Architecture & Protocols for Supporting Routing & QoS in MANET

Navid NIKAEIN

http://www.eurecom.fr/~nikaeinn

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Outline

- Introduction: Issues and Trade-Offs
- Related Work
- Architecture
- Topology Management
- Route Determination
- Quality of Service Support
- Conclusion and Open Issues
Issues in MANET

Mobile ad hoc networks:
- Wireless $\triangleleft$ low-capacity $\triangleleft$ Collision
- Mobility $\triangleright$ time-varying resources $\triangleright$ Link Failure
- Lack of infrastructure $\triangleright$ fully-distributed $\triangleright$ Complex
- Small devices $\triangleright$ Limited resources $\triangleright$ Multihop Routing

Routing & QoS
Routing Issues

- Dilemma at a node:
  "Do I keep track of routes to all destinations, or instead keep track of only those that are of immediate interest?"

- Three strategies:
  - **Proactive**: keep track of all.
  - **Reactive**: only those of immediate interest.
  - **Hybrid**: partial proactive / partial reactive.

 Trade-off between routing overhead and delay
QoS Routing Issues

- State of communication path should be considered in QoS routing:
  - Resource availability and its stability

∴ Cause longer path than shortest path

Trade-off between shortest path and optimal path
Assumption

- Fully symmetric environment
  - All nodes have identical **capabilities**
- Capabilities:
  - Transmission range,
  - Battery life, processing capacity, buffer capacity
- Each node periodically sends a **Beacon**
- All nodes participate in protocol operation and packet forwarding [Michardi, Molva, Crowcroft]
Related Work

Ad Hoc Routing

- Topology-based
  - Proactive
    - OLSR
    - TBRPF
    - DSDV
    - WRP
    - CGSR
    - FSH-HSR
    - LANMAR
  - Reactive
    - DSR
    - AODV
    - RDMAR
    - ABR
    - SSR
    - TORA
  - Hybrid
    - ZHLS
    - ZRP
    - CBRP
    - DDR+
    - HARP

- Position-based
  - Proactive
    - DREAM
  - Reactive
    - LAR
  - Hybrid
    - Terminodes
    - GLS
    - ALM
AN ARCHITECTURE THAT SEPARATES [1]:

- **Route Determination**
  With respect to *Application requirements*

- **Topology Management**
  With respect to *Quality of Network*

Diagram:
- Application
- HARP
- DDR
- Network

QoS Classes:
- Delay TPut BE

QoC:
- Power, buffer Stability

Protocol stack

QoS extension
Outline

- **Topology Management** \([2,3]\)
  - DDR- Distributed Dynamic Routing Algorithm
- Route Determination
  - HARP- Hybrid Ad hoc Routing Protocol
- Quality of Service Routing
  - LQoS- Layered Quality of Service
Topology Management

- Intuition
- DDR- Distributed Dynamic Routing Algorithm
  - Forest Construction
  - Zone Partitioning
  - Zone Behaviors
- Simulation Model
- Performance Results
- Summary
Intuition

Generate a set of preferred paths in the network

Network Topology

Criteria

Forest

TREE   TREE   ....   TREE

ZONE   ZONE   ....   ZONE

BEACON

Time
Forest Construction

- Each node selects the best node in its neighborhood according to the given unique criteria, e.g., degree.
- If identical nodes, select the one with the higher ID.

**Theorem:** Connecting each node to its preferred neighbor yields to a forest [2].

MPR-tree [Qayyum] used in OLSR [Jacquet].

Forest reduces the number of forwarding nodes.
Zone Partitioning

- Tree ↔ Zone
- Maintained using periodical beaonc

Zones:
- Improves delay performance
- Contributes in protocol scalability
Criteria for FC [4]: Quality of Connectivity (QoC)

- Power level $p \prec$ battery lifetime
- Buffer level $b \prec$ available unallocated buffer
- Stability level $s \prec$
- $\Delta t = t_1 - t_2$: period

$$s(x) = \frac{|N_{t_0} \cap N_{t_1}|}{|N_{t_0} \cup N_{t_1}|}$$

$\therefore$ QoC = $\alpha \cdot s + \beta \cdot b + \delta \cdot p$

dling nodes belongs to the nodes with the high quality
Zone Behaviors

- Whatever the network density is, the zone diameter is bounded to 8
- The average ratio of tree-path to shortest path is no longer than 2
- Low Complexity O(N)

Zone Diameter

Tree Path / Shortest Path
Protocol Model

- To study the effect of the proposed topology management on routing performance?
- Hybrid Ad Hoc Routing Protocol (HARP) [5]
  - Dual mode: node level and zone level
  - Intra-zone and inter-zone routing
  - Discover the shortest path
  - Establish forward and reverse path
  - Maintenance
Simulation Model [Johansson, Perkins, Broach]

- Traffic model:
  - CBR
  - 512 byte/packet
  - 4 packets/second
  - Source 10, 20, 30

- Movement model:
  - Random way point [Yoon]
  - 50 nodes
  - 1500mx300m
  - 0-20 m/s (or 1-20m/s)
  - 900 simulated seconds
  - Pause time=0, 30, 60, 150, 300, 600, 900
  - 10 scenarios for each pause time

- Performance Metrics:
  - Packet delivery fraction
  - Avg. E2E delay
  - Routing overhead
Packet Delivery Fraction

- Simple routing has a slightly better PDF in low traffic load
- Routing+TM outperforms simple routing up to 20% as the traffic load increases
Routing + TM significantly improves the delay performance up to 200ms as the network conditions become stressful.
Routing Overhead (pkt)

- Simple Routing outperforms Routing+TM in low/medium traffic load
- Most of the packets produced by Routing+TM are the beacons
- Forest does reduce the broadcasting overhead but not entirely

NOTE: Beacon is local while PREQ is global
Routing Overhead (bytes)

- Simple Routing outperforms Routing+TM in low/medium traffic load
- Forest does reduce the broadcasting overhead

10 sources
20 sources
30 sources
Packet Delivery Fraction

The effect of mobility rate and traffic load on PDF
The fluctuation
The congestion Adaptive Routing

10 sources
100
95
90
85
80
75
70
0
100
200
300
400
500
600
700
800
900
Pause time (sec)
Packet delivery fraction (%)
Routing+TM (QoC)
Routing+TM (Deg)
Flat Routing

20 sources

30 sources

Congestion

Fluctuation

Fluctuation
Avg. E2E Delay

- The effect of mobility rate and traffic load on DELAY
- Shortest path is not enough!
- The load balancing

**Note:** $QoC = \alpha \cdot s + \beta \cdot b$, where $\alpha = 2$ & $\beta = 1$

**Shortest path is not enough**

**Load Balancing**

10 sources  
20 sources  
30 sources
## Summary

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<th>Medium traffic load</th>
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- Topology Management
  - DDR- Distributed Dynamic Routing Algorithm
- Route Determination [5,6]
  - HARP- Hybrid Ad hoc Routing Protocol
- Quality of Service Routing
  - LQoS- Layered Quality of Service
Route Determination [5,6]

- HARP- Hybrid Ad Hoc Routing Protocol
  - Intra-zone and Inter-zone routing
  - Query localization technique [Aggelou, Tafazolli]
- Performance Results [Osafune]
- Summary
Routing

Intra-zone Routing

Inter-zone Routing

Zone abstraction

Shortcut intra-zone routing

- Zone level routing
- Distance estimation
Simulation Model [Johansson, Perkins, Broach]

- **Traffic model:**
  - CBR
  - 512 byte/packet
  - 4 packets/second
  - Source 10, 20, 30

- **Performance Metrics:**
  - Packet delivery fraction
  - Avg. E2E delay
  - Routing overhead

- **Movement model:**
  - Random way point [Yoon]
  - 50 nodes
  - 1500mx300m
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  - 900 simulated seconds
  - Pause time=0, 30, 60, 150, 300, 600, 900
  - 10 scenarios for each pause time
Packet Delivery Fraction

- The effect of mobility and traffic load is not uniform
- Congestion stems from the lack of load balancing in the protocols
- Fluctuation point is a function of network parameters
- The effect of cashing and/or neighboring table in high mobility

Fluctuation

Congestion

10 sources

20 sources

30 sources
The effect of traffic load and mobility on the delay performance is non-uniform. Caching (DSR), route request (AODV), and beaconing/PREQ (HARP+TM). Load balancing.
Routing Overhead (pkt)

- Reaction to mobility (main cause of link failure)
- Caching (DSR), route request (AODV), beaconing and PREQ (HARP+TM)
- Effect of beaconing on battery lifetime [Toh]
- No handshaking is required for beaconing

![Graphs showing routing overhead for different sources: 10, 20, and 30 sources.](image)
Routing Overhead (bytes)

- Reaction to mobility (main cause of link failure)
- Caching (DSR), route request (AODV), beaconing and PREQ (HARP+TM)
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- Topology Management
  - DDR- Distributed Dynamic Routing Algorithm
- Route Determination
  - HARP- Hybrid Ad hoc Routing Protocol
- Quality of Service Routing [7]
  - LQoS- Layered Quality of Service
Quality of Service Routing [8]

- Motivation
- Architecture and Intuition
- Network Metrics
- Application Metrics
- Performance Results
Motivation

- Application QoS  <->  Network QoC

- Whether the communication path can support any particular application delay, or bandwidth?

- Ad Hoc QoS means to provide a set of parameters in order to adapt application to the quality of communication path while routing through the network [7]
Architecture

AN ARCHITECTURE THAT SEPARATES [8]:

- **Application**
- **HARP**
- **DDR**
- **Network**

QoS Classes:
- App. Metrics
- Delay
- TPut
- BE

Network Metrics:
- QoC:
  - Power, buffer
  - Stability, # hops

Path selection phase
Path Discovery phase

Protocol stack
QoS extension
Network Metrics

- Hop count ➢ resource conservation
- Power level
- Buffer Level
- Stability Level

- Trade-off between load balancing & resource conservation
- Compute during path discovery using concave function
- Reflect the quality of the communication paths
- Map this quality to application metrics
## Application Metrics

<table>
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<th>Service</th>
<th>App. Metrics</th>
<th>Net. Metrics</th>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Class</td>
<td>Delay</td>
<td>$h.(r-b)/c$</td>
<td>$h$ : hop count</td>
</tr>
<tr>
<td>2nd Class</td>
<td>Throughput</td>
<td>$c/(2h.(r-b))$</td>
<td>$r$ : buffer size, $b$ : buffer occupancy</td>
</tr>
<tr>
<td>3rd Class</td>
<td>Best-Effort</td>
<td>$1/s$</td>
<td>$c$ : nodes’ throughput, $s$ : stability</td>
</tr>
</tbody>
</table>

- Compute during path selection
- Reflect the quality of service requirement
Delay performance has significantly improved. QoS metric is the key factor for the delay performance due to its load balancing effect.

10 sources  20 sources  30 sources
Packet Delivery Fraction

- QoS metrics has no significant effect on PDF
- Route discovery and route maintenance are the key factors for improving PDF
- Deal with Traffic load/pattern and mobility model/rate

10 sources

20 sources

30 sources
Conclusion-Architecture

Pro-Network  Routing  Pro-Application

Topology management  Route determination

Quality of connectivity (QoC)  Quality of Service (QoS)
Conclusion

- Topology management improves routing
- Load balancing
  - HARP \(\triangleleft\) QoS metrics
  - DDR \(\triangleleft\) QoC metrics
- Control flooding overhead
  - Forest \(\triangleleft\) redundancy & collision
  - Query localization technique \(\triangleleft\) scope
- Scalability \(\triangleleft\) zone abstraction
Conclusion

Routing requires:
- Adaptive topology management
- Load balancing
- Congestion avoidance mechanisms
- Neighboring information

Factors affecting routing performance
- Network size, mobility rate and model, traffic load and pattern, network density

Traffic locality vs. network size
Future Work

- Optimal criteria of forest Construction
- Introduce the congestion avoidance mech.
- Extend the QoS model to support metrics at the link layer (e.g. SNR)
- Simulation with other mobility models and traffic patterns
Publications


Publications


