Performance evaluation of L2 handover mechanisms for Inter-Radio Access Networks

Nicolas Dailly, Philippe Martins and Philippe Godlewski
ENST-Paris - Ecole Nationale Supérieure des Télécommunications
LTCI-UMR 5141 CNRS
46 rue Barrault, 75634 Paris Cedex 13, FRANCE
Email: Nicolas.Dailly@enst.fr, Philippe.Martins@enst.fr, Philippe.Godlewski@enst.fr

***Abstract* – B3G networks will provide seamless data handover between different radio access technologies (RAT). In a near future, the WLAN access will be integrated in GPRS and UMTS radio access networks (RAN). During their communications, the subscribers will be able to switch automatically between the two technologies. In that case, their previous data transfer need to be re-established in the new RAT. This process must be carried out while minimizing the breakdown time and the data loss. This paper intends to evaluate the performances of handover policies between GPRS/UMTS and WLAN RAT and to propose adapted data handover strategies at layer two.**

***Keywords* – WLAN, UMTS, GPRS, Handover, Re-selection, Radio Access Technologies, performances, RLC, LLC, TCP/IP.**

I. INTRODUCTION

The fourth generation of mobile systems will probably rely on different radio access technologies. The main challenge, in such a context, is to provide seamless interconnection and mobility for data services between the different mobile systems. Several cases of interconnection between cellular systems and WLAN have been investigated in [1]. Different approaches are described in [2]. In the "Open" and "Loose coupling", the WLAN and the cellular networks are linked to a common IP network (which can be public or private). The mobility is managed on the network level. Solutions such as Mobile IP [3] or such as Cellular IP [4] can be used to provide a mobility service : the user changes its network system technology but keeps its IP address. In the "Tight" coupling and integration approaches, the WLAN access point (WLAN-AP) is located in the radio-access network (RAN) of the cellular network (see Fig. 1) : the WLAN-AP represents a new radio access technology for the cellular network.

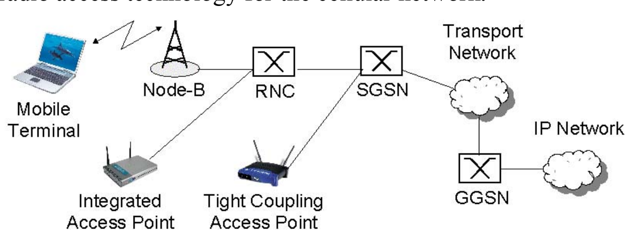

Figure 1. WLAN integration to cellular network

In the tight coupling approach, the WLAN-AP is link to the cellular core network via the SGSN – Serving GPRS Support Node. For the SGSN, the WLAN-AP is seen as an autonomous RAN. In the integrated approach, the WLAN-APs are linked to radio network controllers (RNC). WLAN-AP are managed as UMTS Node-Bs.

This paper intends to evaluate different handover strategies for inter RAT handover. The evaluation will be done in terms of data loss at different levels (RLC, LLC and TCP/IP), transmission delay and breakdown time. Part II describe the approaches to control the handover, Part III describe the architecture and the parameters of our simulator and the Part IV describe the handover procedures. The results of our simulations and some conclusions are provide on the Part V for the WIFI to GPRS handover and on the Part VI for the GPRS to WIFI handoff.

II. HANDOVER INTER-RADIO-ACCESS NETWORK TECHNOLOGIES

The tight coupling and integrated approaches will be able to provide seamless handover. Two approaches can be used to control and trigger the handover. In the "mobile controlled" approach, the mobile made measurements to evaluate the radio link quality. When the mobile detects a cell or a radio interface able to provide a better service (in terms of radio-quality, throughput or service provided), it switches to the new cell. This process is called reselection. It involves a long transmission interruption while the mobile tunes to the new cell, obtains new cell's configuration information and executes the resources reservation process.

In the "network controlled" approach, the mobile sends its measurements to the network. The network analyzes these measurements reports and its own measurements performed in the uplink. It can then decide to take a handover decision. This decision can be based on radio link quality criteria, but also on quality of services or network management considerations. When it has taken an handover decision, the network allocates resources for cell switching and sends an handover command to the mobile. In this way, the time breakdown is shorter than in the reselection approach : the mobile just needs to tunes to the target cell and use the allocated resources.

III. SIMULATOR DESCRIPTION AND PARAMETERS

A. Simulator Description

To evaluate the performance of the different handover strategies, we have design a computer simulator developed in Java language. Our simulator is made up of many objects which reproduce the functionalities of the different equipments of the networks (Mobile terminals, web-servers, GGSN, SGSN, RNC, Node-B and WIFI-AP - see Fig. 1) and their interfaces (Core and RAN transport networks and Air interfaces). Each equipments implements transmission control layers, as describe in Fig 2.

The protocol stack implements GPRS and WIFI air interfaces. The GPRS air interface include an RLC – Radio Link Control – Layer based on a sliding window of 64 RLC blocks for GPRS or a maximum of 512 blocks for EGPRS [5].

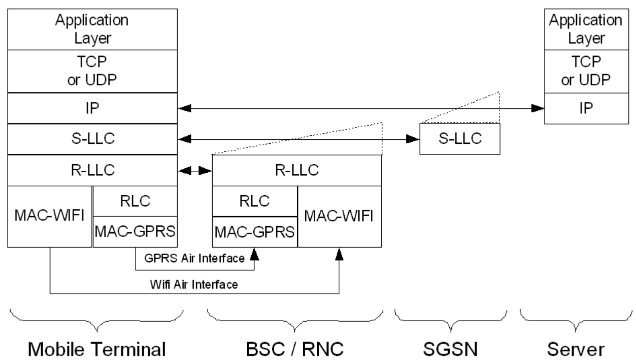

Figure 2. Protocol stack of the simulator

Two LLC layers – Link Layer Control – have been implemented to secure the transmissions with the BSC (R-LLC) and with the SGSN (S-LLC) [6]. The interest of this layer will be describe on the handover strategies. The IP layers implement an UDP protocol or emulate a simplified TCP protocol. The application layer contains the data traffic generators. A mobility manager is associated with each mobile. The traffic and mobility profiles depends on the simulation scenario.

The GPRS air interface is simulated as describe in [7]. The Air interface is composed with several slots. In each slot, the mobiles can send RLC/MAC blocks. The block size depends on the system used (GPRS or E-GPRS) and the coding scheme (from 9,05 kbits/s for the GPRS CS-1 to 61,85 for the E-GPRS MCS-9 [8]). The Abis interface is a PCM frame with several slots of 16kbits/s. One Abis interface is associated to each BSC – Base Station Controller. The slots of the Abis interface are shared between all the BTS under the control of a same BSC. The BTS have a buffer capability of 20 RLC/MAC blocs on uplink and downlink.

The WIFI air interface is modeled as a bi-directional interface where one IP packet can be transmitted each millisecond. The data rate is then noticeably higher than for the cellular interface. The WIFI AP have a buffer capability of 20 R-RLC frames (or 20 IP packets).

B. Simulation Parameters

The simulations parameters are resumed on table 1. We consider 2 cells : one covered by a BTS and one by a WIFI-AP. The cell covered by a BTS has 4 slots configured for GPRS data transmission. The mobile has GPRS and WIFI capabilities but are not able to camp on two systems at the same time. The mobile has GPRS multislot capabilities of 4 slots in downlink and 1 slot in uplink. They use coding schemes MCS-2 (13kbits/s) or MCS-4 (19,4kbits/s).

The mobile trajectory is describe in Fig.3. The mobile made traffic in a first cell (❶, eg. WIFI) during 60 to 90 seconds before the cell switching procedure is triggered ❷. When the communication is re-established on the new cell (❸, eg. GPRS), the traffic generator continue to generate traffic during 90 seconds (it stops at step ❹). 180 seconds after ❺, the mobile leaves the network by proceeding to a detachment procedure.

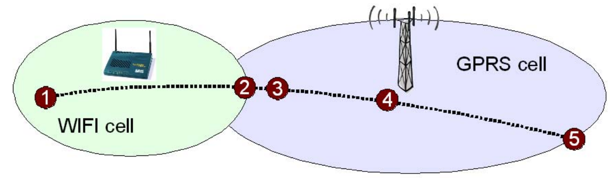

Figure 3. Mobile path

The traffic generator sends data packets each time the IP layer is ready to send data. Then, the application layers have always data to transmit. The data size follows a Pareto law.

Parameters	Value
Mobile arrival rate	Exponential law, 4 mobiles/minute
GPRS mobile multislot capabilities	1 slot uplink, 4 slots downlink
Coding Scheme Used	50% MCS-2 – 13kbits/s 50% MCS-4 – 19,4kbits/s
Number of GPRS air interface slots	4 slots
BTS buffer capabilities	20 RLC/MAC blocks
AP WIFI buffer capabilities	20 IP packets
Data Size	Pareto Law, α=1.1, k=81.5, m=66666 bytes
Cell synchronization time (handover and reselection procedure only)	Uniform law, from 0 to a parameter of the simulation
Time to get System Information configuration and to make resources reservation (reselection procedure only)	Uniform law, from 0 to 8 seconds

Table 1. Simulation parameters

IV. HANDOVER PROCEDURES

This part describes the handover procedures implemented in our simulator.

Fig.4 describes the reselection procedure. When the mobile has taken the reselection decision ①, it stops its activities on the current cell. Then, it switches to the target cell, tunes and monitors the beacon channel to get the system information (① to ④). The mobile can then reserve radio-resources on the new cell and triggers the attachment procedure. At the end of the procedure, the mobile receives the reselection acknowledgment ⑤ and it can resume the transmission in the uplink.

When a reselection occurs from a GPRS to a WIFI cell, the downlink transmission is quickly interrupted due to RLC/MAC transmission window. In case of WIFI to GPRS handover, the WIFI AP discards the IP packet transmission if the packet cannot be delivered to the mobile. All the packets sent during transmission break time are lost. In our simulations, we have considered the case where the WIFI AP is able to detect the mobile departure and can inform the BSC to suspend the downlink transmission to the mobile. In the following, this approach is referred as "Reselection with detection capability". Part B presents our proposal to manage the reselection with a retransmission mechanism at LLC layer. This proposal is referred as "reselection with acknowledged LLC" in the following.

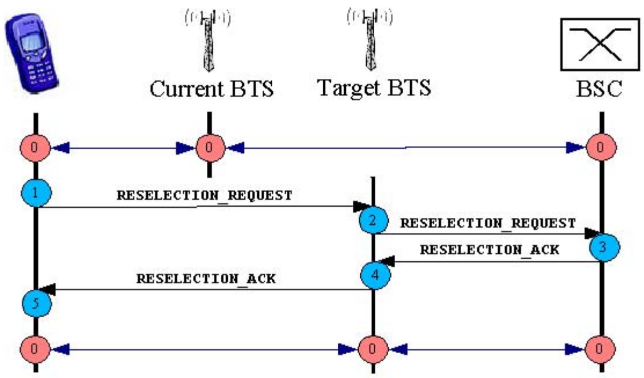

Figure 4. Intra-BSC reselection procedure

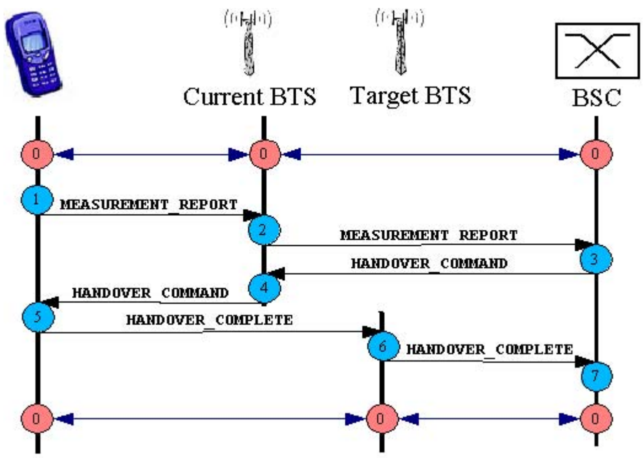

Figure 5. Intra-BSC handover procedure

The handover procedure is described in Fig.5. The mobile sends periodically measurements reports to the BSC ①. When the BSC takes the handover decision, it checks that the target cell is under its control : in that case, it is a intra-BSC handover. Then, the BSC reserves radio-resources on the target cell, suspends the downlink transmission and sends an handover command to the mobile③. When the mobile receives the handover command ⑤, it switches to the new cell. The mobile just needs to tune to the specified channel described on the handover command message and synchronizes with the target cell. The handover is then completed and the BSC can resume transmission in the downlink ⑦.

V. WIFI TO GPRS HANDOVER

A. *Reselection and Handover performances comparison*

Fig.6 represents the number of R-LLC frames lost against synchronization times, for different strategies of cell switching process from WIFI to GPRS (handover, reselection, reselection + detection capability, acknowledged LLC). We can notice that the cell switching operation induces important transmission interruption times and a sensitive decrease of throughput. The transmission delay of frames between the BSC and the mobile is shown on Fig.8. We can notice that the reselection procedure introduces important frame losses that increase with the transmission break duration. These losses are due to the fact that the WIFI AP does not detect when a mobile leaves the WIFI cell. If the WIFI AP cannot deliver the IP packets, it gives up the packet transmission : packets sent or retransmitted during transmission break time are lost. If the WIFI-AP is able to detect the mobile has left the cell, only the frames on the AP buffer will be lost. The BSC will be notified by WIFI-AP to stop downlink transmission and to store new arriving packets. The mobile leaving detection problem can be solved by sending alarms to the BSC each time an IP packet cannot be delivered. Once the transmission is reestablished on the new cell, the frames stored in the BSC can create an overload of the transmission and then more important transmission delays. As we can show on our simulations, reducing data loss increases the transmission delay.

The handover procedure does not introduce any data loss on the downlink. This is due to the fact that the BSC suspends the downlink transmission before triggering the handover command. As for the mobile reselection with leaving detection, this procedure increases the transmission delays even if the transmission time cutoff is short (see Fig.9 for the procedures and transmission cutoff duration).

The performances of these strategies in terms of data loss in uplink are very close. The BSC continues to receive uplink IP packets sent by the mobile because the two base stations are linked to the same BSC. However, the acknowledgments cannot be sent to the mobile on the downlink. The transmission is suspended until the downlink transmission is resumed and the acknowledgments reach the mobile. The transmission break time has a sensitive impact on the performance of the uplink transmission as we can see in Fig.7. Handover strategy minimizes the cutoff time and increases consequently the number of frames transmitted in uplink compared to reselection strategies.

B. *Design and contributions of a LLC layer*

The GPRS system has an LLC layer localized on the SGSN (define as S-LLC layer in this paper). This LLC layer does not introduce any segmentation of the IP packets. It can be used in acknowledged or unacknowledged mode. The acknowledged mode is based on a window sliding mechanism of 256 S-LLC frames. In the current operational networks, this LLC layer is not used. This layer increases data load for a small benefit : the RLC layer is sufficient to ensure a reliable radio transmission and the remaining error can be get back by the TCP retransmission mechanism [9]. However, when we consider a mobile terminal that changes of cell of attachment, the data loss during the transition is more significant and a retransmission mechanism at the LLC level can be beneficial.

In our simulations, we have introduced a retransmission mechanism in the LLC layer. This layer is modeled as a sliding window of 10 frames which are retransmitted every 5 seconds. The Fig.6, 7, 8 and 9 show that the data loss is the same as for the handover, but the performances in terms of transmission delay and number of transmitted frames are strongly reduced. The LLC retransmission mechanism cannot be activated during all the mobile transmission session. If the LLC layer will be activated just before handover, and deactivated when the connection is reestablished on the new cell, it could be possible to take advantage of the LLC retransmission mechanism for the cell switching without decreasing the performances of the intra-cellular transmissions. The activation of the LLC retransmission mechanism can be based on radio or block error rate criteria. It can also be possible to adapt the LLC retransmission mechanism to the transmission conditions, as describe in [10].

These proposal implies that the BSC controls the LLC layer. This can only be done if the LLC layer is localized on the BSC (and not on the SGSN). Furthermore, the efficiency of the LLC control will be more accurate if the mobile periodically sends transmission quality feedback to the BSC. In case of an LLC layer localized on the BSC, a transmission context subsists in case of inter-BSC cell switching. The handover and relocation mechanisms suggested on the UMTS standards can then be used [12][11] (an inter BSC handover mechanism will be the subject of a future paper).

VI. GPRS TO WIFI HANDOVER

When a subscriber switches from a GPRS interface to a WIFI interface, it can take advantage of a significant increase of the throughput and a reduction of the transmission delays on the radio interface. The data packets stored in network buffers during the cell switching process can be quickly delivered to the mobile through the WIFI interface.

To be transmitted on the GPRS radio interface, the IP packets are segmented by the RLC/MAC layer. The size of the segments depends of the coding scheme used by the mobile. If the cell switching occurs when the transmission of an IP packet is being processed, the BSC is not able to get back the transmission of this packet on the new interface. The Fig.10 show the number of RLC/MAC block lost in case of handover or reselection and Fig.11 the associated number of LLC frames lost. We can notice that, in case of reselection many RLC blocks are lost. In case of handover, the downlink transmission is interrupted in the beginning of the procedure : it permits to send more remaining RLC blocks before the mobile stops its activities on the GPRS cell. The impact is that fewer LLC frames are lost in case of handover. Furthermore, as for the WIFI to GPRS handover, the implementation of a LLC layer reduces IP packet loss.

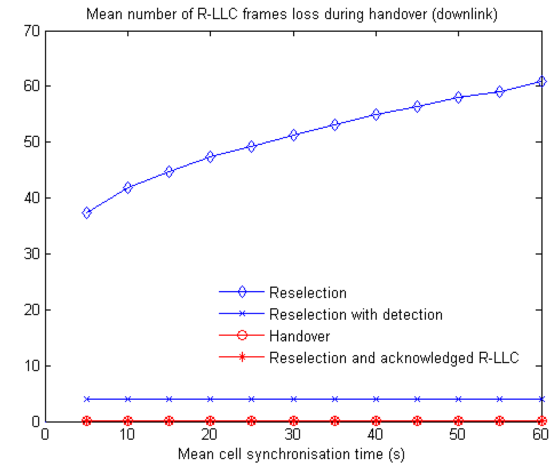

Figure 6. R-LLC frames loss in downlink
(WIFI to GPRS cell switching)

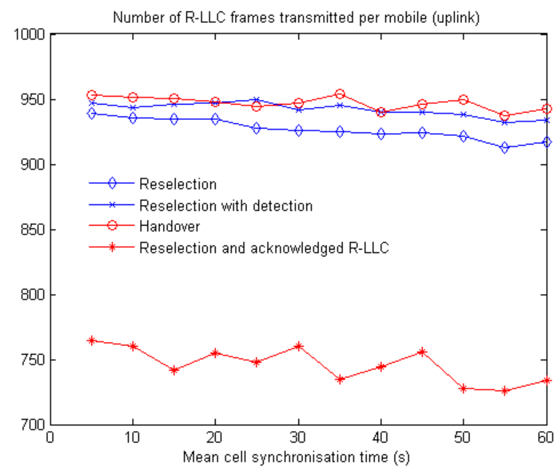

Figure 7. Mean number of R-LLC frames transmitted in uplink
(WIFI to GPRS cell switching)

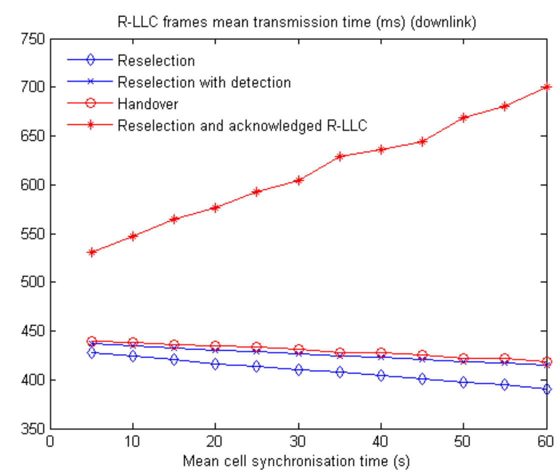

Figure 8. R-LLC frames downlink transmission time
(WIFI to GPRS cell switching)

On the uplink, the mobile should be able to retransmit the last LLC frame incompletely transmitted [5]. Then, in case of cell reselection, no frames will be lost due to transmission interruption.

VII. CONCLUSION

This paper introduces several approaches to manage the GPRS-WIFI inter-RAN handover. It compared the performances of the mobile controlled reselection and of the handover. The performance of a system where the WIFI AP is able to detect the mobile departure and inform the BSC is also evaluated. In Part V-B, we propose to activate an acknowledged LLC layer when an handover occurs.

The handover and "reselection with acknowledged LLC layer" strategies are better in terms of data loss. As for the reselection with detection, they involve network overload which introduces higher transmission delays.

In case of WIFI to GPRS cell reselection, the acknowledged LLC layer prevents from data loss by interrupting the transmission at LLC level. For the GPRS to WIFI handover, it is the only solution to insure a lossless transmission of the LLC frames. The LLC retransmission mechanism can be a good solution to improve the transmission performances, providing that this layer will be activated when an handover occurs.

REFERENCES

[1] 3GPP TS 23.234 V6.5.0, *Technical Specification Group Services and System Aspects; 3GPP system to Wireless Local Area Network (WLAN) interworking; System description (Release 6)*, June 2005

[2] R. Samarasinghe, V. Friderikos, A.H. Aghvami, *Analysis of Intersystem Handover: UMTS FDD \& WLAN, London Communications Symposium*, 8th-9th September 2003

[3] C. Perkins, Ed., *IP Mobility Support for Ipv4*, Internet RFC 3344, August 2002

[4] A. Valko, *Cellular IP: A New Approach to Internet Host Mobility*, ACM SIGCOMM Computer Communication Review, January 1999.

[5] 3GPP TS 44.060 V16.6.0, *Technical Specification Group GSM/EDGE Radio Access Network; GPRS; MS - BSS interface; Radio Link Control/Medium Access Control (RLC/MAC) protocol (Release 6)*, January 2006.

[6] 3GPP TS 44.064 V6.1.0, *3rd Generation Partnership Project; Technical Specification Group Core Network; MS-SGSN; Logical Link Control (LLC) layer specification (Release 6)*, September 2005.

[7] N. Dailly, Ph. Martins and Ph. Godlewski, *Modeling and Performance Evaluation of Dynamic Abis for E-GPRS*, IEEE VTC Spring 2006, Stockholm, May 2005.

[8] GPP TS 45.001 V6.7.0, *Technical Specification Group GSM/EDGE; Radio Access Network; Physical layer on the radio path; General description (Release 6)*, November 2005.

[9] Qixiang Pang, Amir Bigloo, Victor C.M. Leung, Chris Scholefield, *Performance Evaluation of Retransmission Mechanisms in GPRS Networks*, IEEE WCNC'00, Chicago, September 2000.

[10] M Analoui; M.H Rezvani; *Performance enhancement of logical link control using channel quality in GPRS*, IEEE-APCCAS '02. October 2002.

[11] 3GPP TR 25.936 V4.0.1, *Technical Specification Group (TSG) RAN 3; Handovers for real-time services from PS domain; (Release 4)*, Décembre 2001

[12] 3GPP TS 25.413 V6.8.0 *Technical Specification Group Radio Access Network; UTRAN Iu interface RANAP signalling (Release 6)*, Décembre 2005

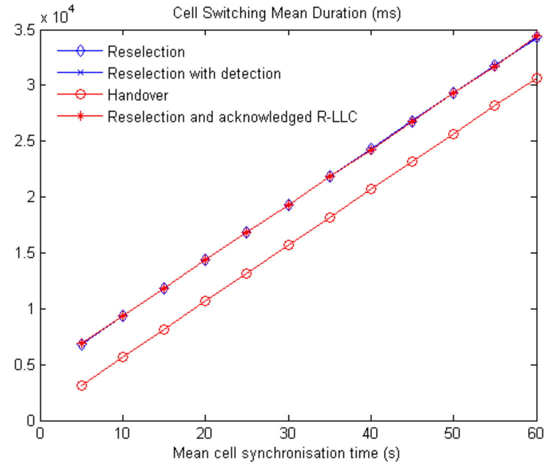

Figure 9: Intra BSC cell switching procedures duration

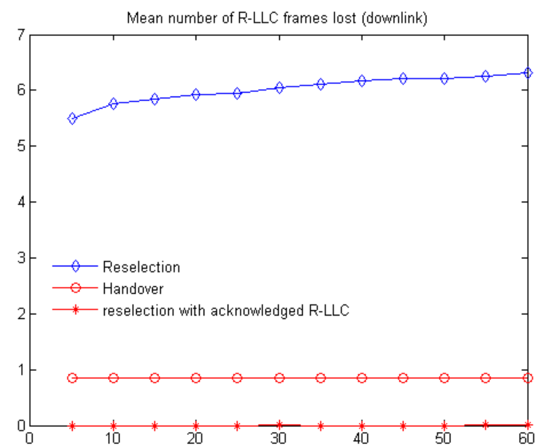

Figure 10. Downlink LLC frame loss
(GPRS to WIFI cell switching)

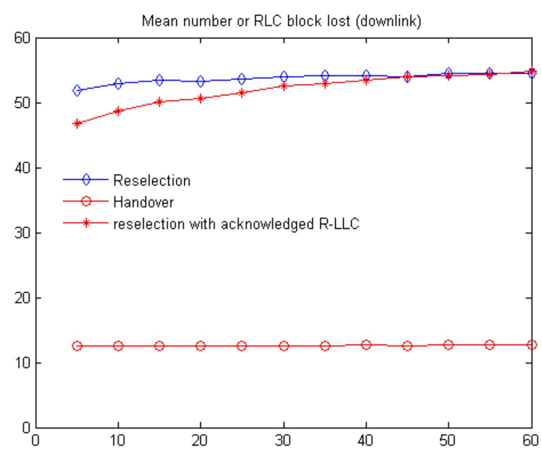

Figure 11. Downlink RLC block loss
(GPRS to WIFI cell switching)