Wireless networks

Routing: DYMO
AODV-DSR: Comparison

- Many studies in the literature
- **DSR**
  - Allows multiple routes
  - Supports unidirectional links
  - Overheards and caches routing info
- **AODV**
  - Does not require long hop lists
  - Supports multicast
  - Hallo messages to check connectivity
AODV-DSR: Comparison (2)

- **With low traffic and low mobility**
  - Both have an acceptable end-to-end delay, and small routing overhead (control packets)

- **With high mobility, high traffic**
  - AODV has an higher routing due to control packets:
    - routes become congested and need to be rediscovered
    - Hallo messages create collisions and interfere with slow start protocols (eg TCP)
  - DSR pays for multiple routes
    - With high mobility it is difficult to make sensible choices
    - Promiscuous overheard, aggressive caching and quick reaction to changes can make routes unstable
AODV-DSR: Comparison (bib)

• Johnson et al

• Nordstrom et al
Dynamic MANET On Demand Routing (DYMO)

• Draft RFC Feb 2011 IETF-MANET working group
• Proposed by Perkins & Chackeres
• Merges features of DSR and AODV
• Goals:
  – Simplify AODV
  – Use more information (accumulates routes as DSR)
DYMO: assumptions

• Same as AODV

• Cooperative nodes:
  – All nodes want to participate fully in the network protocol and \textit{will forward packets for other nodes}

• Bidirectional symmetric links
  – A node which has received a packet from a neighbor is able to route it back to the sender using the same link
DYMO: assumptions (2)

• **Corrupted packets**
  – A corrupted packet can be recognized and discarded by its destination

• **Mobile nodes**
  – Nodes in the network may move at any time without notice.
DYMO

• Similar to AODV
  – Route Discovery and Route Maintainance work in similar way
  – Uses same sequence numbers to prevent loops
  – Do NOT use Hallo packets
• Takes some ideas from DSR
  – RREQ and RREP messages carry information on all intermediate nodes
  – They are used to create Routing Table entries for all intermediate nodes (not only for Source and Destination as in AODV)
DYMO: RREQ RREP

• include informations about traversed nodes
  – Each node: (1) appends itself to the route
  – and (2) updates its RT with the route collected so far creating/updating entries for all intermediate nodes
DYMO: Routing Table

• An entry in RT includes
  – **Destination address and sequence number:** IP address and sequence number of the destination associated with this entry
  – **Prefix:** Indicates that the associated address is a network address, rather than a network address
  – **Next-hop address and interface:** IP address of next hop in route and interface used to send packets
An entry in RT includes (contd.)

- **Route forwarding**: set to TRUE if the route can be used for forwarding messages
- **Route broken**: set to TRUE if the next-hop becomes unreachable or in response to an RERR packet
- **Route Dist**: number of hops to the destination along this route (optional field)
DYMO: RT timers

- Every RT entry can have a number of timers
  - `ROUTE_AGE_MIN`: minimum time a RT entry should be kept
  - `ROUTE_SEQNUM_AGE_MAX`: time after which sequence number in the RT entry should be discarded (to avoid too old info)
  - `ROUTE_USED`: every time a route is used this timer is set to `ROUTE_USED_TIMEOUT`
  - `ROUTE_DELETE`: this is set to `ROUTE_DELETE_TIMEOUT` for a broken route, after it expires the route entry is removed
DYMO: Sequence numbers

• Used as in AODV

• Incremented when:
  – A source node generates a new RREQ
  – A destination node answers to an RREQ with a RREP
  – An intermediate node adds its information in an routing packet

• Complex interactions with timers and Route.dist and Route.broken to avoid loops in routing
DYMO: Sequence numbers (2)

• When a node is rebooted it must not set its sequence number to 0
  – This could produce loops due to old RT entry with positive sequence numbers

• Thus sequence numbers should be kept in persistent memory (if possible)
  – If a sequence number is lost node should wait for ROUTE_DELETE_TIMEOUT before fully participating to DYMO. In this period the node can only handle control messages but it cannot forward packets (it generates only RERR packets)
AODV: RREQ Example

**RREQ**

```
RREQ =
Dest : 7
Dest Seq Num : 180
Orig : 1
Orig Seq Num : 206
Hop Count : 0
```

**Table entry** = <Dest,Next,Metric,Seq>

S

1

2

3

<1,9,5,204>

D

4

5

6

<7,6,2,182>

7

183
AODV: RREQ Example (2)

\[\text{RREQ} = \begin{aligned}
\text{Dest} : \text{7} \\
\text{Dest Seq Num} : \text{180} \\
\text{Orig} : \text{1} \\
\text{Orig Seq Num} : \text{206} \\
\text{Hop Count} : \text{1}
\end{aligned}\]

Table entry = <Dest,Next,Metric,Seq>
AODV: RREQ Example (3)

RREQ =
- Dest: 7
- Dest Seq Num: 180
- Orig: 1
- Orig Seq Num: 206
- Hop Count: 2

Table entry = <Dest, Next, Metric, Seq>

3 aggiorna info per 1

5 puo' rispondere alla RREQ
AODV: RREQ Example (4)

1. **RREQ** = 
   - Dest: 7
   - Dest Seq Num: 180
   - Orig: 1
   - Orig Seq Num: 206
   - Hop Count: 2

2. **Table entry** = <Dest, Next, Metric, Seq>

   - Dest: 7
   - Next: 1
   - Metric: 1
   - Seq: 180

3. 3 aggiorna info per 1

4. 5 puo' rispondere alla RREQ

   - Dest: 7
   - Next: 5
   - Metric: 1
   - Seq: 180

5. **Table entry** = <Dest, Next, Metric, Seq>

   - Dest: 7
   - Next: 5
   - Metric: 1
   - Seq: 180

6. RREQ per 6

7. RREQ per 7
AODV: RREP Example

RREP-1 =
- Dest: 7
- Dest Seq Num: 184
- Orig: 1
- Hop Count: 0

RREP-2 =
- Dest: 7
- Dest Seq Num: 182
- Orig: 1
- Hop Count: 2
AODV: RREP Example (2)

RREP-1 =
Dest : 7
Dest Seq Num : 184
Orig : 1
Hop Count : 1

RREP-2 =
Dest : 7
Dest Seq Num : 182
Orig : 1
Hop Count : 3
AODV: RREP Example (3)

RREP-1 =
Dest : 7
Dest Seq Num : 184
Orig : 1
Hop Count : 2
DYMO: RREQ Example

RREQ =

Dest: 7
Dest Seq Num: 180
Orig: 1
Orig Seq Num: 206
Hop Count: 0

Table entry = <Dest, Next, Metric, Seq>

<1,9,5,204>
<7,6,2,182>
DYMO: RREQ Example (2)

Table entry = <Dest, Next, Metric, Seq>

RREQ =

Dest : 7
Dest Seq Num : 180
Orig : 1
Orig Seq Num : 206
Hop Count : 1
DYMO: RREQ Example (3)

RREQ =
Dest : 7
Dest Seq Num : 180
Orig : 1
Orig Seq Num : 206
Hop Count : 2

Table entry = <Dest,Next,Metric,Seq>

5 puo' rispondere alla RREQ
DYMO: RREQ Example (4)

RREQ =
- Dest: 7
- Dest Seq Num: 180
- Orig: 1
- Orig Seq Num: 206
- Hop Count: 2

Table entry = <Dest, Next, Metric, Seq>

Dest: 7,
Next: 103,
Metric: 2,
Seq: 2,103

Dest: 3,
Next: 193,
Metric: 3,
Seq: 3,193

5 puo' rispondere alla RREQ
DYMO: RREP Example

RREP-1

Node 1: 103
Node 2: 206
Node 3: 193
Node 4: 23
Node 5: 117
Node 6: 117
Node 7: 184

RREP-2

Dest: 7
Dest Seq Num: 182
Orig: 1
Hop Count: 0

3,193 – 2,103

Dest: 7
Dest Seq Num: 182
Orig: 1
Hop Count: 2

5,117 – 4,23
DYMO: RREP Example (2)

RREP-1 =
Dest : 7
Dest Seq Num : 184
Orig : 1
Hop Count : 1
3,193 – 2,103

RREP-2 =
Dest : 7
Dest Seq Num : 182
Orig : 1
Hop Count : 3
5,117 – 4,23
DYMO: RREP Example (3)

RREP-1 =

Dest : 7
Dest Seq Num : 184
Orig : 1
Hop Count : 2

3,193 – 2,103
DYMO: message header

- Conform to RFC 5444 Generalized MANET Packet Message Format
- Format still under discussion
DYMO: address block

- Addresses are built concatenating “head:tail”
  - Head: 192, 168, 42
  - Originator Tail: 50
  - Target Tail: 51
  - IP Originator: 192.168.42.50
  - IP Target: 192.168.42.51
DYMO: TLV block

- associates attributes with addresses (seq numbers, hop counts etc)
## AODV/DSR vs DYMO

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>DYMO</th>
<th>AODV</th>
<th>DSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of generated packets</td>
<td>3757</td>
<td>3700</td>
<td>3777</td>
</tr>
<tr>
<td>Number of sent packets</td>
<td>3619</td>
<td>3561</td>
<td>3605</td>
</tr>
<tr>
<td>Number of forwarded packets</td>
<td>470</td>
<td>482</td>
<td>509</td>
</tr>
<tr>
<td>Number of dropped packets</td>
<td>140</td>
<td>148</td>
<td>220</td>
</tr>
<tr>
<td>Number of lost packets</td>
<td>610</td>
<td>781</td>
<td>776</td>
</tr>
<tr>
<td>Minimal packet size</td>
<td>24</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Maximal packet size</td>
<td>1072</td>
<td>1072</td>
<td>1104</td>
</tr>
<tr>
<td>Average packet size</td>
<td>282.8582</td>
<td>297.8778</td>
<td>288.7804</td>
</tr>
<tr>
<td>Packets dropping nodes</td>
<td>0 1 2 3 4 5</td>
<td>0 3 5</td>
<td>0 1 2 3 4 5</td>
</tr>
<tr>
<td>Minimal delay (CN, ON, PID)</td>
<td>0.000640471(0,1,340)</td>
<td>0.000640471(0,1,0)</td>
<td>0.000640472(5,-1,0)</td>
</tr>
<tr>
<td>Maximal delay (CN, ON, PID)</td>
<td>1.001006484(0,-1,0)</td>
<td>2.271632516(0,5,62)</td>
<td>6.084161062(0,5,98)</td>
</tr>
<tr>
<td>Average delay</td>
<td>0.02780103516</td>
<td>0.04171916814</td>
<td>0.04842961264</td>
</tr>
</tbody>
</table>
AODV/DYMO path discovery
AODV/DYMO packet length

![Graph showing the relationship between the average packet length and the number of nodes. The graph compares two protocols, AODV and DYMO, with the average packet length on the y-axis and the number of nodes on the x-axis. The graph indicates that as the number of nodes increases, the average packet length also increases for both protocols, with DYMO showing a slightly higher average packet length compared to AODV.]
DYMO: References

[Draft DYMO]
I.D. Chakeres C.E. Perkins. *Dynamic MANET On-Demand (DYMO) Routing*. Internet Draft Mobile Ad Hoc Networks Working Group

draft-ietf-manet-dymo-21 2011

[Perkins Royer Gwalani 2003]

[Kum et al 2010]
D-W Kum et al *Performance evaluation of AODV and DYMO routing protocols in MANET* IEEE CNCC 2010