Route Repair in Mobile Adhoc Networks

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Guide
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Route Repair in Mobile Adhoc Networks

Mobile Adhoc Networks

- Characteristics
  - Cooperative engagement of Mobile Hosts
  - No pre-existing communication infrastructure
  - Multihop Network
  - Bandwidth and Power constrained
  - Military and Disaster relief operations

- Routing Protocols
  - Proactive: DSDV
  - Reactive: AODV, DSR
  - Hybrid: Kelpi
**Adhoc On Demand Routing Protocol (AODV)**

- **RREQ**: Route Request
- **RREP**: Route Reply
- **RERR**: Route Error
Route Repair in Mobile Adhoc Networks

**Route Repair in Reactive Routing Protocols**

- Flag an error and re-initiate route discovery
- Routing overhead
  - Result of error broadcasts followed by flooding in the route discovery phase
- Delay
  - Inability to find alternative route without re-initiating route discovery
Route Repair in Mobile Adhoc Networks

Problem Statement

Find an effective technique to reduce routing overhead and delay during route repair in Mobile Adhoc Networks.
Local Route Repair (LRR)

- Initiates Route discovery at the intermediate node.
- Success
  - sends a RERR message to the source with the 'N' flag set.
- Failure
  - sends a RERR message to the source and re-initiates route discovery at the source
• Proactive approach

• Find a node in the neighborhood to take the task of routing packets routed through a link which is about to break

• HREQ : Handoff Request

• HREP : Handoff Reply
### Packet Format of HREQ and HREP

<table>
<thead>
<tr>
<th>Type</th>
<th>Reserved</th>
<th>Hop Count</th>
<th>Broadcast ID</th>
<th>IP address of the Node</th>
<th>Unreachable Next Hop (UNH) IP address</th>
<th>Active Previous Hop (APH) address</th>
<th>IP address of the destination which uses UNP and receives packet from APH</th>
<th>IP address of the Active Previous Hop in HREQ that sends pkt dst 1</th>
<th>IP address of the Active Previous Hop in HREQ that sends pkt dst 2</th>
<th>IP address of the Active Previous Hop in HREQ that sends pkt dst 1 (1.x)</th>
<th>IP address of the Active Previous Hop in HREQ that sends pkt dst 2 (y.z)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

0: Type
1: Reserved
2: Hop Count
3: Broadcast ID
4: IP address of the Node
5: Unreachable Next Hop (UNH) IP address
6: Active Previous Hop (APH) address
7: IP address of the destination which uses UNP and receives packet from APH
8: IP address of the Active Previous Hop in HREQ that sends pkt dst 1
9: IP address of the Active Previous Hop in HREQ that sends pkt dst 2
10: IP address of the Active Previous Hop in HREQ that sends pkt dst 1 (1.x)
11: IP address of the Active Previous Hop in HREQ that sends pkt dst 2 (y.z)
Route Repair in Mobile Adhoc Networks

Routing Handoff

Diagram showing a network topology with nodes A, B, C, D, and E, illustrating the concept of routing handoff in mobile adhoc networks.
Route Repair in Mobile Adhoc Networks

Algorithm

Begin
  :
  :
  :
  if((Power of Received Packet/Threshold Power) < HTH) {
    Create Handoff Request Packet;
    Send Handoff Request Packet;
  }
  if(Received Packet == Handoff Request) {
    Check Neighbor Information Table;
    if(Next Hop Node in HREQ is a Neighbor) {
      if(Any Previous Hop Node in HREQ is a Neighbor) {
        Update Routing Table;
        Create Handoff Reply Packet;
        Send Handoff Reply Packet;
      }
    }
  }
  if(Received Packet == Handoff Reply) {
    if(Handoff Reply is for this Node) {
      Update Routing Table;
    }
  }
  :
  :
End
Computation of Handoff Threshold

- $t$ time required for routing handoff
- $s$ maximum speed of the node
- $d$ distance to covered before handoff is to take place

\[
\frac{RxPr}{RxThresh} \leq HTH \quad (1)
\]

Received Power $\propto \frac{1}{\text{distance}^4}$

\[
RxThresh \propto \frac{1}{R^4} \quad (2)
\]

\[
RxPr \propto \frac{1}{(R - d)^4} \quad (3)
\]

Substituting 2 and 3 in equation 1 we get

\[
\frac{R^4}{(R - d)^4} \leq HTH \quad (4)
\]

\[
\frac{R^4}{(R - (s \times t))^4} \leq HTH \quad (5)
\]
Modeling a Mobile Adhoc Network

- **Model**
  - $A$: Area of the Network
  - $N$: Number of Nodes
  - $R$: Range of Transmission
  - $\phi$: Routes affected by broken link

- **Basic Results**
  - Average Path Length: $\bar{L} = \frac{2\sqrt{A}}{3}$ [Jinyang Li, Mobicom2001]
  - Average Hops: $H = \frac{2\sqrt{A}}{3R}$
  - Flooding Packets: $N$

- **Parameters**
  - PKT: No of packets involved in repairing a broken link
  - DEL: Delay involved in repairing a broken link
1. Number of packets involved in repairing a broken route (PKT)
Number of packets involved in repairing a broken route = RERR broadcast to the sources affected + flooding to discover the route for each route+ RREP unicast from the destination to the source

\[
PKT = K + \phi N + \phi H \\
= \frac{\phi \sqrt{A}}{3R} + \phi N + \phi \frac{2\sqrt{A}}{3R} 
\]  

(6)

2. Delay involved in repairing a broken route (DEL)
Delay involved in repairing a broken route = RERR broadcast to reach the source + RREQ to reach the destination + RREP to reach the source

\[
DEL = k + H + H \\
= k + 2H \\
= \frac{\sqrt{A}}{3R} + \frac{4\sqrt{A}}{3R} \\
= \frac{5\sqrt{A}}{3R} 
\]  

(7)
Analysis of LRR

1. Number of packets involved in repairing a broken route (PKT)
   Number of packets involved in repairing a broken route = RERR broadcast + flooding to
discover the route for each route + RREP unicast from destination to the intermediate node

   \[ PKT = K + \phi N + \frac{\phi \sqrt{A}}{3R} \]

   \[ = \frac{\phi \sqrt{A}}{3R} + \phi N + \frac{\phi \sqrt{A}}{3R} \]  \hspace{1cm} (8)

2. Delay involved in repairing a broken route (DEL)
   Delay involved in repairing a broken route = RREQ to reach the destination + RREP to
reach the intermediate node

   \[ DEL = \frac{H}{2} + \frac{H}{2} \]

   \[ = H \]

   \[ = \frac{2 \sqrt{A}}{3R} \]  \hspace{1cm} (9)
Analysis of Routing Handoff

1. Number of packets involved in repairing a broken link (PKT)
   Number of packets involved in repairing a broken link = HREQ + HREP
   
   \[ PKT = 1 + 1 \]
   \[ = 2 \]

   (10)

2. Delay involved in repairing a broken link (DEL)
   Delay involved in repairing a broken link = HREQ + HREP
   
   \[ DEL = 1 + 1 \]
   \[ = 2 \]

   (11)
Route Repair in Mobile Adhoc Networks

Criteria for Routing Handoff

\[ R > \sqrt{\frac{A}{N}} \]

\[ N > \frac{A}{R^2} \]

\[ \eta \leq \frac{1.23R^2N}{A} \text{ and } \eta \geq 2 \]

\[ N \geq \frac{\eta A}{1.23R^2} \]
Simulation

- Network Simulator
- C++ and OTcl
- AODV and Local Route Repair already implemented
- Routing Handoff Implemented
  - sendHandoffRequest
  - recvHandoffRequest
  - sendHandoffReply
  - recvHandoffReply
Simulation...

- HRQ_ID: parameter which restricts the number of HREQ sent
- HRP_ID: parameter which restricts the number of HREP received.
- 25 Nodes and 50 Nodes
- 100 mts Range
- RxThresh = 1.76125e-10
- Slow Mobility
  - MinPause = 5 sec, MaxPause = 10 sec, MinSpeed = 20 m/sec, MaxSpeed = 40 m/sec, HTH = 3
- High Mobility
  - MinPause = 1 sec, MaxPause = 2 sec, MinSpeed = 40 m/sec, MaxSpeed = 600 m/sec, HTH = 6
Route Repair in Mobile Adhoc Networks

## 25 Nodes (500 x 500)

<table>
<thead>
<tr>
<th>TCP connections</th>
<th>AODV</th>
<th>LRR</th>
<th>HANDOFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>7331176</td>
<td>8163728</td>
<td>8624528</td>
</tr>
<tr>
<td>15</td>
<td>8115248</td>
<td>7381080</td>
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</tr>
<tr>
<td>20</td>
<td>8419144</td>
<td>7784432</td>
<td>8453920</td>
</tr>
</tbody>
</table>

TCP packets received for 25 Nodes (low mobility)

<table>
<thead>
<tr>
<th>TCP connections</th>
<th>AODV</th>
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</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>39082</td>
<td>42038</td>
<td>41422</td>
</tr>
<tr>
<td>15</td>
<td>43347</td>
<td>43305</td>
<td>43841</td>
</tr>
<tr>
<td>20</td>
<td>44890</td>
<td>43335</td>
<td>44651</td>
</tr>
</tbody>
</table>

Routing overhead (pkts) for 25 Nodes (low mobility)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>99.5944</td>
<td>99.3829</td>
<td>99.1753</td>
</tr>
<tr>
<td>15</td>
<td>98.8947</td>
<td>99.1456</td>
<td>99.0845</td>
</tr>
<tr>
<td>20</td>
<td>98.7148</td>
<td>99.2536</td>
<td>99.0334</td>
</tr>
</tbody>
</table>

Throughput (%) for 25 Nodes (low mobility)
Route Repair in Mobile Adhoc Networks

25 Nodes (500 x 500)

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<tbody>
<tr>
<td>10</td>
<td>7497656</td>
<td>7090576</td>
<td>7723448</td>
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<tr>
<td>15</td>
<td>7679576</td>
<td>7709784</td>
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<tr>
<td>20</td>
<td>8094536</td>
<td>7716790</td>
<td>7973664</td>
</tr>
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</table>

TCP packets received for 25 Nodes (high mobility)

<table>
<thead>
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<tbody>
<tr>
<td>10</td>
<td>39570</td>
<td>40895</td>
<td>39804</td>
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<tr>
<td>15</td>
<td>43484</td>
<td>43844</td>
<td>44536</td>
</tr>
<tr>
<td>20</td>
<td>42933</td>
<td>43419</td>
<td>44801</td>
</tr>
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</table>

Routing overhead for 25 Nodes under (high mobility)

<table>
<thead>
<tr>
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<th>AODV</th>
<th>LRR</th>
<th>HANDOFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>98.9254</td>
<td>99.0406</td>
<td>99.4457</td>
</tr>
<tr>
<td>15</td>
<td>98.716</td>
<td>99.4093</td>
<td>98.6894</td>
</tr>
<tr>
<td>20</td>
<td>98.6199</td>
<td>98.375</td>
<td>98.5048</td>
</tr>
</tbody>
</table>

Throughput (%) for 25 Nodes under (high mobility)
Route Repair in Mobile Adhoc Networks

### 50 Nodes (700 x 700)

<table>
<thead>
<tr>
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<th>AODV</th>
<th>LRR</th>
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</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>6305528</td>
<td>5724408</td>
<td>7001456</td>
</tr>
<tr>
<td>30</td>
<td>7288416</td>
<td>6745776</td>
<td>7569112</td>
</tr>
<tr>
<td>40</td>
<td>7991400</td>
<td>6737080</td>
<td>7962256</td>
</tr>
</tbody>
</table>

TCP packets received for 50 Nodes (low mobility)

<table>
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<th>AODV</th>
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<tbody>
<tr>
<td>20</td>
<td>43125</td>
<td>45894</td>
<td>45389</td>
</tr>
<tr>
<td>30</td>
<td>48957</td>
<td>48691</td>
<td>49351</td>
</tr>
<tr>
<td>40</td>
<td>52061</td>
<td>52234</td>
<td>52326</td>
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</tbody>
</table>

Routing overhead (pkts) for 50 Nodes (low mobility)

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<tbody>
<tr>
<td>20</td>
<td>98.6335</td>
<td>98.3769</td>
<td>98.6997</td>
</tr>
<tr>
<td>30</td>
<td>97.3548</td>
<td>98.2126</td>
<td>98.5361</td>
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<tr>
<td>40</td>
<td>98.1511</td>
<td>98.4879</td>
<td>98.1073</td>
</tr>
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</table>

Throughput (%) for 50 Nodes (low mobility)
**50 Nodes (700 x 700)**

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<tbody>
<tr>
<td>20</td>
<td>7085696</td>
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<td>7343312</td>
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<tr>
<td>30</td>
<td>6949472</td>
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<tr>
<td>40</td>
<td>6898712</td>
<td>5927256</td>
<td>7544856</td>
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TCP packets received for 50 Nodes (high mobility)

<table>
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</thead>
<tbody>
<tr>
<td>20</td>
<td>46882</td>
<td>48924</td>
<td>45949</td>
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<tr>
<td>30</td>
<td>52136</td>
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<tr>
<td>40</td>
<td>53167</td>
<td>55037</td>
<td>56670</td>
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Routing overhead (pkts) for 50 Nodes (high mobility)

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<tbody>
<tr>
<td>20</td>
<td>97.5571</td>
<td>97.0997</td>
<td>97.6469</td>
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<tr>
<td>30</td>
<td>96.7787</td>
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<tr>
<td>40</td>
<td>96.3518</td>
<td>97.4998</td>
<td>96.8943</td>
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Throughput (%) for 50 Nodes (high mobility)
**50 Nodes (850 x 850)**

<table>
<thead>
<tr>
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<th>LRR</th>
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<tbody>
<tr>
<td>20</td>
<td>5960912</td>
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</tr>
<tr>
<td>30</td>
<td>8108168</td>
<td>7519288</td>
<td>7686200</td>
</tr>
<tr>
<td>40</td>
<td>7592632</td>
<td>7989944</td>
<td>7544896</td>
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TCP packets received for 50 Nodes (low mobility)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>48572</td>
<td>53726</td>
<td>44473</td>
</tr>
<tr>
<td>30</td>
<td>54584</td>
<td>54146</td>
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</tr>
<tr>
<td>40</td>
<td>57792</td>
<td>63480</td>
<td>57407</td>
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</table>

Routing overhead (pkts) for 50 Nodes (low mobility)

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</thead>
<tbody>
<tr>
<td>20</td>
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<td>96.6441</td>
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<tr>
<td>30</td>
<td>98.1356</td>
<td>98.357</td>
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<tr>
<td>40</td>
<td>97.533</td>
<td>98.0815</td>
<td>97.786</td>
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</table>

Throughput (%) for 50 Nodes (low mobility)
### 50 Nodes (850 x 850)

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>20</td>
<td>7088928</td>
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<td>7508768</td>
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<tr>
<td>30</td>
<td>6901304</td>
<td>64328376</td>
<td>6328376</td>
</tr>
<tr>
<td>40</td>
<td>6845264</td>
<td>6749008</td>
<td>6519672</td>
</tr>
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TCP packets received for 50 Nodes (high mobility)

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<tr>
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</thead>
<tbody>
<tr>
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<td>48586</td>
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<td>30</td>
<td>51642</td>
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<td>53590</td>
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<tr>
<td>40</td>
<td>54965</td>
<td>56271</td>
<td>52438</td>
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Routing overhead for 50 Nodes (high mobility)

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</thead>
<tbody>
<tr>
<td>20</td>
<td>96.8709</td>
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<td>96.6593</td>
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<td>96.8429</td>
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<tr>
<td>40</td>
<td>96.2848</td>
<td>97.1465</td>
<td>96.8833</td>
</tr>
</tbody>
</table>

Throughput (%) for 50 Nodes (high mobility)
Conclusion

• Routing Handoff performance is better than local route repair when the network confirms to the routing handoff criteria.

• Routing Handoff performance is comparable or better than AODV when the network confirms to the routing handoff criteria.

• Routing Handoff performance becomes erratic with respect to AODV and LRR when the routing handoff criteria is violated.

• Routing Handoff performance varies with parameters like HTH, HRQ_ID and HRP_ID.

• It is difficult to predict the values of HTH, HRQ_ID and HRP_ID for which routing handoff would provide the best performance.
Route Repair in Mobile Adhoc Networks

**Future Work**

- Theoretical/Heuristic approach to estimate parameters like HRQ_ID and HRP_ID
- Investigate the benefits of routing handoff in other routing protocols
References


