Integration of Ad Hoc Networks with Infrastructure Networks – A QoS Perspective

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MANETs - Intro

Telecom Network

Public Internet

Wireless Access Networks

e.g. GPRS/UMTS

Infrastructure based Wireless network

Infrastructure based Wireless network

e.g. WLAN

Fixed PC/WS

Mobile PDAs

Laptops

Mobile Communication Devices
MANETs - Intro

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Wireless Access Networks

e.g. GPRS/UMTS

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Wireless Sensors

Laptops

Internet Connectivity

Mobile Ad Hoc Network
QoS for MANETs

**Introduction**
- Today available (if at all):
  - Best Effort Services
  - This is not enough for real-time multimedia traffic

**Motivation**
- We want to increase the usability of Ad Hoc networks
- We want Internet connectivity
  - assumed to be solved in this talk
  - although many open issues still to be solved to be really useful
- We want to provide better than Best Effort Services
- We start with QoS models in fixed networks
  → QoS support in MANETs?
QoS for MANETs

What is QoS?
- No common definition and understanding at all!
  e.g. “The collective effect of service performance which determines the degree of satisfaction of a user of a service” (ITU-T Rec. E.800)

How is QoS achieved nowadays?
- Throw bandwidth on the Problem: “Over Provisioning”
  - Easy for fixed networks!
  - Can be done step-by-step
  - There will always be congestion points!
  - But still only 1 service class (best effort)

- Increase Network Complexity: Traffic Classes, Admission Control, Reservation Protocols, Packet Scheduling,…)
  - Reservation-based (e.g. RSVP/IntServ)
  - Aggregation-based (e.g. DiffServ)
QoS for MANETs

QoS enabled End-to-end services

- FTP
- email
- HTTP
- Multimedia streaming
- Multimedia playback

Shared medium
Decentralized access
Node mobility
Energy constraints
Channel variation
Hidden Terminal
per-node bandwidth fluctuation
topology changes/rerouting
…...
QoS for MANETs

Trade-Offs

- Using IntServ-style mechanisms:
  - Application specifies traffic and QoS requirements.
  - Resource reservation protocol performs admission control and reserves resources at each node on the path.

- In a MANET:
  - It is hard to reserve resources
    - Shared medium reservation requires global coordination
    - Violations can still occur as bandwidth fluctuates.
  - Resource reservation is pinned to a route:
    - Must be redone whenever route changes.
    - This might NOT be a good idea
  - It is hard to estimate resource availability for admission control:
    - Dynamic bandwidth due to node mobility and channel contention.
QoS for MANETs

- **Trade-Offs**
  - In DiffServ-like mechanisms:
    - Application (Ingress node) selects a class of service.
    - Network performs admission control to avoid per class overload:
      - AF PhB assures per-hop throughput.
      - EF PhB assures per-hop low delay.
      - Per Domain Behaviors for end-to-end assurances → Bandwidth Broker
  - In a MANET:
    - *It is hard to maintain assurances:*
      - Flow distribution varies as routes change. Bandwidth fluctuates.
    - *It is hard to perform admission control:*
      - Flows do not pass through common ingress nodes.
QoS for MANETs -INSIGNIA

- **Main characteristics**
  - In-band signaling
  - Packet carries enough information for establishing, maintaining and restoring per-flow soft-state reservation
  - Per-flow differentiation
  - Fast restoration mechanism to overcome re-routing

- **Drawbacks**
  - Per-flow state information in intermediate node
  - Processing power/scalability
  - Fast-Restoration mechanism targeted for **pure** MANET
    - Does not bring advantages when integrated with the infra-structured QoS Signaling.
QoS for MANETs - FQMM

Main characteristics

- QoS model for hybrid per-flow/per-class provisioning
- Adaptive traffic profile
  - Keeps consistent differentiation between sessions (flows/aggregates)
  - Relative percentage of the effective link capacity, in order to keep the differentiation between classes predictable and consistent under the dynamics of the network.

Drawbacks

- Admission Control **NOT** defined
- Traffic control is performed in function of the local network conditions
  - Does not necessarily reflect the end-to-end network condition!
QoS for MANETs - SWAN

Main Characteristics

- Stateless and Distributed Control Algorithms based on Feedback
- TCP AIMD congestion control operates close to the cliff
  → Keep the network under-loaded at the delay-knee
  → Use MAC delay as feedback instead of packet loss
QoS for Ad Hoc Networks

- **Characteristics:**
  - Local Rate Control
    - for TCP based on MAC delay monitoring
  - Source based Admission Control based on Probing
    - For UDP RT using utilization
  - Stateless

- Probing may lead to false admissions
  - When several sessions are simultaneously admitted
  - When mobility leads to re-routing

→ Dynamic Regulation
QoS for Ad Hoc Networks

- **Characteristics:**
  - Regulation (on Admitted RT traffic) based on ECN
  - Result
    - simple, robust, scalable, responsive to changes 😊
    - Less utilization (5-20%) 😞

Our Approach is based on SWAN and adds
- Several Traffic Classes
- Gateway participates in
  - Admission Control
  - External signalling
  - Dynamic Regulation

Detect ECN

Notify SRC

Set ECN
QoS for Integrated MANETs

- **QoS Integration requirements**
  - QoS model/architecture
    - Adaptation/Definition of an ad-hoc model that best fits infra-structured approach
  - Interoperability with External Networks QoS mechanisms
    - infra-structure signaling
    - infra-structure service differentiation approaches
    - Same or similar supported service classes
  - Responsiveness to ad-hoc dynamics
  - Cope with the lack of centralized resource management
    - NO Hard QoS Guarantees
QoS Architecture (1/2)

MN -- Ad Hoc Extension -- IP based Access Network -- External Network -- IP Network -- CN

Access Router

Access Network Gateway
QoS Architecture (2/2)

- **Ad Hoc Extension**
  - Access Router
  - IP based Access Network
  - External Network
  - IP Network

- **Edge Devices**
  - Admission Control
  - Derive PhB
  - Allocate DSCP

**End-to-End Application Layer Signaling (e.g. SIP/SDPng)**

**Adaptive End-to-End Transport QoS based on RTP/RTCP (for multimedia), QoS feedback on packet loss and jitter**

**End-to-End Network Layer QoS Signaling (e.g. RSVP, NSIS) - optional**

**AI (L2) QoS**

**e.g. DiffServ PhBs**

**No assumption about external network**

- **MN**
- **CN**
Integration Network Scenario
QoS for Integrated MANETs

- **Our approach based on SWAN**
- **Bandwidth Probing**
  - Each MN updates Bottleneck Bandwith with minimum available in corresponding class (DSCP)
  - RB=Requested Bandwidth
  - Requires layer-2 bandwidth estimation
  - Access Router
    - checks for resources in infrastructure and translates to external signalling
    - Performs correct QoS mapping togeter with 802.16 BS

- **Renegotiation**
  - Access Router monitors ECN
  - Sends to source Regulate message
QoS for Integrated MANETs

Bandwidth Probing

Classification and 802.16 QoS CID configuration with 802.16 BS
QoS for Integrated MANETs

Dynamic Regulation

Class Y overload:
Start marking ECN bits and dropping packets according to defined rules

Data session

ECN detected
Select sessions to degrade based on user profile

Classification and 802.16 QoS
CID configuration with 802.16 BS

Regulate Message (Flow info)

Application Adaptation or Renegotiation
QoS for Integrated MANETs

- **MN components: Evolution of SWAN**
  - Best effort MAC technology
  - Extension to support 4 traffic classes
  - AIMD algorithm to control shaping rate of lower priority classes
  - Targeting a limited delay depending on the service class
  - Complemented by AC and Congestion control

\[ n \text{ - number of packets exceeding the threshold delay } d_i; \]
\[ s_i \text{ - shaping rate of shaper } i; \]
\[ r_i \text{ - multiplicative decrease factor; } \]
\[ c_i \text{ - additive increase increment; } \]
\[ a_i \text{ - actual rate of traffic crossing the shaper; } \]
\[ g_i \text{ - maximum gap of } r_i \text{ concerning } a_i. \]

\[
\begin{align*}
\text{if } (n > 0) & \quad s_i \leftarrow s_i \times (1 - r_i) \\
\text{else} & \quad s_i \leftarrow s_i + c_i \\
\text{if } ((s_i - a_i) > a_i \times g_i) & \quad s_i \leftarrow a_i \times (1 + g_i)
\end{align*}
\]
QoS in IEEE 802.16

Connections established between BS and SS
- Identified by a 16-bit CID (Connection Identifier)
  - Basic CID, Primary Management CID, Secondary Management CID, Broadcast Management CID
  - Transport CID
  - Broadcast Data CID
- Associated with a specific Service Flow

Service Flows
- QoS Params (bandw., delay,..) identified by 32-bit SFID
- Associated with 4 Uplink Scheduling Services
  - UGS (Unsolicited Grant Service) – VoIP
  - rtPS (real time Polling Service) – Video Streaming
  - nrtPS (non real time Polling Service) – FTP
  - BE (Best Effort)
Classification in IEEE 802.16

- **Process**
  - Incoming packets at the BS are mapped / classified into a specific established service flow
  - Mapping / Classification procedure
    - Packet matching criteria defined by the classifier
    - If QoS parameters are not satisfied by existing CIDs:
      - A new connection can be established
      - The packet can be discarded
      - Default connection may be used
    - Decision depends on network manager / equipment capabilities
QoS Integration: MANET/802.16

- Based on classification
  - as defined in IEEE 802.16-2004 standard
- Different solutions for classification process
  - DSCP field
    - Group of flows differentiation
      - Diffserv approach
    - Lack of differentiation
      - Single service flow differentiation was required
      - However, DSCP may implicitly include more granularity than the class identifier
QoS Integration: MANET/802.16

- Different solutions for classification process
  - IPv6 Flow Label field
    - Marking process
      - Label inserted in the AR based on
        - IPv6 Src / Dest addresses
        - Src / Dest Ports
        - DSCP field information
        - Priority
    - Single service flow differentiation
      - Intserv + Diffserv approach
QoS Integration: MANET/802.16

- **Implicit signaling**
  - DSCP refers to network service and class information or Flow Label fields for larger granularity
  - AR and BS need to do the correct mapping
    - resources reserved end-to-end are the same for the same session flows

- **SWAN QoS ad-hoc protocol messages**
  - transparently transported in the 802.16 network
  - integrated with the infrastructure network

- **SS and BS forward packets**
  - based on the fields required for classification
Thank you!

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