“Mobile IPv6 in heterogeneous environments”

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General information

- About me?
- TLT-6506 Digital Mobile Communication Systems
  - Contains mostly link layer related topics, such as GSM, UMTS, Bluetooth, WiMax, etc.
- Topic of this lecture is more related to IP layer and mobility management
- Research oriented view to Mobile IP and the challenges the heterogeneous environment brings
- Management of the above mentioned links
- Slides gathered from several publications related to my Ph.D. studies/research
  - Concentrating mostly on Mobile IPv6
Outline

- Motivation, terminology and vision
- The status of mobility management today
- Mobile IPv6 functionality
- Mobile IPv6 enhancements
- Mobile IPv6 in Heterogeneous environment i.e. multihoming
- Per-flow mobility management
- Content adaptation
Motivation

- Heterogeneous environment
- Number of different access technologies with different characteristics and services increase
  - UMTS: limited coverage, medium bitrate, secure, price quite high etc
  - GPRS: almost complete coverage, low bitrate, secure, price quite high, etc
  - WLAN: small coverage, high bitrate, secure, low price, etc
  - Bluetooth: very small coverage, low bitrate, secure, low price, etc.
  - Ethernet: only wired, very high bitrate, secure, low price, etc.
  - Different services can also be used through different access technologies
## Motivation

<table>
<thead>
<tr>
<th>Network</th>
<th>Coverage</th>
<th>Data Rates</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite</td>
<td>World</td>
<td>Max. 144 kb/s</td>
<td>High</td>
</tr>
<tr>
<td>GSM/GPRS</td>
<td>Aprox. 35 Km</td>
<td>9.6 kb/s up to 144 kb/s</td>
<td>High</td>
</tr>
<tr>
<td>IEEE 802.16a</td>
<td>Aprox. 30 Km</td>
<td>Max. 70 Mb/s</td>
<td>Medium</td>
</tr>
<tr>
<td>IEEE 802.20</td>
<td>Aprox. 20 Km</td>
<td>1-9 Mb/s</td>
<td>High</td>
</tr>
<tr>
<td>UMTS</td>
<td>20 Km</td>
<td>up to 2 Mb/s</td>
<td>High</td>
</tr>
<tr>
<td>HIPERLAN 2</td>
<td>70 up to 300 m</td>
<td>25 Mb/s</td>
<td>Low</td>
</tr>
<tr>
<td>IEEE 802.11a</td>
<td>50 up to 300 m</td>
<td>54 Mb/s</td>
<td>Low</td>
</tr>
<tr>
<td>IEEE 802.11b</td>
<td>50 up to 300 m</td>
<td>11 Mb/s</td>
<td>Low</td>
</tr>
<tr>
<td>Bluetooth</td>
<td>10 m</td>
<td>Max. 700 kb/s</td>
<td>Low</td>
</tr>
</tbody>
</table>

Motivation

- Multiaccess devices, which integrate both cellular (2G, 3G) and un-licenced wireless networks (IEEE 802.11, Bluetooth)
  - Nokia Communicator 9500 (GPRS, WLAN, Bluetooth)
  - Globetrotter Fusion (GPRS, UMTS, WLAN)
  - Nokia 770 internet tablet (Maemo Linux, WLAN, Bluetooth)
  - HP iPAQ handhelds
- Different types of devices (mobile devices, laptops, PDAs, desktops)
- Overlapping wireless network environments -> capability to choose
- Different users with different preferences
Vision for year 2010

- National Technology Agency of Finland (TEKES): Converging Networks; always, everywhere available, optimal, reliable, high quality, fast, cheap and secure access to services
- Seamless access to context aware services
  - Adaptive context aware applications (e.g. location, connection, device)
  - Always-Best-Connected access
- One-for-all authentication (virtual operators)
- Added value services: presence, location information, Quality-of-Service
- From technology-centric to user-centric world!!
- Towards All-IP networks
Terminology

- Terminology is quite mixed up!!!
- Horizontal vs. vertical handovers
- Layer 2 vs. Layer 3 handovers
- 2G, 2.5G, 3G, 4G
- Loosely vs. tightly coupled mobility management
- Seamless/soft/smooth handover
- Mobile/network initiated handover
- Mobile/network controlled handover
- To which of these we concentrate in this lecture?
  - Mobile IPv6 is in general Mobile initiated and controlled loosely coupled layer 3 handover mechanism for both horizontal and vertical handovers which aims for seamlessness… 😊
Research challenges

• Wireless system discovery
  – L2 scanning vs. L3 or above solutions?
  – Active vs. passive scanning

• Interface selection – Always-Best-Connected
  – Heterogeneous environment with varying availability, quality and services
  – Handover decisions and logic?
  – Real-time knowledge of the available wireless environment
  – Users’ and applications’ preferences
Research challenges

- Mobility and location management
  - Mobile IP (MIP), Mobile IPv6 (MIPv6), Host Identity Protocol (HIP), Session Initiation Protocol (SIP), etc.
- Multihoming and simultaneous access
- End-to-End Quality-of-Service
- Transport layer performance
- Security and privacy
- Adaptive applications
- Positioning systems
Mobility management today
Unlicenced Mobile Access

- Provide access to GSM and GPRS mobile services (voice and data) over unlicensed spectrum technologies (IEEE 802.11, Bluetooth)
- Roaming between cellular and unlicensed wireless networks
- Tightly coupled system (preserves the core network infrastructure)
- Tunneling UMA protocols over unlicensed spectrum and IP
- Secure unlicensed access (EAP-SIM, IPSec, AAA)
- Technology and devices already exists!!

[http://www.umatechnology.org]
Mobility management today

- WLAN and cellular networks provide the mobility management already (link layer)
- Why is the IP layer mobility management then needed?
  - All-IP network
  - L2 handover procedures do not handle IP subnet change
  - Applications need to use one IP address, if the connectivity is needed to be seamless
- Struggle in which layer should the mobility be handled
  - IP layer, TCP layer, application layer (SIP) or then the application itself
  - Idea is the same still (location updating with some signalling)
Mobility management today

- Both Mobile IP and Mobile IPv6 standardized in the IETF, but the usage has been limited
- Several Mobile IP implementations (or MIP-like)
  - Secgo Mobile IP
  - Netseal MPN
  - Telia Connect Pro / Sonera Connect 2.0
- Mostly mobility solutions for a company’s moving employees (secure VPN to company’s intranet)
- MIP combined with IPSec
- Several (research) projects going on (Mobile IPv6 implementations, etc.)
  - Mobile IPv6 for Linux (MIPL), KAME, Cisco, Microsoft, Ericsson, Nokia, etc.
Mobile IPv6 functionality
IPv6

- **Addresses**
  - \((3.4 \times 10^{38})\) addresses (128 bits)
  - Unicast, Multicast and Anycast formats
  - Link-local, site-local, global addresses
- **Simple IPv6 header + extension headers**
  - Hop-by-Hop Options
  - Routing
  - Fragmentation
  - Authentication
  - Destination Options
- **Integrated IPSec** (tunnel and transport modes)
- **Stateless address autoconfiguration** (plug’n’play networking…)
- **Mobility** (Mobile IPv6)
- **Multicast**
- **Transition from IPv4 to IPv6** (tunneling, translation, dual stack)
Mobile IPv6 functionality

- **Functional entities:**
  - Mobile Node
  - Home Agent (handles mobility)
  - Corresponding Node (mobile or stationary)

- **Two IPv6 addresses:**
  - Care-of-Address (changes by the location - subnet)
  - Home Address (valid at home network, used by applications)
  - Mapping the HoA-CoA

- Packets set to HoA are tunneled to the CoA
Mobile IPv6 handover process

• Layer 2 handover (e.g. IEEE 802.11 WLAN)
• IP layer movement detection
  – Neighbor Unreachability Detection
  – Router Solicitations
  – Router Advertisements (including the IP subnet information) (30-70ms)
  – Packets do not go through or receive RA from different subnet
• Care-of-Address configuration
  – Stateless address autoconfiguration
    • CoA formed according to the subnet information and MAC address of an interface
  – stateful address autoconfiguration
    • DHCPv6 server which allocates the addresses
  – Duplicate Address Detection
    • Verify that the formed address is not in use
Mobile IPv6 handover process

- Care-of-Address registration
  - Binding Update (BU) process
  - BU to the Home Agent to refresh the CoA-HoA binding
  - HA tunnel (IPv6 in IPv6) the packets to the current location (CoA)
  - HA intercepts the packets heading to the HoA of the MN and tunnels them to the correct CoA

- Two communication modes
  - Two-way tunneling (IPv6 in IPv6)
  - Route optimization (Use of extension headers)
Mobile IPv6 route optimization

- BUs can be sent to CNs as well
- CNs maintain also the HoA-CoA bindings
- Enables direct communication between the CN and MN (the end-to-end delay is smaller)
- The traffic does not need to go via HA, which might be located quite far away
- Eliminates congestion in the Home Agent
- The handover time is increased
- Return routability (RR) to verify that the MN is who it claims to be
Mobile IPv6 packet delivery

- Two way tunneling
- Route Optimization
  - Routing header
    - Carries the HoA in MN-CN communication
  - Destination Options header
    - For MN originated datagrams
- I will not go into details about packet structures. If interested, refer to RFC 3775
Mobile IPv6 packets and data structures

- Signalling packets
  - Binding Update
  - Binding Acknowledgement
  - Binding Request

- Data structures
  - Binding cache
  - Binding update list
  - Home agent list
Mobile IPv6 security

- IETF RFC 3776
- Threats: man-in-the-middle, hijacking, passive wiretapping, impersonation, denial-of-service
- Signalling (BUs, Return routability signalling)
  - IPSec Encapsulating Security Payload (ESP)
  - Return routability
    - The return routability procedure authorizes registrations by the use of a cryptographic token exchange
    - HoTI: MN -> HA -> CN, HoT: CN -> HA -> MN
    - CoTI: MN -> CN, CoT: CN -> MN
    - CN gets assurance that the MN has the HoA and related CoA
- Data
  - IPSec tunnels
Mobile IP4 vs. Mobile IPv6

- Some benefits of IPv6 protocol
  - Amount of addresses (one global HoA for each node is possible)
  - Stateless address autoconfiguration
  - Integrated IPSec

- Packet delivery
  - No triangular routing (In MIPv4 the ingress filtering was a problem)
  - Route Optimization (direct communication between communicating nodes with Routing header)

- No need for Foreign Agents (MIPv4 is hard to deploy)
- Dynamic Home Agent Discovery (home agents anycast address query)
Mobile IPv6 performance

Mobile IPv6 problems

- MIPv6 procedures take time
  - During that time no sending nor receiving packets
  - Not acceptable, at least to real-time applications

- Movement detection
  - Delay dependent on the RA interval (0-3s or 0.03-0.07s)

- CoA configuration
  - Stateless address autoconfiguration (processing time)
  - Duplicate address detection (1s)

- CoA registration
  - Dependent on the distance of the HA (two-way signalling)
  - Dependent on return routability (return routability and two-way signalling to all CNs)
Mobile IPv6 problems

- A lot of research going on to reduce the MIPv6 delay
  - Movement detection (L2 info, solicited RAs, FastRA)
  - CoA configuration (Optimistic DAD)
  - CoA registration (tunneling from previous AR)
- Multihoming
  - When MN has several interfaces, how to determine to which interface to perform handover and when?
  - Priority? User preferences?
- Per-flow mobility management
  - MN is identified by a HoA-CoA binding
  - How to divide application flows between interfaces?
Mobile IPv6 enhancements
Mobile IPv6 enhancements

- Several enhancements, most important ones are:
  - Fast Handovers for Mobile IPv6
  - Hierarchical Mobile IPv6
  - Flow-based Fast Handover for Mobile IPv6
- Numerous of others also, the idea is usually based on
  - Anticipation (L2 triggers, hints, positioning)
  - Tunneling (from the old AR)
  - Multicast routing
  - Local Home Agent (like a Foreign Agent)
- “Make-before-break” or “Break-before-make”
**Fast Handovers for Mobile IPv6**

- **IETF RFC 4068**
- Creating a new valid CoA related to the new AR subnet via the old link
  - L2 ”scan” and according to MAC address request the related IP subnet [AP-ID, AR-Info] tuple
  - Candidate Access Router Discovery (CARD)
- Tunnel between Previous CoA and new CoA
- Two modes:
  - MN receives FBack on the previous link (proactive)
  - MN does not receive FBack through the previous link (reactive)
Hierarchical Mobile IPv6

- IETF RFC 4140
- Separate the global and local mobility
- Reducing signalling delay and signalling load
- Local domain specific ”HA” called Mobility Anchor Point
- Regional CoA for HA and On-link CoA for MAP
- Tunneling from HA to RCoA and MAP to LCoA
- Route Optimization also possible
Fast Handover for Hierarchical MIPv6

- Joint HMIPv6 and FMIPv6
- Combines the good features of both HMIPv6 and FMIPv6
- Otherwise straightforward combination of the two methods, but the redirection tunneling is done from MAP to the nCoA, NOT from PAR to nCoA
Simulative analysis results (UDP)

Flow-based Fast Handover for Mobile IPv6

- ”Break before make”
- Requirements
  - Flow-cache in every router
  - Hop-by-Hop header
  - IPv6-in-IPv6 Tunneling
- Finding a cross-over router
- Redirect flows to the new CoA simultaneously with the BU process
- Performance depends on the topology (hierarchy) of the network
- NS-2 and MIPL experiments
FFHMIPv6 performance
Vertical handovers with Mobile IPv6

Network Mobility

• Entire networks are changing their point of attachment with respect to the Internet topology
• Mobile networks (taxi, cars, trains, people)
• Mobile Routers (MR) and Mobile Network Nodes (MNN)
• Inside the mobile network the nodes can be stationary or mobile
• Nested and multihomed mobile networks
• Solution similar as Mobile IPv6 for host mobility
Mobile IPv6 and multihoming
Multihoming

- A device with multiple links of different technology
- How to decide which interface to use?
  - At this point we consider that only one interface is in use at a time
  - Static priority (1st Eth, 2nd WLAN, 3rd GPRS) – is this enough for the user?
  - More complex solution that takes into account several parameters?
    - What parameters could be useful and from where to get those parameter values?
    - From the mobile device itself (link layer, IP layer, application layer, user)?
    - Outside the terminal (positioning system, Access Point, Access Router, Correspondent Node, etc.)
    - Polling for QoS?
Cross-layer designing

- Within the mobile device
- Interaction between protocol layers
  - Link layer information
  - Application requirements
  - User preferences
  - Quality-of-Service
    - Radio link
    - End-to-End
Link Layer Information

- Access technology dependent link layer information can be converted into technology independent information
  - Link layer events (Connected, disconnected)
  - Link layer parameters (static/configurable, quality related information, features)
  - Link layer triggers
    - Link Up, Link Down
  - Link layer hints
    - Link Going Down, Link Coming Up
Benefits of link layer information

- Handovers
  - Horizontal handover
    - Anticipation of handover occurrence, performing some of the handover procedures before the actual L2 handover
    - Triggered movement detection of Mobile IPv6, solicited router advertisement
  - Vertical handover
    - Hints are enabling soft handovers (i.e. using two interfaces in the handover process)
    - Providing input for more intelligent interface selection -> always best connected

- Link layer aware TCP (reduce window size to zero?)

- Applications
  - Mobility aware (link layer aware) adaptive applications
  - Input to applications about the link quality
Link layer scanning

- GSM and IEEE 802.11 implement their own handover mechanisms
  - GSM -> mobile controlled, based on signal strength
  - IEEE 802.11 -> signal strength based
    - Does not take into account other things as AP load, related IP subnet, security, etc!!!
    - Scanning and manual handovers?
User policies

- From technology centric to user centric world!!
- User might have some preferences related to the bandwidth, price, security, etc.
- Interface specific priorities?
- Strict policies on parameters (bandwidth > 5Mb, etc)?
- Ease of use to the user -> pre-defined profiles?
- Manual handovers?
Positioning

- Positioning systems such as Global Positioning System (GPS) and Galileo
- Cellular positioning (GSM base stations)
- WLAN positioning (Ekahau)
- Integrated approaches
- Usage related to handovers
  - Can give some guidance when there should be a Access Point nearby (bring related interface up for scanning)
  - Applications that use the position information (context aware applications)
  - Not direct usage, but indirect
  - Power consumption
Interface selection

- Traditionally AP selections are based on signal strength (GSM, WLAN, hysteresis)
- Interface specific priorities
- More parameters included in the decision -> Multiple Attribute Decision Making problem
- What is the most useful system, complexity vs. usability
Sample architecture

Per-flow mobility management

- Dividing flows into different links (same or different access technology) (simultaneous access)
  - Binding different CoA to different CNs (all CN flows goes via e.g. GPRS)
  - Binding flows (saddr, daddr, port/flabel) into a CoA
  - Packet level division?

- Using several HoAs

- Using Multiple CoA-HoA bindings
  - Several CoAs mapped into one HoA
  - CoAs assigned into the application flow, not to the link itself
  - Amount of signalling?

- Using HIP?

- Benefits in horizontal handovers (redirection)?
End-to-End QoS

- IP core network has its QoS architectures (DiffServ, IntServ)
- Access technologies have their own QoS mechanisms
- How to provide End-to-End QoS?
- QoS agents in each end-device? With integrated mobility solution as well?
- Signaling with NSIS? Next Steps in Signaling
Content adaptation

- Variety of mobile devices, software and access technologies
- Can the content be distributed regardless of this variety?
  - Physical limitations (screen, processing power)
  - Different software platforms have different programs
  - Access technology (full quality video stream might not come through the GPRS interface, etc.)
- Context aware applications
- Some adaptation needed
  - Who should perform this?
    - Content provider itself?
    - The mobile device?
    - Somewhere in the network, proxy?
Content adaptation examples

- Video and audio streaming
  - Resolution and codec can change according to the link quality and device screen size
  - Transfer only audio?

- Email
  - Fetch only email headers in a small link and also the body in good ones

- Files
  - Convert files into a different format because the device does not support the original type
Authentication

- Nowadays technology dependent authentication mechanisms
- AAA (authentication, authorization, accounting)
- Intra- and inter-operator AAA
- Radius, Diameter
- Radius Roaming Proxy
- EAP-SIM, IEEE 802.1x
VerHo

- Prototyping "Vertical Handovers for 4G" in a Linux environment
- The lecture quite much covers the variety of research topics and problems
- Prototyping
  - Nokia 770 (Maemo), HP iPAQ (Familiar)
  - Vertical Handover Controller and sample adaptive applications
  - UMTS/GPRS, Ethernet, IEEE 802.11b WLAN, Bluetooth links
Related projects

- IETF
  - Mobile IPv6, DNA, Mipshop, Mobopts, HIP, NEMO, etc.
- IEEE
  - 802.21 (Media Independent Handover)
- 3GPP
  - UMA (Unlicenced Mobile Access)
- Ambient Networks
- Moby Dick
- TEKES GIGA technology programme
- Not to talk about all that happens in the far east…
Thank you!
Any questions?