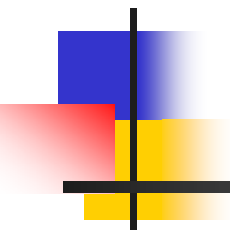


Lecture 7

Mobile Ad-Hoc Networks: Quality of Service



Reading:

- “Quality of Service in Ad Hoc Wireless Networks,” in *Ad Hoc Wireless Networks: Architectures and Protocols*, Chapter 10.
- K. Wu and J. Harms, “QoS Support in Mobile Ad Hoc Networks,” *Crossing Boundaries— an interdisciplinary journal*, Vol. 1, No. 1, Fall 2001.
- H. Zhu, M. Li, I. Chlamtac and B. Prabhakaran, “A Survey of Quality of Service in IEEE 802.11 Networks,” *IEEE Wireless Communications*, August 2004.



Quality of Service Challenge

- “Providing complex functionality with limited available resources in a dynamic environment”
- Supporting QoS requires knowledge of
 - Link delays
 - Bandwidth
 - Loss rates
 - Error rates
- Problem with ad hoc networks
 - Hard to obtain this information
 - Links constantly changing: node mobility, environmental affects, etc.



QoS Services

- Hard QoS
 - Guarantee parameters such as delay, jitter, bandwidth
 - Required for mission-critical applications
 - E.g., air traffic control, nuclear reactor control
 - Not feasible in MANETs
- Soft QoS
 - Aim to meet QoS goals
 - Loss in QoS degrades application but does not have disastrous consequences
 - E.g., voice, video
 - Most research focuses on providing soft QoS



QoS Parameters

- Bandwidth
- Delay jitter
- Delay
- Security
- Network availability
- Battery life
- ...



Why is QoS Hard in MANETs?

- Dynamic network topology
 - Flow stops receiving QoS provisions due to path breaks
 - New paths must be established, causing data loss and delays
- Imprecise state information
 - Link state changes continuously
 - Flow states change over time
- No central control
- Error-prone shared medium
- Hidden terminal problem
- Limited resource availability
 - Bandwidth, battery life, storage, processing capabilities
- Insecure medium



Design Choices for QoS

- Hard state vs. soft state
- Hard state
 - Resources reserved at all intermediate nodes in path for duration of flow
 - If path broken, resources must be explicitly released
 - Requires control overhead
 - May fail to release resources if nodes on path unreachable
- Soft state
 - Resources reserved for small amount of time
 - Reservations automatically renewed as long as flow continues
 - Resources deallocated after timeout period if no new data
 - No explicit tear-down needed
 - Low overhead



Design Choices for QoS (cont.)

- Stateful vs. stateless
- Stateful
 - Nodes keep either global or local state
 - State includes topology information and flow information
 - Global state not scalable
- Stateless
 - No flow or topology information maintained at each node
 - Scalable
 - Difficult to provide QoS without knowing any state information



Aspects of QoS in MANETS

- QoS models
 - What type of services can be provided?
 - Defines the types of service differentiation
- QoS resource reservation signaling
 - Coordinates routing, MAC, admission control and scheduling
- QoS routing
 - Finds path with requested resources
- QoS MAC
 - Provide support for QoS services



QoS Models for the Internet

- Integrated Service (IntServ)
 - Routers keep flow-specific state
 - Bandwidth requirement
 - Delay bound
 - Flow cost
 - Service models
 - Best effort
 - Guaranteed service: fixed delay bound
 - Controlled load service: better than best effort
 - RSVP protocol used to reserve resources in routers
 - Admission control used to accept/decline reservations at hosts
 - Priority queues implemented to provide service guarantees to flows with accepted reservations



IntServ Model for MANETs

- IntServ not feasible in MANETs
 - Scalability
 - State information increases with number of flows
 - Storage and processing overhead
 - RSVP signaling packets use bandwidth needed to send data packets
 - Burden on hosts
 - Mobile hosts must perform admission control, classification of all incoming data packets, and priority scheduling



DiffServ Model

- Differentiated Service (DiffServ) model
 - Traffic separated into small number of classes
 - Routing decisions based on class of packet
 - No per-flow state
 - Scalable model
 - Limited processing for routers
 - Example services
 - Premium service: low loss, low delay, low jitter, end-to-end bandwidth guarantee
 - Assured Service: better than best effort service
 - Olympic Service: three tiers of services
 - Service Level Agreement (SLA) used to receive DiffServ
 - Agreement between customer and ISP



DiffServ Model for MANETs

- No per-flow state ensures scalability → DiffServ may be feasible for MANETs
 - Premium service impossible to support
 - Assured service possible
- SLA difficult to implement in MANETs



New QoS Model for MANETs

- Flexible QoS Model for MANET (FQMM)
 - Hybrid approach: combines features from IntServ and DiffServ models
 - Per-flow QoS for high priority flows
 - Aggregate QoS for lower priority flows
 - Source node responsible for traffic shaping
 - Delaying packets belonging to flow to meet traffic profile
 - Meet criteria such as mean rate, burst size
- Issues with FQMM
 - How many per-flow sessions possible?
 - How do intermediate nodes determine packet information?
 - How should scheduling be performed at intermediate nodes?
- New QoS models still needed for MANETs



QoS Signaling

- Used to reserve and release resources when flows created, removed or changed
- Inform application of success/failure of resource reservation
- Two issues
 - Reliable exchange of QoS signaling information
 - In-band signaling: control information with data
 - Out-of-band signaling: separate control packets
 - Interpretation of QoS signaling information
- Protocols
 - RSVP, Insignia



In-band vs. Out-of-band Signaling

- In-band signaling
 - Low overhead
 - Cannot implement complex functionality
- Out-of-band signaling
 - Adds overhead
 - Higher priority for signaling messages
 - Reduces effective bandwidth for data transmission
 - Easier to implement signaling protocol



RSVP

- QoS signaling for the Internet
- Out-of-band signaling system
- Request message sent via routing protocol to receiver
 - Request includes traffic specifications (rate, burst size)
- Receiver sends back a reservation message to sender
 - Intermediate routers check if they can support requested services
 - If so, allocate resources
 - If not, send error message to receiver
- Receiver initiates resource request
- Flow information periodically refreshed
- Problems for MANETS
 - Too much overhead to apply RSVP to MANETS
 - Not adaptive to dynamic networks



MRSVP

- Extension of RSVP for cellular network with mobile hosts
- Predicts future locations and reserves resources
- Active and passive reservations
 - Other flows can use resources from passive reservations
- Not suitable for MANETs
 - Unpredictability of mobile hosts' future locations
 - Current topology different than future topology so making passive reservations does not make sense



Insignia

- Designed specifically for MANETs
 - In-band signaling
 - Base and enhanced QoS levels
- Per-flow management
 - Resource management adapted as topology changes
 - Intelligent packet scheduling
 - Flow reservation, restoration and adaptation
- QoS reports periodically sent to source node
 - Source node takes action to adapt flows to observed network conditions



Insignia (cont.)

- Routing
 - Any routing protocol can be used
 - Route maintenance procedure will affect QoS
- In-band signaling
 - Establish, adapt, tear down reservations
 - Control information embedded in data packets
- Admission control
 - Determine whether or not to accept reservation
 - Refresh reservation periodically based on current state
- Packet scheduling
 - Weighted round-robin for different flows
- MAC
 - Any MAC protocol can be used
- Automatic reconfirmation or de-allocation of reservation based on data packets received and timeouts



Insignia (cont.)

- Integrated in-band signaling, admission control and packet scheduling
- Useful for multimedia applications
 - Support multiple operation modes (max and min bandwidth modes)
 - Some loss acceptable
- MAC and routing protocols affect ability to support QoS
- Cannot provide absolute guarantees



QoS Routing Protocols

- Goal: search for a path through the network that provides sufficient resources to meet QoS goals
 - E.g., delay, delay jitter, bandwidth
- Concave or additive metrics for paths
 - E.g., bandwidth is concave, whereby each link must satisfy minimum bandwidth constraints
 - E.g., delay is additive, whereby route delay is sum of individual link delays
- NP-complete problem to find paths with two or more metrics
 - E.g., finding delay-constrained least-cost path
 - Use heuristics



QoS Routing Protocols

- Difficulties with QoS routing
 - Overhead high
 - Maintaining link state information difficult
 - Cannot guarantee QoS as in wired networks
 - Route breaks
 - Node failures
 - Must update paths with new paths that have enough resources— may not be possible



CEDAR Protocol

- Core-Extraction Distributed Ad-hoc Routing
- Core: approximation of minimum dominating set
 - Every node in core or neighbor of core node
 - Dominator of node: one core node neighbor
 - Maintenance of core as nodes move
- Core nodes keep link state for high bandwidth, stable links
 - Increase and decrease waves to inform core nodes of current state of links
- Routes created using core path between source and destination as guideline
- Routes maintained
 - Locally
 - Re-initiate route set-up



Ticket-based QoS Routing

- Probe packets (PKT) issued with certain number of “tickets”
 - Tickets determine maximum number of paths that can be probed for suitability
 - Intermediate nodes allocate tickets among neighbors
 - Choose neighbors most likely to satisfy QoS constraint
 - Requires state information
 - Example
 - Source A transmits PKT with 3 tickets to neighbor B
 - B transmits PKT with 2 tickets to C, PKT with 1 ticket to D
 - C transmits PKT with 1 ticket to E, PKT with 1 ticket to F
 - D transmits PKT with 1 ticket to G
 - Etc.
- Multiple suitable paths found, select “best” one



Ticket-based QoS Routing (cont.)

- Reliability
 - Multi-path routing
 - Data sent independently on all paths
 - Destination keeps first copy of data to arrive, discards rest
 - “Best” path selected as primary path, others kept as back-up paths
 - With resources reserved
 - Without resources reserved → best effort
- Provides nice trade-off between control overhead (based on number of tickets) and finding good feasible path
- Issues
 - Performance depends on ticket-issuing and ticket-splitting procedures
 - Global state required at each node → not scalable



QoS MAC Protocols

- Two approaches:
 - Guaranteed resource reservation
 - Provide service differentiation
 - Allow real-time/high priority packets to access channel before non-real-time/lower priority packets
- Still meet the goals of MAC protocols



Cluster TDMA

- Network organized into clusters
 - Select cluster head via
 - Lowest-ID
 - Highest degree
 - Least cluster change
- Cluster head assigns TDMA slots to nodes
- Inter-cluster interference avoided via TDMA or CDMA
- Frame times synchronized throughout network
- Create virtual connections via assigning slots
- Free slots used for best-effort traffic via slotted-ALOHA



MACA/PR

- MACA with Piggyback Reservation
- Data and ACK packets include reservation information in header
- Receivers keep reservation tables
- Bandwidth reservation
 - Reservation information in Data packets inform neighbors of transmitter of next transmission
 - Reservation information in ACK packets inform neighbors of receiver of next transmission
 - Reservation tables also shared among nodes



Providing QoS in IEEE 802.11

- Provide “better than best effort” service
- Service differentiation via
 - Prioritization of different packets
 - Fair scheduling
- Tunable parameters
 - Contention window
 - Backoff algorithm
 - Interframe spacing (IFSs)



IEEE 802.11e

- Enhanced DCF (EDCF)
- All nodes use DCF MAC protocol
- Parameters set according to traffic requirements
 - Prioritizes traffic according to access category (AC)
 - Adjust
 - IFSs
 - Minimum and maximum backoff window sizes
 - Multiplication factor for adjusting backoff window
- Probability of accessing channel affected by these parameters
 - Set parameters such that high priority data has higher probability of accessing channel earlier



QoS in IEEE 802.11

- Other techniques for prioritization
 - Persistent Factor DCF: backoff geometrically distributed with parameter P based on packet priority
- Fair-scheduling techniques
 - Provide fairness in allocation of bandwidth to different traffic classes
 - Often cannot be implemented in existing standard
 - Distributed weighted fair queue
 - Distributed fair scheduling
 - Distributed deficit round robin



Discussion
