Maximum Battery Life Routing to Support Ubiquitous Mobile Computing in Wireless Ad Hoc Networks

By

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Introduction to Wireless Ad Hoc Network

- There is a tremendous interest in wireless network
- Ad hoc wireless network is a collection of wireless mobile hosts (infrastructureless network)
- Most of the ad hoc mobile devices today operate on batteries
Characteristics of Ad Hoc Mobile Wireless Network

- Dynamic topology
- Bandwidth constraints and variable links
- Energy constrained nodes
- Multi-hop communications
- Limited security
Characteristics of Ad Hoc Mobile Wireless Network (contd)

- Determining/detecting changing network topology
- Maintaining network topology/connectivity
- Scheduling of packet transmission and channel assignment
- Routing
Characteristics of Ad Hoc Mobile Wireless Network (contd)

- Determination of Network Topology
- Maintaining Network Connectivity Under Changing Radio Conditions and Mobility
- Transmission Scheduling and Channel Assignment
- Packet Routing
Determination of Network Topology

- Must determine and monitor the dynamics of network topology over time
- The routing protocol need to ensure that link in the route has strong connection
- Must exist at least one path from any node to any other node
- Must aware of its surrounding and its neighboring nodes with which it can directly communicate
Maintaining Network Connectivity Under Changing Radio Conditions and Mobility

- Routing protocol must be able to update the status of its links and reconfigure itself in order to maintain a strong connectivity with other nodes in the network.
- Centralized algorithm is vulnerable.
- A fully distributed algorithm is reliable and robust.
Transmission Scheduling and Channel Assignment

- An efficient transmission scheduling and channel assignment algorithm is needed to ensure that the new transmission will not conflict with an existing one.
- Good Scheduling and Channel Assignment help reduce interference and improve bandwidth efficiency.
Packet Routing

- Ad hoc networks require a highly dynamic, adaptive routing scheme to deal with the high rate of topology changes
  - Table-driven
  - On-demand
  - Hybrid
Importance Issues In Ad Hoc Wireless Network

- Power consumption rate need to evenly distribute among the nodes
- Efficient utilization of battery power is important
- Routing protocol for wire network can’t be use directly for wireless network
Outline

- Designed Properties of Ad Hoc Routing Protocols
- Power-Efficient Ad Hoc Mobile Networks
- Power-Efficient Ad Hoc Routing
- Performance of Different Routing Algorithms Considering Power Efficiency
- Simulation Results
- Conclusion
Desired Properties of Ad Hoc Routing Protocols

- Distributed Implementation
- Efficient Utilization of Bandwidth
- Efficient Utilization of Battery Capacity
- Optimization of Metrics
- Fast Route Convergence
- Freedom From Loops
- Unidirectional Link Support
Power-Efficient Ad Hoc Mobile Network

- Power required by each mobile host
  - Classified into two categories:
    - Communication-related power
    - Non-communication-related power
  - Communication-related power:
    - Processing power
    - Transceiver power
Power-Efficient Ad Hoc Mobile Network (contd)

- Physical Layer and Wireless Device
- Data Link Layer
- Network Layer
Physical Layer and Wireless Device

- Transmission power should be at a minimum level to maintain links
- Allow the ability to adapt to changes in transmission environment
- Excessive transmission power cause interference to other hosts
Data Link Layer

- Energy conservation can be achieved by using effective retransmission request schemes and sleep mode operation.
- It is important to appropriately determine when and at what power level a mobile host should attempt retransmission.
- Node’s transceiver should be powered off when not in use.
In wireless network it is important that the routing algorithm select the best path from the viewpoint of power constraints as part of route stability.

Routing algorithm that can evenly distribute packet-relaying loads to each nodes to prevent nodes from being overused.
Power-Efficient Ad Hoc Routing

- Power-Efficient Routing Protocols
  - Minimum Total Transmission Power Routing (MTPR)
  - Minimum Battery Cost Routing (MBCR)
  - Min-Max Battery Cost Routing (MMBCR)
  - Conditional Max-Min Battery Capacity Routing (CMMBCR)
Minimum Total Transmission Power Routing (MTPR)

- Signal to Noise Formula
- Formula to calculate the total transmission power for route L
- The desired route k calculation
- Doesn’t give the minimum number of hops
Minimum Battery Cost Routing (MBCR)

- The remaining battery capacity of each host is a more accurate metric to describe the lifetime of each host.
- Battery cost function of a host
- Battery cost $R_j$ for route $I$
- To find the maximum remaining battery capacity, we select route $I$ that has the minimum battery cost.

\[ f_i(c_i^t) = \frac{1}{c_i^t} \]

\[ R_j = \sum_{i=0}^{D_j-1} f_i(c_i^t) \]

\[ R_i = \min\{R_j| j \in A\} \]
Minimum Battery Cost Routing (MBCR)

- If all nodes have similar battery capacity, this metric will select a shorter-hop route.
- Only consider the summation of values of battery cost; therefore can overuse any single node.
The power of each host is being used more fairly in this scheme than previous schemes.

No guarantee of minimum total transmission power path under all circumstances

Consume more power to transmit mean reduce the lifetime of all nodes
Using previous scheme, maximize the life time of each node and use the battery fairly can’t be achieve simultaneously.

Use battery capacity instead of cost function.

Choose route with minimum total transmission power among routes that have nodes with sufficient remaining battery capacity.
Performance of Different Routing Algorithms Considering Power Efficiency

- The Structure of the Simulator
  - Ad hoc Mobile Network Formation
  - Mobile Host Migration Engine
  - Route Requests Event Generator
  - Routing Protocols Implementation
  - Power Consumption Computation
Ad Hoc Mobile Network Formation

- Confined space of 100m x 100m
- Each mobile host has a wireless cell size of 25 m radius
Mobile Host Migration Engine

- At the start of each simulation time slot, each node chooses randomly a new direction and moves a distance equal to the product of its speed and the length of a time slot.
- If it hits a boundary of the confined space, it bounces back.
- It moves at a speed of 2 m/s.
Route Requests Event Generator

- Use Poisson process for calculation of the route request
- If a route request occur, then choose two nodes are randomly pick as source and destination
- Request arrival rate is proportional to the number of nodes that power up
- Duration of each call is also exponentially distributed
Routing Protocols Implementation

- A simplified routing implementation, when a new route request arrives or a route is broken, the source node will broadcast a route query message, and all nodes that may receive and forward it will consume the same amount of energy.

- Implement five route selection schemes:
  - Use minimum hop metric
  - Select route base on stability of the route
  - Use minimum battery cost metric
  - Use min-max battery cost metric
  - Use conditional max-min battery capacity scheme
Power Consumption Computation

- Assume power consume for non-communication-related is fixed

- Three cases are considered
  - Power consumption for communication-related is much larger than power consumption for non-communication-related
  - They are the same
  - Power consumption for non-communication-related is much larger than power consumption for communication-related

- All nodes start out with the same battery power level
- Simulation stop when there are only two nodes left
An Ad Hoc Mobile Network Simulation Model
Simulation Results

Figure 3. (a) Expiration time vs. expiration sequence when $\sigma = 10$; (b) expiration time vs. expiration sequence when $\sigma = 1$.
Simulation Result (contd)

**Figure 4.** An illustration of the shortcoming in minimum-hop routing.

**Figure 5.** Expiration time vs. expiration sequence for different values of $\gamma$ when $\sigma = 10$. 
Simulation Result (contd)

Figure 6. a) Average host lifetime vs. increasing $\gamma$; b) standard deviation of lifetime of all nodes vs. $\gamma$. 
Simulation Result (Contd)

Average route length, $\sigma = 10$

- Hop number
- $\gamma$, battery capacity protection threshold

Graph shows the relationship between hop number and battery capacity protection threshold for different values of $\gamma$. As $\gamma$ increases, the hop number also increases, indicating a direct correlation between the two variables.
Conclusion

- Battery power capacity, transmission power consumption, stability of routes, and so on should be considered.
- The two goals: to use each node fairly and extend their lifetimes are not compatible.
- CMMBCR scheme chooses a shortest path if all nodes in all possible routes have sufficient battery capacity.
- Can maximize the time when the first node powers down or the lifetime of most nodes in the networks.
- If power use in communication subsystem is small compare to the overall power consumption then the difference of performance for all protocols is negligible doesn’t matter what routing metric used.