# TABLE OF CONTENTS

Declaration ........................................... i  
Certification .......................................... ii  
Abstract ............................................... iv  
Acknowledgements ..................................... vii  
List of Tables ......................................... xv  
List of Figures ......................................... xvii  
Abbreviations ......................................... xx  

1  Introduction ......................................... 1  
   1.1  Overview of Mobile Ad Hoc Networks (MANETs) ............. 4  
   1.2  MANET's Salient Characteristics ............................. 5  
   1.3  Applications of MANETs ....................................... 6  
   1.4  Routing Classification in Ad Hoc Networks .................. 8  
      1.4.1  Proactive versus Reactive Approaches .................. 9  
      1.4.2  Routing Protocols Overview ............................ 11  
   1.5  MANET QoS Overview .......................................... 18  
      1.5.1  QoS Metrics .............................................. 19  
      1.5.2  Quality of Service models for Internet ................. 20  
      1.5.3  Quality of Service in Ad Hoc Networks ................. 23  
         1.5.3.1  Special Issues and Difficulties in MANETs ........ 23  
         1.5.3.2  Drawbacks of the different QoS Models ...... 24  
   1.6  Organization of the thesis ................................ 26
# Literature Survey

2.1 Overview ............................................................... 29

2.2 Existing QoS Technologies ........................................... 32

2.3 Existing QoS aware routing Protocols ............................ 35

2.4 QoS routing based on route life time ............................... 39

2.5 QoS routing based on Energy ........................................ 41

2.6 QoS routing based on multiple constraints ......................... 43

2.7 Potential Problems for Research .................................... 44

2.8 Summary ................................................................. 45

# Problem Formulation

3.1 Introduction ............................................................. 47

3.2 Objectives and Scope .................................................. 48

# Routing Protocols in MANETs

4.1 Introduction ............................................................. 50

4.2 MANET Routing Protocols Classification .......................... 50

4.3 Routing Classification in Ad Hoc Networks ......................... 51

4.3.1 Destination Sequenced Distance Vector (DSDV) .......... 51

4.3.2 Dynamic Source Routing protocol ............................... 53

4.3.3 Ad Hoc On-demand Distance Vector (AODV) ............. 55

4.4 Performance comparison and analysis of three MANET Routing Protocols ..................... 57

4.4.1 Models used for measuring the performance ................. 58

4.4.2 PDR vs. number of nodes ......................................... 61

4.4.3 Delay vs. number of nodes ...................................... 62

4.4.4 Throughput vs. number of nodes ............................... 62
4.4.5 Control overhead vs. number of nodes ....... 63
4.4.6 Result of Comparison ....................... 63
4.5 Original AODV Route discovery algorithm .......... 64
4.6 Summary ........................................ 65

5 Computation of Multiple Node Disjoint Paths 67

5.1 Introduction .................................... 67
  5.1.1 Unipath Routing in MANETs .................. 68
  5.1.2 Multipath Routing in MANETs ................. 70
  5.1.3 Benefits of multipath routing ................ 71
  5.1.4 Ad Hoc On-Demand Multipath Distance Vector Routing Protocol (AOMDV) .............. 72
  5.1.5 Experimental Results ......................... 73
    5.1.5.1 PDR vs. number of nodes ................. 74
    5.1.5.2 Delay vs. number of nodes ............... 74
    5.1.5.3 Control Overhead ......................... 75
  5.1.6 Analysis of Simulation Results ................. 75
  5.2 Establishing Path Accumulation features in AODV .. 76
  5.3 Proposed method of Multiple Node Disjoint Paths for a MANET ..................................... 77
  5.4 Algorithm for computing Multiple Node Disjoint Paths by making use of Path accumulation feature in AODV routing protocol (MQARP) ........................................ 80
  5.5 Experimental Results ........................... 82
    5.5.1 PDR vs. number of nodes .................... 82
    5.5.2 Delay vs. number of nodes ................. 83
    5.5.3 Control overhead ......................... 83
    5.5.4 Analysis of Simulation Results ............. 84
  5.6 Summary ........................................ 85
6 Design of Quality of Service Aware Routing Protocol (QARP)

6.1 Introduction .............................................. 87
  6.1.1 Route discovery in original AODV ............... 88
  6.1.2 Disadvantages of the route discovery process in an original AODV ................. 90
  6.1.3 Routing protocol components ......................... 91
6.2 Modifying original AODV to avoid unnecessary flooding. 93
6.3 Algorithm to avoid unnecessary flooding using Timestamp (QoS-AODV) ................. 95
6.4 Experimental Results ..................................... 96
  6.4.1 Performance comparison of QARP and AODV ....... 96
    6.4.1.1 Throughput vs. number of nodes .............. 97
    6.4.1.2 Delay vs. number of nodes ..................... 97
    6.4.1.3 Routing Overhead .............................. 98
    6.4.1.3 Analysis of Simulation Results .............. 98
  6.4.2 Performance comparison of QARP and AODV-D .... 99
    6.4.2.1 PDR vs. Pause time ............................ 99
    6.4.2.2 Delay vs. Pause time ........................... 100
    6.4.2.3 Analysis of Simulation Results ............. 100
6.5 Summary .................................................. 101

7 Design of Enhanced Quality of Service Aware Routing Protocol (EQARP)

7.1 Introduction .............................................. 102
7.2 Life time in an original AODV .......................... 103
7.3 Computation of Route Life time ratio based on static Lifetime and TTL .................... 104
  7.3.1 Experimental Results ................................. 106
    7.3.1.1 PDR vs. number of nodes ...................... 106
7.3.1.2 Delay vs. number of nodes .............. 107
7.3.2 Analysis of Simulation Results ............... 107

7.4 Link life time based on Position and Direction of Movement. .............................. 108
  7.4.1 Calculation of Link Life time (LLT) .... 109
  7.4.2 Calculation of Route life time (RLT) based on Position and direction of movement. 111

7.5 Algorithm for Route discovery process in EQARP 112
7.6 Flowchart for Route discovery in EQARP 114
7.7 Modeling the network and simulation parameters ... 116
  7.7.1 Experimental Results. .......................... 116
    7.7.1.1 PDR vs. no. of nodes at high mobility. 116
    7.7.1.2 Delay vs. no. of nodes at high mobility 117
  7.7.2 Analysis of Simulation Results ........................ 118

7.8 Summary.................................................... 118

8 Improvement of Network Lifetime 119
  8.1 Introduction. ................................................................. 119
  8.2 Life time in an original AODV. ................................. 120
  8.3 Modifying the routing protocol by computing energy across the node during route discovery. 120
  8.4 Algorithm to make the efficient usage of energy (EARP). 122
  8.5 Modeling the network and simulation parameters. .... 124
    8.5.1 Energy model in NS-2. ................................. 124
    8.5.2 Experimental Results ................................. 125
      8.5.2.1 Performance comparison of EARP and AODV 126
      8.5.2.2 Performance comparison of EARP and PA-AODV 127
9 Mulitpath QoS Routing in MANETs taking multiple constraints

9.1 Introduction ...................................................... 131
9.2 Using multiple constraints while path finding ................. 132
9.3 Route Discovery in MMQARP ........................................ 134
9.4 Route Selection .................................................... 136
9.5 Algorithm for Route discovery process in MMQARP by
dynamically computing average time stamp, link life
time and energy .................................................. 140
9.6 Modeling the network and simulation parameters .......... 142
9.6.1 Experimental Results ........................................... 143
  9.6.1.1 Performance comparison of MMQARP
        and AOMDV ............................................... 143
  9.6.1.2 Performance comparison of MMQARP
        and EEMLSL ........................................... 146
9.6.2 Route establishment time ...................................... 148
9.7 Summary .......................................................... 149

10 Conclusion and Future Directions ................................... 150
10.1 Major Contributions made ....................................... 151
10.2 Suggestions for future research ............................... 153

Contributions .......................................................... 155

References ............................................................. 157