QOS TOPOLOGY CONTROL, AND ENERGY EFFICIENT OPERATIONS IN SENSOR AND AD HOC WIRELESS NETWORKS

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QoS Topology Control, and Energy Efficient Operations in Sensor and Ad Hoc Wireless Networks
在無線傳感器網絡及 Ad Hoc 網絡中 QoS 拓撲控制、高效能運作等問題

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Abstract

Ad hoc wireless networks and sensor networks have received significant attention in recent years due to their potential applications in battlefield, disaster relief operations, traffic surveillance, environment monitoring and so on. QoS topology control, energy efficient operations are fundamental and important issues in ad hoc wireless networks and sensor networks. This thesis investigates these issues and presents their solutions. The major work of the thesis can be summarized below.

First, we studied the energy efficient QoS topology control problem in ad hoc wireless networks. Two cases of the problem were considered: 1) the traffic demands are not splittable, and 2) the traffic demands are splittable. They were formulated as an integer linear programming problem and a mixed integer linear programming problem, respectively. A greedy algorithm and an approximation algorithm with ratio \( n \) were further proposed to solve the problem, where \( n \) is the number of nodes. Extensive simulations were conducted to evaluate the performance of proposed algorithms.

Second, we proposed an efficient algorithm with \( O(|P|^2 k) \) complexity for timeslot assignment problem in TDMA/CDMA ad hoc wireless networks, where \( P \) is a path and \( k \) is the number of slots in a TDMA frame. The algorithm was further integrated into a QoS call admission scheme for QoS call requests. We proved that a timeslot assignment providing 1 unit of bandwidth on \( P \) can be found in \( O(|P|) \) time if such an assignment exists. The results had been extended
to the case that $P$ can provide 2 units of bandwidth and the general case. Extensive simulations were conducted and the results had demonstrated the superior performance of our method.

Third, we studied the relay node placement problem in the two-tiered wireless sensor networks. Given a set of sensor nodes in Euclidean plane, our objective is to place the minimum number of relay nodes to forward data packets from sensor nodes to the sink, such that: 1) the network is connected, 2) the network is 2-connected. For case one, we proposed a $(6+\varepsilon)$-approximation algorithm for any $\varepsilon>0$ with polynomial running time when $\varepsilon$ is fixed. For case two, we proposed two approximation algorithms with $(24+\varepsilon)$ and $(6/T+12+\varepsilon)$, respectively, where $T$ is the ratio of the number of relay nodes placed in case one to the number of sensors. We further extended the results to the cases where communication radiiuses of sensor nodes and relay nodes are different.

Fourth, we studied the maximal lifetime scheduling problem for sensor surveillance systems with $k$ sensors to 1 target. We proposed an optimal solution to find the target watching schedule for sensors, where the lifetime is the duration up to the time when there exists one target that cannot be watched by $k$ sensors or data can not be forwarded to the base station due to the depletion of energy of the sensor nodes. Our solution consists of three steps: 1) computing the maximal lifetime of the surveillance system and a workload matrix by using linear programming techniques; 2) decomposing the workload matrix into a sequence of schedule matrices that can achieve the maximal lifetime; 3) determining the
sensor surveillance trees based on the above obtained schedule matrices, which specify the active sensors and the routes to pass sensed data to the base station. This is the first time in the literature that this scheduling problem of sensor surveillance systems has been formulated and the optimal solution has been found. We illustrated our optimal method by a numeric example and experiments in the end.

Fifth, we studied the sufficient and necessary condition of 100% deliverability for flooding schemes that are based on only 1-hop neighbors information. We further proposed an efficient flooding algorithm that achieves the local optimality in two senses: 1) the number of forwarding nodes in each step is the minimal; 2) the time complexity for computing forwarding nodes is the lowest, which is $O(n \log n)$, where $n$ is the number of neighbors of a node. Extensive simulations had been conducted and simulation results had shown that performance of our algorithm is significantly better than the existing message efficient flooding methods.

Finally, we studied the collision-free delay efficient data gathering problem in wireless sensor networks. We focused on networks where nodes are equipped with two channels. Optimal solutions were proposed for spider networks and tree networks. We further proposed two approximation algorithms with performance ration of 2 for general cases.
List of Publications

Journal Articles


Conference Papers


Book Chapters


# Contents

Abstract .......................... i

List of Journal publications ........ iv

Acknowledgements ................. vi

List of Figures ........................ xi

List of Tables ........................ xiv

Chapter 1 Introduction ............. 1

  1.1 Background .................... 1

  1.2 Research Contributions ........ 3

  1.3 Organization of the Thesis .... 5

Chapter 2 QoS Topology Control with Minimal Total Energy Cost in Ad Hoc Wireless Networks ............. 7

  2.1 Introduction .................... 7

  2.2 Related Work ................... 9

  2.3 System Model and Problem Specification .... 12

  2.4 Topology Control with Traffics Non-splittable .......... 13

    2.4.1 Formulation ............... 13

    2.4.2 Numerical Results ......... 17

  2.5 Topology Control with Traffics Splittable ........... 18

    2.5.1 Formulation ............... 18

    2.5.2 Our Solution .............. 20

    2.5.3 Experimental Results .... 26
2.6 Conclusion

Chapter 3 Bandwidth Guaranteed Call Admission in TDMA/CDMA Ad Hoc Wireless Networks

3.1 Introduction
3.2 System Model and Problem Specification
3.3 Timeslot Assignment for Special Cases
3.4 Timeslot Assignment for General Case
3.5 Integrated Algorithm for Call Admission
   3.5.1 Route Discovery
   3.5.2 Bandwidth Reservation
   3.5.3 Route Maintenance
3.6 Simulation
3.7 Conclusion

Chapter 4 On Optimal Placement of Relay Nodes for Reliable Connectivity in Wireless Sensor Networks

4.1 Introduction
4.2 System Model and Problem Specification
4.3 Solution to MRP-1
4.4 Solution to MRP-2
   4.4.1 (24+ε)-approximation
   4.4.2 (6/T+12+ε)-approximation
4.5 Extensive Results
## Chapter 5 Maximal Lifetime Scheduling for Sensor Surveillance Systems with $K$ Sensor to 1 Target

5.1 Introduction 77

5.2 Related Work 79

5.3 System Model and Problem Statement 81

5.4 Our Solution 83

5.4.1 Find Maximal Lifetime 83

5.4.2 Decompose Workload Matrix 85

5.4.2.1 A Special Case $n=km$ 87

5.4.2.2 General Cases $n>km$ 93

5.4.3 Determine Surveillance Tree 100

5.5 Experiments and Simulations 101

5.5.1 A Numeric Example 101

5.5.2 Simulations 104

5.6 Conclusion 108

## Chapter 6 Efficient Flooding Scheme Based on 1-hop Knowledge in Mobile Ad Hoc Networks

6.1 Introduction 110

6.2 Related Work 112

6.3 Efficient Flooding Scheme Based on 1-hop Information 116

6.3.1 System Model and Overview of Method 116
List of Figures

2.1 Non-splittable case 17
2.2 Total energy cost versus $n$ 27
2.3 Total energy utilization ratio versus $\lambda_m$ 28
2.4 Average out-degree of nodes versus $\lambda_m$ 29
2.5 Total energy cost versus $R_p$ 30
2.6 Average out-degree of nodes versus $R_p$ 31
3.1 Tow example of timeslot assignment (a); (b) 38
3.2 Success ratio versus $TTL$ 53
3.3 Average # of candidates versus $TTL$ 53
3.4 Success ratio versus $Load$ 54
3.5 Average # of candidates versus $Load$ 54
3.6 Success ratio versus $TTL$ 55
3.7 Average # of candidates versus $TTL$ 55
3.8 Success ratio versus $Load$ 55
3.9 Average # of candidates versus $Load$ 55
4.1 Communication circle of sensor $s$ 65
4.2 Adding backup nodes to the communication circle of $r$ 69
4.3 Adding backup nodes $a, b$ on the links of $v$ 73
4.4 Communication circles of sensor node $s$, relay node $u$ and $v$ 74
5.1 Convert $G$ to $G_k$ (a); (b) 89
5.2 A perfect matching in $G_k$ and its corresponding k-matching in $G$ 89
5.3 An example with 6 sensors and 3 targets

5.4 The surveillance tree for 3 sessions

5.5 (a) $L$ VS surveillance range; (b) $L$ VS the maximal transmission range;

5.5 (c) $L$ VS $n$ when $m=10$; (d) $L$ VS $k$

6.1 Example of edge forwarding

6.2 Neighbor’s area of node $s$

6.3 Construct a new topology

6.4 Example of arcs

6.5 Relationship between two arcs (a) Case 1.1; (b) Case 1.2; (c) Case 1.3; (d) Case 2; (e) Case 3

6.6 Sorting problem is reduced to boundary computing problem

6.7 Reduce the coverage disk to compensate the location error

6.8 An example of optimizing $F(u)$

6.9 Performance VS. the number of nodes (a); (b); (c)

6.10 Performance VS. transmission range

6.11 Performance VS. network size and network load

7.1 Data gathering in line topology

7.2 Data gathering in spider topology

7.3 A tree where degree of the sink is one and its equivalent line topology

7.4 A tree can be processed as a spider
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.5 Collision between two branches</td>
<td>159</td>
</tr>
<tr>
<td>7.6 An example of general graph</td>
<td>161</td>
</tr>
</tbody>
</table>
List of Tables

4.1 The QoS requests and their routes for Fig. 2.1 17

5.1 The initial energy reserves of 6 sensors 102

5.2 The data flows among 6 sensors and the BS 103

6.1 Simulation parameters 139

7.1 (a) Schedule of data distribution; (b) schedule of converse data gathering 162