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Battery and Data Drain of Over-The-Top Applications on Low-end Smartphones

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Abstract: Low-end smartphones with sub $50 price tags provide affordable device ownership to low-income populations. However, their limited capacity, when combined with the need for multimodal connectivity, raises usage concerns in rural off-grid regions. Some off-grid regions in sub-Saharan Africa provide recharge facilities using solar power and charge money for the service. Adding data bundle costs to frequent recharge costs, affordability of low-end smartphones becomes questionable in such areas. Community-controlled solar-powered wireless mesh network models with Session Initiation Protocol capability could alleviate the network usage cost conundrum and consume less power in low-end smartphones with the usage of WiFi. This paper reports on investigations that reveal usage of WiFi consumes less battery than 3G, 2G and Bluetooth. In addition, we feel that lowering recharge costs also requires battery consumption knowledge of the over-the-top applications. Using automated voice calls, this paper reports on battery and data consumption by multiple popular social media applications using one type of low-end smartphone. Data consumption was calculated with the objective of learning how to lower data bundle costs by selecting the application with least data consumption. Battery consumption due to CPU usage by the applications was also measured. Results show that WhatsApp consumes the least battery amongst instant messengers and also the least data over all apps measured. SipDroid consumes the least battery overall. Additionally, the reported experiments provide a framework for future experiments aimed at evaluating battery and data consumption by other smartphone applications.

Keywords: Energy – Global development; Information and Communication Technology for Development (ICT4D); Power and bandwidth consumption.

1. Introduction

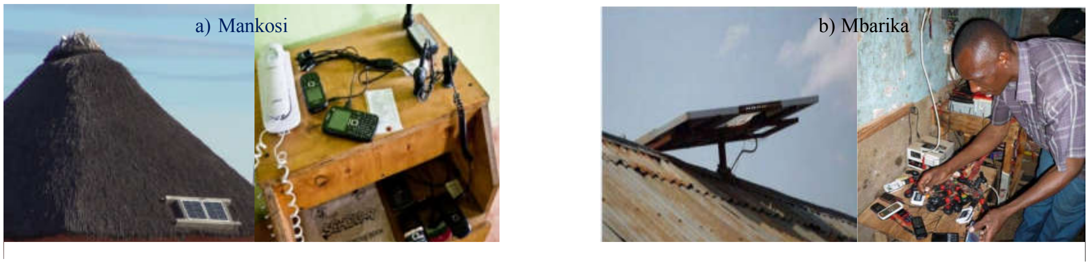
Lack of power infrastructure and low incomes in rural developing regions mean that regular recharging required for smartphone batteries can limit the benefits of Information and Communication Technology (ICT) innovations, many of which are available on smartphones, and not feature phones [1]. An interview by the Guardian discusses some examples of mobile ICT initiatives in developing regions, including health care; mobile money; information and local democracy; and electronic commerce [2]. The interview also identifies important barriers to closing the 'digital gap' with effective use of smartphones in rural regions. Amongst the digital barriers identified, the primary barrier mentioned by the interviewee is:

> *"My biggest concern about smartphones is* ***charging*** *them up – a feature phone can go for a week or more without being charged, but smartphone batteries drain quickly. We need to look at electricity provision, especially in rural and remote areas."* [2]

Molapo and Densmore state that when introducing smartphones in rural areas, plans of consistent, and cheap recharging solutions should be implemented beforehand; and cited battery life of smartphones as the main challenge associated with full adoption of smartphones in rural villages [3].

Around 63% of the population in Sub-Saharan Africa is rural, of which approximately 81% have limited to zero access to electricity [4]. According to the World Bank, gross national income (GNI) per capita in Sub-Saharan Africa as of 2016 is approximately $1516, which includes high, medium and low income areas [5]. Due to uneven income distribution, 73% of sub-Saharan Africans live on less than $2 per day and 51% on $1.25 per day [6]. Smartphone ownership has two main costs for urban users: 1) purchase price; and 2) network usage cost in the form of cellular call and text charges, and mobile data. Both of these costs are significant barriers to smartphone ownership by rural users considering the GNI of sub-Saharan Africa. According to GSMA Intelligence estimates, the smartphone average selling prices (ASPs) are still above US$100 in developing regions [7]. Even though over-the-top (OTT) communication applications (apps) e.g. Messenger, WhatsApp, Skype, and IMO have dethroned traditional voice calling and texting [8]–[10], it is still questionable to consider reduced data bundle costs as affordable for low-income sub-Saharan Africans. Research ICT Africa showed that until mid-2017, the least expensive prepaid 1 Gigabyte (GB) basket was $1.21, in Guinea [11].

In this paper, we argue that smartphone ownership has an additional cost for rural sub-Saharan Africans: device recharge cost. Recharging phone batteries in rural areas cannot be taken for granted as in developed regions in sub-Saharan Africa. Rural inhabitants must pay for such services in off-grid areas: from providers with shoddy mains power or perhaps with renewable solar power. Figure 1 shows such a service being offered by a) (on the left) the off-grid Mankosi community, located in the Eastern Cape Province of South Africa (SA) [12], and b) (on the right) Mbarika ward located in the Mwanza district of Tanzania [13]. The two solar-powered systems differ in that Mankosi channels power to a 12v car-phone charger plug whereas in Mbarika, it is channelled to normal power plugs. The recharge service in Mankosi is offered by a community cooperative at approximately $0.20 [14]. The recharge cost is similar in Mbarika, although instead of a cooperative, the recharging services are privately owned micro-businesses [13]. Note that Mankosi community also has privately owned mobile recharging kiosks in the area that offer the same service at double the cost [14].


a) Mankosi

b) Mbarika

Figure 1: Solar panel and recharge station in Mankosi (left) and Mbarika (right) [12], [14], [16]

Faced with the 'triple play' of purchase, usage and recharge costs, it's only natural that rural users refrain from using smartphones and stick with feature phones. In order to bridge that gap, GSMA intelligence recommends $25-50 smartphones [7]. These smartphones provide all the functionality of an “above $100” smartphone but with limited hardware specifications (specs), and are referred to as Low-end Smartphones (LeSs). If telecommunication operators (telcos) can lower network usages costs with innovative models, costs can drop further. One example gaining attention in Africa is the aforementioned Zenzeleni Networks (ZN), which is a community-owned solar-powered Wireless Mesh Network (WMN) [15]. ZN provides free intra-community voice calls and breakout calls at costs much lower than incumbent telcos. Each mesh router runs Asterisk and Session Initiation Protocol (SIP) clients can be configured on smartphones for voice services.

For our purposes, WMNs offer battery efficiency on phones as they provide Wireless-Fidelity (WiFi) connectivity. It is well established that WiFi consumes less battery in smartphones than: a) 3rd generation (3G) [16]–[20]; b) 2nd generation (2G) [16], [17], [21]; and c) Bluetooth (BT) [16], [20], [22]. It is also well known that OTT apps consume a significant share of smartphone battery, especially due to screen time. Regular use of OTT apps on LeSs, then, results in batteries depleting quickly, with rural users frequenting recharging stations, thereby increasing expenses. Whereas the WMN of Zenzeleni provides a battery-friendly and inexpensive communication model, LeS usage still requires careful management to ensure that both limited battery capacity and airtime last as long as possible. Hence our goal is to identify suitable OTT apps in terms of battery and data consumption.

The work of Om et al. presented an experimental framework and results on how to select the most battery efficient LeS [23]. Investigations presented in this paper build on their research and compare the battery and data consumption of four commonly used instant messengers (IMs): WhatsApp, Messenger, Viber and IMO; and four SIP clients: SipDroid, CSipSimple, MizuDroid and Zoiper. The remainder of the paper is laid out as follows: Section 2 provides work related to battery consumption of IMs and SIP clients. Section 3 presents the research methodology including experimental framework. Section 4 presents experimental findings and discussion, and Section 5 draws conclusions from investigations and presents plans for future work where we offer recommendations to assist a) rural users to better manage the battery consumption of low end devices; b) all smartphone users in selecting the best OTT app in terms of data and battery consumption; and c) researchers with a framework for continued future experiments.

2. Related Work

It is critical to understand how IMs impact battery efficiency of smart devices. In an attempt to provide users with instant gratification, IMs constantly contact the cellular network, instructing it to alert the phone whenever a message arrives thus repeatedly waking the device, especially its screen, from a dormant state [24]. Alcatel-Lucent reported this behaviour as “chattiness” of an app – a measure of how often it connects to the cellular network to send or receive data, a factor that can determine the app’s battery efficiency [25]. The chattier the app, and the user, too, the more the battery drains. Also, voice and video communications use of codecs to compress/decompress media consumes additional energy [26]. Codecs are mathematical formulas and, hence, their algorithmic complexity determines the number of CPU cycles, which has a strong influence on battery usage.

An exhaustive investigation of scholarly articles, reports, and web pages shows that concrete evidence of rankings of IMs based on battery consumption in smartphones in either percentage or milli-Ampere-hour (mAh) units is almost non-existent. Android app performance reports are published by Avast and AVG (now Avast) which reveal the top performance-draining apps for Android devices based on battery consumption [27]–[29]. However, the reports, gathered from a sample of aggregated and anonymised data from Android users around the globe, lack specific details such as smartphone types, performance evaluation techniques, and exact values. In addition, the appendix sections of the reports show the top 10 rankings for performance-draining Android apps (battery, storage and data) for the United States of America and the United Kingdom, and are missing Asian and African regions. The rankings, however, do serve as a guide for selection of the IMs for the experiments reported below.

Since SIP supports voice and video calling, codecs similar to those used in the IMs are used by SIP clients. One benefit of SIP is that it can be set up for free communication (for example, by Zenzeleni described above). However, we found no scholarly articles, reports, and/or web pages with evidence of battery consumption by SIP clients in smartphones in either percentage or mAh units.

In other words, scholarly work exploring battery and data consumption by OTT apps is practically non-existent. Generic reports on battery consumption by popular apps in Asia and Africa regions are also scarce. Experimental results presented in this paper close this gap by providing exact numbers on battery and data consumption by OTT apps.

3. Methodology

This section provides the details of how we evaluate the battery and data consumption by commonly used OTT apps, specifically, IMs and SIP clients. We hope the description provides a realistic experimental framework for future experimentation, as IM and SIP clients continue to evolve, and also as phones and their batteries attain higher specs.

1. *Selection of smartphones:* Since this paper promotes and investigates battery efficient usage of LeSs in rural off-grid regions, it was decided that experiments be carried out using LeSs as well. A quantity of 20 units of LeS model Vodafone Smart4mini (S4M) priced at approximately $50 per unit was acquired from a local vendor. Table 1 shows the important S4M specs [30].

Table 1: Vodafone Smart4Mini specifications

Battery (mAh)	1400
Wireless technologies	GSM, 3G, WiFi 802.11 b/g/n
Claimed talk time	8 hours
Claimed stand-by time	600 hours
Android OS	4.2.2
Memory (MB)	512
Processor	1.3 GHz dual-core
Display/ Resolution	4.0 inches, 480X800 pixels
Cost (USD)	$51.32

2. *Selection of Over-the-Top applications:* We used Avast's Q1 report to choose IMs. This report analysed Android app performances and trends [27]. IMs present in the top 30 of the 50 most installed Android apps were chosen in the following manner:
   a. The top 2 most installed IMs in rankings 1-10,
   b. The top 2 most installed IMs in ranking 11-20, and
   c. The top 2 most installed IMs in rankings 21-30.

   Figure 2(a) shows the top 30 most installed Android apps as presented in the Avast report. The process yielded four IMs mentioned below and their versions used for the experiments:
   a. WhatsApp ver. 2.17.190
   b. Messenger ver. 121.0.0.15.70
   c. Viber ver. 6.9.1.16
   d. IMO ver. 9.8.000000006691

   After selection of IMs, the next step selected SIP clients. We chose four SIP clients to examine, as for IMs. Since we were unable to find any documents that showed rankings of SIP clients, we adopted the following set of steps for their selection:
   a. Open Google Play repository on S4M,
   b. Search for SIP clients using the phrase *"SIP clients"*, and
   c. Select the top four SIP clients shown in the results.

   Figure 2(b) shows the screenshot of the search result (which of course, we had already installed). The top four SIP clients, along with their version numbers, were:

a. Zoiper ver. 1.51
b. CSipSImple ver. 1.02.03
c. MizuDroid ver. 2.4.0
d. SipDroid ver. 4.0 beta

We would like to point out that the Media5-fone client was avoided due to in-app advertisements (in-app ads). Evidence show that in-app ads gobble up more energy, and increase processing time and data consumption [31], [32].

a) Android apps

1 Facebook
2 WhatsApp Messenger
3 Chrome Browser (Google)
4 Messenger
5 Instagram
6 Dropbox
7 Skype
8 Microsoft Word
9 Instant Apps
10 Google Translate
11 Twitter
12 Snapchat
13 Spotify
14 Adobe Acrobat Reader
15 Uber
16 Pinterest
17 Netflix
18 AVG Cleaner
19 Google Play Games
20 Viber Messenger
21 SHAREit
22 Shazam
23 Candy Crush Saga
24 Clean Master
25 Microsoft Outlook
26 Yahoo Mail
27 ZEDGE™
28 Waze - GPS, Maps & Traffic
29 imo free video calls and chat
30 Facebook Lite

b) SIP clients

16:44

Zoiper IAX SIP VOIP So
Securax LTD.
4.5 ★
INSTALLED

CSipSimple
Regis Montoya
4.3 ★
INSTALLED

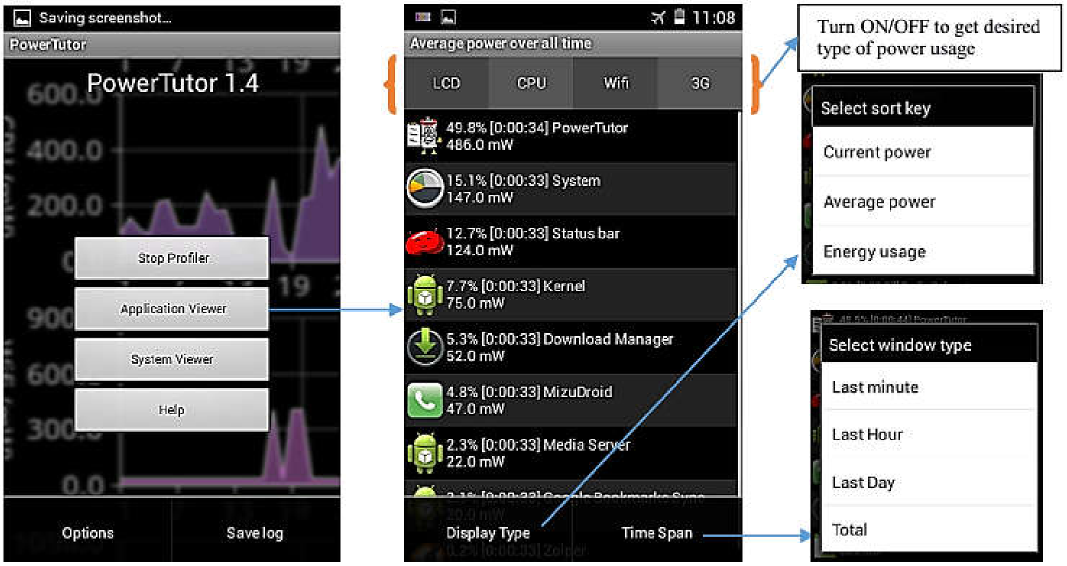
Media5-fone VoIP SIP
Media5 Corporation
4.1 ★
INSTALLED

MizuDroid SIP VOIP So
Mizutech
4.1 ★
INSTALLED

Sipdroid
i-p-tel GmbH
4.0 ★
INSTALLED

Figure 2: (a) Top 30 most installed Android apps by Avast [27]; and (b) top 5 SIP clients based on search results

3. *Selection of the battery profiling app:* The power estimation tool developed by Zhang et al., PowerTutor (PTut) version 1.2 was used to measure average power consumption by the IMs and SIP clients in mW units [33]. The power model in PTut is constructed by correlating the device's measured power consumption with each hardware component's power state. Power usages for apps shown by PTut are calculated as if they were the only app running. For example, the scenario of two apps using WiFi to download data at the same time would consume more battery, as WiFi is pushed into a higher power state, than one app using the WiFi. For such cases, PTut displays power consumed by each app using the WiFi as if it were the only app using the radio. In addition, users can also opt to switch off power usage by the wireless radios, e.g. WiFi or 3G from the display because they are summed with the power usage of apps due to CPU utilization. By doing so, the power usage by the apps due to CPU utilization only can be recorded. PTut has the ability to save the power usage data to a log file. Figure 3 shows the graphical user interfaces of PTut.
4. *Selection of experiment type:* Since the power-centric Zenzeleni Networks serves as motivation for the work presented in this paper, we chose to investigate the preferred form of communication in the community. The findings of Rey-Moreno et al. showed that approximately 80% of Mankosi residents use their airtime for voice calls [14]. Therefore, voice call experiments were prioritized.
5. *Selection of audio for voice calls:* A real world voice call includes many elements besides the two parties talking e.g., background noise, simultaneous silence/talk, tone variations, laughter, sighs, interruptions, etc., similar to a television interview. We use the audio from a television show interview called "*Inside the actor's studio with Robin Williams*" to emulate voice calls. Since the file was in video format, the audio was extracted from the file using open source audio editing and recording software,



49.8% [0:00:34] PowerTutor 486.0 mW
15.1% [0:00:33] System 147.0 mW
12.7% [0:00:33] Status bar 124.0 mW
7.7% [0:00:33] Kernel 75.0 mW
5.3% [0:00:33] Download Manager 52.0 mW
4.8% [0:00:33] MizuDroid 47.0 mW
2.3% [0:00:33] Media Server 22.0 mW

Turn ON/OFF to get desired type of power usage

Figure 3: Different graphical user interfaces of PowerTutor

Audacity [34]. The extracted audio consisted of the following 'conversation' characteristics:

a. *Selection of back and forth talking* – the host questioning and the guest answering;
b. *different tones* – the guest answered questions in different tones of voices and included laughter, scream, and mimicry;
c. *background noise* – the audience claps, screams, laughter, and all three together while the guest or the host were talking. The background music is also background noise; and
d. *simultaneous silence/talking* – there were instances in the interview whereby the guest began answering a question while the question was still being asked, hence simultaneous talking, or took a moment to answer after certain questions, hence simultaneous silence.

The original audio was further split into two chunks, A and B, as shown in Figure 4. Chunk B was a cut-paste of audio at random times and intervals from the original audio. The modified original audio became chunk A. Silence was inserted at every empty audio section in the two chunks. Therefore, if both chunks were played simultaneously, chunk A will start with the audio while chunk B will be silent, and vice versa. In addition, the two chunks were overlapped at randomly to insert simultaneous talking.

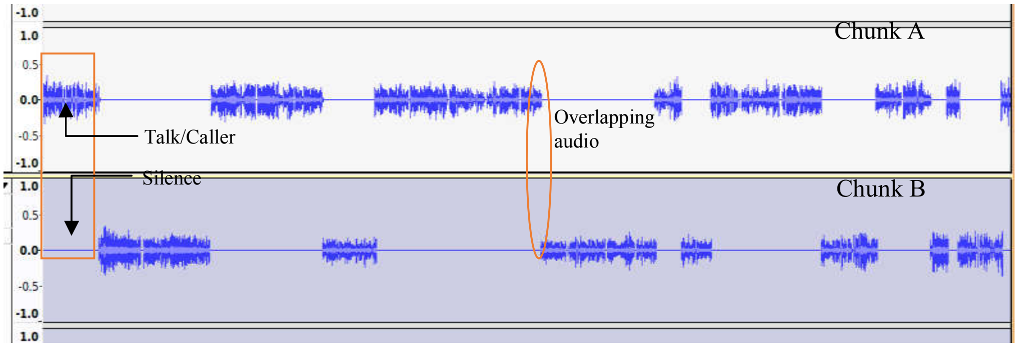


Figure 4: Audio chunks used for voice calls

There are, of course, some obvious dissimilarities between the audio chunks and an actual voice call. For example, a voice call usually starts with short greetings and questions of wellbeing from caller and receiver; while in the voice call experiment, the caller transmits for some time before the receiver starts transmitting. It is important to state at this point that there are continuous efforts towards refinement of experiments in order to make them as realistic as possible by the researchers.

6. *Wireless Mesh Network Testbed Setup:* A 3-node testbed over an area of 230X200 centimetres (cm) was set up in a lab using Mesh Potato-AllWheelDrive (MPAWD) routers as used by Zenzeleni Networks. MPAWDs are 2.4/5 Gigahertz (GHz) dual-band and dual-radio with multiple-input multiple-output (MIMO) capability mesh routers [35]. Figure 5 shows the network setup, detailed as follows:
   a. Three MPAWDs were placed in a straight line, distanced equally from one another.
   b. An MPAWD placed in the middle, MPAWD-252, set up as SIP Master and Internet gateway with its AP (access point) feature disabled.
   c. Two MPAWDs, MPAWD-20 placed on the right side of MPAWD-252, and MPAWD-21 placed on the left, were configured for APs running a Dynamic Host Configuration Protocol (DHCP) server. S4Ms (the phones) connect to these two MPAWDs to authenticate phone SIP settings, and use Internet for IM connectivity through MPAWD-252.
   d. Two personal computers (PCs) with speakers were used for audio playback. Each speaker was placed, in-line with either MPAWD-20 or MPAWD-21 and 200 cm away (the maximum allowed distance).
   e. S4Ms were placed 6 inches from the speakers during calls. This distance was decided after measuring the distance between the ear hole and mouth of the principle experimenter using a tape measure.

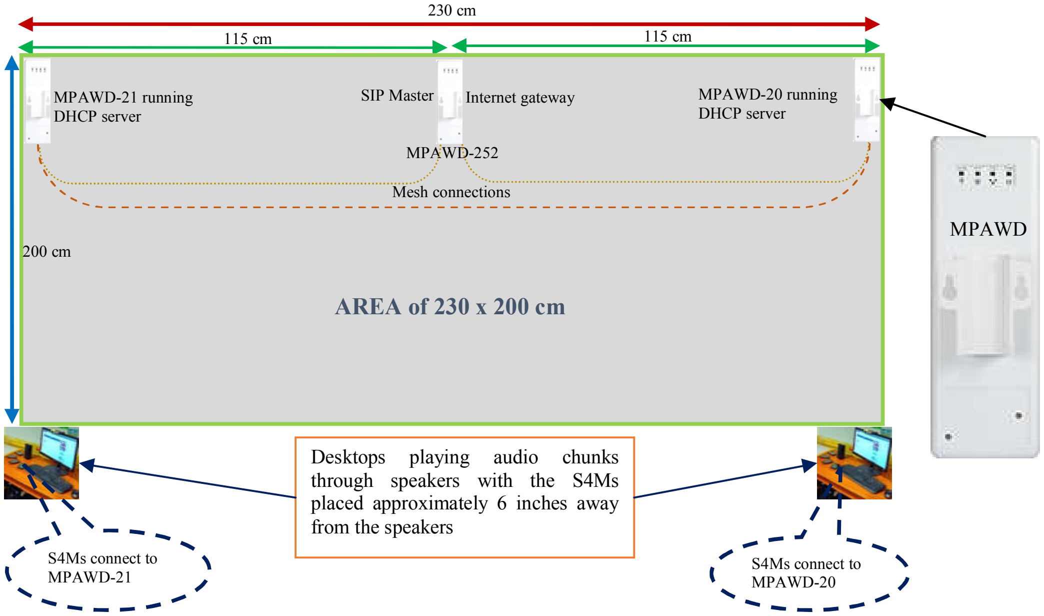


Figure 5: Mesh network testbed setup; smartphones shown next to PCs.

7. *Procedure for Voice Calls:* The following steps were adopted for to generate voice call data:
   a. Conduct 30 minute voice calls.
   b. Conduct calls for each app installed one at a time. For example, in case of WhatsApp calls; i) install and activate WhatsApp on all the 20 S4Ms; ii) finish the WhatsApp tests; and iii) uninstall WhatsApp from all S4Ms. Then repeat (i)-(iii) with another app.
   c. Access PCs remotely so that audio chunks A and B can be played simultaneously from one point for playback synchronization.

   d. Connect five S4Ms at a time to each MPAWD-20 and MPAWD-21, and place them next to the speakers. The number of S4Ms to be connected at a time to each MPAWD was result of a network load test. S4Ms were connected to each MPAWD-20 and MPAWD-21, and calls were placed. As connections increased and went over five S4Ms per MPAWD, the calls started exhibiting poor quality, and even call drops.
   e. Play the audio first before placing calls.
   f. Start PTut in S4Ms before placing/receiving call. PTut continues running in the background.
   g. Call using the S4M in front of the speaker playing audio, and receive on the ringing S4M on the silent side.
   h. Once the call is complete, access PTut on S4Ms, save log, and stop PTut.

8. *Experiment Controls:* Some control measures were adopted to ensure successful execution of experiments. The applied measures are as follows:
   a. Since calls terminating precisely at the end of 30 minutes i.e., 30.00 is next to impossible with so many phones calling each other concurrently, calls were terminated for durations well over 30 minutes but not exceeding 35 minutes.
   b. Repeat dropped calls from beginning to ensure continuous 30 minutes of battery and data consumption numbers.
   c. Auto-updates were turned off.
   d. Speaker volume was set to 50%, whereas PC hardware audio and player volumes were kept at 100%.
   e. Ensure same version of an IM or SIP client was installed on all the S4Ms by using their Android Package Kit (APK) file rather than the Google Play Store.

9. *Results Collection and Evaluation:* For battery consumption, PTut was configured to record consumption excluding the power usage of WiFi radio and LCD screen in the log file. The log file generated by PTut, however, contained data of all the running apps. A Python script was used to extract the relevant battery data from the log file using the CPU ID of the app and export it to a comma separated value (CSV) file. Formula (1) was then used to calculate average battery consumption (ABC) for each app using the CSV file.

$$ABCx = {}^{\sum(PU_n + PU_{(n+1799)})}/_{1800} \qquad (1)$$

Whereby; $ABCx$ = Average Battery Consumption in mW by app x;
PU_n = Power usage in mW at $n \geq 30$ seconds; and
PU_{n+1799} = Power usage in mW at $[(n \geq 30) + 1799]$ seconds.

To obtain data consumption numbers, we used the default data usage app provided with Android version 4.2.2, installed on the S4Ms. Since, calls were conducted for durations longer than 30 minutes, the data consumption results were normalized for 30 minutes (1800 seconds) for each app, i.e., if X amount of data were consumed during Y seconds of voice call, where Y>1800, then the amount of data consumed by X over 30 min, DX30, is equal to (1800*X / Y) Megabytes (MB).

4. Findings and Discussion

Figure 6 and Figure 7 display battery and data consumption results, respectively, for each IM and SIP client, run on all the S4Ms. The names of the apps have been abbreviated as follows: WAP for WhatsApp; VIB for Viber; MESG for Messenger; IMO; SIPD for

SipDroid; MIZU for MizuDroid; CSIP for CSIPSimple; and ZOIP for Zoiper. Then the average values, ABC_x and D_{X30} are presented in Table 2.

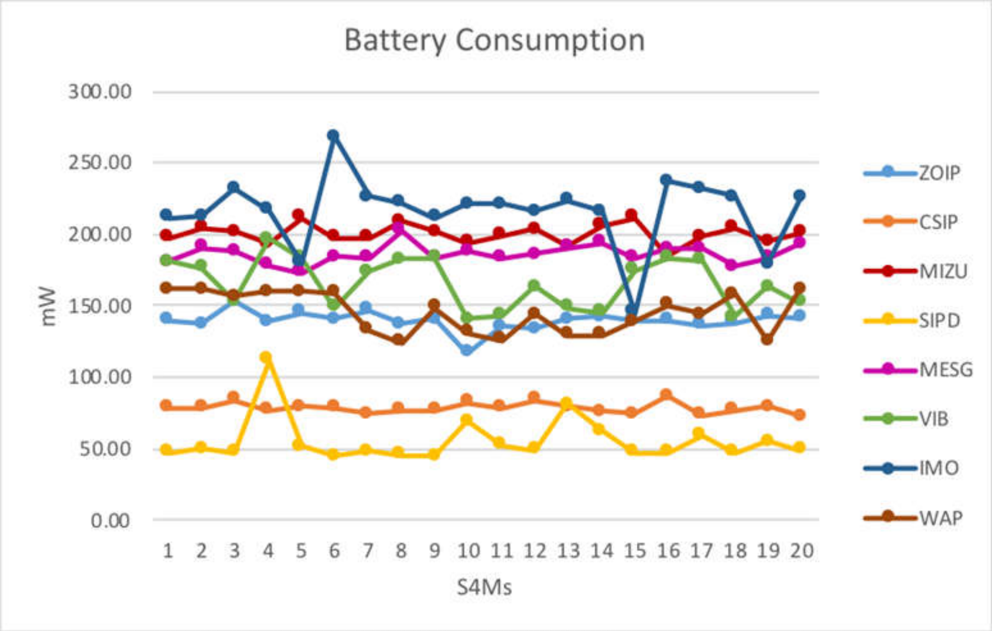


Figure 6: Battery Consumption Comparison of Apps

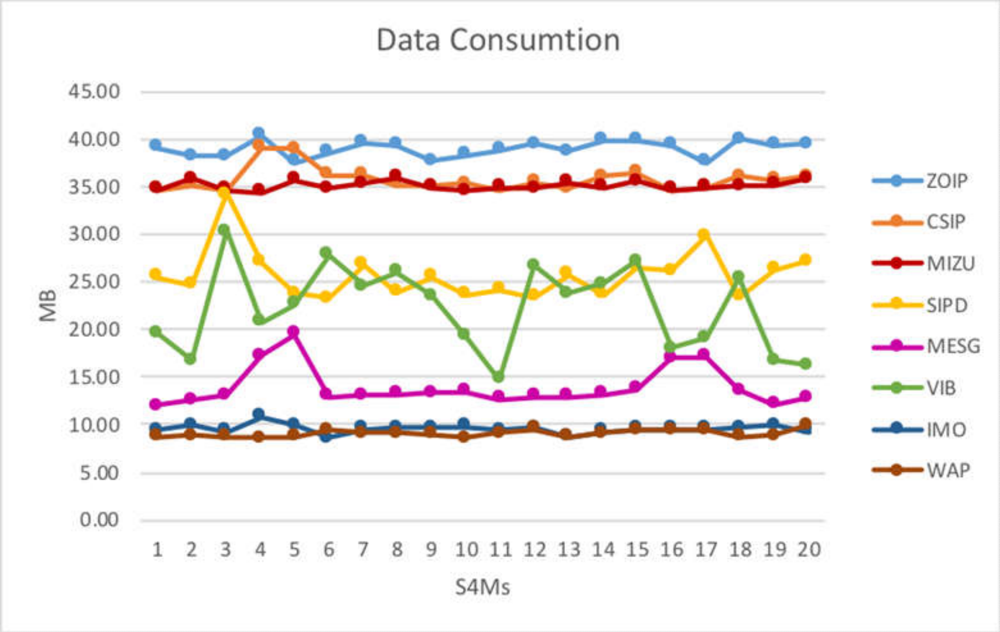


Figure 7: Data Consumption Comparison of Apps

Table 2: ABCx and DX30 of IMs and SIP clients

	IMs				**SIP clients**			
	WAP	VIB	MESG	IMO	SIPD	CSIP	ZOIP	MIZU
ABC_x	145.08	165.96	186.16	216.13	55.47	78.39	139.57	200.03
D_{X30}	9.07	22.18	13.92	9.56	25.72	35.75	38.94	35.07

Starting the discussion with battery consumption, it can be seen from *Figure 6* that SIP clients SIPD and CSIP consumed significantly less battery than all the IMs. SIPD exhibited battery consumption approximately four times less than IMO, 3.4 times less than MESG, 3 times less than VIB, and 2.6 times less battery than WAP. CSIP showed battery consumption approximately 2.8 times less than IMO, 2.4 times less than MESG, 2.1 times less than VIB, and 1.9 times less than WAP. ZOIP showed battery consumption 1.5 times less than IMO, 1.3 times less than MESG, and 1.2 times less than VIB. ZOIP and WAP exhibited almost similar battery consumption. MIZU, however, exhibited battery consumption 1.37 times more than WAP, 1.2 times more than VIB, and 1.07 times more MESG. MIZU showed 1.08 times less battery consumption than IMO. IMO reported certain spike in battery consumption values with some S4Ms. However, the majority of S4M readings for IMO remained similar. The reasons behind such spikes are still unclear and further tests are being carried out to explain the behaviour. Therefore, the three SIP clients clearly showed less battery consumption than every single IM tested.

The IMs however are a clear winner when it comes to data consumption, as shown in Figure 7. Each IM showed less overall data consumption than each SIP client. WAP consumed approximately three times less data than SIPD, and four times less data than CSIP, ZOIP and MIZU, respectively. IMO exhibited data consumption approximately 2.7 times less than SIPD, 3.7 times less than CSIP and MIZU, and four times less than ZOIP. MESG exhibited data consumption approximately 1.8 times less than SIPD, 2.5 times less than CSIP and MIZU, and 2.8 times less than ZOIP. VIB exhibited data consumption approximately similar to SIPD: 1.6 times less than CSIP and MIZU, and 1.8 times less than ZOIP. Amongst the IMs, WAP and IMO showed similar and the least data consumption over MESG and VIB. VIB showed overall data consumption approximately 2.4 times more than WAP and IMO, and 1.6 times more than MESG, thus, becoming the highest data consuming IM.

5. Conclusions, Recommendations and Future Direction

This paper reports on experiments to investigate battery and data consumption during voice calls by eight OTT apps: four commonly used IMs, and four SIP clients. Results of experiments reveal that IMs consume more battery than SIP clients. SipDroid, a SIP client, consumed the least battery; and IMO, an IM, consumed the most. Amongst IMs only, WhatsApp consumed the least battery. Regarding data consumption, SIP clients exhibit higher data consumption than IMs. SipDroid consumes the least data of all SIP clients tested, and WhatsApp consumes the least data of all IMs and SIP clients tested.

In our opinion, establishing any relationship between battery and data consumption behaviours by apps at this point seems inconclusive. Consumption behaviours depend on many factors beyond our control, such as codec used, CPU utilization, wireless radio chattiness, and of course the overall design and architecture of the app. In addition, the results obtained in the experiments could be used for any smartphone since PTut configuration allows for the exclusion of battery consumption data by WiFi and LCD to give actual battery consumption by the app as a result of CPU load. Hopefully, the experimental framework used in this paper can be adopted by researchers to conduct similar experiments and further refinements.

We believe that with the results obtained, recommendations can be offered to users of smartphone and OTT apps for communication. For off-grid rural regions, and low-end smartphone users that prioritise battery life, SipDroid is the most suitable choice due to its low battery consumption, given users subscribe to a voice over Internet Protocol (VoIP) service like Zenzeleni. Note that subscription to a VoIP service requires usage of data, whether mobile data or WiFi. We are advocating the use of rural WiFi, like Zenzeleni Networks because they can provide off-grid rural areas with cheaper data. The combination, then, of WiFi with a client like SipDroid means cheaper data and less frequent battery charging. For heavy chatters, and urban regions with continuous electricity, WhatsApp may be a more suitable choice, since it consumes the least data. WhatsApp can also be used with low-end smartphones, however, with restrictions such as; a) use of 2G mode and texting for chatting; b) avoiding media sharing; c) keep cellular data off when not needed; and d) communicate with a (non-loquacious) purpose.

We close the paper by stating that we continue to refine our experimental techniques and include more tests aimed at providing deeper understanding of battery and data consumption. The following types of media tests would move the analysis beyond voice only on low-end smartphones: media sharing tests, e.g. photos and videos are shared heavily using IMs; video streaming, e.g. YouTube video streaming; web browsing, e.g. consumption during download and upload of data using web browser; audio/video playback; and FM radio, e.g. battery consumption by streaming radio apps, both local and Internet-based.

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