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Exploring the walled garden theory: An empirical framework to assess pricing effects on mobile data usage

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ABSTRACT

This paper performs an exploratory study of mobile usage patterns over three years (2013–2015) in the context of pricing practices such as zero-rating. In recent years, there has been heated ongoing debate regarding whether offering different pricing plans, such as zero-rated services and applications, might slant user behavior toward certain content on the Internet. Our study gathers empirical measurements of mobile application usage to address this research question. We shed light on this issue by performing an exploratory analysis of the effects of different data plans and connection types on mobile data usage, as well as measuring quantitative and qualitative pricing effects of zero-rating on mobile data usage.

First, we perform a longitudinal exploratory study using data collected from the MySpeedTest application. We analyze differences in usage behavior between the top five most used applications in the United States (US) and South Africa (ZA), comparing usage on different connection types (Wi-Fi vs. cellular) as well as for devices on different data plans (prepaid vs. postpaid limited monthly data cap vs. uncapped).

Our findings show that US users consume slightly more cellular data than Wi-Fi data for most of the US top five most used applications, while South African users generally prefer Wi-Fi connections (with the notable exception of Facebook). Further, US users on postpaid plans display much higher average monthly mobile data usage than those on prepaid plans, while South African users on prepaid plans generally display much higher usage than those on postpaid plans.

Next, we perform a deeper analysis into the possible behavioral effects of zero-rating in South Africa. We find in one case that zero-rating WhatsApp on Cell-C's network increases overall usage of the application, regardless of connection type. In the case of zero-rating Twitter on MTN network, we observe increased mobile data usage of the zero-rated application during and immediately after the promotion, but not in the long term. Some of our results yield striking patterns, yet point to the need for richer datasets to confirm these initial findings.

Finally, to gain further insights into the user motivations behind our empirical observations, we implement a mobile-based survey among a randomly selected group of individuals in South Africa and Kenya. We observe that use of zero-rating services is actually quite low among respondents. Further, zero-rating seems to serve more as a popular method for data conservation—an effort toward which respondents show a strong dedication—than as a walled garden that would otherwise discourage users from venturing beyond zero-rated applications.

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1. Introduction

Recent years have seen heated ongoing debate regarding whether offering different pricing plans might slant user behavior toward certain content on the Internet (A4AI, 2015; Leidel, 2015; Shearsl, 2014; van Schewick, 2015). Of particular interest is the practice of zero-rating, which allows Internet service provider (ISP) customers to access and use certain mobile applications or services without incurring data usage charges. The practice is increasingly popular in both developed and developing countries, but it has stimulated a vociferous debate, especially in developing countries (Bathia, 2016; De Guzman, 2014) where the costs of mobile data services are higher relative to per capita incomes (Eisenach, 2015).

Critics of zero-rating cite that the practice may violate the principle of net neutrality, which states that service providers should treat all bits of traffic flow equally, regardless of payment to the service provider (Drossos, 2015; The Centre for Internet & Society, 2014; van Schewick, 2015). A similar argument from consumers claims that zero-rating creates a walled garden that discourages users from venturing beyond the limited array of applications dictated by a zero-rating service provider (van Schewick, 2015; Malcom et al, 2016). The other side of the debate, whose advocates include Mark Zuckerberg and Facebook, insists that zero-rating can provide initial connectivity to consumers who otherwise would not have connectivity at all (Shearsl, 2014). According to proponents of this argument, zero-rated applications and services can serve as a gateway that encourages users to ultimately use a broader range of Internet services (Nowak, 2015).

This paper offers empirical data to address some of the main concerns on the zero-rating debate by investigating how various pricing-related features affect mobile data usage. The study first investigates behavioral discrepancies between users on different data plans and connection types, as well as taking into account pricing practices such as zero-rating. Second, to understand users' motivations on zero-rating usage, it explores the effects of zero-rating practices on mobile Internet usage for a simple random sample of the South African and Kenyan populations.

Obtaining empirical evidence on the relationship between mobile data usage behaviors and mobile data pricing practices such as zero-rating can benefit all stakeholders involved in the ongoing debate. Our study can help network carriers and regulators determine which data plans elicit different types of data usage and whether introducing zero-rated services may affect user behavior. From a policy perspective, better data may dissuade policy makers from making decisions that negatively affect competition in a dynamic telecommunications and Internet services market. Along with network carriers, regulators, and policy makers, mobile applications and organizations alike can benefit from understanding possible behavioral effects of zero-rating to plan future pricing strategies to increase connectivity.

Our research makes three contributions:

1) We compare mobile data usage in the United States vs. South Africa, focusing on the top five used apps in each country and measuring the effects of connection type and data cap on mobile usage behavior;
2) We study the effects of zero-rating pricing on mobile data usage in South Africa; and
3) We perform a qualitative study to investigate the motivations behind zero-rating usage in South Africa and Kenya.

Our study first explores longitudinal mobile usage patterns in South Africa as compared to the United States, the former as a precursor to our pricing analysis on zero-rating and prepaid data pricing, and the latter as a baseline point of comparison with a high-income country where uncapped plans are prevalent. To analyze the effects of zero-rating on mobile usage, we focus on South Africa because zero-rating has become a popular and established practice in the country (Chair, 2015), and we have a significant number of South African users (249) on MySpeedTest. We investigate different zero-rating practices across the main carriers in South Africa and search for any changes in usage breakdowns that may have resulted from these pricing practices. Finally, to understand user motivations behind the behavioral patterns that we observe, we perform a qualitative comparative analysis on zero-rating between South Africa and Kenya by administering a mobile-based survey to users in the two countries. We introduce Kenya into this portion of the study because of the prevalence of zero-rating data plans in the country (Walubengo, 2016). Although the Kenyan and South African economies may vary, Kenya serves as a good point of comparison in our survey analysis because, similar to South Africa, the country has one of the biggest telecommunications markets in Africa (ITU, 2016). This set of users thus serves as an important baseline for comparison against zero-rating in South Africa, since the other countries for which we have data (e.g., the US) do not have extensive zero-rating practices.

2. Prior and related work

We summarize four previous studies investigating data usage practices and patterns: the first two studies analyze behavioral trends on a macro scale, and the last two attempt to understand user behavior at a micro (i.e., per-user) level.

In 2014, the Sandvine Global Internet Phenomena Report (Sandvine Intelligent Broadband Networks, 2014) published findings on fixed and mobile Internet access in various continental regions around the world. Most relevant to this study are mobile access trends prevalent in North America and Africa. The 2014 report claims real-time entertainment and social networking applications dominate peak period mobile traffic in North America. The former accounts for 36.5% of aggregate traffic on the network, while the latter accounts for 26.36%. The high representation of social network traffic, coupled with the fact that social applications typically generate much less traffic than entertainment streaming applications, speaks to the popularity of social networking applications among users. With regard to traffic trends in Africa, the report finds that peak-period mobile traffic is dominated by web-browsing (34.85%) and communications (28.92%) applications. In addition, Africa is the only region in which Opera Mini, a web browser focused on data efficiency, is among the top-ten most popular applications, which may suggest that users in this region are more dedicated to conserving

data usage.

The 2015 Sandvine Global Internet Phenomena Report (Sandvine Intelligent Broadband Networks, 2015) notes a slight increase in North American real-time entertainment traffic and a slight decrease in social networking traffic. Nevertheless, these two categories remain by far the dominant traffic contributors in North America. In Africa, web browsing and communications still dominate traffic composition. Notably, WhatsApp network traffic has increased by almost 50% and now contributes 10.86% of total network traffic.

In 2015, Mathur et al. (Mathur, 2015) performed a multi-dimensional study on data usage practices in South Africa, a region where data costs are high and usage-based data plans are prevalent. They collected 339 survey responses on mobile data usage and cost management practices from June–July 2014, conducted in-depth interviews with 43 of the survey respondents from June–August 2014, and analyzed MySpeedTest data usage logs for 121 unique devices from November 2012–June 2015. The study concluded that mobile users in areas where data access is limited, expensive, or both are very cost-conscious; these users frequently adopt a variety of cumbersome strategies in an attempt to optimize their mobile data usage. For example, users often switch off cellular data connections or postpone mobile use until connected to Wi-Fi, in addition to avoiding data-intensive applications and changing settings to disable automatic software updates.

In 2014, Joe-Wong et al. (Joe-Wong, 2014) presented results from a time-dependent pricing trial with a commercial ISP. In an effort to optimize network capacity by analyzing users' mobile data consumption, their research posits that monthly data caps tend to reduce usage, while time-dependent pricing can increase usage as users consume more data during discounted times.

Although the above studies have made significant progress in exploring Internet access trends and mobile data usage practices as well as in studying the effect of mobile data plans on mobile usage, no previous study uses empirical data to understand how pricing instruments such as zero-rating affect mobile usage.

3. Research methods and data sources

This research makes use of two data sources: (1) application usage data from the MySpeedTest application (MySpeedTest, 2016); and (2) a mobile survey administered to MySpeedTest users in South Africa and Kenya. MySpeedTest is an Android application that collects active measurements on mobile network performance (e.g., throughput and latency), passive measurements on user behavior (e.g., data consumed by and usage frequency of different applications), and various pieces of metadata (e.g., country, data cap plan, battery life). For the purposes of this study, we focus on the relationships between different pieces of metadata associated with each device, and the mobile usage behaviors on that device.

For the longitudinal portion of our study, we analyze usage data measured by MySpeedTest from January 2013 to November 2015. Table 1 below shows the relevant tables in the database and the columns we extracted from them for this study; boldface columns indicate the database join keys.

Collecting, cleaning, and pre-processing the data was iterative because the dataset had not been analyzed extensively prior to this work. The MySpeedTest data were stored in a Postgres database, and we performed the analysis in various iPython notebooks using the Pandas and Matplotlib libraries for analysis and visualization, respectively. MySpeedTest collects measurements at 15-min intervals for every active device-application pair, regardless of whether any usage was recorded in a given interval. We aggregated measurements by date to make our queries more efficient, due to the size of the data collected. We performed all necessary cleaning, pre-processing, and aggregating directly via SQL queries to extract only the relevant data in Table 1 to store into a new table created in the database. This table was more manageable for direct queries. We then queried the database for the desired time period and exported the result into a Pandas dataframe for analysis in iPython.

We also created and distributed a mobile survey to 300 users in South Africa and Kenya (150 respondents per country) to compare

Table 1
Relevant tables and columns extracted from MySpeedTest database.

Table	Column	Description
application	name	Application name
	package	Package name corresponding to application
application_use	**measurementid**	ID of measurement
	package	Package name corresponding to application used in measurement
	total_sent	Counter for total number of bytes sent by end of measurement
	total_recv	Counter for total number of bytes received by end of measurement
network	**measurementid**	ID of measurement
	connectiontype	Connection type used in measurement (e.g., Wi-Fi, 2G, 3G, etc.)
measurement	**measurementid**	ID of measurement
	deviceid	ID of device reporting usage in measurement
	time	Time of measurement (granularity = 15 min intervals)
device	**serialnumber**	Serial number of device
	deviceid	ID of device
	networkname	Network carrier to which device belongs
	networkcountry	Country to which device's network carrier belongs
	datacap	Monthly data cap of device (e.g., unlimited, X megabytes cap, prepaid)
sim	**serialnumber**	Serial number of device
	operatorname	Network carrier to which device belongs
	networkcountry	Country to which device's network carrier belongs

Table 2
Quarterly user breakdown by data cap type.

Quarter	# Users	Unlimited	Limited	Prepaid	Unknown
2013 Q1	4797	2150	2068	0	579
2013 Q2	3784	1694	1664	0	426
2013 Q3	2610	1244	1074	0	291
2013 Q4	2408	1217	941	0	250
2014 Q1	1566	812	592	1	161
2014 Q2	595	362	187	0	46
2014 Q3	1192	756	355	17	64
2014 Q4	919	593	252	24	50
2015 Q1	522	341	150	6	25
2015 Q2	438	224	147	11	56
2015 Q3	338	175	114	9	40
2015 Q4	262	132	92	7	31

users' perspectives on zero-rating and mobile Internet usage behavior in the two countries. To simultaneously encourage survey responses and user installs of MySpeedTest, we introduced two new avenues of recruitment for this portion of our study. First, we performed a pay-per-install method of recruitment. A commercial survey company, On Device Research, ensured 300 survey completions across an unbiased distribution of users split evenly across South Africa and Kenya, with MySpeedTest user installs performed at best effort.[1] Second, to encourage users not to immediately delete the application from their phones, we entered users who held the application for a month into a raffle for a new phone.

4. Data characterization and overview

The dataset contains a total of 12,277 unique users collectively using 67,821 applications throughout the entire period of study from January 2013 through November 2015. The median number of mobile applications per device is 39, though we observe a right skew in the distribution, with a higher average of 57 applications per device.

Table 2 shows a quarterly breakdown of users by data cap type for the duration of our study. We have grouped all data plans with monthly limits between 250 MB and 2 + GB into the "Limited" category. Note that Q4 2015 excludes December.

These results show that 2013 had more active users (about an order of magnitude more than in 2015). In 2014, there were about 1000 active users per quarter, with an aberration in Q2 due to some technical issues with the MySpeedTest application; 2015 saw much lower numbers overall, with a couple hundred active users per quarter. In 2013, we see a comparable amount of users on unlimited plans and users on plans with a monthly limit. This difference in users between the two categories is amplified as the number of overall users drops over the next two years. By 2015, the majority of users are on unlimited plans, although users on limited plans are still well represented in the data. There are at most a handful of users on prepaid plans in each quarter; throughout 2013 there were no users at all who reported being on prepaid plans. It is important to note that the data cap associated with each device is reported by the respective user. This self-reporting may contain factual errors, as users may be unsure of their data plans and can easily misreport this information.[2]

The dataset contains usage information from 1034 US users, with 403 on unlimited plans, 627 on limited plans, and 4 on prepaid plans; in South Africa, the dataset contains usage data from 249 users, with 63 on unlimited plans, 176 on limited plans, and 10 on prepaid plans.[3]

5. Comparing mobile data usage in the United States vs. South Africa

We analyze mobile usage in the United States and South Africa from January 2013 through November 2015. By comparing behaviors between these two countries, we aim to observe differences between mobile usage on different connection types and under different data cap types across a longitudinal period.

We compare and contrast data usage in these two countries to highlight differences in usage patterns and to demonstrate the wariness South African users seem to display toward cellular data usage. This helps drive our later analysis of South African user motivations behind the behaviors that we observe. We study two research questions in this section: 1) Whether cellular vs. Wi-Fi connections affect data usage in each country; and 2) Whether unlimited vs. post-paid limited vs. prepaid data plans affect data usage in each country.

5.1. Top five popular applications in US vs. ZA

Before we examine usage breakdowns based on different connection types and data plans, we explore which types of applications are

[1] Although On Device Research ensured unbiased distribution of respondents, the survey may not be representative of the population of Kenya and South Africa.
[2] A new version of MySpeedTest has tried to improve the system of self-reporting data plan by asking users to update their data plan every quarter.
[3] In fact, South African data plans are predominantly of the prepaid variety, but the MySpeedTest dataset contains more users on unlimited plans (which are considerably less prevalent in South Africa).

most used in each country. For our comparisons, we only consider the top five mobile applications in each country, ranked by total data usage in bytes throughout the period of study from January 2013 through November 2015.

To calculate an appropriate metric for usage of a given application by a particular category of users over a certain period of time, we first compute the average monthly usage of the application across all users in that category (i.e., US vs. ZA). We then compute the median across all months in the period of interest. The median usage metric is more robust to potential outliers in the dataset, while reflecting general usage patterns.

The top-five used applications from January 2013 through November 2015 are shown in Table 3.

These results align with the Sandvine findings that social networking and real-time entertainment applications dominate North American data usage; the top four applications in the United States are Netflix, YouTube, Facebook, and Google+. It makes sense that Netflix and YouTube would be the top contributors to mobile usage in the US, because streaming applications typically generate a lot of traffic. Facebook and Google + are the next most used applications, attesting to the popularity of social media applications in users' mobile experiences.

The Sandvine reports find web-browsing and communications applications to be the top contributors of African mobile traffic, which is reflected in the presence of Chrome and Correo (a mail app) in our list of South Africa's top five applications. Sandvine's 2015 report shows a significant increase in popularity of real-time entertainment, as well as a small increase in traffic contribution of social networking applications, which can explain the presence of YouTube and Facebook in the list.

5.2. *Effects of connection type on mobile data usage for top five popular applications in US vs. ZA*

To understand whether cellular or Wi-Fi connections affect data usage in each country, we measure usage by connection type for the top five applications in each country.

Figs. 1 and 2 show that US mobile usage dwarfs South African mobile usage for the top-five applications in each country. In addition, US users generally access the relevant applications on cellular connections more frequently than on Wi-Fi connections, even for data-intensive streaming applications like Netflix and YouTube. In South Africa, on the other hand, users seem more wary of cellular data usage, preferring Wi-Fi connections for almost all of the listed applications. This difference may imply that US users are not as cognizant of cellular data usage as South African users, who may take more active measures against using mobile data when not in a Wi-Fi area. It also points to the possibility that mobile data in the US is more affordable than in South Africa, or that perhaps US mobile carriers offer better data plan options that allow for more cellular data usage and are typically not prepaid (i.e., pay-as-you-go).

Interestingly, of the top-five applications in the United States, Facebook has the second highest median of average monthly Wi-Fi and cellular usage in the United States, behind only Netflix. In fact, Facebook and Google + report higher usage than YouTube, even though as a streaming application YouTube generally uses much more data. This finding underscores the popularity of social networking applications among users in the United States. In South Africa, Facebook has the highest median of average monthly Wi-Fi and cellular usage and is the only application showing higher cellular usage than Wi-Fi usage. The popularity of Facebook indicates a preference for social media use in South Africa over other Internet activities (Stork et al, 2013; Mirani, 2015).

In contrast, YouTube data usage is relatively low compared to communications and social networking applications, perhaps implying that South African users may be more cautious of using data-intensive real-time streaming applications than communications and social networking applications on their mobile devices. Although this metric of YouTube data usage is fairly low, YouTube is the most used application by number of bytes in South Africa. This discrepancy may be due to extremely high usage by certain outliers, which would rank the application very high in terms of total data usage, whereas the metric comparing median of average monthly usage per device mitigates the influence of these outliers and reflects a lower YouTube usage on a typical device.

Finally, the fact that Wi-Fi usage of Google Play Store app nearly doubles cellular usage indicates that users may adopt various strategies to optimize mobile data usage, including changing settings to disable automatic software updates and postponing use until connected to Wi-Fi, as stipulated by Mathur et al. (Mathur et al, 2015). These observations all indicate a higher dedication among South African users to conserving data usage when on a cellular connection.

5.3. *Effects of data cap type on mobile data usage for top five popular applications in US vs. ZA*

To understand whether unlimited, limited, or prepaid plans affect data usage in each country, we measure usage breakdown by data cap type for the top five applications in each country, throughout the entire period of study.

Figs. 3 and 4 show that, in the US, users on limited and unlimited plans have much more data usage than those on prepaid plans. On

Table 3
Top 5 apps by total data usage for US vs. ZA.

US	ZA
1. Netflix	1. YouTube
2. YouTube	2. Facebook
3. Facebook	3. Chrome
4. Google+	4. Correo
5. Browser	5. Google Play Store

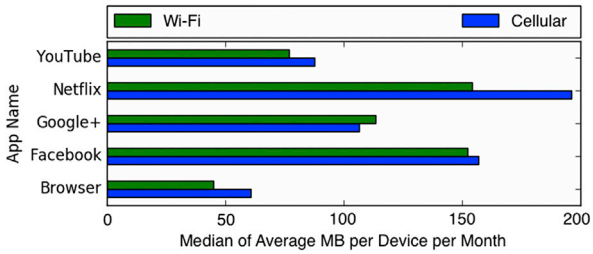

Fig. 1. Usage breakdown by connection type for top 5 apps in the US.

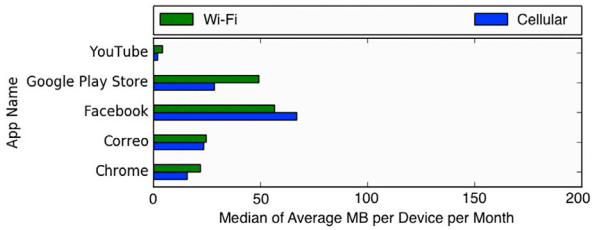

Fig. 2. Usage breakdown by connection type for top 5 apps in South Africa.

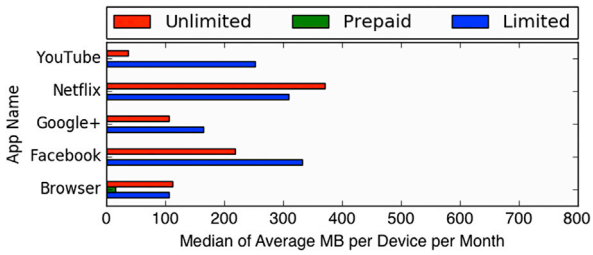

Fig. 3. Usage breakdown by data cap type for top 5 apps in the US.

the other hand, users on prepaid plans in South Africa show much higher usage than those on other types of plans.[4] Unfortunately, the number of South African users on prepaid plans in our dataset is small, so it is difficult to draw general conclusions from these findings; nevertheless, even this small dataset indicates trends that warrant further exploration.

5.4. Differentiated effects of data cap and connection type on mobile data usage in US vs. ZA

We now study the individual effects of: (1) mobile data usage on Wi-Fi vs. cellular connections and (2) mobile data usage on unlimited vs. limited vs. prepaid plans.

We study usage for YouTube and Facebook, the two applications that are in the top five for both the United States and South Africa. Table 4 shows the results of the usage breakdown by both features for each application in the two countries, again using median of average monthly usage as our metric of comparison.

We first explore usage in the US, recalling that breakdown by only connection type revealed higher cellular usage than Wi-Fi usage. By holding data cap type constant and comparing usage on different connection types, we find that users on limited plans contribute most to this difference for these two applications, using both apps significantly more on cellular than on Wi-Fi. This finding is consistent with the possibility that limited data plans in the US have higher monthly data caps, placing fewer constraints on cellular usage. Interestingly, US users on unlimited plans report lower Wi-Fi and cellular usage than those on limited plans. A possible confounding factor is that users who have unlimited data caps may also have other means of Internet access, whereas users with limited data plans may be more financially constrained and less likely to have alternative means of Internet access. Users on prepaid plans contribute almost no appreciable usage, but the small amount of usage on YouTube is higher on Wi-Fi connections than on cellular connections, as users would likely not want to use up their prepaid cellular data on a data-intensive streaming application.

In South Africa, when comparing usage on different connection types while controlling for data cap type, we see that users on

[4] Due to the low number of users on prepaid plan (only 10) these results may exhibit some skew.

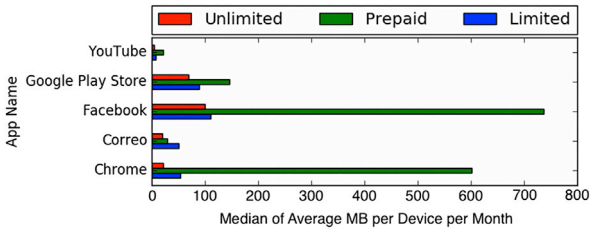

Fig. 4. Usage breakdown by data cap type for top 5 apps in South Africa.

prepaid plans have the highest average usage. Oddly enough, cellular usage of Facebook is three times that of Wi-Fi usage among this category of users, implying that prepaid users make up the category that contributes most to the overall higher cellular than Wi-Fi usage on the application. This finding reflects the increasing pervasiveness of the social media application among users in South Africa. Looking at YouTube usage for each data cap type, we observe that the preference for Wi-Fi over cellular usage for the app is clearly reflected in the table for users on all data cap types, confirming cellular data conservation practices for usage of streaming applications.

6. Zero-rating effects on mobile data usage in South Africa

In addition to the above comparisons between mobile usage behaviors in the United States and South Africa, we perform a more focused study on the effects of zero-rating on mobile data usage in South Africa. We focus on South Africa because zero-rating services have been offered by major South African operators for some time (Chair, 2015) and mobile data in the country is relatively expensive in comparison to other African countries (RIA, 2013).

Several carriers have implemented zero-rating promotions in South Africa. MTN, the dominant operator, was the first to offer Facebook for free. Cell C, another major market player, has also embraced zero-rated Free Basics and WhatsApp to gain market share in a de facto duopoly market dominated by Vodacom and MTN (Futter and Gillwald, 2015).

In the context of zero-rating, our study compares data usage on WhatsApp between the four predominant carriers in South Africa: Vodacom, Cell C, MTN, and Telkom.[5] Cell C zero-rated WhatsApp for mobile users on its network from November 19, 2014 to August 31, 2015, before switching to a bundle offer under which users could use the app for 30 days up to a usage cap of 1 GB, excluding voice calls, for ZAR 5 (approximately USD 0,36[6]).

We also explore Twitter usage, motivated by the fact that MTN had zero-rated this application in a temporary promotion from May 1 to July 31, 2014, and again during the ICC Cricket World Cup from February 14 to March 29, 2015. Although the Cricket World Cup ended in March 2015, the offer was maintained and is still active (excluding multimedia content and images) today. With this knowledge, we want to explore whether temporal usage patterns reflect this time-dependent zero-rating.

Table 5 summarizes the most popular zero-rated practices in South Africa from May 2014 until present.

6.1. *Effects of zero-rating WhatsApp on cell C's network*

We now study Wi-Fi vs. cellular mobile usage behaviors before, during, and after Cell C's WhatsApp zero-rating period. We compare mobile usage across different mobile operators, with the goal of analyzing whether mobile usage behaviors reacted to the different types of promotions, transitioning from no offer to completely zero-rating the app to the bundle offer of a generous monthly usage allowance for a small fee.

Fig. 5 shows WhatsApp's usage by connection type for the four main South African carriers before the zero-rating period. Overall, WhatsApp usage on Cell C during this time is similar to usage on the other carriers; users exhibit comparable overall median of average monthly usage and display higher cellular than Wi-Fi usage. Interestingly, Cell C has the lowest Wi-Fi usage on WhatsApp, with a median of around 2.5 MB of average monthly usage per device. Cellular usage on the application is about three times as high, at around 7.5 MB.

Fig. 6 shows WhatsApp's usage breakdown by connection type for the four main South African carriers during Cell C's zero-rating period. Cell C usage has gone up, with Wi-Fi usage increasing almost sevenfold to a median of around 17 MB of average monthly usage per device, and cellular usage increasing almost threefold to a median of around 22 MB. This result indicates that zero-rating WhatsApp may have had remarkable effects on its usage,[7] increasing the application's use not only on cellular connections, but even more so on Wi-Fi connections. During this period, WhatsApp has become much more popular overall, regardless of connection type

[5] In addition, Cell C, in collaboration with Facebook, launched Free Basics on its network on July 1, 2015. Although we wanted to conduct a similar comparative study on Free Basics data usage for Cell C vs. the other network carriers in South Africa, upon searching for the app among our entire user base, we found that only a handful of users had the app installed, and they were all on a network called Airtel. Thus, due to the current lack of available data, we are at the moment unable to properly study the effects of launching the zero-rated Free Basics application in South Africa.

[6] Historical exchange rate, first week of September 2015, ZAR/USD = 0.0720. Source Oanda.

[7] Similar conclusions on the effect of free content services on usage are found in Galpaya, Zainudeen, and Suthaharan (2015), even though Galpaya's research approach is based on nationally representative surveys. One of the findings of their nationally representative survey conducted in Myanmar shows that when telecommunications companies offer content for free, and users know about it, adoption levels are high.

Table 4
US vs. ZA usage breakdowns by data cap and connection type for YouTube and Facebook.

App Name	Data Cap	US		ZA	
		Wi-Fi (MB)	Cellular (MB)	Wi-Fi (MB)	Cellular (MB)
YouTube	Unlimited	24.587	10.893	2.444	1.904
	Limited	88.588	133.549	4.331	1.508
	Prepaid	0.049	0.021	8.721	0.034
Facebook	Unlimited	94.597	116.971	49.427	25.399
	Limited	144.927	290.357	42.036	68.579
	Prepaid	0.000	0.000	139.814	443.703

Table 5
Zero-rating practices among South African carriers.

Carrier	Application	Offer	Duration
Cell C	WhatsApp	No offer	Before 11/19/14
		Zero-rated	11/19/14-08/31/15
		Bundle offer	09/01/15-present
Cell C	Free Basics	No offer	Before 07/01/15
		Zero-rated	07/01/15-present
MTN	Twitter	No offer	Before 05/01/14
		Zero-rated	05/01/14-07/31/14
		No offer	08/01/14-02/13/15
		Zero-rated	02/14/15-present
Vodacom	Facebook Flex	Zero-rated	01/17/17-present

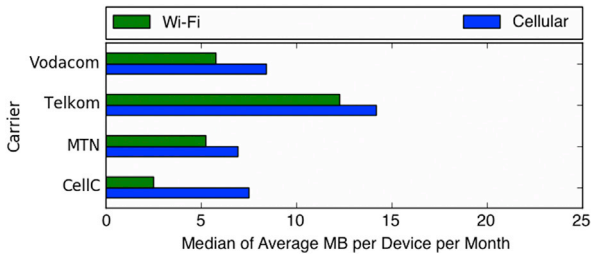

Fig. 5. WhatsApp usage breakdown for ZA carriers: no offer.

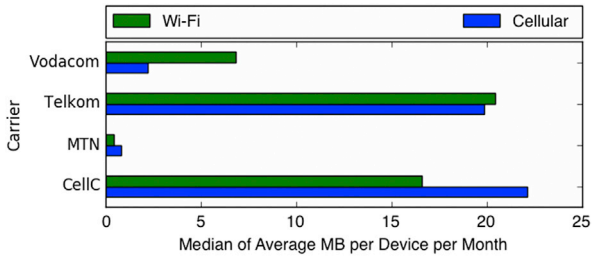

Fig. 6. WhatsApp usage breakdown for South African carriers: Cell C zero-rating offer.

(Sundararajan, 2013).

Interestingly, we also observe behavioral changes in WhatsApp usage for the other three carriers during this period. Both Vodacom and MTN overall usage of the app have decreased, while overall usage on Telkom has increased. Wi-Fi usage on both Vodacom and Telkom have become higher than cellular usage during this period as well. Unfortunately, the number of unique users on each carrier in our dataset during this period is not high enough to draw conclusive results. Table 6 summarizes the number of users in the dataset over this period.

Fig. 7 shows WhatsApp usage by connection type for the four main South African carriers during its bundle offer period. We observe that the single user on Cell C does display a high monthly median usage on WhatsApp, comparable to usage seen during the zero-rating

Table 6
Number of WhatsApp users for each carrier and time interval.

Carrier	Before 11/19/14	11/19/14-08/31/15	08/31/15-present
Vodacom	89	10	1
Cell C	46	4	1
MTN	60	4	0
Telkom	14	1	0

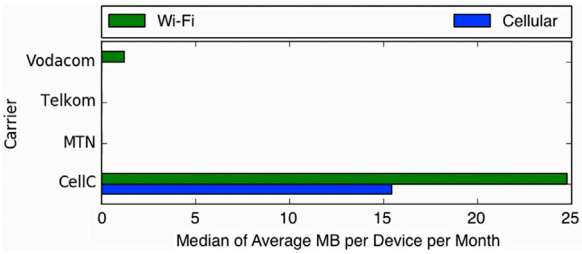

Fig. 7. WhatsApp usage breakdown for ZA carriers: Cell C bundle offer.

period, and certainly much higher than usage before any of Cell C's promotional offers. This observation is not statistically significant; the single data point is merely suggestive and points to the need to gather more data to explore this effect in more detail.

6.2. *Effects of zero-rating twitter on MTN's network*

We now examine the effects of MTN's time-dependent zero-rating of Twitter during promotional periods by studying temporal usage patterns. MTN zero-rated Twitter from May 1 to July 31, 2014, and from the beginning of the ICC Cricket World Cup in February 2015 onward. Fig. 8 shows the corresponding time-series plot of average daily Twitter usage per device on Wi-Fi vs. cellular connections.

Our results generally indicate much higher cellular usage than Wi-Fi usage throughout the year, aside from a small bump in Wi-Fi usage over cellular usage in October 2014. The period from the end of March through the beginning of May 2014 reflects the lack of data in the beginning of the second quarter due to a drop in usage resulting from problems with the MySpeedTest application.

The largest increase in both cellular and Wi-Fi data usage seems to correspond to the holiday season in December. This result makes sense, because social media platforms like Twitter are often used during holiday seasons for advertising and marketing, searching for and sharing gift ideas, posting wish lists, and spreading general holiday cheer (Stringfield, 2013).

The period from June to July 2014 shows the second most significant peak in cellular data usage. This characteristic suggests that MTN's promotional zero-rating of Twitter during this period may have had some effect on user behavior. Cellular usage seems to increase around early June, reflecting a slight delay in users' response to the announcement of the promotional offer. Usage peaks at slightly over 40 MB a day in mid-July, near the end of the event, before gradually decreasing throughout August and September. The fact

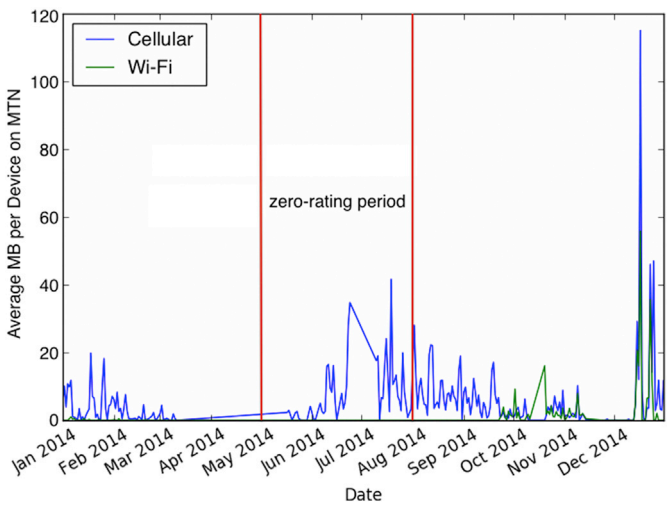

Fig. 8. Time series of average twitter usage per device on MTN.

that usage remains relatively high throughout the months immediately following the promotion suggests that the promotion does seem to maintain some heightened level of interest and use in the application for a while, but by the end of the year cellular usage of the app has returned to the pre-promotion levels seen at the beginning of the year. Thus, our results suggest that promotional events like zero-rating Twitter for a certain period of time may not have lasting effects on the application's popularity, though it may increase short-term usage during and immediately following the promotion. Because our dataset contains zero MTN Twitter users after January 2015, we are unable to analyze the zero-rating effects during the Cricket World Cup.

7. User motivations and attitudes concerning zero-rating in South Africa and Kenya

To better understand user motivations behind zero-rating usage, we administer a mobile-based survey to 150 Kenyan users and 150 South African users. In this section, we report and compare our main findings, most of which are consistent across both countries. Although the recruitment method used may introduce a bias towards users who are more inclined to respond to incentivized methods of recruitment, the method nonetheless yields a large and representative sample size.

7.1. Mobile internet usage, access, and conservation practices in South Africa and Kenya

Table 7 displays a comparison of how often respondents in each country claim to perform different activities during online mobile sessions.

These results show that social networking and messaging applications dominate online mobile usage for both Kenyan and South African respondents. Entertainment and education- or work-related applications show less frequent usage. Overall, respondents in both countries follow similar online mobile usage patterns.

Table 8 shows how often mobile users use various methods to conserve mobile data, giving us insights into the variety and extent of data conservation practices among our respondents.

These results indicate that closing inactive applications and avoiding data-consuming applications are the most popular methods of conserving mobile data among survey respondents in each country. Tracking data usage and turning off mobile data entirely are less commonly used alternatives; fewer respondents opt to turn off their devices entirely to conserve data. Overall, we do see a deliberate effort among respondents in both countries to conserve mobile data using these techniques. These results corroborate Mathur et al.'s findings (Mathur et al, 2015) that both South African and Kenyan users display a strong inclination toward active data conservation methods.

The presence and effects of zero-rating practices among respondents are captured using a set of questions that investigate whether users know about zero-rating services, and if so, whether they have used or are currently using these services.

Our survey data show that 39% of Kenyan respondents know about zero-rated plans offered by their mobile carrier throughout 2015; more than a half (53%) have used a zero-rated plan in the past and about a quarter (26%) are currently using one. In South Africa, less respondents than in Kenya (23%) know about zero-rated plans throughout 2015, with 29% having used one in the past and only 15% currently using one.

Fig. 9 shows why respondents currently use a zero-rated plan or have used one in the past. The largest percentage of respondents in each country claim they have used or are currently using a zero-rated plan to access popular zero-rated applications like Facebook, Wikipedia, and Twitter for free. Compared to South African respondents, many more Kenyan respondents claim that paid plans are too expensive, and therefore they find it more convenient to use zero-rating plans, indicating that zero-rated applications are used to help conserve mobile data usage.

Table 7
Online mobile Internet usage distribution of Kenyan and South African respondents.

Activity	Never		Hardly ever		Sometimes		Most of the time		Always	
	SA	Kenya	SA	Kenya	SA	Kenya	SA	Kenya	SA	Kenya
Email	3%	1%	8%	2%	23%	29%	26%	22%	39%	46%
Social networking	0%	1%	5%	0	19%	10%	31%	26%	45%	63%
Messaging	1%	1%	2%	1%	10%	8%	22%	21%	65%	69%
Entertainment	6%	3%	7%	7%	43%	41%	19%	29%	25%	21%
Education/work related	7%	2%	5%	4%	35%	31%	27%	31%	25%	31%

Table 8
Data conservation practices among South African and Kenyan respondents.

Activity	Never		Hardly ever		Sometimes		Most of the time		Always	
	SA	Kenya	SA	Kenya	SA	Kenya	SA	Kenya	SA	Kenya
Turn off device	31%	30%	27%	37%	32%	27%	4%	5%	6%	2%
Turn off mobile data	18%	17%	16%	15%	35%	43%	17%	17%	15%	8%
Close inactive applications	7%	8%	5%	16%	28%	24%	29%	19%	31%	33%
Avoid high data applications	7%	6%	13%	8%	29%	34%	29%	26%	22%	26%
Track data usage	20%	12%	15%	22%	28%	36%	21%	12%	15%	18%

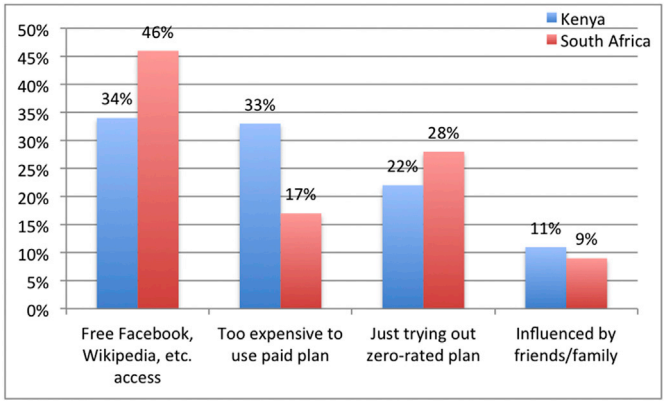

Fig. 9. Reasons for using a zero-rated service.

The survey also indicates that 59% of Kenyan respondents claim to use regular applications and services more often than zero-rated ones, while 30% use both types equally. Only 11% use zero-rated applications more than regular ones. We find a similar distribution in South Africa, where 54% of respondents use regular applications more often than zero-rated ones, 30% use both types equally, and 15% use zero-rated applications more than regular ones. These results imply that while consumers may try to conserve data usage by using zero-rated applications, the majority still use regular applications and services more often than zero-rated ones. In fact, a majority of the respondents in both countries who have used zero-rated plans in the past were no longer using them at the time of the survey.

Fig. 10 shows a distribution of various reasons why respondents stopped using a zero-rated service.

The majority of respondents in each country (65% in Kenya and 57% in South Africa) report that given the choice, they would prefer to use a non-zero-rated application with full functionality instead of a zero-rated application with limited functionality. These findings serve as a counterpoint to the walled garden argument that zero-rated applications discourage consumers from using the full Internet. In fact, our respondents prefer to use full-service applications on paid plans, even with the option of using a limited-service application on a zero-rated plan. Our Kenya survey data include only two users who had not used the Internet prior to using a zero-rated plan, with one now using a paid plan and one not. In South Africa, we find no users at all for whom zero-rating served as an initial exposure to the Internet. Thus, we do not find strong evidence for or against zero-rating as a gateway to full Internet usage for new Internet users. Instead, our results indicate that zero-rated applications and services offer consumers a way to save on mobile data usage in conjunction with other methods of data conservation, an effort toward which both South African and Kenyan users show strong inclinations.

8. Conclusions and policy implications

This paper studies three aspects of the effects of mobile data pricing on mobile data usage behaviors: (1) An exploratory analysis comparing mobile usage patterns between the United States and South Africa; (2) An analysis on the effects of zero-rating WhatsApp and Twitter in South Africa; and (3) A survey-based study on zero-rating attitudes and behaviors in South Africa and Kenya. The aim of the first portion of the study is to explore how overall data costs affect mobile data use; the second portion explores how different pricing strategies affect mobile data use; and the last portion explores user perceptions and attitudes that can help explain the effects observed in the first two parts of the study.

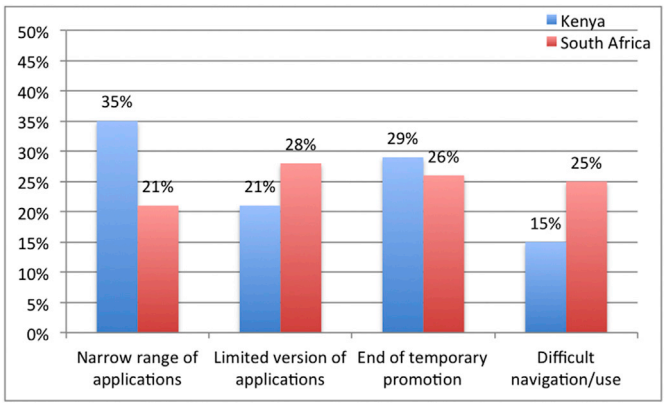

Fig. 10. Reasons for no longer using a zero-rated service.

Exploring mobile data usage in the United States vs. South Africa, we find that social networking and entertainment applications are popular in the United States, while the most popular applications in South Africa are more varied, ranging from web-browsing to communications to social networking to entertainment applications. Further investigation of mobile usage behavior reveals that US users display higher overall mobile usage than South African users, and exhibit higher cellular than Wi-Fi usage even for data-intensive applications. On the other hand, South African users seem wary of cellular data usage, generally preferring Wi-Fi usage, perhaps indicating a higher dedication to conserving cellular data usage. Although in general South African users are more cognizant of cellular data usage, Facebook presents an exception to this observation. As one of the most prevalent social media applications in both the United States and in South Africa, Facebook displays higher average cellular than Wi-Fi data usage for both countries.

When assessing the effects of zero-rating on mobile usage in South Africa, we find that overall usage of WhatsApp increases during a zero-rating period, regardless of connection type. This increase in popularity of a zero-rated application is corroborated by the case of zero-rating Twitter on MTN, where we observe increased usage of the app on MTN during and immediately following the zero-rating period. On the other hand, we find that users may not be willing to continue heightened use of the application in the long term after the promotion has ended.

Analysis of qualitative survey data in Kenya and South Africa shows the popularity of zero-rated services both in Kenya and in South Africa. One of the more interesting findings is that the majority of zero-rating users prefer full-service applications on a paid plan to limited-service applications on a zero-rated plan. These findings suggest that rather than creating a walled garden discouraging users from using the full Internet, zero-rating in fact provides a popular method of data conservation.

These findings bring upon important policy implications and recommendations. Banning zero-rated services through regulation in order to preserve the open internet as we know it may limit Internet use for price sensitive users and for those who cannot afford data services otherwise. Rather, to reduce some of the harms that could arise from zero-rated services, policy makers should monitor the effects of zero-rating on Internet use in the medium and long terms, for both Internet and non-Internet users. As this study has demonstrated, some of the assumptions of the walled garden theory are withdrawn by simply monitoring mobile usage reactions to different plans and promotions.

A natural extension of the study would be to analyze the effects of zero-rating usage on people who are not yet using the Internet, to more conclusively differentiate between the "walled garden" and "gateway drug" effects on Internet use. It may also be interesting to see if users are more likely to adopt zero-rated services offered by one network over another network. Conducting a nationally representative ICT access and use survey would ensure an unbiased sample and stronger research conclusions.

We must also actively recruit more MySpeedTest users for the longitudinal portion of our study. As our conclusions show, a larger and more diverse sample of users is particularly important in South Africa. We especially want to target recruitment toward users on prepaid plans and across all network operators, so that we can re-run our analysis code to assess pricing effects on mobile usage for a broader dataset.

Finally, it may be interesting to narrow the scope of this research from a broad exploratory analysis to a study on the predictive powers of various pricing features on mobile data usage.

Acknowledgments

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References

Alliance for Affordable Internet (A4AI). (2015). *Measuring the impact of mobile data services in developing countries*, 20 October 2015. [Online]. Available: http://a4ai.org/measuring-mobile-data-services/.

Bathia, R. (2016). *The inside story of Facebook's biggest setback". The long read. The Guardian*. May 12, 2016. Available: https://www.theguardian.com/technology/2016/may/12/facebook-free-basics-india-zuckerberg.

Chair, C. (2015). *Africa supply side assessment of Zero rating. Presentation at IGF*. November 10, 2015. Available at: http://www.researchictafrica.net/presentations/Presentations/2015_Chair_Zero%20Rating%20presentation_IGF2015.pdf.

De Guzman, N. F. (2014). *Zero rating: Enabling or restricting internet access?* Internet Society. September 24, 2014. Available: https://www.Internetsociety.org/blog/asia-pacific-bureau/2014/09/zero-rating-enabling-or-restricting-Internet-access.

Drossos, A. (2015). *The real threat to the open internet is zero-rated content*. World Wide Web Foundation. Available: http://webfoundation.org/wp-content/uploads/2015/02/The-_real-_threat_open_Internet_zerorating_logos.pdf.

Eisenach, J. A. (2015). *The economics of zero rating. NERA economic consulting*. March 2015. Available: http://www.nera.com/content/dam/nera/publications/2015/EconomicsofZeroRating.pdf.

Futter, A., & Gillwald, A. (2015). *Zero-rated Internet services: What is to be done?*. Policy Paper 2015: Broadband 4 Africa September 2015. Available: http://www.researchictafrica.net/publications/Other_publications/2015_RIA_Facebookzerorating_policy_paper.pdf.

Galpaya, H., Zainudeen, A., & Suthaharan, P. (2015). *A baseline survey of ICT and knowledge access in Myanmar*. August 2015. Available: http://lirneasia.net/wp-content/uploads/2015/07/LIRNEasia_MyanmarBaselineSurvey_DescriptiveStats_V1.pdf.

International Telecommunications Union. (2016). *World telecommunication/ICT indicators database 2016. Indicator on percentage of individuals using the internet*.

Joe-Wong, C., Ha, S., Sen, S., & Chiang, M. (2014). *Do mobile data plans affect Usage? Results from a pricing trial with ISP customers*. Available: http://www.princeton.edu/~cjoe/MTA_PAM.pdf.

Leidel, S. (2015). *Zero rating: Why are people using a half-baked Internet*. DW Akademie, 12 February 2015. Available: http://www.dw.com/en/zero-rating-why-are-people-using-a-half-baked-Internet/a-18887956.

Malcom, J., McSherry, C., & Walsh, K. (2016). *Zero rating: What it is and why you should care*. Electronic Frontier Foundation, 19 February 2016. Available: https://www.eff.org/deeplinks/2016/02/zero-rating-what-it-is-why-you-should-care.

Mathur, A., Schlotfeldt, B., & Chetty, M. (2015). A mixed-methods study of mobile users' data usage practices in South Africa. In *Proceedings of the 17th ACM International Conference on Ubiquitous computing, ser. UbiComp '15. ACM, 2015* (pp. 1209–1220). Available: http://dblp.uni-trier.de/db/conf/huc/ubicomp2015.html#MathurSC15.

Mirani, L. (2015). Millions of Facebook users have no idea they're using the Internet Quartz. February 9, 2015. Available: http://qz.com/333313/milliions-of-facebook-users-have-no-idea-theyre-using-the-Internet/.

MySpeedTest. (2016). *MySpeedTest by GTNoise*. Available at: https://play.google.com/store/apps/details?id=com.num&hl=en.

Nowak, P. (2015). *Why 'zero rating' is the new battleground in net neutrality debate*. CBC News: Business, 07 April 2015. Available: http://www.cbc.ca/news/business/why-zero-rating-is-the-new-battleground-in-net-neutrality-debate-1.3015070.

Research ICT Africa (RIA). (2013). *How do mobile and fixed broadband stack up in SA?*. RIA Policy brief South Africa No 2, July 2013. Available at: http://www.researchictafrica.net/polbrf/Research_ICT_Africa_Policy_Briefs/2013_Policy_Brief_2_How_do_mobile_and_fixed_broadband_stack_up_in_SA.pdf.

Sandvine Intelligent Broadband Networks. (2014). *Global internet phenomena: 2h 2014*, 21 November 2014. [Online]. Available: https://www.sandvine.com/downloads/general/global-Internet-phenomena/2014/2h-2014-global-Internet-phenomena-report.pdf.

Sandvine Intelligent Broadband Networks. (2015). *Global Internet phenomena report: Africa, middle east & north America*, 04 December 2015. [Online]. Available: https://www.sandvine.com/downloads/general/global-Internet-phenomena/2015/global-Internet-phenomena-africa-middle-east-and-north-america.pdf.

van Schewick, B. (2015). *Net neutrality and zero-rating, filing at federal communications commission*. Available: http://apps.fcc.gov/ecfs/document/view?id=60001031582.

Shearsl, M. (2014). *No. 208 net neutrality, zero-rating & development: What's the data?* Center fo Democracy and Technology. Available: https://www.intgovforum.org/cms/wks2014/index.php/proposal/view_public/208.

Stork, C., Calandro, E., & Gillwald, A. (2013). Internet going mobile: Internet access and use in 11 African countries. *Info, 15*(5), 34–51.

Stringfield, J. (2013). *Study: Twitter's influence on holiday shopping*. Twitter, 07 October 2013. Available: https://blog.twitter.com/2013/study-twitters-influence-on-holiday-shopping.

Sundararajan, A. (2013). *Network effects*. Available: http://oz.stern.nyu.edu/io/network.html.

The Centre for Internet & Society. (2014). *What is net neutrality and why it is important*, 20 January 2014. Available: http://cis-india.org/news/times-of-india-january-20-2014-what-is-net-neutrality-and-why-is-it-important.

Walubengo, J. (2016). *Zero-rating of mobile services in Kenya. Study commissioned by Research ICT Africa*. Under publication.