Profiling Power Consumption of VoIP Applications on Android Smartphones

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VoIP applications are getting popular due to their features of low cost and convenience. They have a high business potential over Wi-Fi or 3G network for smartphones applications. One possible barrier to the widespread adoption could be the high power consumption. And this in turn is due to higher CPU utilization introduced by sophisticated encryption algorithms for the sake of security. In this research we have studied the power consumption of five popular VoIP applications, including Skype, Viber, Tango, Line and Rynga, on two different Android based smart phones: i. Google nexus S and ii. Taiwan Mobile, over Wi-Fi and 3G network. Besides we also compared the accuracy of two power measurement tools, PowerTutor and Symbolic Regression and Clustering (SRC). As per our experimental results, we observed that Skype has the highest power consumption of 3.544 W in Google Nexus S with 3G. Each VoIP consumes more power in Google Nexus S than Taiwan Mobile with Skype and Tango recorded the highest change of 0.6 W. This is possibly due to the combined effect of differences in CPU frequency and operating system. We also found that the Wi-Fi is more efficient than 3G and SRC is more accurate power measurement tool than PowerTutor.

Keywords: VoIP, Android, Smart phones, power consumption, 3G, Wi-Fi.

1. Introduction:

Voice-over-IP (VoIP) services are rapidly gaining acceptance [1] over traditional circuit-switched voice communication networks such as the public switched telephone network (PSTN). Two most compelling reasons are lower costs [1], and new functionality that is difficult to achieve with traditional voice networks. VoIP over Wi-Fi or 3G network has emerged as a critical application [1] for Android based smartphones with a high business potentiality. High power consumption is a critical issue that presents a barrier to the widespread adoption [1] of VoIP applications on smartphones. In order for smartphones to receive VoIP calls the receiving interface needs to be on continuously. Unfortunately, the energy consumption of these interfaces when there is no data transfer taking place is comparable to that of when the interface is active.

These devices operate on a strict energy budget and limited lifetime on a single charge. Consider a recent 4.3 inch Smartphone device, which features a rechargeable 3.7V lithium-ion battery at a capacity of 1730 mAh (i.e., 1.73 *3600 seconds * 3.7V = 23,044 Joules). Such a device is advertised to offer 450 minutes (i.e., almost 8 hours) of talk time and up to 355 hours (i.e., almost 15 days!) in stand-by mode. These numbers assume that the users are neither running any of their favorite applications nor using any power hungry features such as a bright LCD, GPS, Wi-Fi, 3G and others. But even in the absence of all aforementioned features and applications, the lifetime of a Smartphone is considerably lower due to location, movement, signal strength, cell traffic and battery age. Consequently, this brings the energy lifetime of a Smartphone on a single charge, down to a day or so, depending on the Smartphone vendor and model [2].

We are motivated to address the research questions towards experimenting the power consumption of VoIP applications on Android based smartphones: (I) which is the most energy efficient and inefficient VoIP application? (II) Which is the most energy efficient networking interface? (III) Which is the most accurate power measurement tool?

To answer the third question, we used an external power meter to measure power consumption of five different VoIP applications over 3G and Wi-Fi network interfaces on two different Android based smartphones and compared the relative error between Power Tutor and SRC. For the second question we used the most accurate power measurement tool and compared the power consumption over 3G and Wi-Fi network interfaces. Finally to answer the first question we used the most efficient interface and most accurate tool and compared the power consumption of those VoIP applications.

2. Background:

Overview of Voice over IP:

There are several steps involved in sending voice communication [3] over the Internet. First, the analog audio signal is encoded at a sampling frequency compatible with the human voice (8KHz in our case). The resulting data is partitioned into frames representing signal evolution over a specified time period. Each frame is then encapsulated into a packet and sent using a transport protocol (usually UDP) towards the destination. The receiver of a VoIP communication decodes [3] the received frames and converts them back into analog audio signal. Unlike media streaming, VoIP communication is interactive, i.e. participants are both speakers and listeners at the same time. In this respect, delays higher than 100-150 msec can greatly impair [3] the interactivity of conversations, and therefore delayed packets are usually dropped by the receiver codec.

One of the most popular standards used in VoIP deployments is the Session Initiation Protocol (SIP) [3]. The widespread deployment of Wi-Fi and 3G networks adds an interesting dimension to VoIP in terms of support for mobility.

The main characteristics of VoIP applications can thus be summarized as:

- VoIP applications do not require higher throughput but cannot tolerate jitter [3]. They are very sensitive to delays that can directly affect the voice quality.
- Voice requires quality of service in terms of low latency and jitter, low packet loss and high availability. On the other hand, most of the power saving mechanisms trade off with the latency and availability.
- VoIP wireless phones require support for seamless roaming capabilities to enable user mobility.
- Security in terms of prevention of denial of service attacks and eavesdropping is a must for the wireless media. Energy consumption depends on the complexity of the algorithms.
- VoIP is an isochronous traffic stream with a packetization rate of 20ms. (G.7 11 codec)[4].

Elements of Energy Consumption in wireless communications:

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor. The most common wireless technologies use electromagnetic wireless telecommunications. The energy consumed by a communicating device can be factored into following elements [5] [6] [7].

Transmission: This accounts for the energy spent in data packet transmission.

Reception: This accounts for the energy spent by a node in data reception.

Idle listening: Refers to the energy consumed when the radio of the node is waiting to receive potential packets but the media is idle.

Overhearing: Refers to the energy used by a node when it is receiving packets on the media meant for another destination.

Control Overhead: This factor accounts for the energy used to send and receive control packets.

Reliability: This element pertains to energy consumed in meeting the protocol reliability requirement, i.e., data retransmissions because of lossy media, collisions and mobility.

Turnaround time: This is the time required to switch modes from transmit to receive and vice versa.

Power Measurement tools:

PowerTutor, a component power management and activity state introspection based application that allows software developers to see the impact of design changes on power efficiency. PowerTutor uses a linear power consumption model built by direct measurements during careful control of device power management states. It also provides users with a text-file based output containing detailed results and can be used to monitor the power consumption of any application[8] [9] [10].

Symbolic Regression and Clustering (SRC) algorithm is an application-level power profiling technique where all three behaviors: nonlinearity, asynchronicity, and heterogeneity of power consumption in smartphones have been considered.

Comparison of power measurement tools is shown in Table 1. The major difference in terms of technique adopted is that the PowerTutor is linear assumption and requires a state of discharge curve, whereas SRC is designed to accept the nonlinear, asynchronous and heterogeneous properties as well.

Table 1 Comparison of power measurement tools SRC and PowerTutor

Tools	Technique	Modeling approach
PowerTutor	State of discharge in battery and linear regression	Device-centric
SRC	Symbolic regression and clustering	On-demand-centric

VoIP APKs:

For this experiment, five popular VoIP applications Skype, Viber, Tango, Line and Rynga had been used. A comparative description of these VoIP applications is shown in Table 2. This comparison is based on the network types such as peer-to peer or client server, signaling protocol like SIP, open source or any proprietary one and the consumed bandwidth.

Table 2 Comparison of VoIP applications under tests

VoIP APKs	**Network Type**	**Signaling protocol**	**Bandwidth Consumption**
Skype	Peer-to-peer (P2P)	Session Initiation Protocol (SIP)	60MB/hour (only audio)
Viber	IM2Net	Proprietary one	14.4 MB/hour (only audio)
Tango	Peer-to-peer	Open Source	NA
Line	NA	NA	NA
Rynga	NA	NA	NA

Survey:

Energy consumption of VoIP in smart phones has seen a significant interest of work in recent times. Our study for the energy consumption characteristics of 3G and Wi-Fi reveals significant and non-intuitive implications for energy-efficient VoIP application design. A comparative description of the relevant works are shown in Table 3. First one is based on the power consumption of 3G, GSM, and Wi-Fi on mobile phones and compared with each other. Second one is based on the study of energy consumption of VoIP applications over Wi-Fi based mobile phones. Third one is based on the energy consumption for video streaming applications in mobile phones using both Wi-Fi and 3G. Fourth one measures the energy consumption for peer to-peer applications over 3G. Fifth one performed energy consumption measurements using a P2P chat application.

Table 3 Comparison of similar works

Paper	**Problem Statement**
Energy Consumption in Mobile Phones: A Measurement Study and Implications for Network Applications [11]	How do the energy consumption characteristics of network activity Over 3G, GSM, and Wi-Fi on mobile phones compare with each other?
Energy Consumption and Conservation in Wi-Fi Based Phones: A Measurement-Based Study [4]	Study of the energy consumption of VoIP applications over Wi-Fi based mobile phones.
Energy Consumption of Mobile YouTube: Quantitative Measurement and Analysis [12]	Measure the energy consumption for YouTube-like video streaming applications in mobile phones using both Wi-Fi and 3G.
Energy-Consumption in Mobile Peer-to-Peer Quantitative Results from File Sharing [13]	Measure the energy consumption for peer to-peer applications over 3G.
Energy Consumption and Conservation in Mobile Peer-to-Peer Systems [14]	Performed energy consumption measurements using a P2P chat Application.

3. Experimental Study:

In this section, we first described the experimental setup including hardware and software based power measurement tools, VoIP applications under test and the two smart phones. In the next section firstly we have presented the comparison of instantaneous power consumption error between PowerTutor and SRC, followed by a comparison of power consumption between 3G and Wi-Fi and finally the comparison of power consumption between different VoIP applications.

Experimental Setup:

Our test bed is composed of a monsoon power meter, which is an external power measurement tool, two software based power measurement tools SRC and PowerTutor. Google Nexus S and T Mobile are taken as the device under test (DUT). Table 4, and Table 5 represents the detail configuration of these DUT. The Major differences are the OS and the CPU frequency. Five popular VoIP applications Skype, Viber, Tango, Line and Rynga are taken as the applications under test (AUT).

Table 4 Description of Nexus

Hardware component	Description
OS	Android OS, v4.1.2 (Jelly Bean)
Chipset	Hummingbird
Processor	1 GHz Cortex-A8 (single-core)
Display	Super AMOLED capacitive touchscreen, 16M colors
GPU	PowerVR SGX540
Wi-Fi	Broadcom chipset BCM4329GKUBG TE1043 P21

Table 5 Description of T Mobile

Hardware component	Description
OS	Android OS, v2.3 (Ginger Bread)
Chipset	NA
Processor	Qualcomm MSM7227, 800MHz single-core processor
Display	4.3-inch capacitive touch screen, 480x 800pixels screen resolution
GPU	NA
Wi-Fi	NA

Experimental study to determine the most accurate tool:

In order to compare the accuracy of the SRC and PowerTutor, we have considered the measurement of power monitor as ground truth power and calculated the percentage error for those tools to compare. Figure 1 and 2 represents the Comparison of Error between SRC and PowerTutor using 3G in Nexus S and T Mobile respectively.

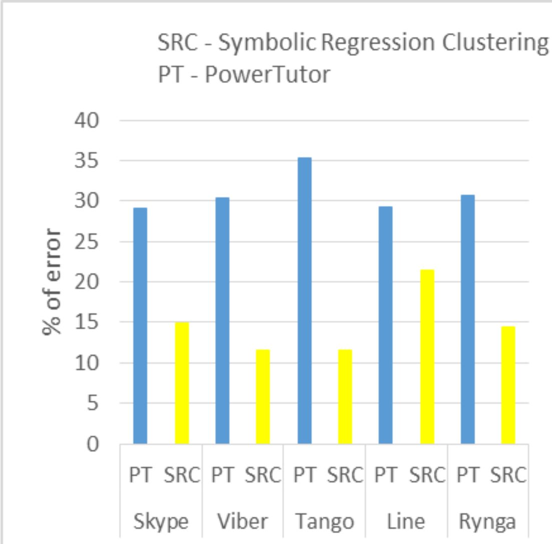

Fig: 1 Comparison of error between SRC and PowerTutor in Nexus S using 3G

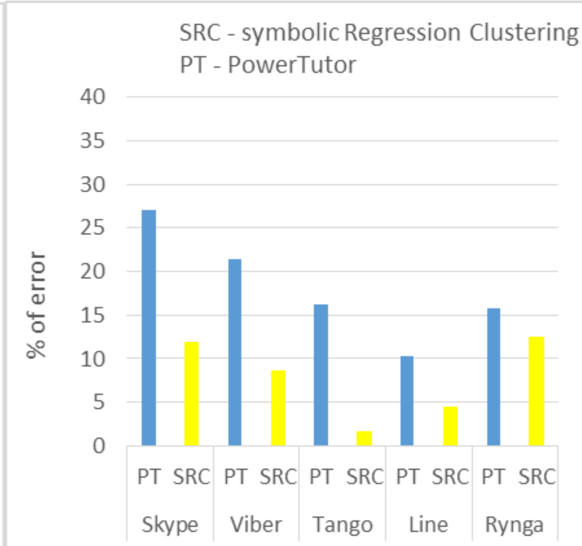

Fig: 2 Comparison of error between SRC and PowerTutor in T Mobile using 3G

Experimental study to determine the most Efficient Interface:

In order to compare the efficiency of the 3G and Wi-Fi, we have selected SRC, the most accurate tool determined in sec 3.2, to measure the power consumption. Figure 3 and 4 represents the comparison of power consumption between 3G and Wi-Fi in Nexus S and T Mobile respectively. SRC is selected to measure the power consumption.

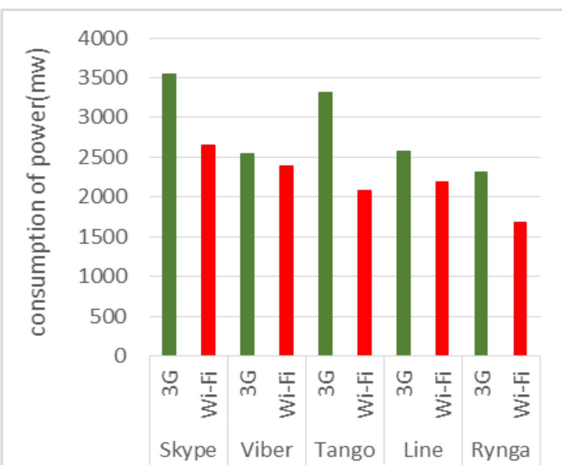

Fig: 3 Comparison of power consumption between 3G and Wi-Fi in Nexus S using SRC

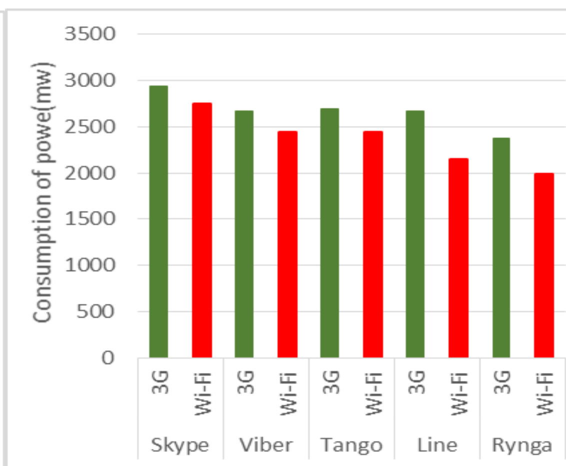

Fig: 4 Comparison of power consumption between 3G and Wi-Fi in T Mobile using SRC

Experimental study to determine the difference in power consumption between two smartphones:

In order to study the effect of different smart phones on the power consumption of VoIP applications, we have calculated the difference in power consumption from sec 3.3 and Figure 5 represents the difference in power consumption between T Mobile and Nexus S for both 3G and Wi-Fi.

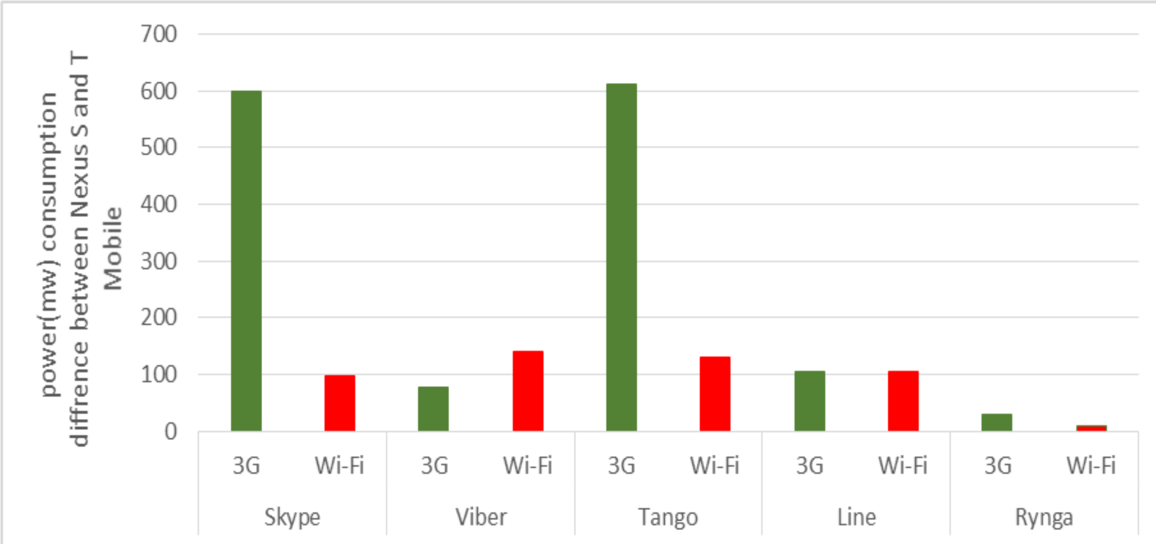

Fig: 5 Comparison of increase in power consumption between T Mobile and Nexus S

3. Conclusion:

We observed that under each test conditions SRC turned out the most accurate power measurement tool with a maximum recorded error of 21.46% while the maximum recorded error for PowerTutor is 39.27%. As per as the networking interface is concerned 3G has emerged as more power consuming than Wi-Fi. For 3G the maximum and minimum power consumption are 3.54 watt and 2.37 watt respectively while for Wi-Fi the maximum and minimum power consumption are 2.85 watt and 1.98 watt. Skype is recorded with a highest power consumption of 3.544 watt and Rynga has a lowest power consumption of 1.98 watt among all the VoIP applications. Finally a significant increase in power consumption has been detected, for all the VoIP applications while transit from T Mobile to Nexus S. Both Skype and Tango exhibits a maximum increase of 0.6 watt during this transition. Finally as per as the power consumption of VoIP applications on Android based smart phones are concerned, the following conclusions are drawn:

1. SRC is more accurate power measurement tool than PowerTutor.
2. 3G consumes more power than Wi-Fi in Android based smart phones.
3. Skype is the most power hungry VoIP application.
4. Nexus S consumes more energy than T Mobile.

Possible explanation of these conclusions are as follows, for first one, in SRC all three behaviors: nonlinearity, asynchronicity, and heterogeneity of power consumption in smartphones have been considered while PowerTutor is a linear assumption. For second one, in Wi-Fi, the association overhead is comparable to the tail energy of 3G, but the data transfer itself is significantly more efficient than 3G for all transfer sizes[15]. For third one, Skype used a highly sophisticated voice engine for betterment of voice quality and a highly complicated encryption algorithm for security and for the fourth one, CPU frequency is 200 MHz more in Nexus S than T Mobile and assembled with different version of OS.

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