Quality of Service in Wireless Systems

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Outline

• QoS Review
  • QoS Requirements
  • QoS Mechanisms
  • IntServ/RSVP
  • DiffServ
    ⇒ see Mobile Communication Networks Course (B.S.) for details

• QoS in WLANs – 802.11e
  ⇒ see Mobile Communication Networks Course (B.S.) for a review of MAC mechanisms

• Next Steps in Signaling (NSIS)

• QoS and Mobility Management

• QoS in UMTS
QoS over the Air Interface

- QoS has to be provided end-to-end
- Weakest part of connection limits its quality
- Lots of QoS problems on wireless links due to fading, mobility, etc.
  => high and fast variation of quality of wireless link
- Different mechanisms may be used on different parts of the end-to-end connection
- Application of the mechanisms to the air interface
  - reservation (IntServ) => appropriate where the amount of resources and the number of connections is small and the QoS requirements are hard
  - differentiation (DiffServ) => appropriate where a large number of connections has to be handled or QoS requirements are moderate
  - overprovisioning => appropriate where resources are abandon (typically not true for air interface) or traffic volume is known (may hold for access network)
- UMTS provides a mix (variety) of the techniques in different parts (levels) of the system
QoS in WLANs – 802.11e
QoS Enhancements – 802.11e

- **Ideas:**
  - **Hybrid Coordination Function (HCF)**
  - Contention and Contention Free Periods (CP and CFPs)
  - **Enhanced Distributed Channel Access – EDCA**
    - Enhanced DCF
    - Differentiation of access for different traffic classes
    - Differentiated services (DiffServ)
  - **HCF Controlled Channel Access – HCCA**
    - Extension to PCF
      - Polling of stations in CFP
      - Provision of maximum access time to medium (TXOP)
      - Enforcement of superframes
    - Guaranteed service (IntServ)
  - QoS-enhanced Basic Service Set (QBSS) replaces BSS
802.11e – EDCA (Enhanced Distributed Channel Access)

- Review of DCF (Distributed Coordination Function)
  - CSMA/CA
  - Transmits the frame directly if the medium is found idle for DIFS (DCF InterFrame Space)
  - Otherwise, defer the transmission and start the backoff process
  - Backoff_time = rand[0, CW], CW_{min} < CW < CW_{max}
  - Backoff timer decreases only when the medium becomes idle
  - Transmits the frame if backoff timer expires

- EDCA: Priority-based access scheme
  - Replaces DIFS with different AIFS (Arbitration InterFrame Space), depending on traffic characteristics
  - Adapts the contention window size to traffic characteristics
  - Different random backoff times and AIFSs to provide differentiated services

- The relative performance is not easy to control
  - The performance is NOT proportionally to the backoff factor ratios
  - It depends on the number of contending stations
**802.11e – EDCA**

- Enhancement of access during Contention Period (CP)
- Multiple backoff instances for data streams => different priorities
- Priority over legacy stations (ensured for \(CW_{min}[TC]<15\))

Parameters per Traffic Category (TC):
- AFIS  Arbitration Inter Frame Space
- CW    Contention Window (min & max values)
- PF    Persistency Factor (parameter for calculation of CW after unsuccessful transmission attempt)
802.11e – EDCA

Up to 8 transmission queues per station

Legacy: one priority

802.11e:
up to 8 independent backoff instances

Scheduler (resolves virtual collisions by granting TXOP to highest priority)
802.11e – HCCA (HCF Controlled Channel Access)

- Provides policing and deterministic channel access by controlling the channel through the HC (Hybrid Coordinator)
- Operates in CFP (Contention Free Period) and CP (Contention Period)
- Supports IntServ
- Admission (or rejection) of stations based on Traffic Specification (TSPEC)
  - min, mean & max data rate
  - delay bound
  - nominal & maximum MSDU size
  - user priority, maximum burst size
  - ...
- HC derives schedule to provide the guaranteed QoS requirements
802.11e – HCF

- Operates both EDCA and HCCA
- Includes CFP and CP phases
- Provides IntServ and DiffServ
WiFi (Wireless Fidelity) – formerly WECA

- Non-profit organization testing interoperability of 802.11 products

**Scope:**
- *Wi-Fi products based on IEEE radio standards:*
  - 802.11a, 802.11b, 802.11g
  - single, dual-mode (802.11b and 802.11g) or multi-band (2.4GHz and 5GHz)
- *Wi-Fi wireless network security:*
  - WPA (Wi-Fi Protected Access) – Personal and Enterprise
  - WPA2 (Wi-Fi Protected Access 2, IEEE 802.11i) – Personal and Enterprise

**Support for multimedia content over Wi-Fi networks:**
- WMM (Wi-Fi Multimedia), subset of the IEEE 802.11e
  - Enhanced Distributed Channel Access – EDCA
  - 4 access categories (voice, video, best effort, background)
  - traffic differentiation (DiffServ)
- WMM scheduled access, extended subset of 802.11e
  - optional
  - HCF Controlled Channel Access – HCCA (reservation-based)
  - several Transmission Specification (TSPEC) parameters, such as data rate, PHY rate, packet sizes, service interval, and burst size.
Next Steps in Signaling (NSIS)
Next Steps In Signaling (NSIS)

- Developed by the IETF nsis working group (RFC 4080)

- Framework aiming at
  - Interworking between different QoS mechanisms
  - Simplified QoS signaling
  - Support of mobility

- Same signaling problem as with RSVP is addressed

- Differences to RSVP
  - In contrast to RSVP, NSIS remains usable in different parts of the Internet without requiring a complete E2E deployment
  - Signaling can be used for purposes other than resources reservation
NSIS – Overview

• NSIS aims at providing a global model that supports several signaling applications by separating the protocol stack into two layers
  - NSIS Signaling Layer Protocol (NSLP)
    - Contains different signaling applications, e.g. QoS signaling, NAT, Firewall, etc.
    - Communicates with NTLP
  - NSIS Transport Layer Protocol (NTLP)
    - Interface between the NSLP and IP
    - GIST (General Internet Signaling Transport protocol)
      - Common signaling transport service for different signaling applications
      - Interacts with other security and transport protocols, e.g. TCP, IPSec
NSIS – Overview

Signaling Application 1 (NAT-FW)

Signaling Application 2 (QoS)

GIST General Internet Signaling Transport

Transport Security Layer (TLS)

UDP
TCP
DCCP
SCTP
IPSec
IP

Signaling application-specific functionality

Routing of per-flow signaling messages
1. Discovery of next node
2. Transport of signaling message
3. Reusing of existing transport and security protocols
NSIS – NTLP/NSLP Scenario

Initiator

NSLP A
GIST

NSIS node supporting signaling application A

No NSIS support

Responder

NSLP A/B
GIST

NSLP A/B
GIST

Host
Router1
Router2
Router3
Router4
Host
QoS – NSLP

- RSVP-like operation, however only unicast is supported
- Sender- and receiver-initiated reservations
- Support for different QoS models such as Intserv, Diffserv, etc.
- Four types of messages
  - RESERVE: creates, modifies or deletes reservation state
  - QUERY: discovers available resources along a certain path
  - RESPONSE: acknowledgement indicating reception of RESERVE or QUERY message
  - NOTIFY: notification in case of errors
Sender-Initiated Reservation

(1) Sender initiates and completes the reservation issuing a RESERVE message
(2) Receiver responses with a RESPONSE (ACK) message

Faster establishment of a reservation
(1) Sender initiates a QUERY message to inform the receiver and to prepare the network
(2) Receiver prompts the reservation issuing a RESERVE message
(3) Sender responses with a RESPONSE (ACK) message

Similar to RSVP mechanisms (except for the RESPONSE message)
NSIS – Summary

• Support of different signaling applications

• Decoupling of “application” (called discovery) and transport of signaling messages

• Flexible flows, each session has an ID
  - Flow ID can be changed → support of mobility

• Receiver- and sender-oriented reservation

• Better Scalability and extensibility than other mechanisms
Applying a Mix of Techniques to Provide E2E QoS

IntServ (Transit Network)

DS Domain

NSIS Domain

IntServ

IntServ (Transit Network)

IntServ

IntServ
QoS and Mobility Management
How Mobility affects QoS?

• No support of mobility in current QoS mechanisms
  – NSIS enables changing the flow-ID which can be utilized for mobility support. However, mobility is supported by other protocols and not by NSIS

• After movements, the user has to reserve resources again
  – Availability of resources in the new location
  – Reservation latency (in addition to the handoff latency)
  – Releasing of resources reserved on the old path

• Solution
  – Couple between QoS and mobility mechanisms $\rightarrow$ fast reservation and releasing of resources
Coupling between QoS and Mobility Solutions

- **No coupling**
  - Protocols work separately

- **Hard coupling**
  - One protocol for mobility and QoS, e.g. Wireless Lightweight Reservation Protocol (WLRP)

- **Loose coupling**
  - Mobility and QoS protocols work separately. However, any change or event in one protocol affects the another, e.g. Simple QoS

- **Hybrid coupling**
  - Take the advantages of hard and loose couple solutions, e.g. QoS-aware Mobile IP Fast Authentication (QoMIFA)
Wireless Lightweight Reservation Protocol (WLRP)

- MN sends reports periodically for tracking purposes
- Network defines the neighbors, where the MN may move to, from the mobility profile (mob-profile)
- Passive reservations in neighbors
- Passive reservation at a BS changes to active upon the arrival of the MN to this BS

BS defines the possible cells the MN will move to from mob-profile

Passive reservation request

Active reservation

BW will be passively reserved and used for best effort until arrival of MN
Simple QoS

- Integrating RSVP with MIP
- E2E RSVP session between the CN and MN
- RSVP tunnel between the HA and FA to offer the QoS guarantee for tunneled packets
QoS-aware Mobile IP Fast Authentication (QoMIFA)

- Integrating RSVP with MIFA
- Extension of RSVP through adding a new object to transport MIFA control messages
- Handoff and resources reservation are achieved simultaneously
Summary

• Mobility highly affects the performance of QoS mechanisms

• QoS mechanisms should interact with mobility solutions
  – Loose coupling
    - Less complex and less efficient
  – Hard coupling
    - More complex and more efficient
  – Hybrid coupling
    - Less complex and more efficient (same as hard coupling in ideal case)
QoS in UMTS
UMTS/GSM Network Architecture

- **Base station**
- **GSM RAN**
- **node B**
- **UTRAN**
- **GSM Core** (Circuit switched)
- **GPRS Core** (Packet Switched)
- **MSC**
- **GMSC**
- **HLR**
- **AuC**
- **EIR**
- **SGSN**
- **GGSN**

Quality of Service in Wireless Systems
To realize QoS, a Bearer Service with clearly defined characteristics is to be set up between both communication partners.
QoS Classes and Attributes

• Four different QoS classes
  – Conversational class
  – Streaming class
  – Interactive class
  – Background class

• UMTS Bearer Service attributes
  – Traffic class
  – Maximum bit rate (kbps)
  – Guaranteed bit rate (kbps)
  – Delivery order (y/n)
  – Maximum SDU size (octets)
  – SDU format information (bits)
  – SDU error ratio Residual bit error ratio
  – ....
QoS Handling in UMTS Networks

- Network planning determines the max number of users the network can serve

- Each time a call is setup, Call Admission Control (CAC) is executed. A new call is accepted if the QoS requested by the call can be guaranteed while guaranteeing the QoS of established calls

- Policing, scheduling and congestion mechanisms are performed each time a packet is sent/received

- Data packets are sent according to a **Packet Data Protocol (PDP)** context
  - Contains the QoS profile
  - More than one PDP context can be assigned to the same user
  - Terminated at the GGSN
Conclusions

- **Best effort**
- **Packet Marking**
- **Integrated Services**
- **Differentiated Services**
- **Next Steps in Signaling**

No distinction between packets within the network (if no resources are available packets are queued or dropped).

Each packet is marked with a request for a type of service; nodes select routing paths and/or forwarding behaviors to satisfy the service request.

First attempt of IETF to develop a service model that supports per-flow QoS guarantees; requires complex architecture along any edge-to-edge path.

### Quality of Service in Wireless Systems

- **Best effort**
  - Activated by: Net
  - Relative QoS level: Best effort

- **Packet Marking**
  - Activated by: Net
  - Relative QoS level: Packet marking

- **Differentiated Services**
  - Activated by: Net
  - Relative QoS level: Differentiated Services

- **Integrated Services (RSVP)**
  - Activated by: Net + App
  - Relative QoS level: Integrated Services
Conclusions

- Best effort
- Packet Marking
- Integrated Services
- Differentiated Services
- Next Steps in Signaling

Minimalist counterpart to IntServ, throwing out everything that isn't essential to the provision of some aggregate service levels.

Different signaling applications can be used. Moreover, it uses transport and security mechanisms. It is more flexible and scalable.

<table>
<thead>
<tr>
<th>Relative QoS level</th>
<th>Best effort</th>
<th>Packet marking</th>
<th>Differentiated Services</th>
<th>Integrated Services (RSVP)</th>
</tr>
</thead>
<tbody>
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<td>Activated by:</td>
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</table>

Quality of Service in Wireless Systems
Control Questions

• Why do we need QoS support?

• What is the main objective of QoS classification?

• How can QoS be offered in 802.11e standard?

• What are the differences between IntServ and DiffServ?

• What are the benefits of NSIS?

• Compare between NSIS, DiffServ and IntServ?

• How can mobility affects the offered QoS for a mobile user? How can these effects be reduced?

• How can QoS be guaranteed in UMTS networks?
References

Books on 802.11:
- J. Schiller, „Mobile Communications (German and English)“, Kap 7.3, Addison-Wesley, 2002.

Details on 802.11e:

Web Links for 802.11:
- The IEEE 802.11 Wireless LAN Standards
  http://standards.ieee.org/getieee802/802.11.html
- Introduction to the IEEE 802.11 Wireless LAN Standard
  http://www.wlana.org/learn/80211.htm
References

Basics, IntServ and Diffserv


NSIS


QoS and Mobility Management


UMTS