IP Technology in 3rd Generation Mobile Networks

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Trends in Networks:
Convergence of Data-Networks and Mobile Networks

Trends in Mobile Networks:
- IP transport in the backbone
- Transport voice & data over IP
- Push IP into the RAN
- Terminate IP in the mobile host
- Separation: Transport ↔ Control

Trends in the Internet:
- Enable wireless access
- Support mobility
- QoS beyond “Best Effort”
- Security and AAA
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Agenda

- Intro: IP Protocol Family & IETF Standardisation
- Part I: Internet Evolution, Internet-on-Air
  - Principles & Architecture
  - Mobility Support by Mobile IP
  - Quality of Service concepts
- Part II: Mobile Network Evolution, IP Based Multimedia Subsystems (IMS)
  - Evolution/Motivation; Session Initiation Protocol
  - IMS Architecture, Registration, Session Control
  - Interworking, Conferencing, QoS
  - IMS Demonstrator
- Protocol Enhancements: Robust Header Compression, Wireless TCP
- Summary, Questions & Answers
IP Protocol family & IETF Standardisation

Internet Protocol IP:
- Layer 3 Protocol (Network Layer)
- Packet (IP datagram) transmission between hosts (packet size up to 65535 bytes, often restricted by Layer 2 protocols)
- Routing using 32 bit addresses (v4)
- Most frequent transport protocols:
  - Transmission Control Protocol (TCP)
  - User Datagram Protocol (UDP)
- Popular application layer protocols:
  - HyperText Transfer Protocol (HTTP)
  - File Transmission Protocol (FTP)
  - Simple Mail Transfer Protocol (SMTP)

![IP Protocol Stack Diagram]

IP Version 6 (IPv6)

IPv6:
- Basic Header 40 Bytes
- 128-bit Network Addresses
- Flow label (QoS)
- No fragmentation in the network
- Built-in Security
- Neighbor Discovery
- Extension Headers:
  - Routing, Fragmentation, Authentication, Encryption

IPv4:
- Basic Header 20 Bytes
- 32-bit Network Addresses
- Type of Service field
- Router may fragment packets
- IPsec as an enhancement
- ARP (Address Resolution Protocol)
- Options
IP Protocol: Quality of Service Basics

- Advantages of Packet-Based Transport (as opposed to circuit switched)
  - Flexibility
  - Optimal Use of Link Capacities, Multiplex-Gain for bursty traffic

- Drawbacks
  - Buffering/Queueing at routers can be necessary
  - Delay / Jitter / Packet Loss can occur
  - Overhead from Headers (20 Byte IPv4, 20 Byte TCP)

- Protocol Improvements for Real-Time Applications necessary
  - Packet Prioritization (DiffServ, TypeOfService field in IPv4)
  - Resource Reservation (IntServ)
  - Connection Admission / Traffic Policing / Shaping
  - Header Compression

... More about those later

IETF Standardization Process

Internet Engineering Task Force, IETF (see http://www.ietf.org)
- No formal membership; very informal process
- Protocols are developed in Working Groups (e.g. IPNG, mobileip, mpls, tewg, diffserv, rohc, seamoby, sip)
- Each WG belongs to one of 8 Areas: Applications, General, Internet, Operations and Management, Routing, Security, Sub-IP, Transport, User Services
- Area Directors form Internet Engineering Steering Group IESG
- Implementations (running code) required for standards
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Evolution of traditional Internet: Internet-on-Air (IoA)

Extension of principles and architecture of traditional Internet to mobile scenarios:
- Separation of transport, control, and services (transport in core, intelligence at edges)
- Flexible 3rd-party applications (Voice over IP is one of them)
- End-to-end IP routing
- Enhanced network services
  - Mobility (of terminals and users), Location information
  - Quality of Service (QoS)
  - Authentication, Authorisation, and Accounting (AAA)
  - Security
  - Charging
- Independent of wireless access technology (e.g. WLAN, UTRAN, GERAN)
Internet-on-Air: Separation of Transport, Control, and Services

Multiple radio standards: GSM, EDGE, 3G/UMTS, WLAN, DECT, Bluetooth, ...

Economic Consequence of Separation: Opening of the Value Chain

Closed market of few, monolithic suppliers

Competitive market of many, differentiated suppliers
Simplified IoA Architecture (without application level)

Simple Example of IoA Network

Legend:
- AS: Application Server
- BS: Base Station
- CR: Core Router
- MH: Mobile Host
- LR: Leaf Router
- NS: Network Services

- WLAN Access Network
- Transport Core Network
- Application Services Network
- Network Services Network
- Inter-AD Network

Transport

Signalling/Control

Legend:
- AS: Application Server
- BS: Base Station
- CR: Core Router
- MH: Mobile Host
- LR: Leaf Router
- NS: Network Services
Transport: no End-to-End IP Routing in UMTS

Two totally separated, non-integrated IP/ATM transport infrastructures

Gap in end-to-end routing of user-level IP packet

IoA Transport: IP Routing to the Base Station

Continuous end-to-end routing of user-level IP packets

Uniform, integrated IP transport infrastructure
IP Mobility Support: Mobile IP

- Problem: Hierarchical structure of IP addresses (subnetmask)
  - at transition to other subnet (L3 handover), "normal" IP routing not sufficient
- Solution: Extension of IP routing mechanism, "Mobile IP" (RFC 2002)

Mobile IP: Principles & Terminology

- Mobile Node (MN) with fixed IP address IP1
  - Home Network: subnet that contains IP1
  - Home Agent (HA): node in home network, responsible for packet forwarding to MN
  - Visited Network: new subnet after roaming / handover
  - Care-of Address (CoA): temporary IP address within visited network
  - Foreign Agent (FA): node in visited network, responsible for packet forwarding to CoA
Mobile IPv4 illustrated

Mobile IP: Triangle Routing

1. Packets to the MN are sent using IP₁.
2. HA tunnels them to FA, using CoA₁.
3. Packets back to the CN are sent using IP₂ (without any tunneling).

Mobile IPv4 illustrated

Mobile IP: Agent Discovery

- Mobile Node finds out about FA through Agent Advertisements (can be triggered by an Agent Solicitation from the MN).
- Care of Address of the MN is determined, either:
  - Dynamically, e.g. using Dynamic Host Configuration Protocol (DHCP)
  - Or: use IP address of FA as CoA
- MN registers at FA and HA
- Registration with previous FA simply expires
Mobile IP: Additional Issues

- Authentication, in particular for registration requests
- Route Optimization: avoid triangular routing
- MIPv6
  - Large (128 bit) address space ➔ unique c/o addresses
  - Stateless autoconfiguration & neighbor discovery
  - No Foreign Agents
  - Route optimization through IPv6 routing header
- Handover Optimization (seamless handover)
  - e.g. by predicting handover & temporarily multicasting data
- Context transfer (QoS, Header Compression, see later)

Enhanced Network Services in IoA

- Terminal mobility can be supported by Mobile IP
- User mobility can be supported, e.g. by Session Initiation Protocol (SIP), see IMS section
- New applications require concepts for
  - Quality of Service (real-time applications, e.g. voice, video) [chosen for this tutorial]
  - Security (e.g. Internet banking, electronic cash)
  - Accounting & Charging (content based)
- Combination of concepts & carrier-grade implementation required
Quality of Service in IoA: Scope

User Plane QoS
- End-2-End Packet Delay (in particular interactive applications)
- Delay Jitter
- Packet Loss
- Throughput/Goodput

Application Level QoS
- e.g. Video/Voice Quality (depending on codecs)

Signalling Plane
- Call Setup Delays
- Fraction of blocked Calls

Behavior at Handover
- Dropped Calls
- Delayed / Lost packets

Reliability Aspects
- Failure probabilities of entities
- Downtime distribution

[Considered in the following]

QoS Solution I: Over-Provisioning

- Design network to be able to deal with worst-case traffic scenario
- Advantage:
  - no impact on architecture, protocols and user equipment
  - simplicity
- Problems:
  - Traffic depends on number of active users, user mobility, type of application, daily utilization profile → difficult forecasting
  - Data traffic tends to be very bursty (even ‘self-similar’)
  - waste of resources if planned for worst-case scenario
  - can be very expensive
  - Unforeseeable events can occur (new applications; changes in user behavior, e.g. always-on)
QoS Solutions II: DiffServ

- Basic Idea: reduce queueing delay/loss for critical traffic by preferential treatment at routers
  - improve per-hop transmission behavior
- Packets marked by DiffServ Code Points (DSCPs, 6bit)
- Various scheduling disciplines at routers possible (e.g. static priority, weighted fair queueing)
- Advantage: Simple and scalable
- Problem: No performance guarantees unless used in conjunction with connection admission and traffic shaping/policing at ingress routers

QoS Solutions III: IntServ/RVSP

- Fundamental Idea: Reserve necessary resources for each traffic flow along its transmission path, which requires:
  - Connection Admission Control (CAC): traffic specification + info about available resources at router ➔ admission decision (if no, then re-routing)
  - Packet Classification: which flow does it belong to?
  - Packet Scheduling: make sure, flow obtains resources as specified
QoS Solutions III: IntServ/RSVP (cont’d)

- Signalling by Resource Reservation Protocol (RSVP)
  - Path Message: sender initiated, description of traffic parameters and path
  - Resv Message: receiver initiated, causes connection admission/reservation along path; specifies QoS parameters
  - Other messages for reservation teardown and error treatment
  - Soft-State concept: periodic refresh of reservation required

- Advantages:
  - Fine Granularity: per flow treatment, flexible set of QoS parameters
  - Able to provide QoS guarantees (if admission, classification, scheduling is performed correctly)

- Disadvantages
  - Scalability problem: management of state for each single flow
  - Complexity (already connection admission can be complex, e.g. effective bandwidths, etc.)

Possible QoS Concept for IoA

- DiffServ in core, RSVP in access
- DSCP marking at Leaf Routers
- RSVP signalling tunnelled through core
- RSVP signalling initiated by User equipment or by proxy in access network

Legend:
- AS: Application Server
- BS: Base Station
- CR: Core Router
- MH: Mobile Host
- LR: Leaf Router
- NS: Network Services
Integration of QoS & Mobility: Context transfer

- At inter-subnet (L3) handover: necessary to transfer QoS context to new access network
- Possible solutions
  - Perform MIP handover first, transfer QoS context later ➔ possibly temporarily reduced QoS
  - Anticipate handover, set up QoS context in advance in new access networks ➔ full QoS as soon as Layer 3 connectivity established
    But: simultaneous reservation in several access networks, waste of resources
- Analogous problem for AAA or other context (e.g. for Robust Header Compression)

IoA QoS: Open Issues [also for IMS QoS]

- Who provides traffic parameters and QoS requirements?
  - User itself?
  - Application layer in mobile station?
  - Automatic mapping of application type and user class?
- QoS Interworking
  - How to map IntServ microflows to DiffServ codepoints?
  - Interworking with QoS mechanisms of external IP networks?
- End-to-end delay
  - What delay budgets assigned to different domains?
- Granularity
  - Complex per-flow signalling and connection admission necessary?
  - Or: Will users accept ‘soft’ QoS (as provided by simple service classes without connection admission)?
  - Should we concentrate on the bottleneck ‘Radio Link’ and use over-provisioning everywhere else?
- Relevance/Benefit of Multi Protocol Label Switching (MPLS) and QoS Routing?
Summary: Internet-on-Air

- Extension of principles and architecture of traditional Internet to mobile scenarios
- Separation of transport, network services, and applications
  - Flexible 3rd-party application provisioning
- Independent of wireless access technology
- Continuous end-to-end IP routing
- Mobility Support using Mobile IP
- Enhanced network services
  - Quality of Service (support of DiffServ, IntServ, MPLS)
  - Security, AAA, and Charging
- and combinations of those concepts

Several aspects still in research
- Seamless handover
- Various QoS questions [also true for IMS QoS]
- Scalability and carrier grade implementation

IP multimedia subsystem tutorial

Smith, Product Management Mobile Internet
Siemens, Information and Communication Mobile
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Trends in Mobile Networks: GPRS, UMTS, IMS

Part II

Trends in the Internet:
- Enable wireless access
- Support mobility
- QoS beyond “Best Effort”
- Security and AAA

Part I

Internet-on-Air

Agenda (IMS)

Introduction to IP Multimedia Subsystem (IMS)
- Evolution of mobile networks
- Motivations for the IMS
- Session Initiation Protocol (SIP)
- IMS Architecture overview
  - Registration
  - Session control
  - Interworking with PSTN
  - Conferencing
  - Services
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- Summary
### 3GPP R99 Architecture

- **SS7 Switch**
- **PSTN / ISDN**
- **SCP LNP**
- **IN / Camel**
- **Iu-cs ATM**
- **3G MSC**
- **3G GMSC**
- **IP**
- **3G-SGSN**
- **UTRAN**
- **3G GMSC**
- **TDM transit network**
- **AAA : MAP**
- **Global IP Network**

NEW:
- R4 CS-Voice domain over IP/ATM
- Voice trunking
- Separation of control and transport

### 3GPP R4 Architecture

- **ISUP / BICC**
- **Megaco/H.248**
- **VoIP core (IP / ATM)**
- **Global IP Network**
- **AAA : MAP**
- **SS7**
- **MGW/MGW**
- **MSCS**
- **RNC**
- **Lu-cs ATM**
- **Lu-ps ATM**

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IP Technology in 3rd Generation Mobile Networks
**NEW:**

R5 IP Multimedia Subsystem  
- complementary to CS and PS domain  
- IP multimedia telephony

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**3GPP R5 architecture**

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**Status of IMS in 3GPP**

- Originally: planned to finish IMS specs in 3GPP by end 2001
- Estimation today:
  - 2Q 2002: stage 1 & 2 standards: requirements and functional architecture, basic features
  - Enhanced features -> Rel’6
- Some functional areas stabilize (e.g. basic call flows)
- Several areas rather open (e.g. security, charging)
- Additional functions are identified as necessary over time (e.g. BGCF)
Motivations for IMS

**UMTS IP based Multimedia**
- Applications provide new revenue streams for MNOs
- IMS provides infrastructure for integrated real-time/data services.

**IMS benefits:**
- IMS provides standardized infrastructure for integrated applications:
  - Standardized interfaces to applications
  - Standardized and secure authentication, authorization,
  - Standardized charging for services
  - QoS control on the bearer plane for services
  - Global roaming and access to home services
- Without IMS:
  - Proprietary application islands
  - Often non-compatible protocols used
  - Higher OAM
  - Difficulties for charging, security, QoS

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**SIP: End-To-End and Proxies**

- **User agent**: An application program which initiates SIP requests and also acts upon (accepts, rejects or re-directs) incoming SIP requests.
- **Location server**: Location servers provide SIP redirect or proxy servers information about a callee’s possible location(s).
- **Proxy server**: A server which takes requests on behalf of other user agents or servers and forwards them to the next hop.
- **Redirect server**: A server which accepts a SIP request, maps the address into zero or more new addresses and returns these addresses to the client. Unlike a proxy server, it does not initiate its own SIP request.
- **Registrar**: A registrar is a server that accepts REGISTER requests. A registrar is typically co-located with a proxy or redirect server and may offer location services.

**SIP – Basic messages**

- **Requests**
  - INVITE initiate call
  - ACK confirm final response
  - BYE terminate (and transfer) call
  - CANCEL cancel searches and “ringing”
  - OPTIONS queries features supported by other side
  - REGISTER register with location service

- **Responses**
  - 1xx Intermediate results (180 Ringing)
  - 2xx Positive confirmations (200 OK)
  - 3xx Redirections (302 Moved Temporarily)
  - 4xx Request-Errors
  - 5xx Server-Errors
  - 6xx Global Errors
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Network Entities and Reference Points
Network Entities and Protocols

Network Entities

- CSCF (Call State/Service Control Function)
- PCF (Policy Control Function)
- HSS (Home Subscriber Service)
- SLF (Subscription Locator Function)
- MRF (Multimedia Resource Function)
- BGCF (Breakout Gateway Control Function)
- MGCF (Median Gateway Control Function)
- MGW (Media Gateway)
- T-SGW (Transport Signaling Gateway)
- R-SGW (Roaming Signaling Gateway)
- AS (Application Server)
- SCP (Service Content Provider)
- IM-SSF (Service Switching Function)
- OSA-SCS (Service Capability Server)

Additionally:
- Charging Entities
- Security Entities
- Lawful Interception
- Firewalls
- DNS, DHCP, TRIP, ...
- QoS Entities
- OAM and NM
- ...
HSS

Database for subscriber related information
- Identification (SIP, Mail, E.164, Label, IMSI, ...)
- Location management (P-CSCF, S-CSCF, IP address)
- List of authorized services
- List of subscribed services
- Quintuplets for Security

P-CSCF (Proxy CSCF)

First contact point of an operator's network (for the mobile terminal)
- Forwarding of SIP messages between terminal and core network
- Generation of charging records
- Translation of IDs other than SIP URIs into SIP URIs (e.g. E.164 numbers)
- Termination of confidentiality and integrity
- Authorisation of bearer resources and QoS management
- Detection of emergency calls and selection of a emergency S-CSCF
- Translation of SIP URIs for local services
- Lawful interception
- SIP header compression
I-CSCF (Interrogating CSCF)

First contact point of an operator's network (for other operators)
- Forwarding of SIP messages (proxy functionality)
- Assignment of a S-CSCF
  - during registration
  - during invite (for services for not registered subscribers)
- Generation of charging records
- Hiding of internal network configuration/capacity/topology

S-CSCF (Serving CSCF)

Performs session control and service triggering
- Acts as a registrar according to RFC2543
- May behave as a Proxy Server as defined in RFC2543, i.e. it accepts requests and services them internally or forwards them on, possibly after translation.
- May behave as a User Agent as defined in RFC2543, i.e. it may terminate and independently generate SIP transactions.
- Interaction with service platform(s)
- Provides endpoints with service event related information
- Generation of charging records
- Authentication (based on quintuplets from HSS)
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Summary

Levels of Registration
Registration in a Roaming Scenario

Home Network of MS A

- HSS-A
- I-CSCF-A
- S-CSCF-A

User Profile

Network visited by MS A

P-CSCF-A

REGISTER

Home Network of MS B

- HSS-A
- I-CSCF-A
- S-CSCF-B

User Profile

Network visited by MS B

P-CSCF-B

REGISTER

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IP Technology in 3rd Generation Mobile Networks
Routing of Mobile-To-Mobile Calls

Routing of Mobile Calls to CS or PSTN (3GPP)
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MRF Functions

The MRF is responsible for all functions of the core network which interact with the user plane

Agreed
  - Conferencing
  - Announcements
  - Transcoding

Additional
  - Interactive voice recognition
  - Text to speech processing
  - Generations of Tones
  - DTMF
MRF Architecture

MRF-C (Controller)
- Controls the media stream resources in the MRFP.
- Interprets information coming from an AS and S-CSCF (e.g. session identifier) and control MRFP accordingly.
- Generates Call Detail Records (CDRs)

MRF-P (Processor)
- Controls bearers on the Gi interface.
- Provides resources to be controlled by the MRFC.
- Mixes incoming media streams (e.g. for multiple parties).
- Sources media streams (for multimedia announcements).
- Processes media streams (e.g. audio transcoding, media analysis).

Application Server
- Conference booking
- Floor control mechanism
- Session Control. Conference IDs

MRF Architecture Diagram:

- AS
- ISC
- SIP
- Sr
- ?
- S-CSCF
- Mr
- SIP
- MRF-C
- Mr
- H.248
- MRF-P
- Gi

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Services are Home Controlled

- The Serving CSCF (S-CSCF) is located in the Home Network.
- The Visited Network only provides a proxy (P-CSCF): all calls are always first routed to the Home Network.

Alternatives to Deploy Services in IMS

- OSA API Services
- Administrative Domain of the 3rd Party Service Provider
- CORBA Transport
- OSA API
- CAP
- OSA SCS
- IM-SSF
- SIP Application Server
- Administrative Domain of the IMS Operator
- Services
- S-CSCF
- ISC
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IMS QoS: User Plane Data Path

Example: Mobile to external Application Server

IMS User Plane Protocol Stack:
RTP over UDP over IPv6

External IP networks and other IMS networks
**IMS QoS: Bearer Hierarchy**

- **Air Interface**
  - TE
  - MT
  - UTRAN/GERAN
  - CN Iu EDGE NODE
  - CN Gateway
  - TE/AS

- **End-to-End Service (IP Bearer Service)**
  - TE/MT Local Bearer Service
  - UMTS Bearer Service
  - External Bearer Service
  - UMTS Bearer Service
  - Radio Access Bearer Service
  - CN Bearer Service
  - Backbone Bearer Service

- **User Equipment**
  - RAN
  - 3G SGSN
  - 3G GGSN

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**IMS QoS: 3GPP Architecture**

New Entities in UMTS Rel’5:
- Policy Control Function (co-located to P-CSCF)
- IP Bearer Service Manager (Policy Enforcement Point)
IMS QoS: Functional Elements

- **P-CSCF / PCF**
  - Authorization token
  - SDP, 5-tuplets, FlowSpec
  - DSCP

- **SIP**

- **GGSN / PEP**
  - QoS Table / GateSpec
  - DSCP mandatory
  - RSVP/IntServ optional
  - Authorization token
  - Traffic Flow Template

- **UE**
  - QoS Profile
  - SDP
  - DSCP optional
  - RSVP optional

- **COPS**
  - Push/Pull

- **PDP Context**

IMS QoS: Functional Elements (cont’d)

- **Pre-conditions for SIP QoS Assured Sessions**
  - IETF specification of Integration of Resource Management and SIP

- **GGSN / PEP**
  - DiffServ Edge Function (compliant to IETF), RSVP/IntServ Function (FFS) [optional]
  - RSVP Sender/Receiver Proxy [optional]
  - Service-based Local Policy Enforcement Point
  - Binding Mechanism Handling (PDP Configuration Options)

- **P-CSCF / PCF**
  - Authorize QoS resources (SDP)
  - PCF ⇒ Policy Decision Point for service-based local policy control
  - PCF exchange authorization information with GGSN via Go interface
  - P-CSCF (PCF) final decision on enabling and disabling the allocated QoS
  - Session release, P-CSCF (PCF) shall revoke the resource authorization
  - Binding Mechanism Handling (generate an Authorization Token)
IMS QoS: SDP Descriptions

- IP flow 5-tuples
- Flowspec (RSVP)
- DSCP

5-tuples:
- Source Address
- Source Port
- Destination Address
- Destination Port
- Protocol

Flowspec:
- Token rate [r]
- Bucket depth [b]
- Peak rate [p]
- Minimum policed unit [m]
- Maximum packet size [M]

Mapping by:
- Calculation?
- Codec tables?

IMS QoS: SIP/SDP Call Flow (3GPP)

1. Invite (SDP)
2... (SDP)
3... (SDP_Final)
5. Resources Reserved
8. 180 RINGING
9. 200 OK
10. ACK

Codec Reduction
Service Control
Res. Authorization
Res. Reservation
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Summary

Summary (IMS)

- IP Multimedia subsystem is standardized by the 3GPP as part of UMTS Rel 5
- IMS is a control infrastructure and provides
  - Secure authentication and service authorization
  - Session control for packet-based connections
  - Interworking with PSTN/2G networks
  - Conferencing
  - Standardized and secure interfaces to applications
- Key benefit
  - Secure infrastructure and control for 3G data, real-time and integrated real-time/voice services.
Agenda

- Intro: IP Protocol Family & IETF Standardisation
- Part I: Internet Evolution, Internet-on-Air
  - Principles & Architecture
  - Mobility Support by Mobile IP
  - Quality of Service concepts
- Part II: Mobile Network Evolution, IP Based Multimedia Subsystems (IMS)
  - Evolution/Motivation; Session Initiation Protocol
  - IMS Architecture, Registration, Session Control
  - Interworking, Conferencing, QoS
  - IMS Demonstrator
- Protocol Enhancements: Robust Header Compression, Wireless TCP
- Summary, Questions & Answers

Protocol Enhancements: Motivation

- Wireless links tend to show poor performance
  - Large delays
  - Low throughput
  - Bit errors / packet losses due to radio transmission
- Protocols in IP family not originally designed for such links
  - Increased volume due to headers
  - Deficiencies of TCP flow control
  - ... many more (e.g. applications HTTP → WAP)
- Protocol Enhancements are required, two examples discussed here
  - Robust Header Compression (RoHC)
  - Enhancements for Wireless TCP
Robust Header Compression (RoHC)

Motivation
- IP voice packets: header 40/60 Bytes, average payload 25 Bytes
- TCP ACK packets: header 40/60 Bytes, payload often 0 Bytes
- Data in many header fields ...
  - ... hardly ever changes e.g. source/destination address within same IP flow
  - ... or changes in a regular pattern
- Idea: reduce header length by compression, e.g.
  - differential encoding of fields
  - and/or variations of Huffman compression
- Compression can be applied to several protocol headers, e.g. RTP/UDP/IP

Robust Header Compression (RoHC)

- Synchronized compression context required in compressor and decompressor
- Lost packets \(\rightarrow\) Synchronization disturbed
  - Additional mechanisms for context synchronisation required: Robustness
    - Error detection by Cyclic Redundancy Codes (CRC)
    - Loss detection through sequence numbers
- Reduced compression efficiency price for error robustness
- Current RoHC methods: 40 Bytes RTP/UDP/IP header \(\rightarrow\) on average 1 or 2 bytes
### RoHC in UMTS

- **RoHC** optional part of Packet Data Convergence Protocol (PDCP)
  - Headers compressed only over radio link
- In principle compression already in GGSN possible, but
  - Flow identification/separation necessary
  - Large number of flows (up to $10^4$ active flows)

### RoHC: Ongoing Work

- **Application of RoHC methods for SIP compression**
  - Compression of whole SIP messages
  - Goal: Reduction of call-setup delay
  - (SIP message up to several thousand Byte)
- **Optimized use of Compression**
  - Trade-off: Data-Volume vs. Error
  - Robustness on
    - Application Layer
    - RoHC Layer
    - Link-Layer
  - Optimization across whole protocol stack required
Protocol Enhancements: Wireless TCP

- End-to-end flow control using ACK packets
- Trigger events: duplicate ACKs and timeouts
- Problem: TCP flow-control designed for congestion avoidance in wired networks
  - can be counter productive for wireless links (long round-trip times, packet loss)

Wireless TCP: Common Approaches

- Split-Connection Approach
  - End-to-End flow control terminated before wireless link
- Link-Layer Approach
  - Local Retransmission of lost packets
  - Hide losses from sender
- Explicit Notification Approach
  - Explicitly notify TCP sender of the condition of the network / type of the loss
- End to End Approach
  - Enhance TCP Protocol Stack at Sender and Receiver to achieve better throughput

[Source: G. Reuss]
Wireless TCP: Split Connection

Proxy is located between the 2 end-hosts (i.e. MH & FH) to split the TCP connection into 2 parts

Advantages
- Shields the end-host in the wired network from the wireless network characteristic
- Wireless Local Recovery by Proxy
- Conservation of bandwidth of the wireless link
- Reduced header size for optimized transport protocol over wireless link
- Smaller and simpler wireless protocol between MH and Proxy

Disadvantages
- Modifications required at MH
- No end-to-end TCP semantics
- Not usable with IPSEC, since access to the TCP header needed
- Requires buffer management at Proxy

[Source: G. Reuss]
**Wireless TCP: Link-Layer Approach**

- Proxy detects losses over the wireless link
- Proxy does local retransmission before the sender timeouts. Hides the wireless losses from the Sender

[Source: G. Reuss]

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**Wireless TCP: Link-Layer Approach (cont’d)**

- **Advantages**
  - No modification to end hosts

- **Disadvantages**
  - TCP-aware link layer solutions cannot be used with IPSec
  - Sender may not be fully shielded from wireless losses
  - TCP End-to-End retransmission scheme and Link-Layer retransmissions ➔ possibly duplicate retransmissions

[Source: G. Reuss]
Wirless TCP: End-to-end approach

- TCP Protocol Stack at Sender and Receiver enhanced
e.g. SACK, FACK, D-SACK, Eifel
- Possible enhancements
  - Differentiate Losses
    e.g. no slow-start for wireless losses
  - Efficient Utilisation of Bandwidth
    e.g. no initial slow-start
  - Detection of Multiple Losses
- Advantages
  - End-to-End semantics and layered architecture of network protocols are preserved
  - IP packet encryption can be used
- Disadvantage
  - Modification at end host

[Source: G. Reuss]

Wireless TCP: Performance Comparison (ns simulation)

Source: Master Thesis, D. Höllisch

- Single source scenario with burst errors on wireless link (ε1=1 ≅ ca 28% packet loss)
  ➔ Snoop (Split-TCP) together with SACK (end-to-end approach) provides best goodput
- Congestion scenario (20 ON/OFF TCP sources) with same wireless link model:
  ➔ Combination SACK with Snoop shows much lower goodput than Snoop by itself
Agenda

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