VoIP Call Signaling Performance and Always-On Battery Consumption in HSDPA, WCDMA and WiFi

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***Abstract*—Wireless broadband enables the use of VoIP with handheld mobile deices. Likewise, multi radio terminals provide the user with ubiquitous access. Even though broadband access might be available in different locations, performance still depends on the wireless technology used. We study the main signaling delays that take place in a voice call (registration and voice call setup delays) and compare them for different wireless accesses: HSDPA, WCDMA and WiFi. Likewise, possible optimizations with always-on mode and their drawbacks are presented. Signaling delays and total battery lifetime affect the perceived end user experience directly, and thus are important items to consider in addition to the overall voice quality.**

Keywords-HSDPA, VoIP, IMS, signaling, battery consumption, WiFi, WCDMA

I. Introduction

HSDPA networks are intensively being deployed to provide broadband connectivity to mobile devices, such as handheld terminals and laptops. Likewise, WiFi connectivity is every day more available in both private and public hotspots and even city wide coverage deployments [2][8]. These broadband wireless accesses are able to support VoIP applications over a packet data connection instead of traditional circuit switched calls. With the introduction of multi radio devices with WCDMA, HSDPA and WiFi capabilities as well as integrated VoIP clients, ubiquitous connectivity across any of these networks is possible using the same mobile terminal. However, while the mobile terminal and client are the same, performance differs depending on the wireless access in use, HSDPA, WCDMA or WiFi.

This paper sets out to study the signaling performance of VoIP applications with multi radio mobile devices by conducting a methodic performance analysis and possible optimization possibilities with and their tradeoff to battery lifetime. The key contributions are a throughout evaluation and quantification of VoIP signaling performance over different wireless accesses available in multi radio terminals. Likewise, performance optimization possibilities such as always-on modes and its tradeoffs in regards to battery consumption are presented. Signaling delays and battery lifetime affect the end user experience directly and thus should be considered.

The remainder of the paper is organized as follows. In Section 2 we introduce the previous work in the topic, Section 3 describes our research approach, Section 4 presents the results and analysis, and in Section 5 we draw conclusions and describe future work.

II. Prior Work

SIP call setup delays and signaling performance have been studied previously mostly for Internet scenarios. ITU-T E.721 [11] recommendation and [13], provide call setup delays recommendations for circuit switched and Internet Telephony systems respectively. Additionally, [5] provides guidelines for Internet Telephony call setup and signaling transfer delays. In regards to 3GPP based wireless accesses, [12] provides simulations for transfer delays with 3GPP signaling, while [6] and [18] modeled signaling performance. Further, [4] provides measurements for a WCDMA setup using laptop clients for local, international and overseas calls. Most of the mentioned research focuses on simulations, and does not consider some end user cases such as calls in wireless environments starting from different states. Additionally, performance with different wireless radio accesses and configurations under the same conditions is not available. Also, the available works do not use an embedded VoIP client in a handheld mobile terminal, which yield different delay values than with a PC. HSDPA signaling performance has not been evaluated either. Our research aims at covering these items. The importance of evaluating a mobile terminal relies in the fact that the eventual substitution of CS based calls in 3GPP networks (HSDPA and WCDMA) for VoIP calls will take place with a handheld mobile device and not with a PC or laptop. Likewise, multi radio can provide ubiquitous access via different wireless access technologies that perform differently. Furthermore, the use of VoIP instead of CS calls has an additional impact in regards to battery lifetime. The work most closely related to ours is [9], which makes an empirical analysis of radio resource control timers and their effect on energy consumption for NAT keep-alive messages. [20] and [21] provide simulations on the same topic. Our work extends this research by presenting measurements during actual IMS registrations over multiple accesses.

The lack of actual measurement performance values in literature could be mainly due to the unavailability of integrated VoIP clients in the terminals and available HSDPA networks. However, with the introduction of some Nokia multi radio devices with VoIP capabilities (e.g. N95, 6110), using SIP based VoIP applications without a PC is possible [14][15].

The VoIP server can be any IETF or IMS based server reachable via one of the wireless accesses.

III. Methodology and Test Environment

The evaluation methodology consisted of a variety of VoIP calls using mobile devices and capturing SIP packets directly from the mobile terminal wireless interface. Additionally, battery consumption was monitored during the exercises. With such variables we are can evaluate the different wireless access available from the following test objectives:

a) SIP registration delays

b) VoIP call signaling delays (post-dial, answer-signal, and call-release delays)

c) Always-On registration impact to battery lifetime

The two main activities in VoIP calls are: first, a registration to the VoIP server which is required to make and receive calls, and second, the voice call setup itself. The packet captures were carried out with a Nokia proprietary tool with a function similar to TCPdump [19], which prints out the headers of packets on a network interface. Subsequently, the captures were analyzed with Wireshark Protocol Analyzer [22]. Battery consumption when registered to IMS was monitored over a period of several hours with a Nokia proprietary tool.

In order to do a fair evaluation, all the calls were carried out with the two identical terminals with exactly the same setups, registered to the same VoIP server in the IMS system, and via the same wireless access in an interference free environment. The measured scenarios were WiFi-to-WiFi, HSDPA-to-HSDPA and WCDMA-to-WCDMA calls. The maximum transfer bitrates were set in the RNC and HLR configurations to model different wireless access scenarios. For WCDMA, maximum uplink and downlink transfer rates were fixed at 64/64 kbps and 128/128 kbps. For HSDPA only the uplink was fixed at 128 kbps. In the case of WiFi, transfer rates were left with default configuration (802.11g and maximum transfer rate enabled). Figure 1 shows the test environment setup.

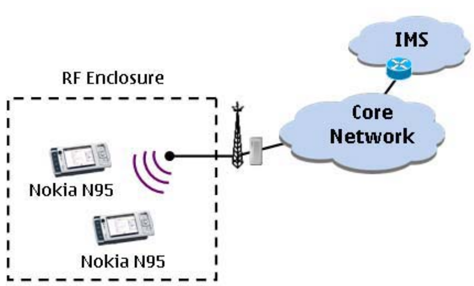

Figure 1. Test Environment

The core network and IMS system were privately owned and under very low load. The wireless access systems were based on Nokia RAS5.1 for WCDMA and HSDPA tests with default settings. For WiFi tests, a Belkin Wireless Pre-N Router with default configuration was used. The core network and IMS system were based on Nokia equipment. The tests executed consisted of multiple iterations of each of the voice call scenarios and registration to the VoIP server. We provide average result values from the measurements. The measurements took place during spring 2007.

It must be noted that the measurements in this paper are based on IETF SIP signaling [17] and not 3GPP signaling [1]. Since 3GPP specifications require additional signaling messages, we expect delays to be longer than with IETF specification. Both the Nokia IMS system and N95 terminal support both signaling specifications. However, IETF signaling was selected to provide a wider system scope and allow future comparisons.

While it could be interesting to know the differences in delay with VoIP originated calls to the PSTN, our interest is in the difference in performance in the wireless access interface. Therefore, it is troublesome to get directly comparable results because when a call takes place, multiple gateways, proxy servers and networks could be traversed. Therefore, delays could fluctuate and it might not be possible to identify the origin of such discrepancies. However, research in [4][5] provide simulations for similar scenarios in Internet Telephony systems.

IV. Analysis and Results

A. SIP Registration Setup

The IETF signaling [17] and delay measurements for SIP Registration to the VoIP server in the IMS system are depicted in Figure 2.

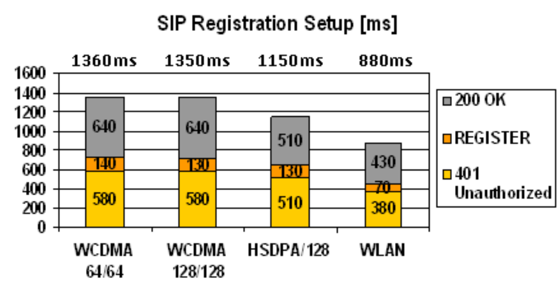

Figure 2. SIP Registration Signaling Delays

The measurements show that the registration times with HSDPA and WCDMA are about 30% and 50% higher than with WIFI. While this might not seem much, we should remember that SIP registration requires a very limited number of messages. Therefore, as more messages are required, such as with 3GPP SIP registration, delays will increase.

B. Voice Call Signaling

The IETF signaling [17] and delay measurements for voice call setups when a PDP context [7] is active and the terminal is registered to the IMS system are depicted in Figure 3.

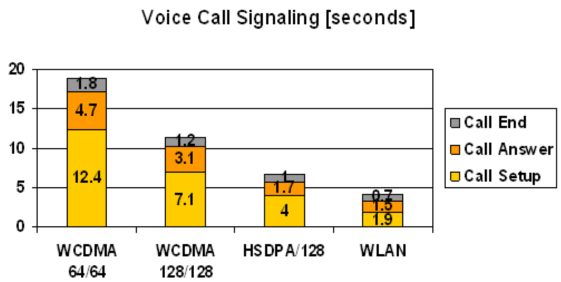

Figure 3. Voice Call Signaling Delays

The results show an expected increment in the call signaling delays depending on the access used. Since all of the network elements were located in a private network, the environment could be though of as providing local calls. Our results also show that an embedded mobile VoIP client experiences an increased delay compared to a PC client, such as the one measured in [4] with a WCDMA network.

E.721 [11] recommends values call setup delays for circuit switched calls. The recommended values for call setup (post-dial delay) are 3s for local, 5s for toll and 8s for international connections, with 6s, 8s, and 11s as 95% values. The "call answer" (answer-signal) delay reflects the time it takes from the moment the receiving end accepts the call until the call is actually established. E.721 recommendation is 0.75s for local, 1.5s for toll, and 2.0s for international connections, with 1.5s, 3.0s, and 5.0s as 95% values. Finally, "call end" (call-release delay) is the time it takes for the call to be terminated. [4][5]

VoIP calls setup delays in a cellular system might experience additional delays in cases were there is no active PDP context, and also due to a required registration to the IMS. The PDP context activation delay was ~3 seconds in our tests. Simulations in [18] propose 2.24 seconds. Based on these values, calls with always-on enabled can be in line with E.721 recommendations. However, when the PDP context is not active, the delay with WCDMA can vary between 11 to 17 seconds, and thus, above the recommended values. HSDPA delay in this case is around 8 seconds, which is similar to the recommendation for international calls. However, additional delays from e.g. traversed networks, gateways, and proxies could result in larger total delays than those recommended.

C. Always-On Battery Consumption

Some multi radio mobile devices provide a special mode called "always-on". Enabling this mode will keep the terminal registered to IMS system all the time. For VoIP applications, this mode would allow a faster voice call setup delay since the packet data connection (PDP context) would be active and the terminal registered all the time. In the case of VoIP, a user is not reachable unless he is registered to the VoIP server. There are other applications that can also benefit from this mode such as Push E-Mail, Push-to-Talk, Presence and instant messaging.

Maintaining the terminal registered to the IMS system has an effect in battery consumption because the terminal is periodically sending messages to keep the connection alive. While for PC clients this could be a trivial issue, for handheld devices battery lifetime is a critical aspect.

The measurement results with always-on mode show battery consumption peaks in WCDMA and HSDPA when the terminal is registered to IMS. The increased battery consumption is due to the cell state changes from CELL_PCH to CELL_DCH and subsequently to CELL_FACH state. The frequency of these cell state changes was periodical and occurred once every 50 minutes. The average consumption was 1.3W for CELL_DCH state and 0.5W for CELL_FACH. The consumption for each required peak during IMS registration depends on the duration of both the CELL_DCH and CELL_FACH states. Our tests had average durations of 10 and 5sec for cell states in WCDMA peaks and 15 and 5sec for HSDPA. These durations show that the default settings used in the radio access network were not optimized for reduced battery consumption.

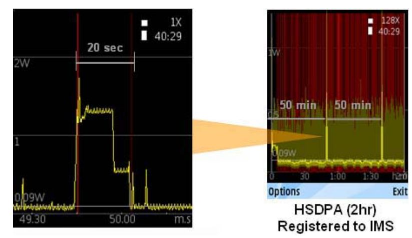

Figure 4. Cell State Changes in WCDMA and HSDPA when Registered to IMS

In the case of WiFi, battery consumption bursts are not continuous and not clearly defined. Each burst period can last 5-10 minutes. Our measurements showed an average consumption increase of 0.05W when using WiFi. However, the exact consumption of WiFi depends also on the AP configuration, client, scanning frequency and additional power saving features such as 802.11e [10][16]. Figure 5 shows an example of the consumption bursts with WiFi.

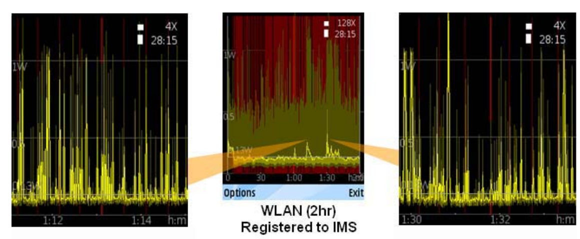

Figure 5. WiFi Consumption when Registered to IMS VoIP Server

The total effect of IMS registration at different message intervals can be modeled by considering the consumption at CELL_DCH, CELL_FACH, and CELL_PCH and the percentage of time spent in each of the states. As a result, the more frequent messages are sent, the more time the terminal will be in CELL_DCH and CELL_FACH states. Likewise, the duration of these states can be defined in the radio access network to optimize battery consumption by making the cell state change periods as short as possible, e.g. 3 and 2 seconds for CELL_DCH and CELL_FACH during each message transmission [9]. Table 1 shows the impact of IMS registration to battery lifetime in our test bed configuration and for optimized radio resource control settings. While the total hours of battery life is estimated for a 3.7V 950mAH battery, the life decrease rate (%) will be the same for any other battery.

TABLE I. ESTIMATED IMPACT OF ALWAYS-ON REGISTRATION TO IMS WITH DIFFERENT RADIO RESOURCE SETTINGS

Message Period (min)	Not Optimized RRC (DCH 15s, FACH 5s)		Optimized RRC (DCH 3s, FACH 2s)	
	Total Life (hours)	Life Decrease%	Total Life (hours)	Life Decrease%
1	9	95%	40	80%
2	18	91%	67	67%
3	26	87%	86	57%
4	33	84%	100	50%
5	39	80%	111	45%
7	51	75%	128	36%
10	66	67%	143	29%
15	85	58%	158	21%
20	99	51%	167	17%
30	119	41%	177	12%
45	138	31%	184	8%
50	142	29%	186	7%
60	149	26%	188	6%

Our estimation shows that always-on IMS registration for VoIP will reduce battery lifetime by 7% in an optimized network. However, if the network is not optimized it could reduce lifetime up to 30%. Other IMS applications such as Push E-Mail, Push-to-Talk and Presence also require periodic messages. Likewise, some network elements such as network address translators (NAT) require periodic keep-alive messages. Common default timeout settings in NATs are 5-10 minutes for TCP and 1 minute or less for UDP. Keep-alive messages over UDP are commonly required in connections that involve virtual private network (VPN) gateways, such as enterprise Push E-mail. The maximum timeouts possible depend on the NAT manufacturer, e.g. 6min for Cisco [3][9]. These short intervals have a big impact on energy consumption and decrease battery life considerably.

V. CONCLUSIONS

Multiple measurements were carried out to evaluate and characterize the signaling performance in different wireless accesses. The test results show that the signaling delays in HSDPA and WCDMA are still considerably higher than with WiFi. Furthermore, in HSDPA and WCDMA networks, the final voice call setup delays depend on the state of the mobile terminal when the call is originated. In cases were a PDP context has not yet been activated, the total voice call setup can take a long time. On the other hand WiFi delays are in line with ITU-T recommended values. Our measurements also emphasized the differences in performance results between embedded VoIP clients over PC clients. Long call setup delays can be partially tackled by enabling always-on mode. This mode will maintain the terminal registered to the IMS system all the time, however, at the cost of a decrease in battery lifetime. Battery consumption should be considered carefully by operators in order to optimize radio resource settings in their networks to save battery. Always-on registration to IMS is not a VoIP specific feature and applies also to other services such as Push E-mail, Push-to-talk, and Presence, which also require sending periodic messages. Moreover, network elements such as NATs may require periodic keep-alive messages at very short periods, thus, decreasing battery lifetime even further.

Signaling delays are likely to remain in a similar way for some time until future 3GPP systems with lower round trip times and header compression techniques are deployed and become widely available. Likewise, WiMAX systems should yield similar performance to WiFi. However, in practice users will experience a combination of different wireless accesses available in hotspots, city areas and countries. Future work includes evaluating mobility issues between 3GPP based systems and WiFi/WiMAX and possible issues in signaling.

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