Adaptive Bandwidth Management in Heterogeneous, Mobile, Wireless Networks

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Overview

- Quality of service (QoS) challenges in MANET
- Architectural design
  - Dynamic MBN creation/maintenance
  - Landmark ad hoc routing (LANMAR) with backbone support
  - Quality of Service (QoS) provisioning
- Performance Results

Quality of Service (QoS) Challenges in MANET

- Hierarchical, heterogeneous, mobile wireless networks (e.g., MOSAIC)
  - Typically 2 or 3 levels
  - **Hundreds to thousands of nodes**
- Variety of users and applications
  - Different bandwidth and delay demands
  - Diverse traffic characteristics
- The bandwidth allocation and management scheme must be aware of the hierarchical structure and must account for the diverse capabilities of nodes
- Sensitivity to network load due to broadcast nature and bandwidth limits
- Avoid single point of failures
- Mobility!!!

Quality of Service (QoS) Challenges in MANET

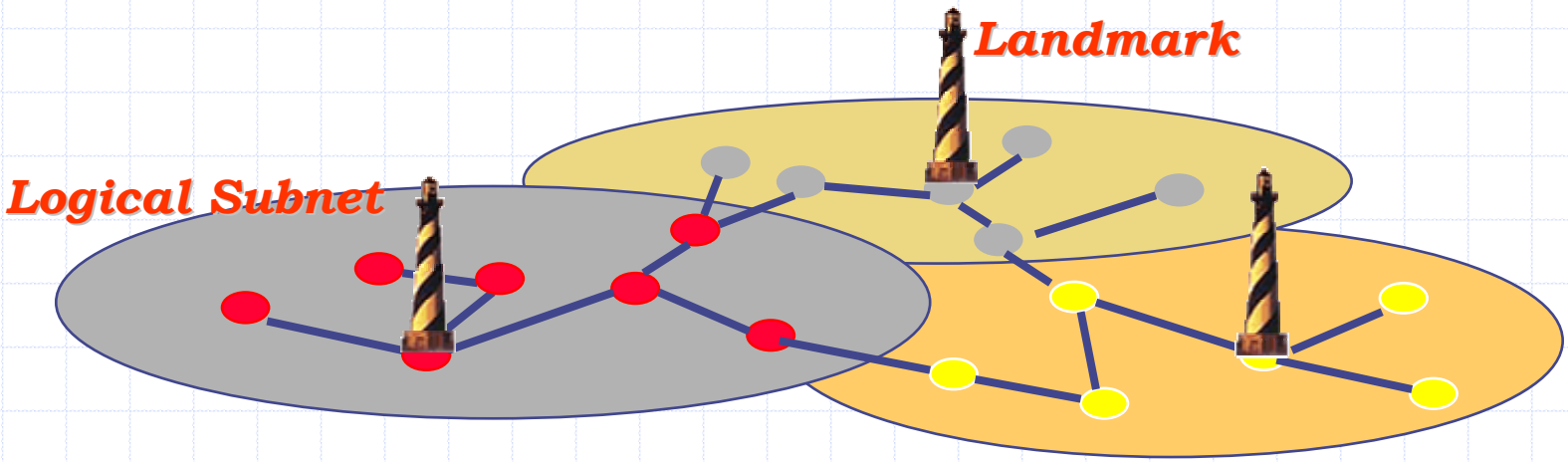
- InterServ
  - Control overhead will adversely affect network performance
  - Resource reservation difficult to maintain for each flow since paths constantly change
  - Scalability issues with maintaining flow state information at each node
- DiffServ
  - All nodes are potential ingress and egress routers in mobile environment, thus scalability may become a problem
  - Degradation of service if traffic overload within class

Architectural Design

- The large, heterogeneous mobile network will be organized using hierarchical mobile backbone networks (MBN)
- Landmark Ad Hoc Routing (LANMAR) to address scalability
  - Enhanced to support QoS
- Hierarchical QoS approach for time and computation efficiency as well as scalability

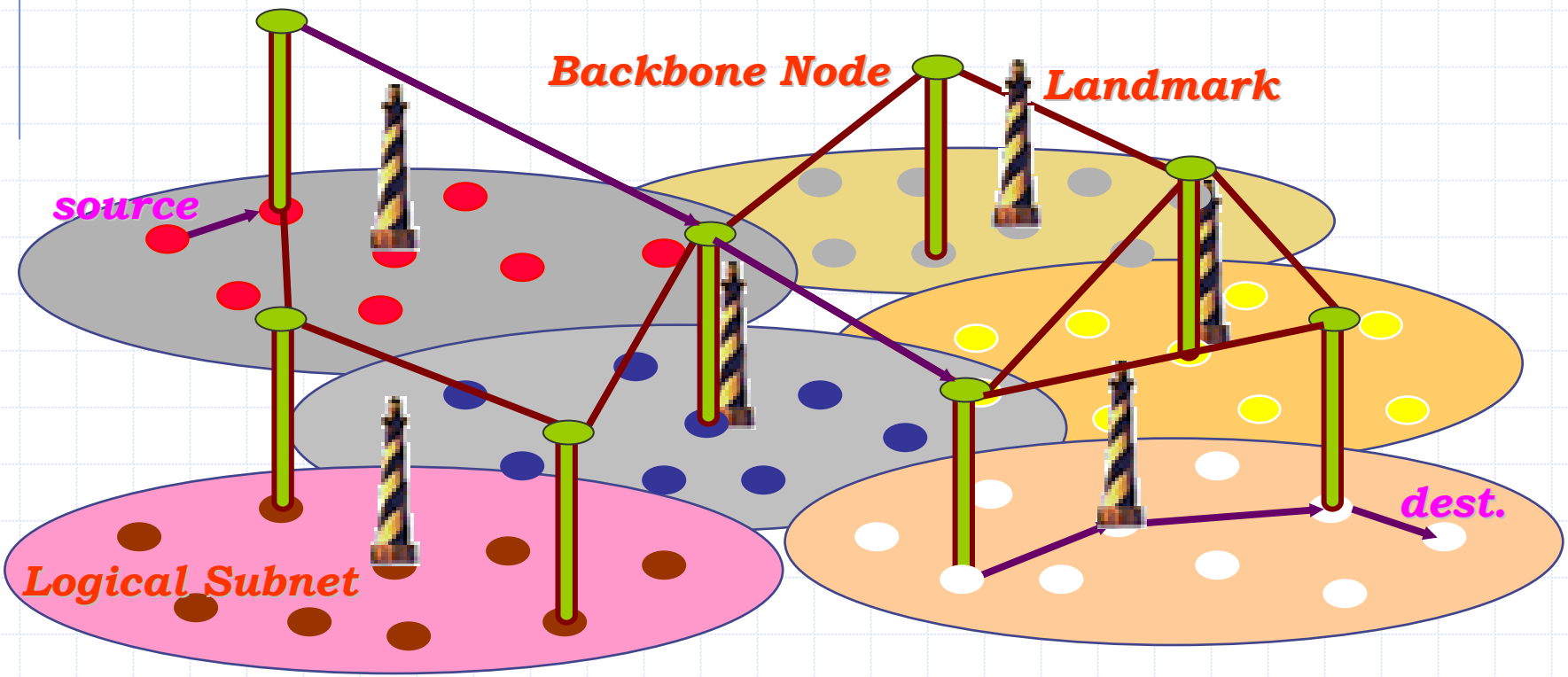
Landmark Ad Hoc Routing (LANMAR)

- A packet to local destination is routed directly using local routing table (scope routing)
- A packet to remote destination is routed to corresponding Landmark based on logical address
- Once the packet gets within Landmark scope, the direct route is found in local routing tables
- Benefits: dramatic reduction of both routing overhead and table size; scalable to large networks



Mobile Backbone Networks with LANMAR

- Backbone nodes are connected via powerful “long-range” radios
- Long hop paths are reduced to few hops by utilizing backbone links
- Backbone nodes are similar to gateways in the wired network
- Capability of supporting QoS



Important Components of Proposed QoS Scheme

- QoS extension of LANMAR, Fisheye
- Real time bandwidth measurement in mobile ad hoc networks
- Call acceptance control
- Soft bandwidth reservation
- Mobility adaptation
- Scheduling and policing
- Coexistence with best effort traffic

QoS Extension of LANMAR Routing

- Scope routing protocol carry available bandwidth information
  - Fisheye
- Landmark updates carry min and max available bandwidth
- Based on nodes in associated subnet group and along forwarding paths

QoS Extension of FISHEYE Routing

- Link state updates carry bandwidth information during periodic scoped flooding

Bandwidth Measurement

- Easy when TDMA MAC schemes are used
  - Slots determine available bandwidth
- We target random access MAC
  - CSMA based IEEE 802.11 MAC DCF
  - Shared broadcast medium (i.e., channel bandwidth not dedicated to single user)
  - Channel access not predetermined

Bandwidth Measurement Approach

- Monitoring physical radio status
- Two radio states
  - Radio busy (e.g. transmitting, receiving, carrier sensing busy)
  - Radio idle
- Available bandwidth calculation

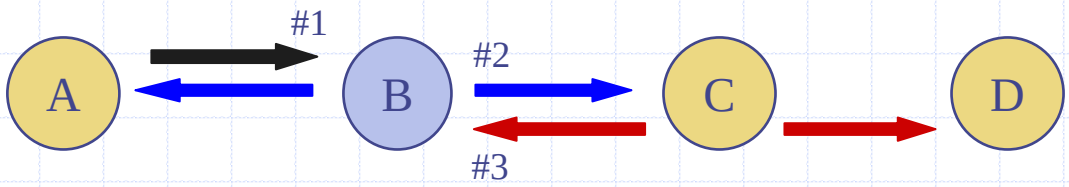
  T: sampling time window for calculating real time bandwidth

  T_{idle}: period radio is in idle state in the last time window T

  W: Maximum bandwidth

  Estimated available bandwidth: $BW_{available} = \frac{T_{idle}}{T} * W$

Requested Bandwidth in MANET Environment



- Bandwidth required is actually 3x more than application requested bandwidth for 3 or more hop scenarios
- Adjust application requested bandwidth accordingly

Call Acceptance Control (CAC) – Routing Protocol Dependent

- Admitting or rejecting new flows
  - Consult routing table for available bandwidth along path
  - If requested bandwidth <= min bandwidth along path, accept the flow
  - If min bandwidth < requested bandwidth <= max bandwidth, probe path
    - Intermediate nodes check if available bandwidth is adequate to support requested bandwidth
      - If adequate, forward request to next hop to destination
      - If not adequate, send REQUEST_REJECT to source
      - If request reaches destination, sends REQUEST_ACCEPT if requested bandwidth is met, REQUEST _REJECT otherwise
  - If requested bandwidth > max bandwidth along path, reject the flow
  - Flow may retry several times with some waiting time before being rejected

Call Acceptance Control (CAC) – Routing Protocol Dependent

- Adjusting admitted flows
  - If the path is not longer able to fulfill the QoS requirement due to mobility, re-routing, etc
    - Suspend flow and initiate call admission up to a threshold number of times (using exponential backoff) in hopes to find other paths before giving up
  - Flows to suspend based on data packets that experienced bandwidth requirement violation
    - Suspend all flows indicated in data packets that experience problem
    - Investigate other methods to select flows to suspend

Soft (Implicit) Bandwidth Reservation

- Used during call admission and maintenance of admitted flows due to mobility, re-routing
- Periodically monitor available bandwidth for call admission process
- **Admitted flows will be taken into account during periodic bandwidth measurement**
  - Bandwidth is thus reserved implicitly

Mobility Adaptation

- Bandwidth measurement scheme can adapt to mobility, topology as well as traffic changes
- Each data packets contains bandwidth requirement using IP option
- Intermediate nodes monitor the available bandwidth changes
- If bandwidth requirements are no longer fulfilled
  - Send “SUSPEND” packets to the source nodes of those flows whose bandwidth requirements are no longer fulfilled
  - Source nodes suspend flow upon SUSPEND receipt and again re-initialize call admission

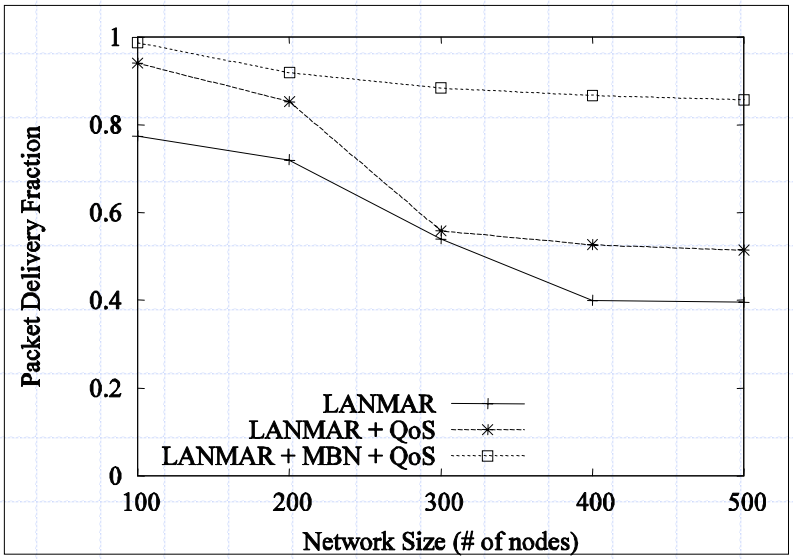
Coexistence with Best-Effort Traffic

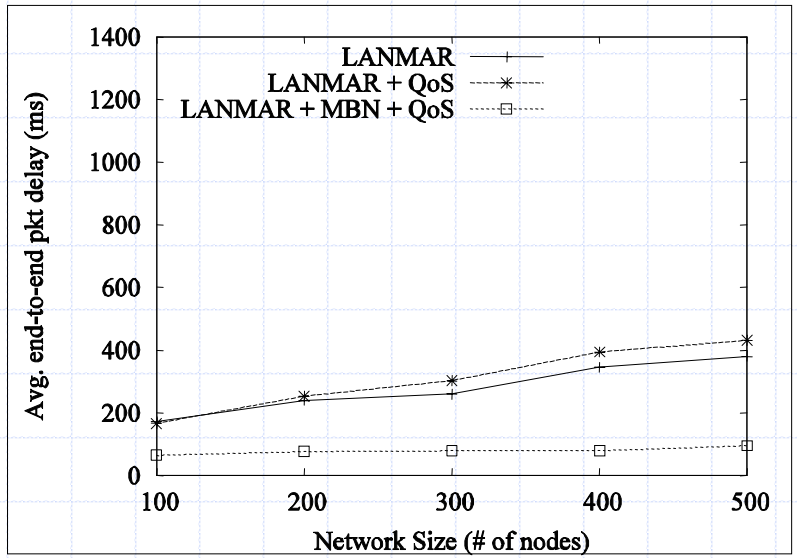
- Certain amount of bandwidth is pre-reserved for best-effort traffic to prevent non-QoS flows from starvation
- Best-effort traffic can use bandwidth exceeding its pre-reserved portion when QoS bandwidth not fully utilized
  - Return to QoS traffic if needed
- A priority based scheduling could be adopted, such as Strict Priority or WFQ, to improve performance

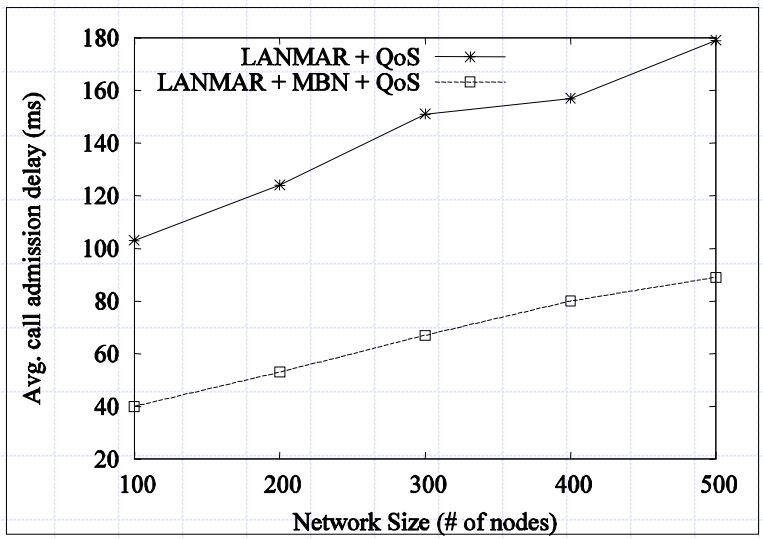
QualNet Network Simulator

- Simulator used for research
- http://www.qualnet.com
- Commercial version of GloMoSim developed at UCLA
- Fast, efficient and detailed network simulator for both wired and wireless networks
- Ability to simulate thousands of nodes without using abstraction

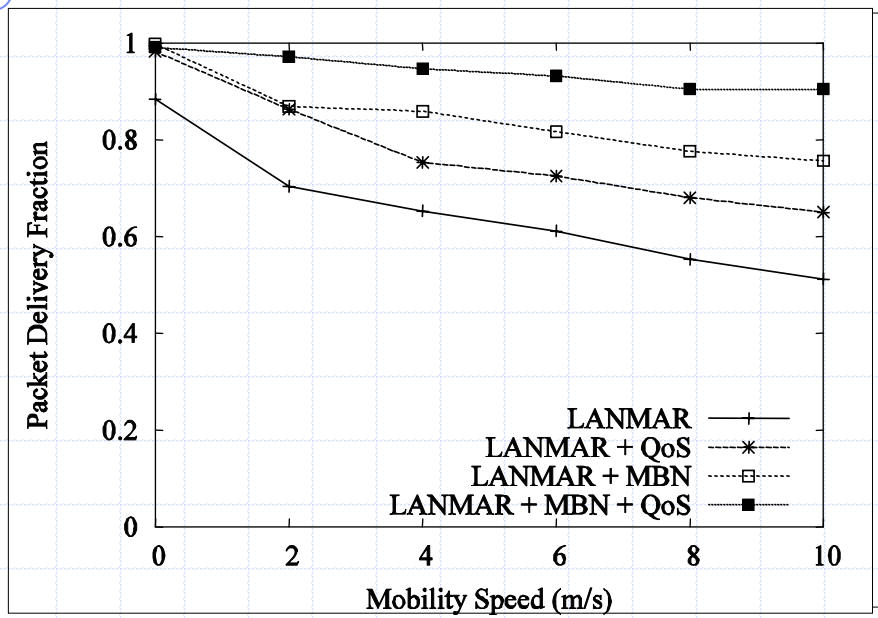
Network Size Experiments

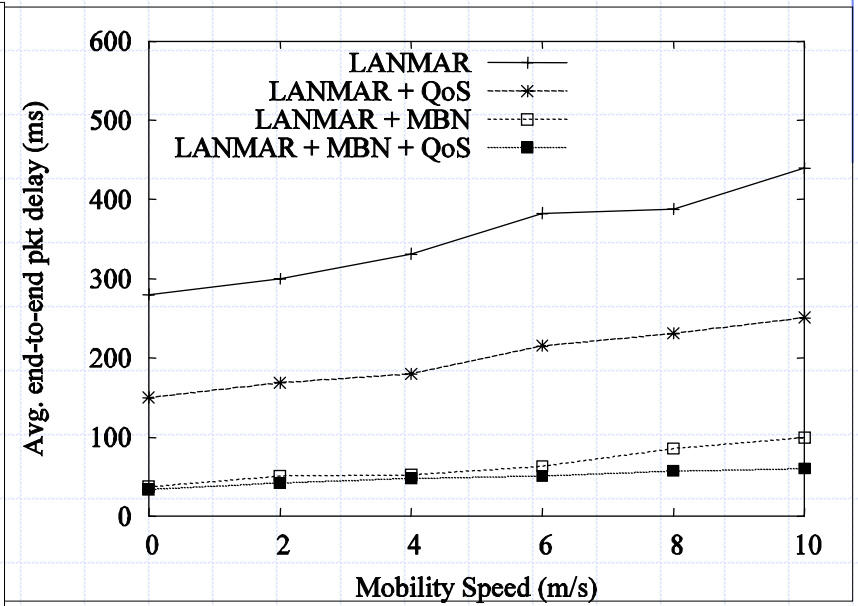






Mobility Experiments





Experiment Conclusion

- LANMAR provides scalability
- Backbone decreases routing hops
  - Reduces loss caused by channel
  - Reduces loss cause by mobility (longer range radio covers larger area)
  - Reduces end-to-end-delay
  - Reduces call admission delay
- QoS only admit flows if bandwidth is available
  - Reduces congestion and contention
  - Preserves admitted flows