



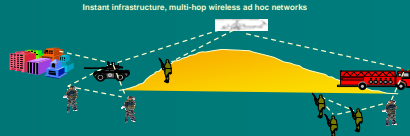
# Adaptive Bandwidth Management in Heterogeneous, Mobile, Wireless Networks

(CECOM Phase II SBIR by Scalable Network Technologies, Inc.)



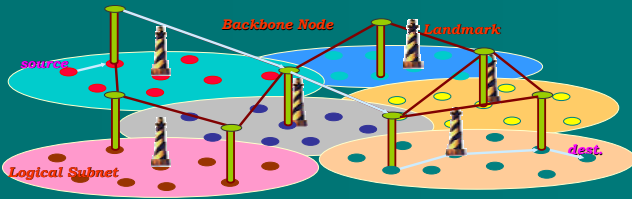
## Objectives

- Quality of service architecture for heterogeneous, mobile, wireless ad hoc network
- Protocols for bandwidth provisioning
- High-fidelity models of proposed protocols
- Detailed simulation study using QualNet
- Performance evaluation of proposed schemes
- Prototype deployment of proposed schemes



## QualNet Network Simulator

- Scalable, fast and accurate simulation
- Ability to simulate thousands to nodes
- Parallel runtime support
- <http://www.qualnet.com>



## QoS Components

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

## Quality of Service (QoS) Challenges in MANET

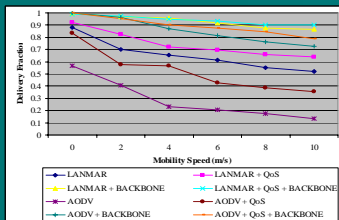
- Hierarchical, heterogeneous, mobile, wireless networks (e.g., MOSAIC)
  - Typically 2 or 3 levels
- Hundreds to thousands of nodes
- Variety of users and applications
- Different bandwidth and delay demands
- Diverse traffic characteristics
- Bandwidth allocation and management scheme must be scalable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

## Call Acceptance Control (CAC) – Routing Protocol Dependent

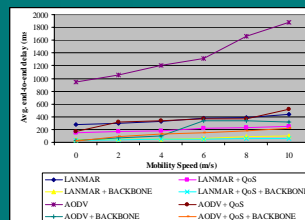
- Consult routing table for available bandwidth along path
- If requested bandwidth  $\leq$  min bandwidth along path, accept the flow
- If min bandwidth  $<$  requested bandwidth  $\leq$  max bandwidth, probe path
  - Intermediate nodes check if available bandwidth is adequate to support requested bandwidth
    - 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

## Performance Evaluation

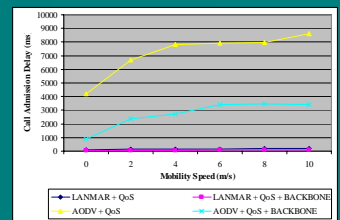
- 5000m x 5000m field
- 1000 nodes
- Ground radio
  - 375m range, 2Mbps
- Backbone radio
  - 1200m range, 11Mbps
- Mobility varies from stationary to 10m/s
- 30 QoS flows randomly selected, each with rate of 40Kpbs



LANMAR + QoS + Backbone achieves best data delivery



LANMAR + QoS + Backbone achieves best average end-to-end delay



LANMAR + QoS + Backbone achieves best call admission delay

## Results

- LANMAR provides scalability
- Backbone decreases routing hops
  - Reduces loss caused by channel
  - Reduces loss caused by mobility (longer range radio covers wider area)
  - Reduces end-to-end delay
  - Reduces call admission delay
- AODV needs to search for route before admitting flows, which results in longer call admission delay
- LANMAR already has routing information to determine call admission
- QoS scheme only admits flows if bandwidth is available
  - Reduces congestion and contention
  - Preserves admitted flows