Evaluation of Signaling Loads in 3GPP Networks

Journal Club 2007-08

Session 4

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April, 4th 2008

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Article Reference

Title: **Evaluation of Signaling Loads in 3GPP Networks**

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Journal title: IEEE Wireless Communications - Feb. 2008, Volume 15, Issue 1

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

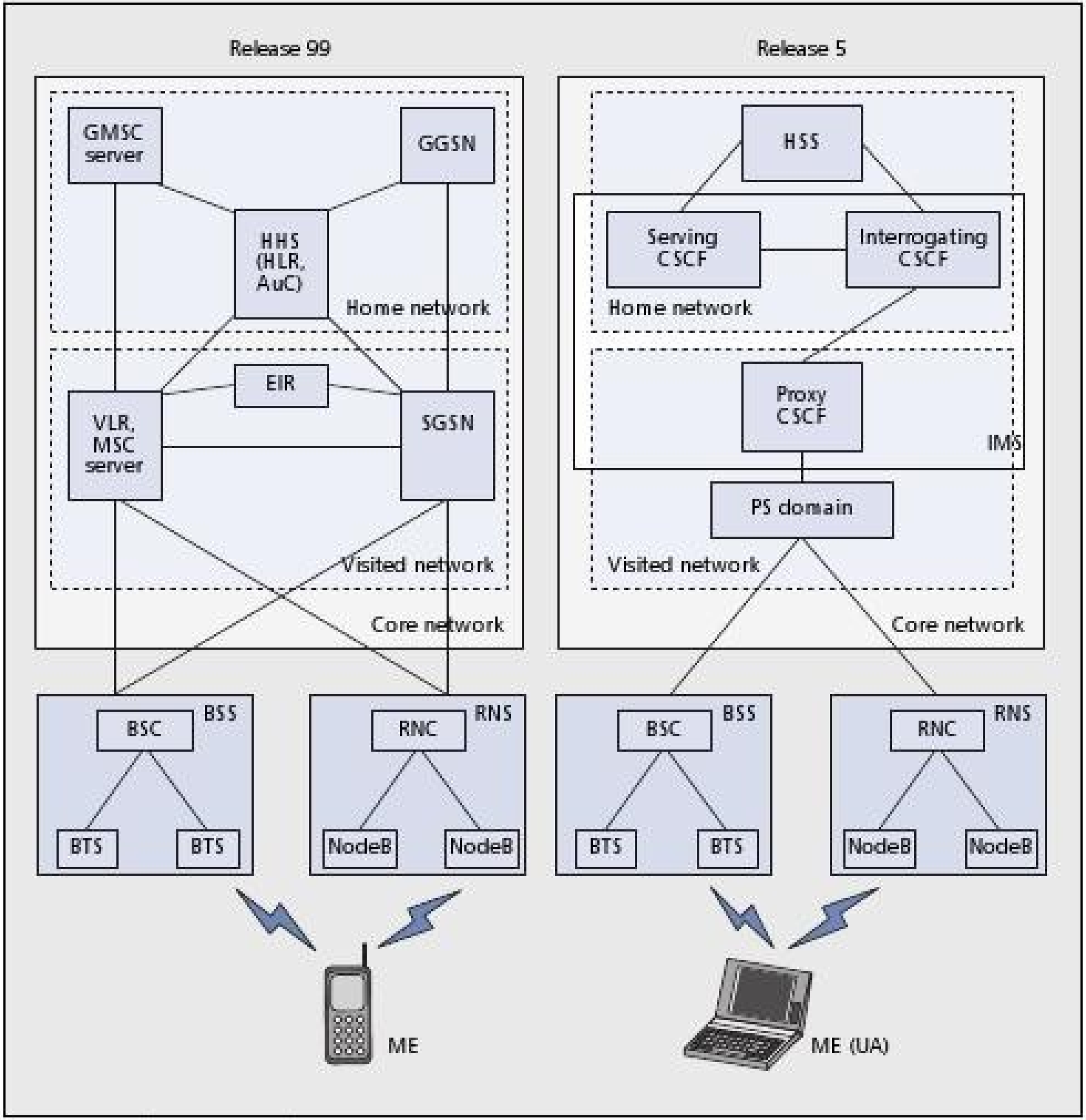


Figure 1. *a) Release 99; b) Release 5 architecture [4].*

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

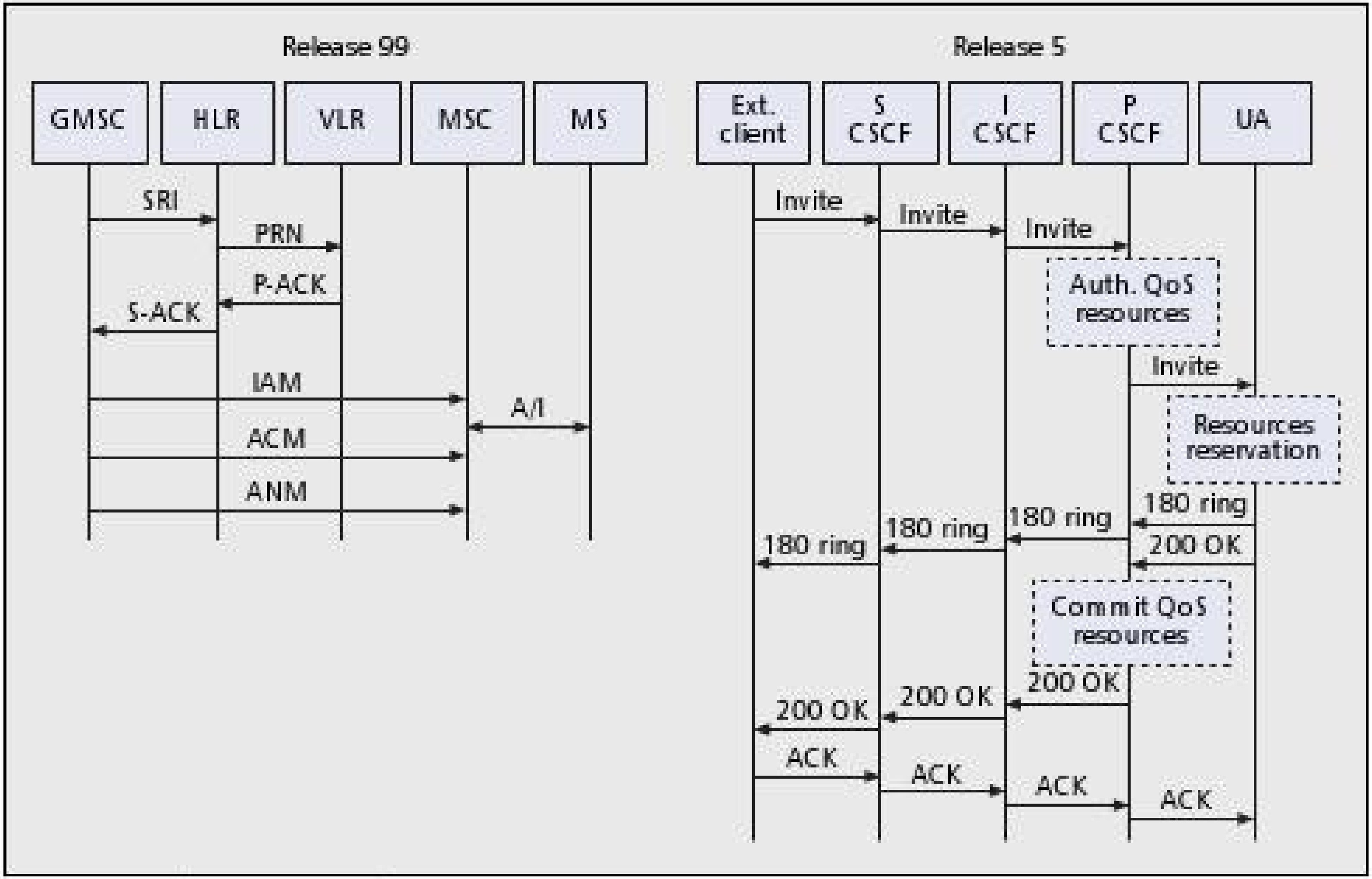
3GPP Release 99 vs. Release 5

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

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.
    - $\mathbf{P_{roam}}$ probability that a certain mobile device is roaming
    - $\mathbf{P_{home} = (1 - P_{roam}) * P_{actv}}$

Parameters	Description	Value
M	No. of MSC/SGSN per network	160
L	MSC/SGSN area perimeter	190km
d	Density of users	$83/\text{km}^2$
v	Average speed	30km/h
R_{up}	Power up rate	2/day/term
R_{down}	Power down rate	2/day/term
R_{in}	Incoming call rate	24/day/term
R_{out}	Outgoing call rate	24/day/term
P_{roam}	Percent of roaming users	10 percent
P_{actv}	Percent of active users	10 percent
$N = d(L/4)^2M$	Number of mobile users	30 million
$\lambda_{updtM} = dvL/\pi M$	Inter-MSC/SGSN update rate	6710/s
$\lambda_{updtB} = 3\lambda_{updtM}$	Inter-BSC/RNC update rate	20130/s

Table 1. *Main parameters affecting signaling loads.*

I	Rate	Reference procedure	Formula	Value
1	l_{up}	Power up	$R_{up}N$	694/s
2	l_{down}	Power down	$R_{down}N$	694/s
3	l_{hog}	Inter-BSC/RNC handover	$l_{updtg}\ P_{actv}$	2,013/s
4	l_{hoM}	Inter-MSC/SGSN handover	$l_{updtM}\ P_{actv}$	671/s
5	l_{lu}	Location update	l_{updtM}	6,710/s
6	l_{in}	Incoming call	$R_{in}N$	8,333/s
7	l_{out}	Outgoing call	$R_{out}N$	8,333/s
8	l_{relN}	Network call release	$R_{in}N$	8,333/s
9	l_{relM}	Mobile call release	$R_{out}N$	8,333/s

■ **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_{TOT} / B_{CROS}
  - B_{TOT} / $B_{CROS\ MM}$
  - B_{TOT} / $B_{CROS\ CM}$

i	R99				R5			
	L^T_{iH}	L^C_{iH}	L^T_{iR}	L^C_{iR}	L^T_{iH}	L^C_{iH}	L^T_{iR}	L^C_{iR}
1	1245	0	1245	807	12,084	0	12,084	3922
2	1065	0	1065	627	5724	0	5724	1802
3	600	0	600	0	530	0	530	0
4	4733	0	4733	627	1484	477	1484	477
5	1065	0	1065	627	477	0	477	477
6	465	246	465	465	13,038	4028	13,038	8056
7	123	123	123	123	13,462	6254	15,635	12,508
8	50	50	50	50	3816	1908	3816	3816
9	50	50	50	50	3816	1908	3816	3816

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

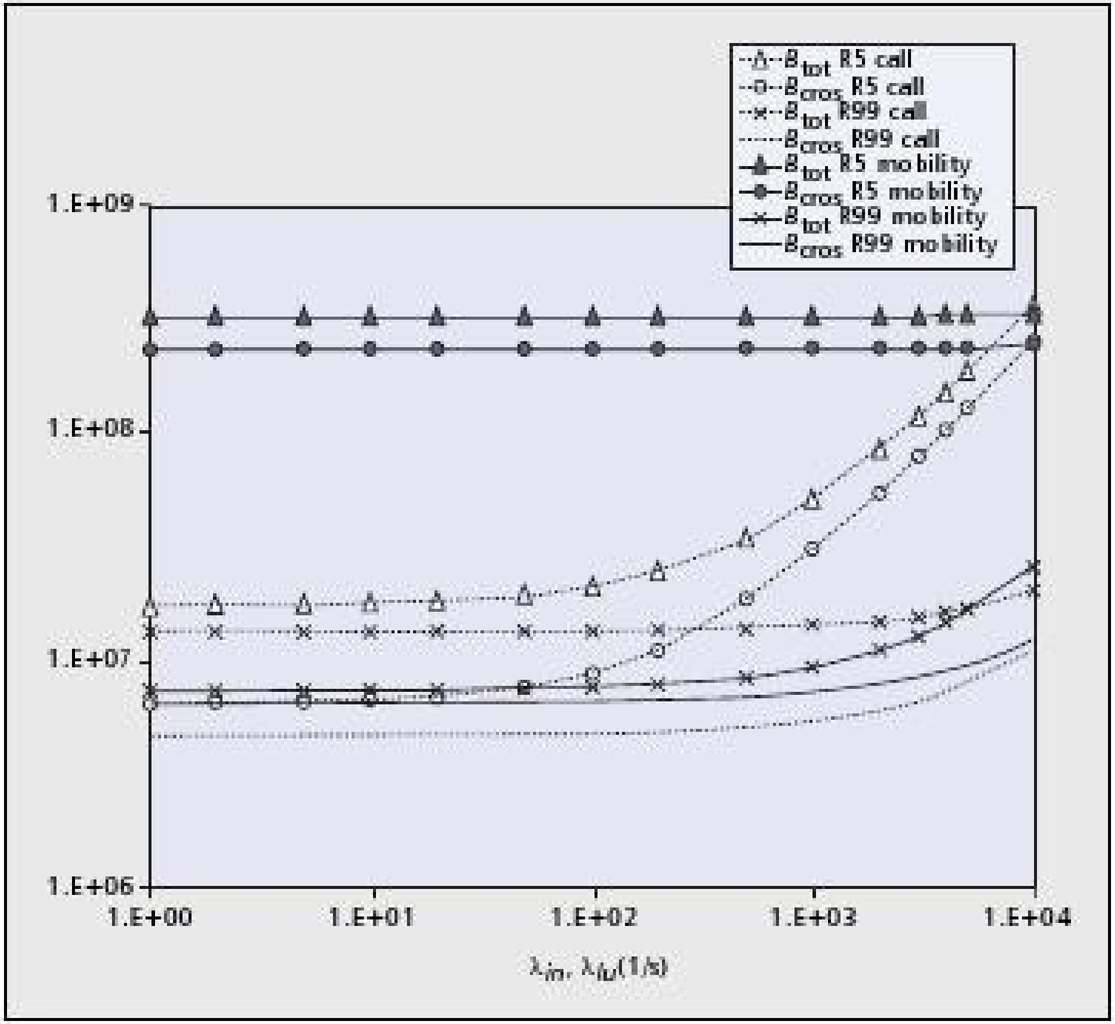


Figure 3. *Release 5 and Release 99 signaling loads (in bits per second) vs. call rate (dashed) and mobility rate (continuous).*

Results and Analysis (ii)

- The increments due to Call Management are almost negligible for Release 5 but dominant for Release 99

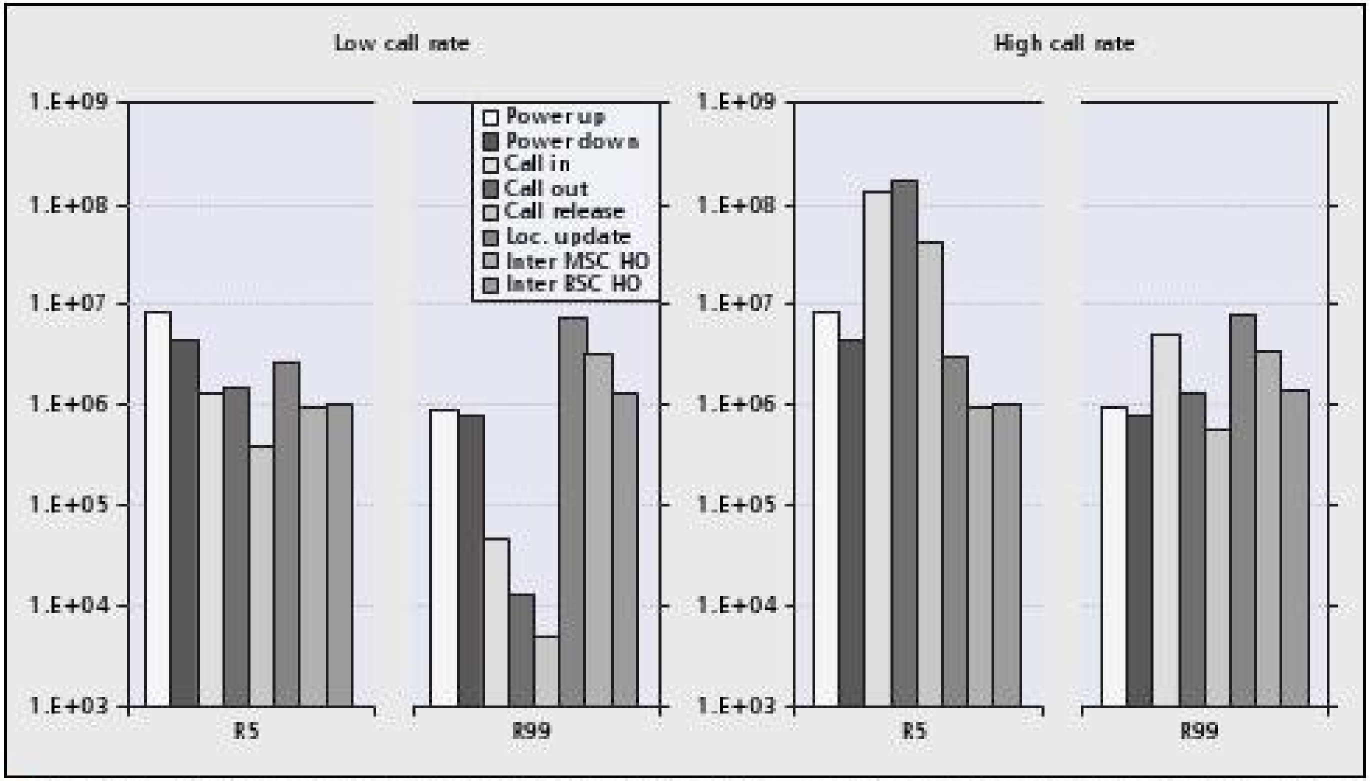


Figure 4. *Release 5 and Release 99 total signaling load* B_{TOT} *in bits per second for low and high call rate scenarios.*

Results and Analysis (iii)

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

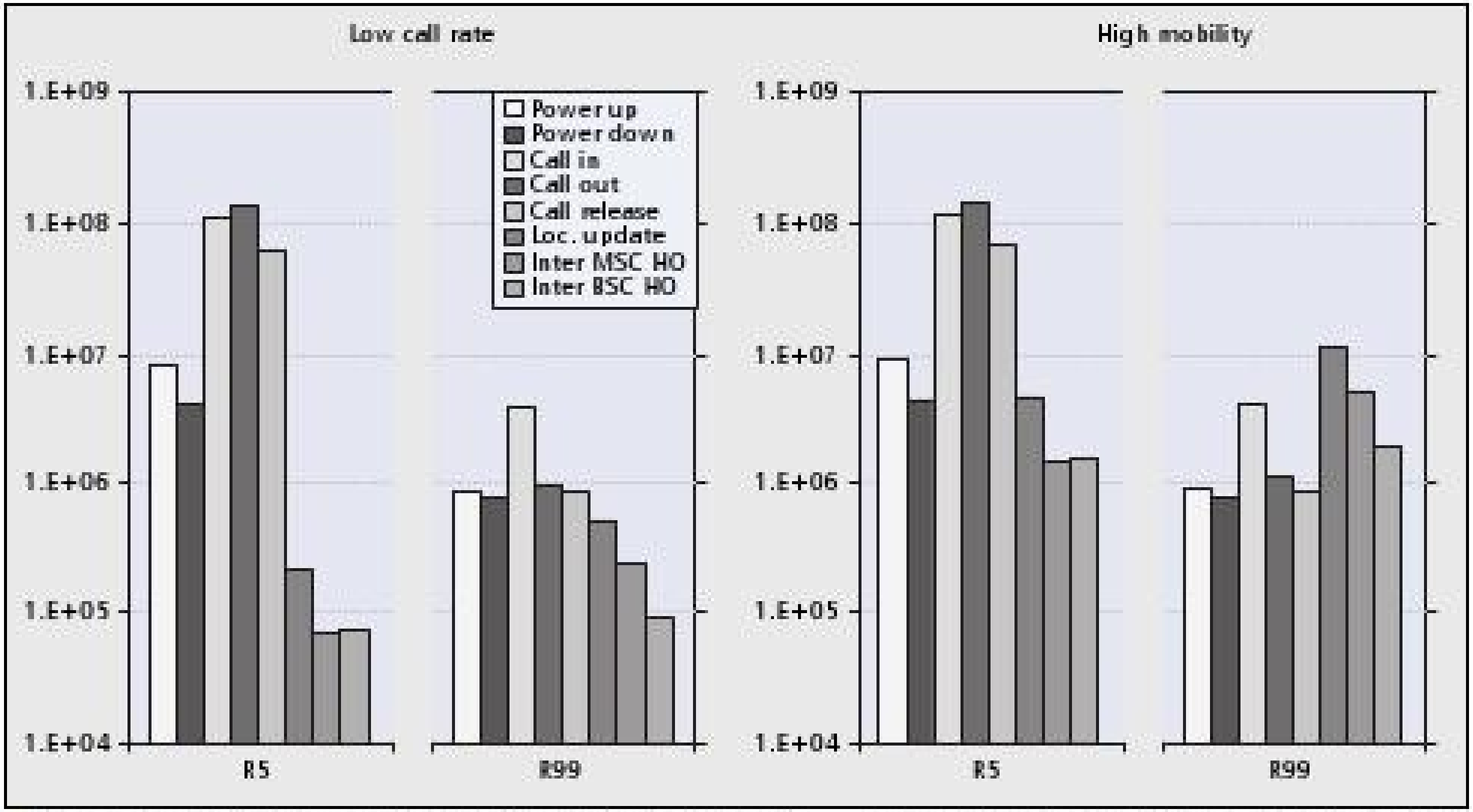


Figure 5. *Release 5 and Release 99 total signaling load B_{TOT} in bits per second for low and high mobility scenarios.*

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 rat
  - 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!!!