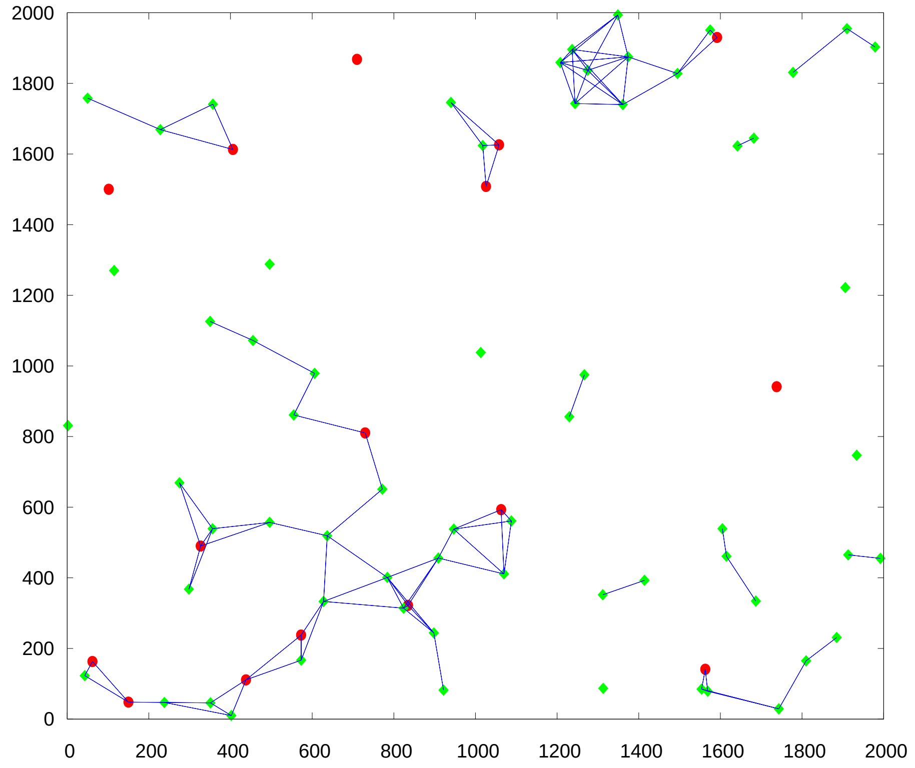
Results (1.2): dtnd



Measurements (2)

- Emulation environment
  - Dedicated emulation machine: 2 x Intel dual core @ 3.7 GHz (16 GB RAM)
  - Xen 3.0 (unstable) for up to 100 virtual machines (32 MB memory each)
  - Debian 2.6.16.13
  - AODV UU from Uppsala University + AODV extensions implemented
  - ns-2 + nsemulation patch to simulate motion + wireless connectivity
  - tcpdump
- AODV Extension Overhead
  - Repeated ping from one node to another
  - 2000m x 2000m area, 200m wireless communication range, 0…5 m/s
  - 20, 40, 80 nodes
  - 0, 5, 10, 20, 50, 100% of which support DTN
  - Compare against plain AODV overhead

Measurements (2)



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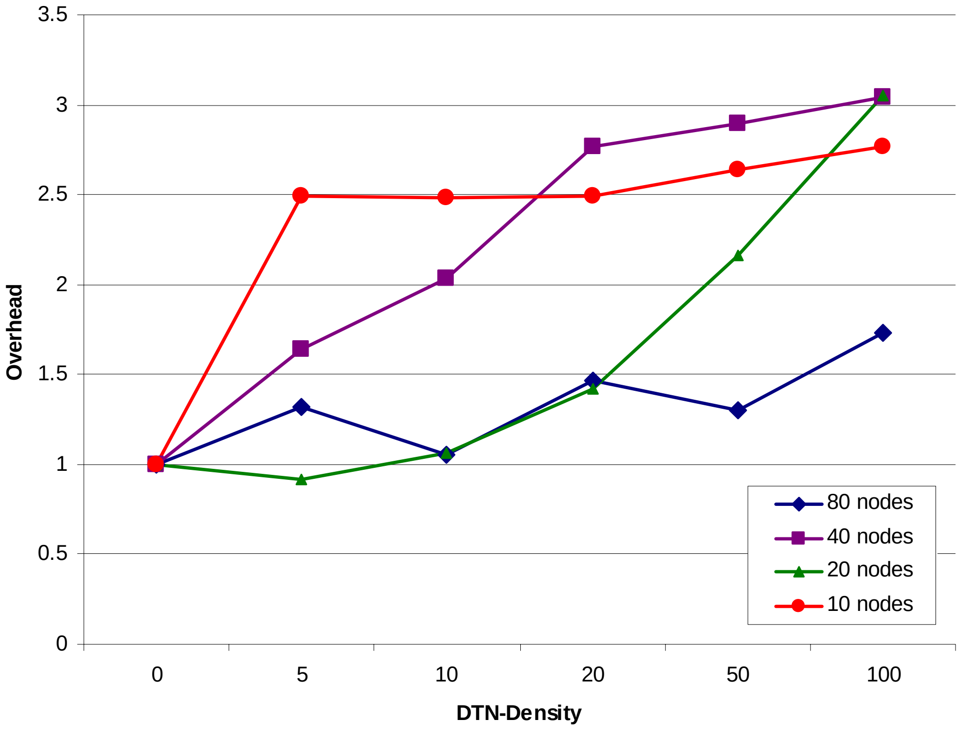
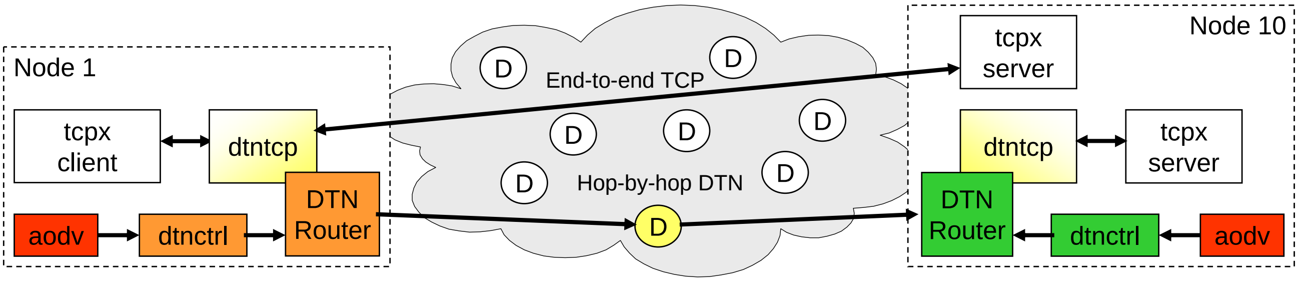


Measurement (3)

- dtnd from the DTN reference implementation (Intel, UC Berkeley)
- tcpx + dtntcp
  - Send via plain TCP end-to-end whenever a path exists upon transfer initiation
  - Otherwise fall back to DTN
- Initial tests with chain of 10 nodes and on/off links
- Proof of concept emulations
  - 2000m x 600m area, 10 nodes: random walk, 0…20m/s, 29200 bytes every 150s
  - Hack: n > m routing
  - Transmission from node 1 to node 10 in regular intervals
  - DTN augmented TCP-based delivery well in most cases with only 5min lifetimes



Discussion: API and Applications

- Current approach: implicit signaling (e.g., TCP connect())
  - Little chance to communicate EIDs
  - Approach limited to locating DTN routers
  - Cumbersome retrieval of “search results”
    - Correlation may be tricky
    - How long to wait? (TCP timeout? …?)
    - Protocol-dependent feedback does not work with all protocols
- Better: dedicated API for explicit control
  - Trigger route search independently
  - Allow providing and retrieving parameters as needed
  - Current thoughts: interfacing through dtnd vs. bypassing dtnd
- Applications need to be adapted for mobility anyway

Discussion: Routing Integration

- Simple case: just find DTN routers
  - Implicit service location
- Advanced case: learn about DTN route metrics
  - Data volume + processing overhead vs. improved routing decisions
- How much subsequent handshaking is needed?
  - Mutual authentication (which may decide about accepting a bundle)
  - Possible other reasons for not accepting a bundle
  - How much information can and should we convey *before*?
    - Taking into account that AODV is expensive
  - How will DTN routing protocols work in ad-hoc environments?
- How to embed routing hints in DTN bundles?
  - (and processing/queuing hints for the local DTN router)

Conclusion and Next Steps

- AODV extensions enables route search to locate DTN routers
  - Re-using a reactive routing protocol as opposed to separate service location
  - Insights into requirements for underlying routing protocols
- Allows applications to make e2e vs. hop-by-hop tradeoffs
- Allows DTN routers to discover peers beyond next hop
- Allows DTN routers to forward packets instead of bundles
- DTN-based communication may outperform end-to-end TCP

Next steps:

- Interaction with emerging DTN routing protocols
- Performance tradeoffs in different MANET environments
- API, applications and policies
- Internet Draft describing all the details