Least Cost Remote Learning for Under-Served Communities

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Abstract. Remote teaching and learning (RTL) is a system of education, wherein teachers and learners are not in the same location but separated by time and space. Global pandemics such as the COVID-19, necessitate social distance, thereby rendering traditional "contact" based classroom learning unfeasible. e-Learning which is a viable alternative often depends on reliable Internet. Unfortunately, Internet penetration in many areas of the world is still abysmally low. RTL in these under-served regions of the world is thus a major challenge. In this paper, we review the state of RTL and consider feasible options for under-served communities. Requirement for RTL, including data and associated cost of attending classes online are also considered. Finally, recommendations for achieving least cost RTL for under-served communities are given.

Keywords: e-Learning · Remote teaching · Distant learning · Rural development · Network connectivity

1 Introduction

Remote teaching can implicitly be defined as teaching from a distance or one in which the teacher and students are not physically in the same location. There are a number of formalized definition for remote teaching, among which are "a setting where the learners and teachers (or information source) are separated by time and distance and therefore cannot meet in a traditional classroom setting" [1]. The Merriam-Webster dictionary defines it as a means of education where teachers and students meet outside the conventional classroom environment, but rather use electronic means to have classes [2]. A common thing among the numerous definitions is the partial or complete absence of a formalized physical teaching and learning environment such as a physical classroom. This instead is mostly replaced with electronic alternatives such as emails, videos, voice recordings, lecture slides or presentations and virtual classrooms.

Remote Teaching and Learning (RTL) up until now might have remained a luxury rather than a necessity; however in times of epidemic outbreaks such as the recent COVID-19 pandemic caused by a type of Coronavirus and transmitted via interpersonal contacts [3], the world has had to adopt it. A fundamental requirement for live and interactive RTL is the Internet. In many developed

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countries of the world, Internet access is common place, however, this is not the case globally especially in Africa and parts of Asia. A report by the International Telecommunication Union (ITU) shows that in 2019, less than 30% of Africans had access to Internet. Similarly in the same period only 48% of Asians could access the Internet. These figures are in sharp contrast to those of Europe (83%) and the United States (77%) [4]. Figure 1 shows the global Internet penetration rate according to the ITU.

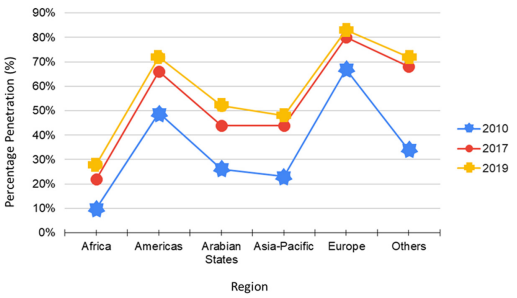

Fig. 1. Global internet penetration rate [4]

In a similar report by the Internet World Stats [5], 500 million users accessed the Internet in Africa as at end of 2019. This number represents less than 40% of the entire African population and only 11% of the total number of global Internet users. This low Internet penetration rate can be attributed to a number of factors many of which are not unrelated to poverty and under development. We refer to these areas as under-served communities.

In this paper, we perform a survey of RTL in under-served areas of the world, such as Africa and parts of Asia. We consider a number of RTL options and their viability in these parts of the world. We perform a systematic analysis, taking into consideration the amount of data required and the cost of accessing the Internet in these under-served communities. From these we make suggestions on the best ways to achieve low cost RTL in these communities.

The rest of the paper is arranged as follows: a review of RTL options is done in Sect. 2, followed by a data requirement to cost mapping in Sect. 3. These are followed by our recommendations for under-served communities in Sect. 4, while Sect. 5 concludes the paper.

2 Review of Literature

2.1 Learning Platforms

Television: The Television (TV) has for a long time played a vital role in education. The term educational or instructional TV refers to the utilization

of television and/or television programs to argument learning [6]. Though particularly useful in teaching younger children (in pre- and elementary school), it has also found useful application in high school and tertiary institution. It is thus a very useful RTL tool [7]. Educational TV is often applied in a number of ways, such as: i.) One-way broadcast: wherein student viewers simply watch live or pre-recorded lesson(s) via the TV. Communication here is purely unidirectional, from the teacher to the student(s). ii.) Pseudo-Interactive broadcast: a model similar to the direct broadcast, however, a moderator can pause the playback to allow for audience engagement in form of questions or to emphasize certain concepts. iii.) Two-way Interactive broadcast: wherein teaching is augmented with telecommunication, thereby allowing for a two-way communication between the teacher (who is live) and the student(s). Asides from the traditional teacher-student learning, the TV also plays a prominent role in indirect teaching. This, often referred to as"edutainment", is one in which educational contents are infused into entertainment programmes. This indirect learning is targeted at all ages, and includes TV stations such as: Nickelodeon with programmes primarily designed for children and teenagers, to National Geographic and Discovery World targeting a wider and older age bracket. In [8], the authors did a comprehensive survey of the role of TVs in education in Kenya. They considered different types of TVs and their functions as it relates to education. A similar work was done in [9], but targeted at teachers' view and use of TVs as a learning tool in a city in Nigeria.

Radio: Radio has long since been a tool of mass media. Its relative affordability and easy of understanding has helped its wide spread global adoption. With respect to RTL, radios have played a pivotal role, especially in under-served communities. They have been used as a medium: to reach/inform local farmers, for spiritual guidance by religious leaders and for formal teaching and learning as is the case with RTL. The authors in [10], surveyed various ways radios have been used in RTL in developing countries. Some of these include: literacy and language training, family planning and farming best practices. In [11], the authors discussed open challenges to effective learning using radios; while in [12], initiatives for radio-based learning in under-served communities are discussed.

Podcasts: A Podcast is akin to a radio programme, albeit one that is available on-demand and accessible through the Internet. It is a digital audio file shared among listeners through the Internet [13]. Podcasts unlike regular audio streaming are episodically and uses RSS (Really Simple Syndicate). This provides automatic notification and the ability to download new content [15]. Podcasts have in recent times gained widespread popularity with about 1 million active podcasts and over 50 billion streams till date [14]. Among the numerous advantages of podcasts, the two most important for education are: on-demand listening, such that listeners can listen to whatever they want, from wherever they are and at any time they want [17] and replay value or replayability. As an educational tool, [13,15,16], have surveyed the applications of podcasts as an excellent tool

for RTL new languages. Salas and Moller [18] have also shown the advantages podcasts and other multimedia platforms have on learners when used in tandem with traditional learning techniques. The authors in [17] and [19], extensively surveyed the impact of podcasts in education and gave numerous examples to justify their usefulness educational tools.

Despite the advantages of podcasts, some of its inherent disadvantages are its inability to hold students' attention, which might be a major challenge. Similarly, if not well managed Podcasts, might end up being distractions to students. There is also the risk of teachers becoming complacent, replacing actual teaching with podcasts. Students might also abandon actually studying/reading books in favour of podcasts. Finally, podcasts might be restrictive if used alone, rather than as a tool to augment traditional teaching [16,18].

Webinars: Webinar or Web-seminar are presentations (usually video), workshops or lectures delivered in a virtual room through the Internet [20]. UNICEF defines it as an online learning event, meant to impact knowledge or skills using audio-visuals [21]. Two major reasons behind the widespread global adoption of webinars are the relative ease of setting them and limited resources (financial) requirement. Costs of auditoria, accommodation, security, flight and other logistics often associated with physical conferences/seminars are eliminated with Webinars. These are traded for Internet access.

Webinars have found applications as marketing and sales tool [23], as conference/business collaboration tool [22] and for RTL [21,22]. Unlike webcasts (such as Podcasts) which are often uni-directional broadcast, Webinars allow for interaction between the audience and presenter(s). Webinars are excellent tool for RTL in under-served communities because they are cheap to setup, can be recorded and distributed to students/participants, can be assessed through multiple platforms (mobile, web, computers etc.); and allow for interactivity through audio Q&As, opinion polls, direct messages and text-based chats. For bandwidth conservation, webinars can also be audio only, with accompanying slides distributed afterwards. Of these factors, perhaps the most important advantage of webinars is their ability to be recorded and distributed to participant, to be replayed (repeatedly) at convenient times. Specifically because in most rural/developing communities, stable Internet connectivity (if in existence) is a luxury not many can afford.

Zoom [22], Skype [24], Google Meet [25], BigBlueButton [26] are some of the common platforms for hosting webinars. Skype and Zoom both offer features tailored to education such as: whiteboards, annotation and integrated into Learning Management Systems (LMS). Google Meet is a part of the Google Ecosystem and has excellent integration with Google Classroom. BigBlueButton (BBB) unlike the platforms (which only incorporate educational features as add-ons) was designed ground up for education and online learning. It features include: webcam integration, private/public chat, polling, breakout rooms, single and multi-whiteboards etc.

Massive Open Online Course (MOOC): Massive Open Online Course (MOOC) as the name connotes are courses availed to a large number of learners, freely through the Internet [43,51]. Initially provided and managed by Universities, MOOC became popular in the early 2010s and were popularized by MOOC providers such as edX (2012) [32], Coursera (2012) [33] and Udemy (2010) [34]. Though MOOCs are in themselves free, providers often require learners to pay to access courses with edX being an exception to this. Born from a collaborative effort of a number of Universities (MIT, Harvard, University of California, etc.), edX offers its courses as truly open (and free) to learners.

Despite their numerous advantages and being around for close to a decade, MOOCs are only just beginning to be appreciated in developing countries of Africa and Asia [52]. This poor penetration can be attributed to two factors: i.) their complete reliance on stable Internet connectivity, as the Internet is a major requirement for accessing MOOCs [53]; ii.) lack of accreditation of MOOCs as suitable substitutes to traditional class-taught courses by education authorities [54,55]. However, in recent times, there has been a steady increase in MOOCs in a number of third world countries. Adham surveyed a number of MOOC platforms in Arab countries with SkillAcademy and Edraak being the prominent ones [42]. In Africa, with the exception of a few instances, the closest semblance to MOOCs is the University correspondence learning. Correspondence learning is a form of education where students and teachers are not in the same physical location. Unlike e-Learning or MOOC, there are few or no actual classes in correspondence learning; rather the exchange of assignments, projects and study materials between lecturers and students is done through announcement boards, posts and/or "pigeon holes" [41]. The African Council for Distance Education (ACDE) serves as a unifying body for open and distance education providers in Africa. Some of its members include the National Open University of Nigeria [38], University of South Africa (UNISA) [39] and Zimbabwe Open University [40] etc. Outside the ACDE, African Universities either provide online courses to students directly (such as the UCT Online short courses [37] and the Distance Learning Institute of the University of Lagos (Unilag) [36]), or through MOOC providers (such as those on edX and FutureLearn [35]).

Notwithstanding the technological and infrastructural limitations, efforts are been made to improve MOOCs in Africa. The Rwandan Kepler project is one such example and is one in which students are camped together in IT-enabled camps and taught using MOOC platforms [44]. The "MOOCs for Africa and future emerging countries" of the Swiss Agency for Development and the "New Economy Skills for Africa Program ICT" are other examples [48]. To narrow the digital divide and provided necessary infrastructure, a number of global trust funds in collaboration with the World Bank have incorporated projects targeted at improving economies and education in Africa through digitization. Notable examples of these are the New Economy Skills for Africa Program (NESAP) [45,48], Africa Centres of Excellence [46] and Digital Economy for Africa (DE4A) [47] projects.

2.2 Educational Learning Management Systems

According to the World Bank, "the world is facing a learning crisis" and if unchecked, 56% of children would be half as productive as they should be when they reach adulthood [58]. The UNESCO provides a list of Learning Management Systems (LMS), which includes: ClassDojo, Edraak, Moodle, and Google Classroom [49]. Beyond these, there are a plethora of alternatives including Sakai, Blackboard, PowerSchool, etc. These systems provide resources and tools for managing virtual classrooms and/or remote learners. They incorporate features such as: assignment management, automated marking and grading, whiteboards, chat rooms and resource sharing.

However, despite their rich features sets, many do not address the peculiar nature of under-served areas. For instance, in many parts of Africa, electricity is a still a challenge as many communities are either not connected to the electric grid or where connectivity exists, the supply is irregular and often times completely unavailable for days. Network connectivity is also a challenge in these areas. It is therefore pertinent that LMS support asynchronous and offline functionalities. Only a few solutions support these, notably Kolibri, Paradiso and Moodle. In Kolibri, only one device needs to connect to the Internet and once connected, contents are downloaded to it. Upon returning to the community, the downloaded content are distributed to other devices via local networks [50]. This is a very viable option for remote locations in Africa. Paradiso operates in a similar manner but targets single individual without the re-distribution feature.

Prices of smart phones are dropping and are now more readily accessible to learners in under-served areas. Though, many African dwellers still use feature phones, the mobile operating system KaiOS [59] brings "smartness" to such phones, thereby allowing users run advanced applications on low end devices. With such OS, mobile based LMS could therefore be a suitable platform for learning management in low income areas. Tools such as Cell-Ed and Ustad Mobile are viable options that fit the bill. Cell-Ed, is a mobile based LMS that incorporates micro-lessons, assessments and customized certifications. It also works offline and does not require persistent Internet connection [60]. Like Cell-Ed, Ustad Mobile offers similar features but in a more robust and holistic manner. With features such as virtual classrooms, course work and assignment submission, it is a complete LMS squeezed into a phone. Though it can be used offline, users need to occasionally connect to the Internet to synchronize and update learning contents [61]. Apart from Cell-Ed and Ustad Mobile, other LMS providers also have mobile versions of the systems on both Android and Apple IOS. Though these systems provide similar functionalities as Ustad, they often require persistent Internet connection.

3 Data Requirements and Costing

In this section an analysis of the cost of accessing the Internet vis-à-vis RTL alongside the quantity and accessibility to data required are considered.

3.1 Data Cost

The Internet is a fundamental requirement for RTL. Accessing the Internet can be achieved wired or wirelessly. The proliferation of mobile devices including phones, laptops and tablets have in recent times heightened the adaptation of wireless networks. This is specifically the case, when access is required by anyone and from anywhere. Despite the widespread global adaptation, there are many areas of the world where people have limited wireless network coverage and when available, are often barely affordable. Accessing the Internet for RTL in under-served communities is thus a challenge.

In order to effectively mimic real/physical classroom based teaching, RTL require live two-way video streaming, virtual whiteboards and interactive forums for questions and answers. These require large volume of data, which in most times is outside the reach of learners in these low income areas of the world. Figure 2 shows a comparison of 1 GB data bundle prices for a number of African countries. Data prices were cheapest in Egypt at US$1.13 and most expensive in South Africa at $8.28. The average price of 1 GB data bundle is approximately $2.60 [64].

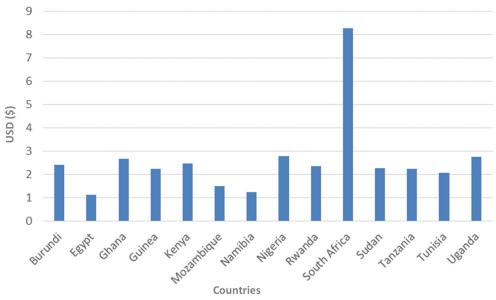

Fig. 2. Comparison of 1 GB data cost across select African nations

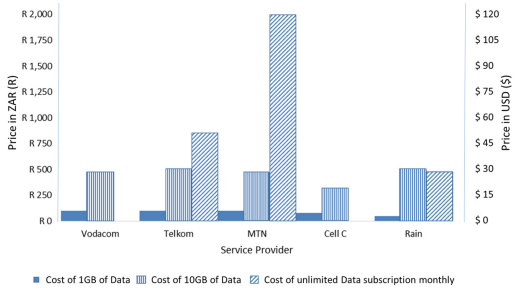

Fig. 3. Cost of data bundles in South Africa

A number of option do exists, including the use of night or off-peak data bundles. These are often times relatively free or significantly cheaper than their peak/day-time counterpart. Survey reports, have shown that it is imperative that learners be on a data bundle, as off bundle prices are exorbitant. In South Africa for instance, in an article published by Fin24 [56], it was reported that telecommunication services providers MTN and Vodacom charged up to 2,100% more for out-of-bundle data. It was also reported that while on contract, a 20 GB data bundles from Vodacom cost ZAR329 ($20) or ZAR0.02 ($1.2E10^{-3}$) per megabyte, while the out-of-bundles rate was ZAR0.44 ($2.6E10^{-2}$) per megabyte. This is an estimate of about 2,100% higher for out-bundle than in-bundle. Similarly, MTN's 25 GB data bundle costs ZAR1,250 ($75), equating to about ZAR0.05 ($3.0E10^{-3}$) per megabyte while out-of-bundle costs $6.0E10^{-2}$ per megabyte. This represents a 1,880% difference between in and out-bundle charges.

Data bundle prices for major operators in South Africa are compared in Fig. 3. Cell C and Vodacom as at the time of writing, did not have unlimited data bundles for wireless network but Cell C offered unlimited plan through fibre to home connections. For month-on-month unlimited plan, Rain offered the best price at ZAR479 ($29), while MTN was the most expensive at ZAR1,999.00 ($120).

3.2 E-Learning Data Requirements

On the average a typical University lecture includes 5 min for introduction to a lesson, 40 min of lesson and about 15 min of questions and answers. Table 1 shows a comparison of e-Learning related components, their respective data demand and corresponding costs. On the table we assumed an average uncompressed data size and a cost of ZAR120 ($7.2) per Gigabyte of data. Average file sizes and content counts per Gigabyte were obtained from [65,66] and WhatsApp mobile application.

On Table 1, a sixty minute live online lecture, viewed at 720p (1280×720 resolution) would cost the learner at least ZAR144 ($8) to attend. This is excluding the cost of downloading study materials in pdf or pptx format. If these were included the price could rise to about ZAR150 ($9). However, if the same lecture was audio based only, the cost would drop to about ZAR10 ($0.6) – study materials inclusive. These could be supported with instant messages (chats), which are relatively cheap. On the table, we included the cost of chat using an over-estimated rate of 1 message per minute. Using WhatsApp's data consumption per message as a yardstick, the cost of an hour of interactive chat session cost a negligible fraction of a Cent.

4 Recommendations for Under-Served Communities

As defined in the introductory section, under-developed or under-served communities are remote locations such as villages and townships with limited electricity

Table 1. Mapping of data requirement and cost for e-Learning

Method	Format	Comment	Avg. usage/session	Avg. quantity/GB	Cost (US$)
Document	PowerPoint		30–40 Slides	2,860 Slides	0.1
	Word	Word document in "docx" with basic fonts	12 Pages	18,874 pages	$4.8E10^{-3}$
	PDF		12 Pages	3,146	$2.8E10^{-2}$
	Excel		2 Pages	166 pages	$8.7E10^{-2}$
Interactive	Image	We assume a single Powerpoint slide to contain at least one image, however uncompressed (1.5 MB/image) in JPEG format	30–40	588	0.49
	Audio	MP3 file with 44.1 kHz sample rate and 16 bits depth	60 min	2000 min	0.22
Presentation	Video	720p HD video at 30 frames per second and bitrate of 1.5 Mbps	60 min	60 min (1.2 GB)	8.65
	Podcast	MP3 audio file with 128 kb/s bit rate	60 min	18:12:16 Duration	0.39
Webinar/Virtual classroom	Video	720p HD video at 30 frames per second and bitrate of 1.5 Mbps	60 min	60 min (1.2 GB)	8.65
	Audio	MP3 audio file with 128 kb/s bit rate	60 min	18:12:16 Duration	0.39
	Chats	Text only at an over-estimated rate of 1 message/minute	60 messages	13.5 * 106 messages	$3.0E10^{-5}$
	Whiteboard	Predominantly white image at 1.5 MB per image	30–40	588	0.49
Assessment sheets	Excel		2 Pages	166 Pages	$8.7E10^{-2}$

supply and Internet access. This section focuses on options for RTL for such communities.

4.1 Television

The advantages of educational TV are numerous, including but not limited to higher retention rates, improved grades and enhancement of story-telling and narrative skills [27,28]. Educational Television utilizes cheap and widely available technology (TV and playback device), thereby making it suitable for applications in remote/distant learning in rural and lower socio-economic communities [27,29].

4.2 Podcasts

For developing countries with limited Internet connectivity and network bandwidth, podcasts can make for an excellent choice in delivering RTL. With regards duration, a study carried out by Misener [31] showed, that the median duration of language learning podcasts was about 20 min for children educational podcasts and about 45 min for high school and college content. By recording podcasts in mono rather than stereo and at a bit rates of 64 kbps or 96 kbps, the podcast's file size can be made smaller; as both of these would result in about 0.5 MB and 0.75 MB of file size per minute respectively. Therefore, a 45 min lecture, recorded at 64 kbps would be approximately 21.6 MB in size. These can be made even smaller by compression or using a different file format such as the open source Ogg vorbis audio format [30].

4.3 Webinars

Despite the advantages webinars have, Internet remains a major concern especially in under-served communities. An hour long lecture on BBB can consume as much as a Gigabyte of data when streamed live or downloaded afterwards. A Gigabyte of data on the average costs about ZAR121 ($8.53) in South Africa [56] and NGN1,000 ($2.56) in Nigeria. While these might not seem cheap for an hour of learning, these rates are extremely expensive for communities where a large percentage of the citizenry survive on less than $2 a day [57].

4.4 Low Cost Options

– **Asynchronous lectures:** wherein lectures are pre-recorded and distributed to learners. This is recommended because the recordings would be available for learners to download at their most convenient times. This might for instance be at night for learners on cheaper night data plans or during the weekends when data traffic might be less.

- **Compression:** Video resolutions play an important role in determining size. Larger dimensions (in pixels) translate to larger video sizes and by extension bit rate required to download or stream the video. Using YouTube as a reference, video files are available in the following resolutions: 1920×1080 (1080p), 1280×720 (720p), 640×480 (480p), 480×360 (360p), 426×240 (240p) and 256×144 (144p). From [63], a 30 min video at 360p would have an average size of 375MB, while the same video at 1080p would average 3.3 GB in size. The importance of Video resolution can therefore not be overemphasized.
  Beyond resolution, frame count is an equally vital factor to consider. Frame per second (FPS), represents the number of image frames to be displayed every second; and can range from 12 to 60. When considering the educational space, a typical lecture comprises of a white board with texts. The content on the screen (white board and texts) do not change very often, hence, a low FPS of between 15–30 could suffice. This could further reduce the size of video recordings.
- **File Format:** Saving documents as certain file types could also significantly reduce their size, while retaining the same information. For instance, the pdf format is a globally accepted file format, that is smaller and non-editable (by default) compared to Microsoft Word or Powerpoint file format. Saving Lecture notes and presentations in pdf format can thus be highly beneficial. LaTeX offers an even smaller footprint, but requires the file to be recompiled by the recipient. These text files (in pdf or LaTeX) can be accompanied with audio recordings of associated lecture. Like with text documents, audio files can also be saved in formats that utilize smaller disk space. Compared to the Microsoft wav file format, mp3, m4a and ogg offer smaller file footprint, yet maintain the audio quality. A combination of lecture notes/slides in pdf or LaTeX format and embedded or accompanying audio recording of lectures could be a light weight alternative to live or pre-recorded lectures. These low profile documents can be sent as emails or distributed to students using social media platforms such as WhatsApp and WeChat.

4.5 Hardware

Though the focus of this paper is not on hardware, it is worth mentioning required hardware necessary to access the various e-Learning channels. Most e-Learning platform are deployed in a form of client-server architecture, where both the learners and teachers are clients and the learning platform (LMS, service applications) is the servers. For Moodle, a popular open source LMS, the minimum requirement for the clients is any device with a web browser. The underlying operating system is insignificant, however, read/write support is required [67]. For live interactive online learning, both teachers and learners would need additional hardware, including a web camera, speaker and microphone. A comprehensive hardware requirement specification is given in [62]; including a system with at least 1 GHz processor, at least 16 GB of storage space, 1 GB RAM, sound card with microphone & speakers, video adapter & monitor and network interface card (wired or wireless). For software, the general requirements are any

operating system, modern browser and audio codecs. With most of the processing being done remotely, light weight and comparatively inexpensive devices can be used. This is particularly advantageous for under-served communities, as basic laptops, Chromebooks, cheap android tablets and even single board computers (such as the Raspberry Pi, Tinker Board and Odroid) would suffice.

4.6 Corporate and Governmental Participation

Participation of corporate organizations and government can go a long way in improving RTL in under-served communities. Efforts could be in terms of infrastructure support, such as the INITIC Raspberry Pi labs projects in Togo [68], Kepler project in Rwanda [44], the MTN digital libraries in Nigeria and South Africa, and Samsung Digital Transformation centre in Cape Town. Support can also be in form of direct funding as with the Global Partnership for Education (GPE), Africa Centres of Excellence [46], Digital Economy for Africa (DE4A) [47] projects

Governments can also play key roles in enabling RTL. These can be in form of policies and/or direct intervention. Some notable governmental efforts include: enacting policies that ensure access to educational websites are zero-rated, as is the case in South Africa and Zambia; providing infrastructure for 4G coverage, as done in Kenya [69]; and running educational programmes on dedicated government owned TV and Radio stations. The latter has been implemented in a number of countries in Africa [70].

5 Conclusion

Remote Teaching and Learning (RTL) has never been more relevant as it is today. As at the time of writing, the ravaging global pandemic and consequent national lock downs have forced a global review of our ways of life. With respect to teaching and learning, schools and various educational institutions have now turned to RTL and e-Learning models. However, a fundamental requirement for RTL is the Internet, which Unfortunately is not readily available in remote and low-income (under-served) areas. In this paper, we have reviewed the state-of-the-art with regards RTL and considered options that are feasible in these under-served communities. We identified the requirement for remote learning, in terms of data and the associated cost. Finally we made some recommendations on how to achieve least cost RTL for under-served communities. For low income areas Radios & TVs are the best RTL tools, as they are comparatively cheaper than most of the other options. For Internet-based learning, the global drop in price of Internet and smart phones has helped increase Internet accessibility in Africa to about 28.2%. With this development, learning options such as podcasts, asynchronous and self-paced MOOCs might now be considerable. However, widespread live online classes and webinars might still be some years away.

It is important to note that the approaches discussed in this work are not exhaustive, as there are others not covered, such as distribution of educational content on CDs and USB drives, augmented reality, Text-based RTL using social media tools. This work also did not consider infrastructural requirements that need to be in place for RTL nor were actual examples of live online lectures used. Furthermore, only high level details of data compression techniques and options were given. These could be avenues for extending this work in the future.

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