Evaluation of Signaling Loads in 3GPP Networks

Journal Club 2007-08
Session 4
Xavier Milà
xavier[dot]mila[at]upf[dot]edu
April, 4th 2008
Universitat Pompeu Fabra (UPF)
Article Reference

Title: Evaluation of Signaling Loads in 3GPP Networks

Author: Tonesi, D.S.; Salgarelli, L.; Yan Sun; La Porta, T.F.;


Bibliographic details: February 2008, pages 92 - 100

Publisher: IEEE

Digital Object Identifier: 10.1109/MWC.2008.4454709

ISBN: ISSN 1536-1284
Outline

- Introduction
- Releases 5 and 99 Architectures
- Signaling procedures
- Signaling loads and procedures loads
- Results and Analysis
- Conclusions
- Application to my Master Thesis
Introduction: Release 5 introduces IMS

- A core network completely based on the IP protocol stack is defined in Release 5
- As we already know: IMS, yes, but why?
  - low cost of operations and maintenance: easy integration with other IP networks
  - support for multimedia services: all which runs over TCP/IP, p.e: VoIP services
  - BUT: higher complexity on the signaling plane, higher computational costs...
    - cause Release 5 managed by more network components than in Release 99
    - IMS based on SIP: heavier in terms of both message size and comp. complexity than the SS7 Mobile Application Part (MAP)
    - Then, impact on the cost, impact on the size of the network infrastructure.
- Article FOCUS: comparison of the signaling loads inside these 2 core networks.
  - in terms of mobility management and call management for voice services
  - Modifications to signaling mechanisms in Release 5 are introduced,
Release 99 and Release 5 Network Architectures
3GPP Release 99

- access network:
  - GSM radio access network, GERAN: BSC controls.
  - UMTS radio access network, UTRAN: RNC controls.

- core network:
  - circuit-switched components [CONSIDERED, voice]
    - MSC: circuit switched calling
    - GMSC: between core network and PSTN
  - and packet-switched components [NOT CONSIDERED, data]
    - SGSN (serving GPRS support node)
    - GGSN (gateway GPRS support node): between GPRS core network and other networks.
3GPP Release 5

- access network (like the previously explained Release 99)
  - GSM radio access network, GERAN: BSC controls.
  - UMTS radio access network, UTRAN: RNC controls.
  - SIP User Agents

- core network:
  - packet-switched components [CONSIDERED, voice & co.]
    - SIP Proxy server: P-CSCF (in the visited or home network)
    - SIP Registrar server: S-CSCF (always in the home network)
    - I-CSCF: SIP server, entry point for a particular domain
    - HSS interrogated for obtaining the user location
3GPP Release 99 vs. Release 5

- **[Services]** Different services provided
  - Release 5 provides integrated services, fully integration with Internet.
    - video streaming, IM, etc.
  - Release 99 only voice and text services.

- **[Architecture]** All traffic in Release 5 carried by a packet-switched architecture.

- **[Protocols]** Release 99, SS#7 protocol stack from 2G networks, with the MAP application layer protocol on top of the SS#7 protocol. Release 5 uses SIP (simpler than MAP), but **heavier** in terms of message size cause text-based nature + **more signaling** messages in IMS -> then, **higher signaling loads in Release 5!**
Signaling procedures

- [Article's GOAL] Evaluate Signaling loads inside the core network
  - do not consider signaling messages exchanged over radio
  - only considered the management of voice calls

- Signaling divided in (1) Mobility Management:
  - Power up and power down: SIP registration / deregistration
  - Inter-BSC handover and inter-MSC/SGSN handover
  - Location update, when changes the MSC or SGSN area, but not while during a phone call (difference with handover)

- and (2) Call Management:
  - [Establishment] Incoming and outgoing call (mobile <-> network)
  - [Termination] Network / Mobile originated call release
One example: Incoming calls

Figure 2. a) Release 99; b) Release 5 incoming call.
Characterization of signaling loads

- **Signaling loads**: [units of time needed] for carrying out the 9 previous signaling procedures

- **Evaluation schema**:
  - $B_{\text{TOT}}$: total amount of traffic per unit of time inside the core network
  - $B_{\text{CROS}}$: part of $B_{\text{TOT}}$ that crosses the network boundaries
  - $B$: generic signaling load split in:
    - $B_{\text{MM}}$: signaling load due to mobility management
    - $B_{\text{CM}}$: signaling load due to call management
  - $\lambda_i$: rate of procedure $i$: how often every procedure is executed
  - Network parameters: mobility rate, density of users...
  - Loads (in bytes) of the signaling procedure: $L_{iH}$...
Parameters and procedures rates

- **Considerations:**
  - A much higher number of mobile users in the network and more MSCs and BTSs: network capacity increased
  - A higher frequency of usage of mobile terminals.
  - **Scenario:** Germany, with average density of users of 83 users/km²
    - 30 million users at averaged 30 km/h handled by 160 MSCs.
    - $P_{roam}$ probability that a certain mobile device is roaming
    - $P_{home} = (1 - P_{roam}) * P_{actv}$
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M$</td>
<td>No. of MSC/SGSN per network</td>
<td>160</td>
</tr>
<tr>
<td>$L$</td>
<td>MSC/SGSN area perimeter</td>
<td>190km</td>
</tr>
<tr>
<td>$d$</td>
<td>Density of users</td>
<td>83/km$^2$</td>
</tr>
<tr>
<td>$v$</td>
<td>Average speed</td>
<td>30km/h</td>
</tr>
<tr>
<td>$R_{up}$</td>
<td>Power up rate</td>
<td>2/day/term</td>
</tr>
<tr>
<td>$R_{down}$</td>
<td>Power down rate</td>
<td>2/day/term</td>
</tr>
<tr>
<td>$R_{in}$</td>
<td>Incoming call rate</td>
<td>24/day/term</td>
</tr>
<tr>
<td>$R_{out}$</td>
<td>Outgoing call rate</td>
<td>24/day/term</td>
</tr>
<tr>
<td>$P_{roam}$</td>
<td>Percent of roaming users</td>
<td>10 percent</td>
</tr>
<tr>
<td>$P_{actv}$</td>
<td>Percent of active users</td>
<td>10 percent</td>
</tr>
<tr>
<td>$N = d(L/4)^2 M$</td>
<td>Number of mobile users</td>
<td>30 million</td>
</tr>
<tr>
<td>$\lambda_{updtM} = d v L / M$</td>
<td>Inter-MSC/SGSN update rate</td>
<td>6710/s</td>
</tr>
<tr>
<td>$\lambda_{updtG} = 3 \lambda_{updtM}$</td>
<td>Inter-BSC/RNC update rate</td>
<td>20130/s</td>
</tr>
</tbody>
</table>

**Table 1.** Main parameters affecting signaling loads.
<table>
<thead>
<tr>
<th></th>
<th>Rate</th>
<th>Reference procedure</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$I_{up}$</td>
<td>Power up</td>
<td>$R_{up}/N$</td>
<td>694/s</td>
</tr>
<tr>
<td>2</td>
<td>$I_{down}$</td>
<td>Power down</td>
<td>$R_{down}/N$</td>
<td>694/s</td>
</tr>
<tr>
<td>3</td>
<td>$I_{ho}$</td>
<td>Inter-BSC/RNC handover</td>
<td>$I_{updt_g}P_{act}$</td>
<td>2,013/s</td>
</tr>
<tr>
<td>4</td>
<td>$I_{hoM}$</td>
<td>Inter-MSC/SGSN handover</td>
<td>$I_{updt_M}P_{act}$</td>
<td>671/s</td>
</tr>
<tr>
<td>5</td>
<td>$I_{lu}$</td>
<td>Location update</td>
<td>$I_{updt_M}$</td>
<td>6,710/s</td>
</tr>
<tr>
<td>6</td>
<td>$I_{in}$</td>
<td>Incoming call</td>
<td>$R_{in}/N$</td>
<td>8,333/s</td>
</tr>
<tr>
<td>7</td>
<td>$I_{out}$</td>
<td>Outgoing call</td>
<td>$R_{out}/N$</td>
<td>8,333/s</td>
</tr>
<tr>
<td>8</td>
<td>$I_{rel_N}$</td>
<td>Network call release</td>
<td>$R_{in}/N$</td>
<td>8,333/s</td>
</tr>
<tr>
<td>9</td>
<td>$I_{rel_M}$</td>
<td>Mobile call release</td>
<td>$R_{out}/N$</td>
<td>8,333/s</td>
</tr>
</tbody>
</table>

Table 2. Procedure rates.
Procedure loads

- $L_i$ values for Release 99 and Release 5

- Size of the SIP messages in Release 5 measured by using *Tcpdump* on the P-CSCF and S-CSCF -> real messages exchanges carried out.

- Obtaining:
  - $B_{\text{TOT}} / B_{\text{CROS}}$
  - $B_{\text{TOT}} / B_{\text{CROS MM}}$
  - $B_{\text{TOT}} / B_{\text{CROS CM}}$

<table>
<thead>
<tr>
<th>$i$</th>
<th>$L_{IH}^R$</th>
<th>$L_{IH}^S$</th>
<th>$L_{IR}^R$</th>
<th>$L_{IR}^S$</th>
<th>$L_{RH}^R$</th>
<th>$L_{RH}^S$</th>
<th>$L_{IR}^R$</th>
<th>$L_{IR}^S$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1245</td>
<td>0</td>
<td>1245</td>
<td>807</td>
<td>12,084</td>
<td>0</td>
<td>12,084</td>
<td>3922</td>
</tr>
<tr>
<td>2</td>
<td>1065</td>
<td>0</td>
<td>1065</td>
<td>627</td>
<td>5724</td>
<td>0</td>
<td>5724</td>
<td>1802</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>0</td>
<td>600</td>
<td>0</td>
<td>530</td>
<td>0</td>
<td>530</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>4733</td>
<td>0</td>
<td>4733</td>
<td>627</td>
<td>1484</td>
<td>477</td>
<td>1484</td>
<td>477</td>
</tr>
<tr>
<td>5</td>
<td>1065</td>
<td>0</td>
<td>1065</td>
<td>627</td>
<td>477</td>
<td>0</td>
<td>477</td>
<td>477</td>
</tr>
<tr>
<td>6</td>
<td>465</td>
<td>246</td>
<td>465</td>
<td>465</td>
<td>13,038</td>
<td>4028</td>
<td>13,038</td>
<td>8056</td>
</tr>
<tr>
<td>7</td>
<td>123</td>
<td>123</td>
<td>123</td>
<td>123</td>
<td>13,462</td>
<td>6254</td>
<td>15,635</td>
<td>12,508</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>3816</td>
<td>1908</td>
<td>3816</td>
<td>3816</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>3816</td>
<td>1908</td>
<td>3816</td>
<td>3816</td>
</tr>
</tbody>
</table>

Table 3. $L_i$ values for Release 99 and Release 5 in bytes.
Results and Analysis (i)

Dashed lines:
- signaling loads in both Releases as a function of the call rate

Continuous lines:
- as a function of the mobility rate

Figure 3. Release 5 and Release 99 signaling loads (in bits per second) vs. call rate (dashed) and mobility rate (continuous).
Results and Analysis (ii)

- The increments due to Call Management are almost negligible for Release 5 but dominant for Release 99
Results and Analysis (iii)

• The components due to mobility management (location update and handovers, intra-handovers not considered!) increase similarly for both releases.

*Figure 5. Release 5 and Release 99 total signaling load $B_{TOT}$ in bits per second for low and high mobility scenarios.*
Conclusions

- Switching from Release 99 to Release 5 will cause signaling delays tens of times larger than the current ones.
  - Cross-network links tens of times more capable are required.
- Traffic exchanged in Release 5 100 times larger.
- The worst case: “the outgoing call while roaming”
- A possible solution to reduce the size of SIP messages is to compress them.
- SIP signaling predominant for the call management part.
  - Smaller SIP messages make the difference for high call rates.
  - Less benefit from SIP compression for high mobility rates.
- Open Issue: complexity cost of this SIP compression.
Application to my Master Thesis :)

- If the I-CSCF is integrated with the S-CSCF, 4 SIP messages are eliminated -> **reduction in # of messages of 25%!!!**
- My proposal viewed as improvement of Release 5...
- ...taken into account:
  - network usage patterns
  - size of the network
  - distribution of users and type of their subscribed services...
- DHTs here? How?

*All your comments will help me for sure!!!*