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Mobile Video Comparison to Help Deaf People Make Informed Choices: a South African Case Study with Provincial Data

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Abstract: Deaf people use sign language to communicate and use mobile video calling to communicate with one another. Mobile video utilises much more bandwidth than text and voice communication modes, resulting in higher expenditure for communication by Deaf signers. We surveyed multiple Deaf communities to explore their level of mobile phone usage as a mode of communication. The findings indicated that despite high data cost video telephony is frequently utilized resulting in revenue generation for mobile service providers at the expense of poor Deaf end users. In South Africa, unlike for text and voice calls, both users of a video communication pay for upstream and downstream data. This paper presents a test bed comparison of the data usage and cost of the three mobile video applications with the four South African mobile network operators used by the Deaf communities. The results indicate which applications perform best on which networks and at what cost. The results can help anyone working with Deaf end users to help them make informed decisions about the use, and cost, of mobile video in South Africa.

Keywords: Content technologies: language (sign language); Global development and Information and Communication Technology for Development (ICT4D); Energy consumption.

1. Introduction

In recent years the use of video telephony, especially on mobile devices, by Deaf[1] communities in the Western Cape Province (WCP) of South Africa (SA) has increased. Sign language, used as a mode of communication by the Deaf community, is a rich visual form of communication combining facial expressions and hand gestures to communicate. As affordable devices with front facing cameras become more prevalent in SA, the use of video telephony by members of the Deaf communities will increase simply because they prefer to communicate in sign language, which requires video telephony.

The access and use of ever growing mobile technologies combined with social networking by Deaf people [1] has been a key driver in the adoption of video calling applications. Alexander Graham Bell initially intended to invent a telephone for Deaf people, which resulted in the invention of the voice-orientated telephone [2]; resulting in a historical disadvantage for Deaf persons until the advent of the smart phone. Many Deaf people prefer to communicate using Sign Language, which requires video telephony. Many Deaf people come from impoverished communities, which often result in the sharing of mobile phones to keep in contact with family and friends. There are barriers to their

[1] Deaf with a capital D refers to a Deaf person who primarily uses sign language to communicate, which differs from a deaf or hard of hearing person.

choices, however, due to: 1) the high cost of mobile phones with a good quality front facing camera, needed for video calling; and 2) the high cost of prepaid data in South Africa. Although many Deaf people use texting as a form of communication, not all Deaf people are literate enough in reading and writing; i.e. their textual literacies vary depending on their education, and communicating in sign language remains their preference.

A survey was done to investigate the mobile usage patterns of Deaf people in the Western Cape. Preliminary analysis indicates that Deaf people often use their mobile phones to communicate in sign language with family, friends and various Deaf non-governmental organizations (NGOs). While this in itself is not a problem, with further investigation it becomes evident that poor and disadvantaged Deaf people in South Africa are forced to pay mobile operators much more than hearing population in order to communicate in sign language, which is data intensive. When Deaf people video call, upstream and downstream data is paid by both parties as opposed to a voice call, which is only paid for by the caller (per minute/second). This is why someone without airtime can talk; but only when someone else calls them. Payment by the Deaf community for upstream and downstream data by both parties is akin to a double penalty for being Deaf, and being penalised for needing to communicate in sign language. This paper seeks to address the (most probably) unintended consequence of South African mobile pricing by collecting and analysing data on mobile video in terms of bandwidth usage. Our goal is to empower Deaf people to make the best video calling option currently on offer, with regards to bandwidth consumption and pricing.

A section of our survey with Deaf people around the province focussed on social networking and the different video telephony applications in use by Deaf people to communicate using sign language. The findings from this section of the survey indicate that a Deaf person uses multiple video telephony applications to communicate. Table 1 provides a breakdown of these applications and shows a noticeable preference for IMO. "Digital Statistics In South Africa 2017", a white paper compiled by Qwerty Digital [3] reporting on the digital statistics in South Africa, states that 13 million South Africans use their mobile phones for social media. The white paper provides a comparison to the Deaf statistics with a 49% prevalence for Facebook, 45% use Whatsapp, 19% for Skype and Twitter with a 26% share. IMO and Facetime were not included or mentioned in the white paper included in Table 1.

Table 1: Video calling application used by Deaf compared to the South African national statistics

Video calling application	% Used by Deaf people as per the survey	% Used by South African as per the national statistics
Whatsapp	14	45
Facebook	3	49
IMO	33	n/a
Skype	7	19
Twitter	3	26
Facetime	3	n/a
Other	1	n/a

Table 2 shows the distribution of Deaf participants per Mobile Network Operator (MNO) in comparison with the national distribution within South Africa. The comparison shows that the distribution of Deaf people subscribed to the four major MNO's is on par with the national distribution. Our preliminary analysis of the survey responses relating to the reasons for Deaf participants choice of mobile network are as follows: 1) 26% of Deaf participants indicated loyalty to the brand; 2) 17% subscribe to a network because it gives free airtime with purchases or earn airtime on special offerings; 3) 6% of the participants bought the mobile phone with the network as a package deal; 4) affordability is the most prevalent of all the categories with 30% of participants; 5) 6% of participants state that ease of use is the reason for choosing a specific network and lastly 6) 2% chose network connectivity. 13 % of the answers were discarded due to errors or irrelevant answers. Table 3 below provides in detailed breakdown per network for the 6 categories of network choice.

Table 2: Mobile networks operators the Deaf subscribe to compared with national statistics

Mobile Networks	% Used by Deaf people as per the survey	% Used by South African as per the national statistics.
Vodacom	37	41,2
MTN	28	34,9
Cell C	20	17,3
Telkom	2	4,5

Table 3: Deaf peoples reasons for choosing a mobile network

Category	Provider				Total
	Vodacom	MTN	CellC	Telkom	
Brand loyalty	11	13	2	0	26
Free airtime	6	6	4	0	17
Bought the phone from the mobile network provider	2	2	2	0	6
Affordability	15	2	11	2	30
Ease of use	4	0	2	0	6
Connectivity	2	0	0	0	2
Error/Irrelvant Answer	2	9	2	0	13
					100

Increased use of video calling applications by Deaf people directly leads to increased use of mobile data over an Internet connection, which means increased revenue for mobile network vendors (actually double, as explained above). Figure 1 shows the price of 1 Gigabyte (GB) of prepaid mobile data over a two-year period for the major MNO's in South Africa. Vodacom and Cell C have been constant over the two-year period at a cost of R150 ($US12), while MTN showed an increase to R160 ($US13) for the same period. In an attempt to gain market share, Telkom has steadily decreased per GB cost to R99 ($US 8) for prepaid data[2]. Research has repeatedly shown that data in South Africa is very costly for consumers, with South Africa ranked as the 25th most expensive out of 40 African countries when it comes to data cost at R99 ($US 8)/GB [4]. The high cost of data adversely affects Deaf consumers, as they are effectively penalised for communicating via video calling.

This paper presents preliminary results of an experimental study conducted to compare the three most commonly used video telephony applications[3] (WhatsApp, IMO and Skype) identified by Deaf people over SA's four MNO's as listed in Table 1. Based on repeated and timed video calls, i.e. the same video calls conducted over each of the three user identified video apps, and each of those conducted over each of the four MNO's, our experimentation is geared to answer the following questions:

1. which application uses the most mobile data?;
2. based on the data usage, what would it cost?; and
3. which application is the most cost effective on which MNO?

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[2] Of course, the size of a prepaid bundle determines the price per GB; and larger bundles mean fewer dollars/rands per GB. The costs shown here are for a 1 GB bundle; and not for say, a 100GB or 200GB bundle which would cost much less per GB. Unfortunately, larger bundles are not affordable for poor Deaf customers.

[3] Facebook Messenger (and Lite) was discarded because of the similarities with WhatsApp in terms of architecture (see Section 0).

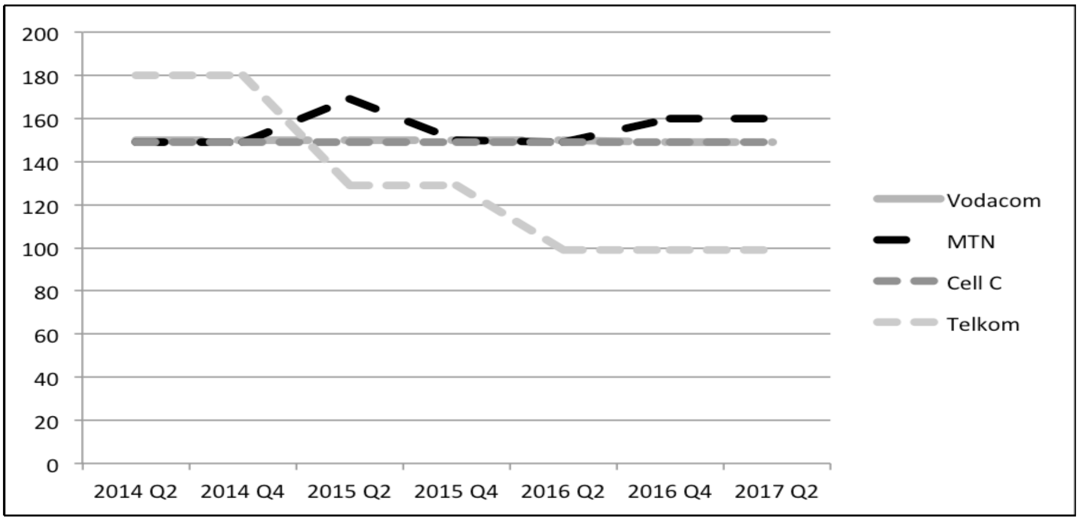

Figure 1: MNO price changes per 1 GB data over 2 years

Our motivation for this investigation is clear: we wish to provide feedback to the people whom we interviewed in the Deaf communities involved in the survey, to give them a summary of which video telephony applications are best suited on which particular mobile network providers. The results of this study should enable them to make informed choices on which application would best suit their needs both financially and socially. The results may be used to lobby mobile network operators to provide concessions/rebates to Deaf people when they purchase mobile data. All subscriber identity module (SIM) cards undergo the Regulation of Interception of Communications and Provision of Communication - related Information Act (RICA) process in SA, which essentially binds a person to a SIM card and therefore it is not impossible for such concessions to be granted by South African MNO's.

2. Related Work

The exponential growth of video telephony applications in recent years; from fewer than 20 million consumers in 2004 to more than 140 million consumers in 2015 [5], directly leads to increased revenues for mobile network operators. Many studies have been conducted comparing video telephony applications over various platforms with different testing parameters. For example, a measurement study on Google Talk, iChat, and Skype with emphasis on design and performance, provides feedback on future application design in high bandwidth and low latency environments, recommending that video generation, protection, adaptation and distribution be taken into account.[6].

Becker et al. [7] investigated the performance of applications over Long-Term Evolution (LTE) networks, and other researchers have investigated how the changes in bandwidth affect Instant Messaging (IM) application like Skype, Windows Live Messenger, Eyebeam and X-Lite with regard to performance [8]. The findings indicate that out of the three applications tested, Skype performed the best when dealing with bandwidth changes. Skype employs a transmission rate adaptation policy as the bandwidth fluctuates and takes various other parameters, like round-trip time (RTT) and jitter, into account when adapting its transmission speed to avoid packet loss. The findings report that low quality and low frame-rate video without disruptions performs better than high frame-rate video with disruptions as an end user experience. Their recommendation is that video chat applications should be adaptable when it comes to video bit-rate in order to keep the audio level acceptable. Does video degradation and quality have an impact on sign language intelligibility? Tran .et al [9] conducted laboratory experiments using pairs of American Sign Language signers conversing using a smartphone application transmitting over frame rates lower than the recommended ITU-T standard. The results and recommendation of this study is that even with frame rates as low as 10fps/50kbps, the sign language viewed by signers was good enough to understand. However it was found that signers adapted to sign at slower speeds to make up for the lower frame rate; however it must be noted that they would opt for this only for short conversations. Slow signing leads to increased bandwidth, which in turn leads to higher costs.

Yu et al. performed a measurement study of Facetime, Google Plus Hangouts and Skype over mobile and WiFi networks [10]. Their key results can be summarized as follows: modern smart phones are capable of encoding, transmitting and decoding high quality video in real time over mobile and WiFi networks. In a wireless link with weak signal, the mobile video quality is vulnerable to sporadic packet loss and delay on the network. In related work, six video telephony applications were compared to determine whether any of the applications can be used for language teaching [11]. Out of the six applications, (CUworld, ICQ, MSN Messenger, Paltalk, Skype and Yahoo Messenger), the results yielded MSN Messenger and Skype ranked first and second, respectively, based on the results of evaluation sheets provided to students who tested the applications.

With respect to our objective to analyse different video apps over different networks, the above concise survey showcases generic enquiries into mobile video characteristics. Our study differs in how we choose to concentrate only on testing video telephony applications that are popular amongst Deaf participants who took part in the study.

3. Selection Criteria

As shown above in Table 1, Deaf people use video telephony applications to communicate with friends and family, as well as Deaf organizations that support them in a social capacity. Table 2 shows the four major SA mobile network vendors that these same Deaf people subscribe to in order to obtain access to the Internet, which enables them to use video telephony applications. Also shown in Table 2 are the national statistics as per Q4 2017 for South Africa with regard to the market share held by the four major MNO's. It is notable to mention the minimal variance between the Deaf and national statistics. Our objective, then, is to test which applications perform most economically on which mobile networks based on data usage and data cost. To determine these characteristics, we designed a controlled experimental setup where we measured the use of the same video conversations with different mobile video apps over those four mobile networks. The preliminary results provide Deaf people and anyone working with Deaf people with different options in choosing the best application on a specific mobile network, based on data usage, and thereby cost. This section provides some background on the survey we conducted; from which this experimental study originates. Section 0 details the experimental procedure, data collection and analysis. Results are presented in Section 0.

We developed a mobile phone-based survey to collect information on Deaf people's use of mobile phones and expenditure on telecommunications. We leveraged our long-standing relationship with various Deaf organizations within the Western Cape, such as the National Institute for the Deaf (NID), DeafNet, Deaf Community of Cape Town (DCCT) and DeafSA. All these organizations are active in many Deaf communities, and provide the people of those communities with various services. On this particular survey we collaborated with DeafSA to visit their branches in Cape Town, Paarl, Vredenburg, Beaufort West, and George; as well as NID and Khayelitsha School for the Deaf. We invited 10 members from each community to partake in our survey. Statistics SA (Stats SA) [12] in their 2011 census reported that 7,5% (2 870 130) of the SA population lives with a disability. 5,4% (222 333) of the identified disable citizens resides in the WCP of SA. The Census 2011 reports that 0,7% (288 389) of the SA population over the age of 5 suffers from severe hearing loss. Furthermore 0,5% of the WCP population suffers from severe hearing disability as stated in the report.

Our selection criteria for inclusion in the survey was: 1) 5 Deaf had to be employed and 5 unemployed; 2) each participant had to be fluent in sign language and 3) all participants should be 18 years or older. We entrusted the selection of participants to the staff of each organizations who interacts with the community on a regular basis. To comply with ethical standards, we obtained necessary ethical clearances both from our institutional review board, and also by engaging the community on ethical issues such as providing research objective and procedural information with the help of sign language interpreters (to be sure participants understood in their own language). We did the same to obtain informed consent, i.e. all procedures were conducted in sign language with the help of qualified interpreters.

In general, collecting information from Deaf people using a conventional paper based questionnaire format is inadequate, as their medium communication is sign language. Many of the Deaf people we engage in WCP have low textual literacy, yet they are perfectly fluent in sign language. South African Sign Language (SASL) is the preferred communication language for Deaf people. SASL has a variety of dialects just like English, Afrikaans or isiXhosa in different areas across the country/province. In some areas difficulty was experienced due to the different dialects or forms of sign language. We came to the conclusion that although sign language is the standard mode of communication, there are variances in the different communities that we visited based on how and where people are schooled (each school tends to embrace a particular vernacular); and the other languages spoken by family members, e.g. children of hearing adults. These differences are attributed to the English, Afrikaans and Xhosa cultures Deaf people grew up with and signs are adapted accordingly. Instead of paper, then, we opted to employ a mobile tool with sign language videos on it, because most Deaf people know how to use a mobile phone; and again, they prefer to use sign language over text.

We extended Open Data Kit (ODK)[13] [14], an open source toolkit that performs data collection with mobile devices, to ask questions and receive answers in video clips. We employed the services of a qualified sign language interpreter (SLI) to interpret our text-based questions to sign language; and stored these videos on the mobile devices. Our extension to ODK's interface was to provide an interface leveraging those sign language videos for Deaf end users. Where appropriate, we could collect data like numbers and yes/no answers with standard graphical user interface (non-video) interfaces. When free-from answers were required of Deaf users, we simply used ODK to record videos of Deaf people signing their answers, and stored those video answers such that they linked to the sign language questions that were asked. These sign language answer videos were subsequently sent to an SLI; in fact, we sent the same answers to two different SLI's to ensure accuracy of translation. The resulting verified textual answers were then re-integrated into ODK's traditional text forms; such that in the end, we could employ standard ODK tools to analyse the sign language answers from Deaf people, albeit in text. The participants could answer the questions in the following ways: 1) in the form of picture(s) taken using the mobile phone camera; 2) typed-in numbers using an on-screen numeric keypad, 3) button selection using the mobile phone touch screen and 4) recording answers in sign language videos using the phone's front facing camera. A social auxiliary worker together with a SLI attached to each Deaf community assisted us with community engagement and interpretation services. Each participant was shown how to use the video-enhanced ODK survey on a mobile device (we often used 5 or 6 at a time) with the help of a tutorial with sample questions (in sign language). Participants were allowed to do the tutorial multiple times until they felt comfortable to complete the full survey on their own. The social worker and SLI, in addition to members of our team, were also available to answer questions while the Deaf participants completed the survey; to assist with the use of the tool[4].

As discussed above, the purpose of the survey was explained to all participants, i.e. the security and privacy regarding storage and use of their responses provided during survey. To this effect, all responses were removed from the mobile phones; and cleaned and vetted by the researchers. The responses that were in sign language video were translated back into English by the SLI who did the original translation. We then vetted the translated video material by requesting a second SLI, e.g. one attached to the community, to confirm that the responses were correctly translated, as various Deaf communities also tend to have regional and/or community-based variations in sign language, e.g. dialects of South African Sign Language.

4. Experimental Design

4.1 Laboratory Setup

In order for the results of this study to be practical and of use to Deaf people, the research team came up with the following qualifying criteria for the mobile phoned required for this study: it should be an affordable low–mid range Android smartphone with front and rear facing cameras, with 3G capability. The Xiaomi Redmi 2A model fit the qualifying criteria as described in Table .

Table 3: Xiaomi Redmi 2 specifications, costing only R1300 (US$ 100), the Redmi 2A could be considered an upper end low-end smartphone, or a lower end mid-range smartphone depending on one's perspective. In any case, the Redmi 2A is clearly beyond a 'feature' phone despite its modest yet fully functional specifications; at least for the sake of our experimentation.

Network	3G HSDPA 850/1900/2100
Display	Resolution 720x1280 pixels, 16:9 ratio
Operating system	OS Android 5.1.1 (Lollipop)
CPU	Quad-core 1,2 GHz Cortex-A53
Internal Memory	8 GB, 1 GB RAM
Camera	Primary 8MP Secondary 2MP, 720
Battery	Li-Po 2200 mAh
Cost	R1330 ($100)

4.2 Mobile Video Applications

Video telephony, or Mobile Instant Messaging (MIM), applications have increased in popularity in recent years [15][16] due to growth of feature loaded smartphones. MIM is predicted to overtake the traditional Short Message Service (SMS) with the decline in data costs in many countries. MIM popularity can be attributed to fact that one can send messages, pictures, and videos in real time over mobile and/or WiFi networks, as well as the fact that many MIM applications are platform independent. From our survey, Deaf users indicated that the following were very popular: IMO, Skype and Whatsapp.

IMO is an MIM application that allows hosts to connect to hosts via the phone's contact list who have IMO installed. IMO.IM prides itself as a company that connects people; therefore IMO is also capable of connecting contacts of contacts using the IMO application. Very little has been published regarding the architecture of IMO and how its messaging

[4] Note that the video-enhanced ODK allowed us to more efficiently survey a group of Deaf people. Sign language interpretation to a group with a text-based questionnaire is much more time consuming, and does not allow people to complete a survey at their own speed.

system works. Through actual use of the application, we find that it allows different types of messages to be sent, as well as voice and video calling. In 2014, it was reported that IMO has adopted Web Real-time Communications (WebRTC) which allows real time communications through popular web browsers [17], thus increasing platform independence with a single code base (as opposed to platform-dependent versions of popular messengers like Facebook and WhatsApp).

Skype allows for two-party and multi party video calls over a Peer-To-Peer (P2P) overlay network [18][19], where end users are directly connected to one another. Skype's architecture consists of three components: 1) login service, 2) supernode, and 3) hosts. The login service is distributed across the Internet, which manages and audits user logins. Every host/client is any Skype application that initiates a Skype conversation with another host. Hosts connect to supernode to access the Skype network, which could be another host already part of the network. Therefore, hosts have to maintain a list of hosts to which it could potentially connect. Skype communicates over standard TCP and UDP protocols

WhatsApp is another MIM application, similar to Skype and IMO, that is able to transfer various types of messages (text, pictures, video and location services) between hosts. It uses a version of eXtensible Messaging and Presence Protocol (XMPP) to exchange messages [20]. Whatsapp is based on a client-server model where a host connects to a server with the connection staying active while the application is online. Another investigation identified that Whatsapp uses different servers to handle different types of messages, with text and multimedia services hosted on a cloud service provider SoftLayer and the calling component within the Facebook infrastructure [21].

4.3 Testing Platform

The testing platform used four Redmi 2A's, one for each of the MNO's; Vodacom; MTN; Cell C and Telkom. Video calls were made over 1 and 5-minute intervals with 3 iterations per network resulting 12 calls per network per video telephony application. Table 4 shows how applications IMO (I), Skype (S) and Whatsapp (W) were tested on 3G mobile networks using the 4 major South African mobile service providers. Video calling to the same network was excluded from the study as certain service providers provide this as either a free add-on or at reduced rates. At this stage, it is pertinent to point out that LTE was omitted and can be included in future studies, as members of Deaf communities do not always reside in areas where LTE coverage is readily available.

Table 4: Network Platform

Network	Vodacom	MTN	Cell C	Telkom
Vodacom	N/A	I, S, W	I, S, W	I, S, W
MTN	I, S, W	N/A	I, S, W	I, S, W
Cell C	I, S, W	I, S, W	N/A	I, S, W
Telkom	I, S, W	I, S, W	I, S, W	N/A

4.4 Testing Parameters

All mobile phones used in the study were standardised in terms of the operating system, application testing software and monitoring software. To monitor and collect the mobile data usage, the following free tool was installed on all phones from the Google Play Store: Data Usage Monitor. The data collected from the monitoring is compared to the default monitoring software that forms part of the operating system, such as battery consumption and application testing software similar to the data usage collected by Whatsapp. All other applications are disabled on the mobile phone while testing. See Table 5 for mobile phone testing parameters and software versions.

Table 5: Mobile phone parameters

Parameter	Version
Android Operating System	5.1.1 LMY47V
IMO	9.8.00000009201
Skype	7.46.0.596
Whatsapp	2.17.427
Data Usage Monitor	1.13.1403
Network Type	3G

4.5 Testing Procedure

To obtain a baseline before running the actual tests, initial tests of 1-minute video calls of 3 iterations for each network were conducted. The baseline tests are meant to ensure that all monitoring software is performing correctly; meaning the correct data was collected and corresponds with the operating system and application reports. AccuBattery and Data Usage Monitor were installed on all phones to capture battery and mobile data usage, respectively. Each application was restarted after every video call and any statistics captured cleared for all logs.

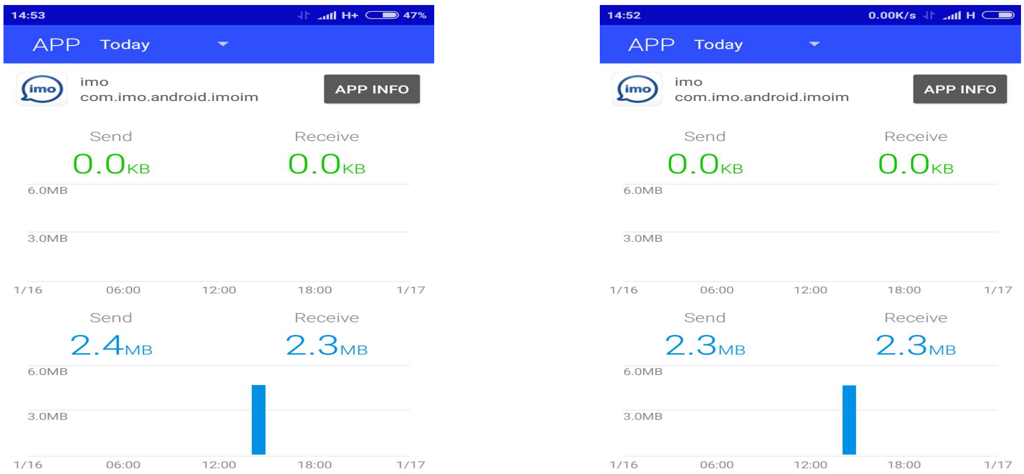

Figure 2: IMO Sender and Receiver data

Figure 2 shows how much data was used for both sender and receiver when making an IMO video call. Both sender and receiver have send (upstream) and receive (downstream) transmissions when making a video call. This clearly illustrates how *both* video communicants are liable to pay for *both* send and receive portions of a video call (data); which is very different to a telephone call or Short Message Service (SMS) where only the sender is required to pay. This method of revenue generation by MNOs on video communication comes with a clear 'double burden' disadvantage to the Deaf community. The data usage for Whatsapp and Skype was captured in a similar way, and also requires the user to pay for upload and download portions.

The testing for the 5-minute calls are done a bit differently: conversations are simulated with YouTube videos (conversation dialogues). Each phones is placed facing another phone running the video; and this is done in a laboratory setting. Incidentally, this means both phones connect to the same cell tower. Mobile data charges accrue nonetheless.

Monitoring is started once the caller's phone starts the video call, and is ended when either the caller or receiver ends the video call. In our case, the researcher ended the call. Due to the fact that data monitoring starts as soon as the caller starts the call, the undertaking was that the receiver answers the call within a 30 second window, to negate any delay in answering the call.

5. Results

Preliminary results indicate minimal variance in data usage and therefore pricing of a one minute or less minute video call over the four major MNO's using these three video telephony applications. Table 7 shows that Whatsapp uses slightly less bandwidth for video calls to its competitors, who uses double the amount of data for a video call of similar timeframe.

Skype performs well on the Telkom network, using the least amount of data, which amounts to lower costs to the end user. The following pricing was used as per the specific MNO's offering for data between 25–30 Megabyte (MB), with Vodacom and Cell C pricing 30 MB of data at R12, which equates to 40 cents per MB, and MTN with a price of R12 for 25 MB at 48 cents per MB, Telkom is by far the best priced at 29 cents per MB as shown in Table 6.

Table 6: MNO Data Pricing

Network	Price (Rands)	Bundle	In-bundle rates
		Size MB	per MB (Cents)
Vodacom	12	30	0,40
MTN	12	25	0,48
Cell C	12	30	0,40
Telkom	7	25	0,29

Table 7: Baseline Video Calls

Application	MNO	Call Duration (Minutes)	Total Data Usage (MB)	Data Cost (Rands)
Whatsapp	Vodacom	0,50	1,02	0,41
	Cell C	0,52	2,06	0,82
	MTN	0,50	2,03	0,97
	Telkom	0,51	2,33	0,68
Skype	Vodacom	1,01	3,87	1,55
	Cell C	1,01	4,27	1,71
	MTN	1,02	3,21	1,54
	Telkom	1,00	3,06	0,89
IMO	Vodacom	1,00	2,27	0,91
	Cell C	1,00	3,64	1,46
	MTN	1,00	3,35	1,61
	Telkom	1,00	3,77	1,09

The results of the video calls between 4 and 5 minutes is shown in Table 8. As with the baseline video calls, Whatsapp video calls use more data on the MTN network, however perform better on the Cell C network. Skype data usage is significantly less on Cell C as opposed to its competitors. However, Telkom's lower data price makes it more affordable that any other network. IMO performed very much similar to Skype with Telkom again charging the least amount for data.

Table 8: 5 minute video calls

Application	MNO	Call Duration (Minutes)	Data Usage	Data Cost
Whatsapp	Vodacom	4,60	11,70	4,68
	Cell C	4,39	9,80	3,92
	MTN	4,58	12,20	5,86
	Telkom	4,53	11,23	4,82
Skype	Vodacom	4,67	10,30	4,12
	Cell C	4,67	3,61	1,44
	MTN	4,47	12,00	5,76
	Telkom	4,38	4,38	1,27
IMO	Vodacom	4,46	13,40	5,36
	Cell C	4,47	11,20	4,48
	MTN	4,46	13,70	6,58
	Telkom	4,46	13,17	3,82

Many Deaf people would prefer quality to cost, however the result shows a higher preference for IMO amongst Deaf people, mainly because of the high cost associated with data in South Africa. Through our own investigations of quality, IMO provides a best effort service, as opposed to the other video calling applications. Upon further analysis of the survey data, we can speculate that Deaf people who are in a better position financially opt for better quality video calling.

The *preliminary results* indicate that Cell C on average uses the least amount of data for video calls longer than 2 minutes. Due to Telkom's lower pricing per Megabyte (MB), the network is more financially viable for video calling using Whatsapp, Skype and IMO. Figures 3 - 5 provides graphical representations of the three video calling applications performance for a 5-minute video call based on data usage (in MB) and cost per call (in Rand) over the four mobile networks.

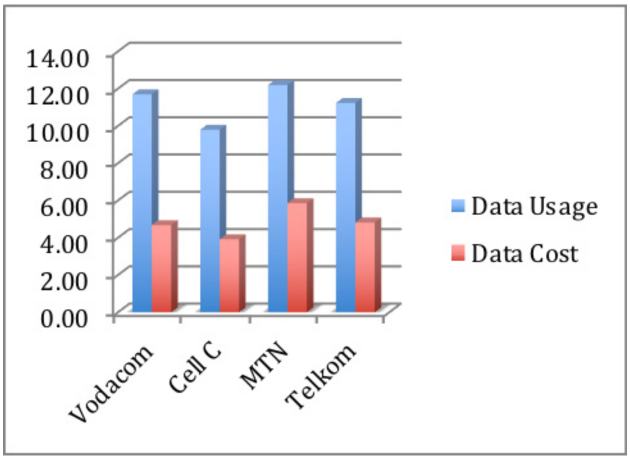

Figure 3: Whatsapp data usage and call cost for 5-minute video calls over MNO's

Figure 3 shows that 5-minute Whatsapp video calls uses less data and therefore costs less on the Cell C network when compared with the three competitors.

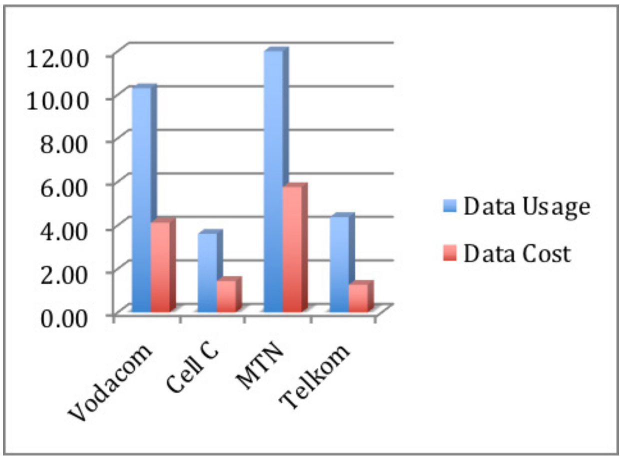

Figure 4: Skype data usage and cost for 5-minute video calls over MNO's

A 5-minute Skype video call, as shown in Figure 4, behaves similar to Whatsapp on Cell C, however the data usage is much less resulting in lower costs. Figure 5 shows that IMO performs best when used on the Telkom network.

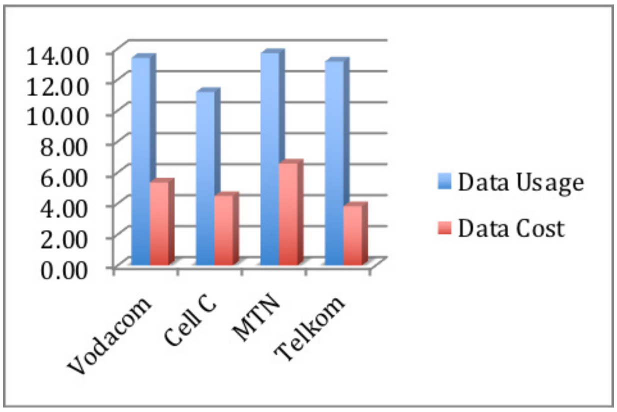

Figure 5: IMO data usage and cost for 5-minute video call over MNO's

6. Conclusions and Future Work

Mobile video telephony has the potential of providing Deaf people with remote mobile-Health, education, emergency services and many other scenarios which Deaf people do not have full access to. However the mobile data costs in South Africa are very high compared to the rest of the world, and this is a challenge for many Deaf South Africans. To summarise the results, the average data usage for the mobile video applications across the four mobile networks are as follows: IMO has the highest data usage, Whatsapp usage is slightly lower and Skype shows the least amount of data usage. With regard to cost effectiveness of the mobile network operator, the results show Cell C to be the most cost effective of the four with MTN the most expensive network to make a video call irrespective of the mobile video application used.

We need to convey this information back to the Deaf communities that we surveyed, and make this information more widely available via public media (and not just at research venues like IST-Africa). A proposed timeframe for the dissemination of the results and findings is between Q4 2018 to Q1 2019. We fully recognise that Deaf participants won't likely act immediately on this information, as we are creatures of habit, and habits are difficult to change. However, by putting the information out there, by returning to the Deaf communities, we a) make them aware of the costs and alternatives, and b) simply by going back to Deaf communities with results and our interpretation of the data, we develop trusting and growing relationships with these communities, so we can work together in the future to help Deaf people attain affordable and accessible mobile video solutions in South Africa, and beyond.

Further research is required to obtain more video call statistics by involving the Deaf communities to actually make video calls using sign language over longer periods of time and increase the frequency of the calls. Involving Deaf users would have the additional benefit of being able to ask them about video quality, too, and then correlate that to video app/mobile operator combinations. It would also be advantageous to see how the same study is done with an LTE network as opposed to the 2G/3G configurations used in this study. An Android application will be developed to collect statistics for the following: 1) video calling application; 2) time of the call; 3) data consumed per call; 4) source network; 5) destination network and 6) duration of the call.

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