Affordable Connectivity and Digital Entrepreneurial Ecosystem for Rural Africa

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***Abstract*— Innovation on sustainable ICT technologies to realize affordable broadband connectivity for rural and underserved communities is a crucial component of the effort to achieve the aim of "leaving no one behind by 2030" as championed by the United Nations. Digital connectivity and the creation of a digital entrepreneurial rural ecosystem (DERE) are two interconnected interventions necessary to achieve digital inclusion with rural communities as the main target. This paper defines the ecosystem components for the DERE, which include affordable broadband, sustainable business models and co-creation of relevant ICT services involving beneficiary rural communities. This framework presents a proof of concept on rural SMEs-driven digital inclusion being implemented at four sites in South Africa.**

Keywords*— *Affordable broadband; Business model innovation; Digitalization; Digital transformation.

I. Introduction

Digital transformation of African societies demands universal access to broadband Internet primarily focussed on rural communities, where broadband Internet and ICT services access is currently lacking, thereby limiting participation in the digital economy. Due to COVID-19 containment and response measures, many rural societies are now painfully realizing their exclusion from the digital economy and the COVID-19-induced societal changes being created. These digitally excluded communities are now having difficulty to provide basic societal services such as online schooling, access to clinical e-health information and improving their businesses (e.g., agriculture). The digital entrepreneurial rural ecosystem (DERE) described in this paper aims to promote digital inclusion by accelerating the deployment of innovative and affordable digital broadband connectivity solutions, and building a framework for sustainable digital business enterprises, which is expected to accelerate ICT service creation and a digital innovation ecosystem for rural communities. The overarching goal of any related digital transformation initiative should be to develop an Africa-wide digital connectivity accelerator programme in the short run and to facilitate a continent-wide digital connectivity and digital SME ecosystem (DSE) in the long-term. The DERE ecosystem model incorporates frameworks to assess and implement the model to enable co-creation with local communities and possible uptake in regional African countries.

The specific objectives of the DERE model described in this paper are to achieve the following outcomes:

1. Support the development of an enabling telecom regulatory environment, including capacity building in networking for sustainability for national telecom regulators and relevant aspects of emerging wireless standards, spectrum innovation technologies, and associated business ecosystems.
2. Strengthen the digital SME ecosystem existing in rural communities (e.g., accelerator labs and innovation hubs). This is aimed to develop innovative ICT services and inclusive business models for the different layers of digital connectivity and for affordable rural network innovation.
3. Enable broadband network innovation and the concept of networking for sustainability. This is to support internetworks powered by green energy technologies to facilitate affordable broadband and digital inclusion for the rural and underserved population.
4. Develop a network of rural ICT based digital SME ecosystems (DSEs) that would be able to propel national and rural economic transformation. It could also facilitate regional economies of scale by extracting benefits from the emerging digital service economy in Africa through regional pilots in selected African countries.
5. Promote a three-pronged approach to ensure sustainability, complementing existing networks and integrating new network technologies such as 5G which are expected to propel development of 4th Industrial Revolution (4IR) services.
6. Identify synergetic opportunities for emerging network technologies (such as wireless AI and software defined networks) to facilitate rural and underserved communities to benefit maximally from digital transformation, especially in driving sustainable economic development.

II. Methodology

Rural dwellers and specifically the younger population are among the most marginalized on the development spheres and therefore constitute one of the last miles in achieving the Sustainable Development Goals (SDGs). One of the important targets of the work reported in this paper is to improve

entrepreneurial capacity of young ICT entrepreneurs based on sustainable network technologies and ICT based digital SME ecosystems (DSEs). Sustainable rural connectivity remains one of the tools for socio-economic transformation and sustainable development in South Africa and other African countries, particularly in addressing joblessness, poverty and income inequality.

However, low income and low population density contribute to low rate of return on telecom investments, which makes it highly unprofitable for large private sector network operators to roll out services in rural areas. The case of low profit in the context of a large availability of high-demand wireless spectrum – with strong potential for building universal Internet access, deepening ICT-based services, and developing youth entrepreneurship – brightens the prospect of turning this challenge into a development opportunity in Africa. In a previous paper [1], the authors described a sustainable connectivity solution based on spectrum sharing networks and green radio technologies, to address this developmental challenge. The paper presented a spectrum innovation ecosystem, a thinking-outside-the-box solution to achieve digital inclusion, rural connectivity, and sustainable development in the context of South Africa, which is also applicable to other African countries.

Emerging network technologies such as TV White Spaces (TVWSs) and the smart spectrum sharing approach pioneered by South Africa's Council for Scientific and Industrial Research (CSIR) provide an opportunity for a real change that could unleash a rural-oriented, commercially viable, and green telecommunication infrastructure in Africa [2–5]. This approach allows lower costs in building the network infrastructure, green energy powering of networks and operational aspects of spectrum sharing radio networks (SSRNs). This promotes local small network operators and enables affordable last mile WiFi access for local communities. The spectrum sharing radio technologies, managed by geolocation spectrum databases, could help identify underutilized spectrum, so called "white spaces", that could be repurposed for broadband services in different geo-locations. Working with relevant stakeholders, and promoting public-private partnership, the DERE will be able to leverage this emerging opportunity to promote rural connectivity, digital inclusion, and socio-economic transformation in Africa.

Digital inclusion is the primary goal of the DERE ecosystem described in this paper. The development of the DERE ecosystem is deemed necessary to enable rural digital entrepreneurs (RDEs) to accelerate the digital and economic transformation of rural communities and the effort to bridge the rural and urban digital divide in Africa. A description of the ecosystem components of DERE such as affordable broadband, sustainable business models and co-creation of relevant services involving youth and rural communities is presented with a proof of concept on rural SMEs-driven digital inclusion being piloted at four sites in South Africa. Partnering with the major ICT technology and service providers, the programme empowers local network operators to provide innovative ICT services to currently underserved and digitally excluded rural and township communities. This alliance is anchored on public-private partnership, and the creation of rural private digital business ecosystems in South Africa and in the rest of Africa.

The strategic approaches adopted in this framework hinge on innovation and capacitation with specific elements that include mapping of relevant stakeholders, de-risking rural digital sub-sector, networking and spectrum regulation for sustainability, nurturing platform, and promoting developmental changes. The unique position of the rural digital entrepreneur (RDE) in the DERE ecosystem in emerging economies is shown in Fig. 1 below.

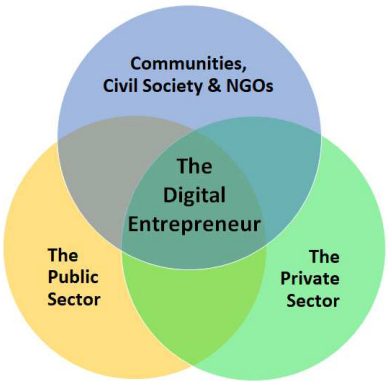

Fig. 1. The rural digital entrepreneur's unique position in ecosystem.

Based on the DERE ecosystem, rural digital entrepreneurs (RDEs) have the opportunity to play important roles in the following areas:

i. The RDE is required to contribute to the public sector, by improving ICT service provision in public institutions such as schools, health clinics, police stations, and local municipalities. RDEs are also expected to support job creation through value added services. The awareness of the public sector on the benefits of digital inclusion, in connection with the COVID-19 pandemic, has given the RDEs a unique position in the DERE entrepreneurial ecosystem to enable digital transformation and value/job creation in rural communities.

ii. RDEs as private business owners also have a unique opportunity to digitally transform and improve the operation of rural private sector businesses and industry (e.g., agriculture, mining, transport, health, etc.). The RDEs can also play the role of greening the telecommunication industry by testing and incorporating green and low power networks, supplied by alternative energy sources.

iii. RDEs interface and interact with communities, civil society and NGOs to understand their specific needs and challenges.

iv. Thus RDEs become interlocutors between these three sectors – public, private, and communities / civil society / NGOs – and are required to develop sustainable business models which satisfy all three sectors by leveraging their unique position in the DERE ecosystem shown in Fig. 1. There are many factors affecting sustainable rural businesses, which are discussed in a separate section below.

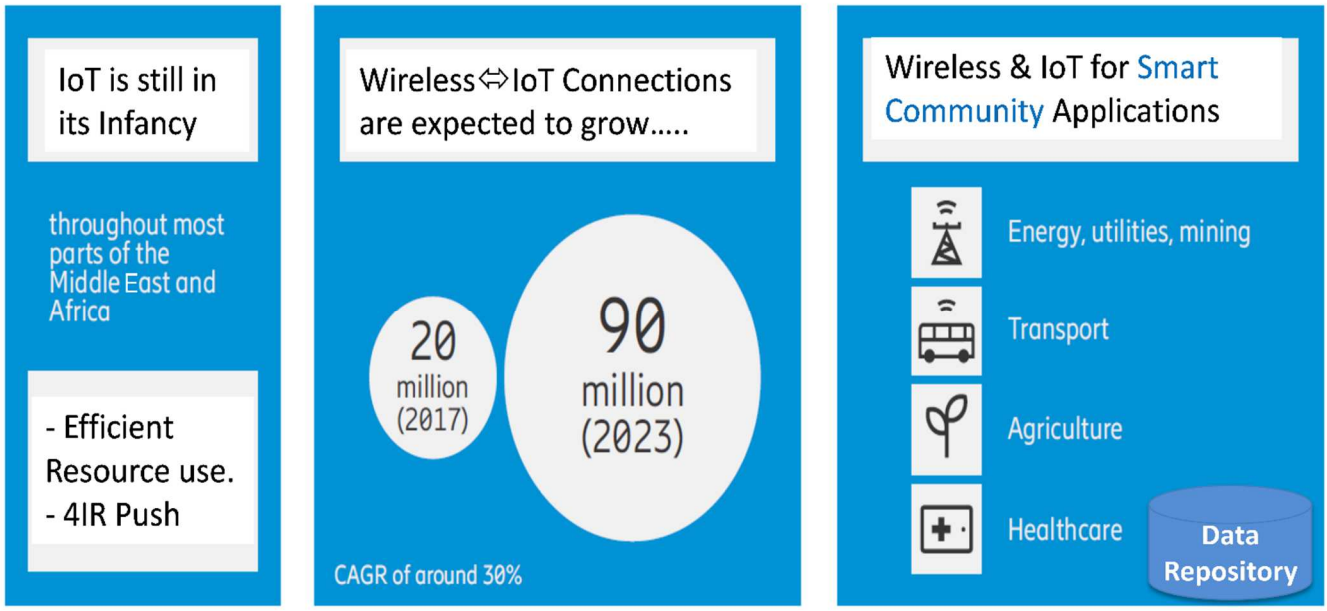

Fig. 2. Proliferation of wireless network-enabled IoT services. (*Note: CAGR = Compound Annual Growth Rate*)

A. Sustainable businesses through value added IoT services

Considerations of Internet of Things (IoT) services through the deployed RDE networks for rural connectivity is promoted in the DERE ecosystem. This enables sustainable value added service creation and digital businesses based on the enabled services. The connection of smart sensors for IoT applications in the areas of clinical health systems, water quality monitoring, and smart agriculture is expected to enable short term and long term data collection through the digital networks deployed by the RDEs. Fig. 2 shows ongoing proliferation of wireless IoT applications in Africa and expected growth over the next few years [3, 6].

This paper discusses the use of TVWS and WiFi based wireless IoT connectivity. However, other types of low-cost networks such as LoRa, LP-WAN and NB-IoT networks are also possible to use.

III. Spectrum Sharing and Affordable Networks

For the DERE ecosystem to function properly, the availability of sufficient shared spectrum and associated low-cost network technologies is crucial. The CSIR Spectrum Innovation Ecosystem (SIE) and associated green network technology offerings are a collection of innovative spectrum management toolboxes which allow countries, national regulatory authorities, industry, and digital entrepreneurs such as WISPs and stakeholders of the wireless network innovation ecosystem to benefit from efficient utilization of national spectrum resources.

The SIE is anchored on a national spectrum regulation such as the one enacted by the Independent Communications Authority of South Africa (ICASA) [4]. The SIE enables dynamic spectrum allocation and is implemented based on study of radio frequency propagation characteristics (currently in the VHF and UHF frequency bands), communication protocols, telecommunication standards, and inbuilt regulatory data from spectrum regulators [1–3]. Implementation of a number of computational algorithms in software is done using high performance computing machines enabling cloud spectrum service access. The driver for such technology development and implementation stems from the fact that licensed spectrum in the UHF and VHF bands is under-utilized while freed spectrum due to digital TV migration is highly contested by other mobile network technologies. The development of cognitive radio technologies and the drive for efficient utilization of spectrum resources by communications regulators is evident. National communications regulators provide data including information specifically pertinent to protected entities (such as a TV transmitter's maximum power, its antenna height, its antenna radiation patterns, its GPS location, the call sign, station name, and service type). The other set of information integrated in the system are the regulatory device emission limits and the required protected contour distances in each class of services so that primary licensed operators are protected from unwanted interference [2].

It is also expected that the ecosystem proposed will promote new network technology developments and service creation potential, to address one of the important national development goals of providing affordable broadband and digital inclusion to under-served communities. Furthermore, future proofing and enabling the concept of networking for sustainability and future wireless 5G+ network deployments are being developed by the authors and several other research teams around the world. A number of projects to include affordable wireless broadband features in the 5G standards are being created so that emerging wireless standards support use cases, and enable digital connectivity, even in low-income rural environments which require low-cost networks [7]. The goal of leaving no communities behind in the digital economy of the future can only be addressed through rural community requirements driven communications technology standards.

A. The Spectrum Innovation Ecosystem

The CSIR Spectrum Innovation Ecosystem (SIE), as described in Fig. 3, is a four-layered enabling system comprising:

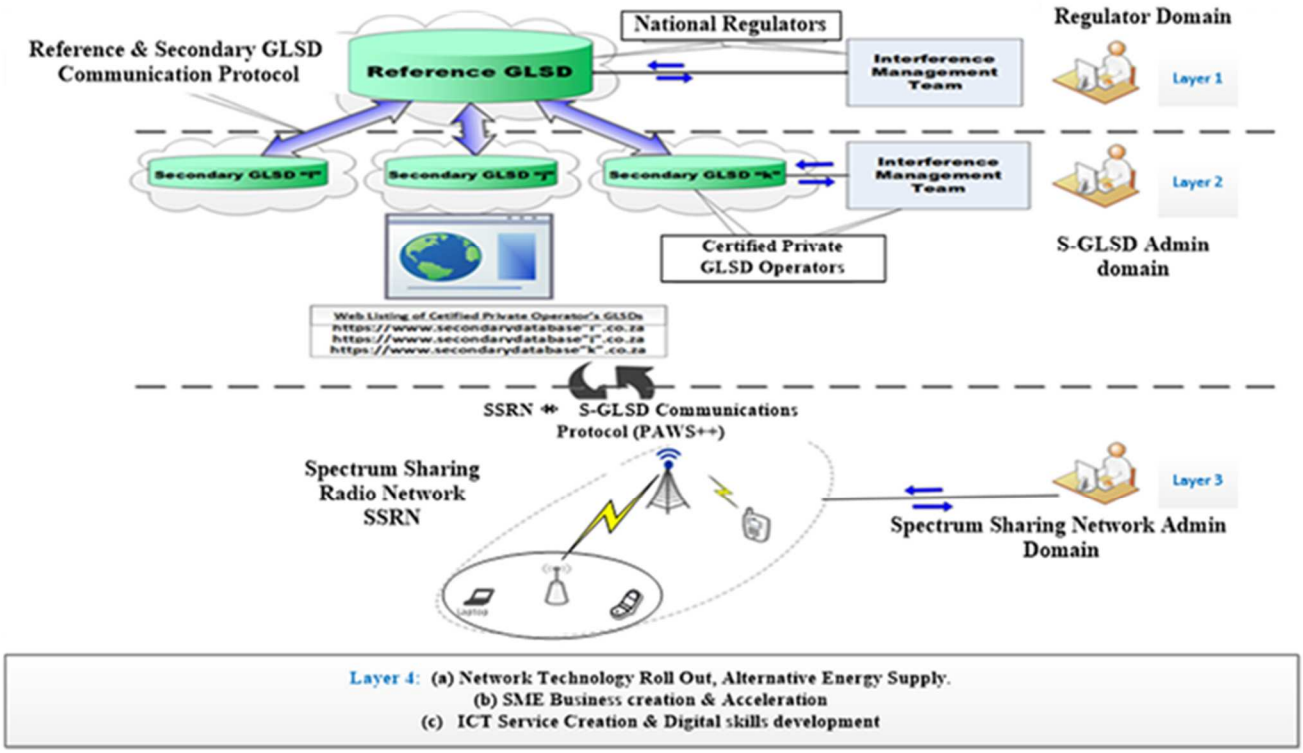

Fig. 3. The CSIR Spectrum Innovation Ecosystem (SIE).

(Notes: GLSD = Geo-Location Spectrum Database; ICT = Information and Communications Technology; PAWS = Protocol to Access White-Space; SME = Small and Medium-sized Enterprise; S-GLSD = Secondary Geo-Location Spectrum Database; SSRN = Spectrum Sharing Radio Network)

- Layer 1 are the telecom regulatory authorities, performing overview monitoring of the national spectrum availability through the reference Geo-location Spectrum database (R-GLSD). The regulator also monitors the ecosystem operation to ensure the efficient utilization of spectrum and minimum interference operation of the ecosystem components through its interaction with the Secondary-GLSD.
- Layer 2 are the private or government entities, operating the Secondary-GLSD (S-GLSD) in the SIE ecosystem. The S-GLSD interfaces with Network operators through a standard protocol, providing spectrum availability and device operational parameters. It also provides network planning and radio device type approval guaranteeing a successful spectrum sharing network deployment.
- Layer 3 are the spectrum sharing network operators providing affordable broadband services to rural underserved communities and device manufacturers who want to approve their devices in accordance to the regulations.
- Layer 4 are network operators and SIE system partners that provide support for the creation of sustainable digital rural enterprises. The SIE also provides extension support for value added ICT service creation, improvements in sustainable rural digital businesses and development of skills.

IV. Sustainable Business Models

Sustainable rural digital businesses require a sustainable business model, which is even more difficult to achieve in an environment with low incomes and low basic infrastructure availability. However, as society is becoming increasingly dependent on fast reliable broadband connectivity for running its government, private businesses and social services, the business case is changing from not being a priority, to being a basic necessity for reliable digital services and associated low-cost broadband Internet access. This has become even more pronounced due to the COVID pandemic situation.

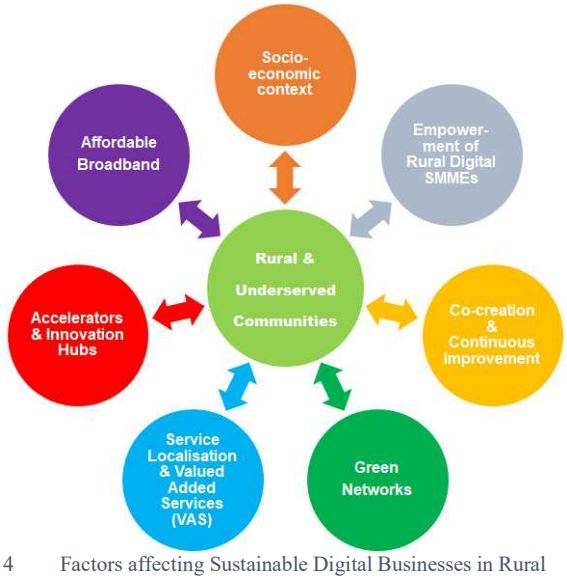

Fig. 4 Factors affecting Sustainable Digital Businesses in Rural Communities.

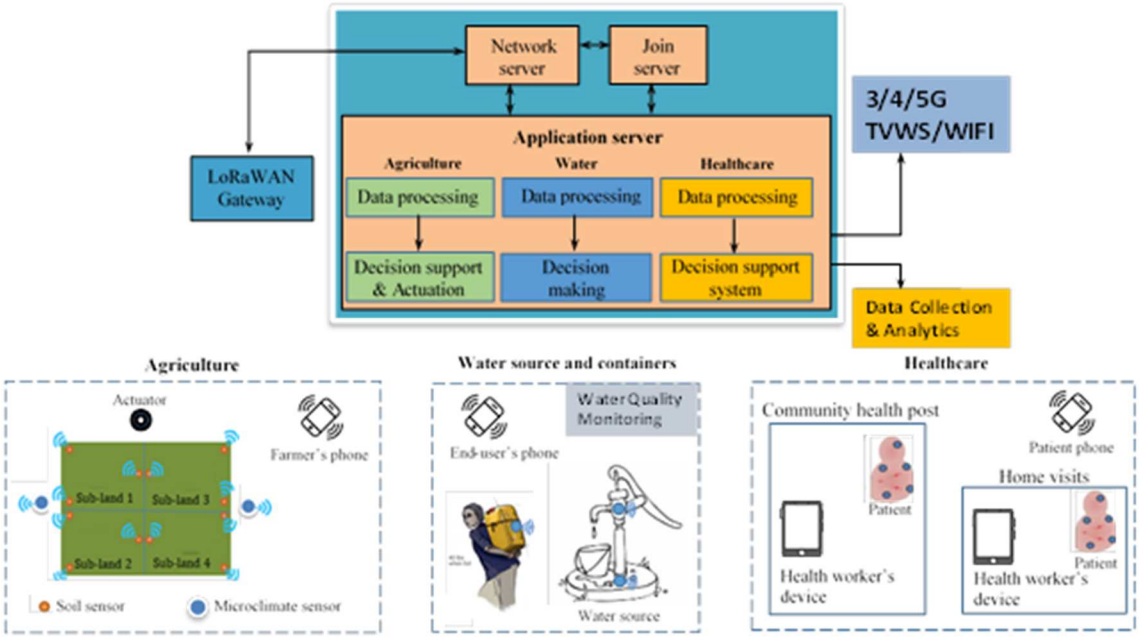

Fig. 5. Connecting smart sensors wirelessly to create societal services and smart communities.

A number of factors affect sustainable digital rural businesses. Fig. 4 shows some of the factors that the DERE proof of concept ecosystem will encounter, as it is being rolled out at four sites in South Africa. The four sites have been chosen for their geographic spread across the country, and are hosted at four rural underserved communities in the provinces of KwaZulu-Natal, Eastern Cape, Free State and Western Cape. The sustainability factors need to be addressed in a collaborative and co-creative manner with the concerned digital rural entrepreneurs and the four beneficiary communities [1, 3, 5]. Business model innovation in general [8] and the creation of sustainable business models in particular [5], will be investigated as critical factors to the long-term success of digital rural entrepreneurship and overall sustainability of the digital businesses.

A. Connecting Sensors to Rural Networks

Connecting smart sensors to rural wireless networks will give digital entrepreneurs the opportunity for data collection and future value added services such as smart agriculture, water quality monitoring, smart health, and intelligent transportation systems. Fig. 5 shows a functional block diagram of a wireless sensor-based data collection system and application of machine learning algorithms for predicting demand and resource utilization. Such a wireless sensor system is expected to provide the building blocks and to support expertise resulting in smart rural communities, thus contributing to the sustainable development goals (SDGs). A similar network was also given in [6].

V. Conclusions and Future Work

The latest ITU/UNESCO and GSMA statistics show that over half of the developing world's population is still not connected to broadband Internet, let alone digital services, and that in Africa alone only an estimated 26%-34% have mobile broadband connections (fixed broadband connections being comparatively negligible) [9, 10]. Most of these digitally excluded communities are situated in emerging economy countries with large rural populations. This paper describes the interventions to create a rural digital entrepreneurial ecosystem (DERE) by enabling rural digital entrepreneurs (RDEs), and briefly outlines a case study of four rural communities in South Africa. A future paper will describe the full details of the case study, including facilities installed, scope, practical benefits, initial business models and lessons learned from the four communities.

The RDEs are enabled to provide affordable broadband connectivity and contribute to the development of relevant digital services in a sustainable manner. The spectrum innovation ecosystem (SIE) developed at the CSIR in South Africa, sponsored by the United Nations Development Programme (UNDP), plays an important role in enabling affordable spectrum sharing TV White Space (TVWS) networks integrated with WiFi last-mile access to end-users in the four rural beneficiary communities. The next step is connecting the RDEs broadband wireless networks with smart IoT sensors, which is expected to enable data collection in sectors such as health, agriculture, biodiversity protection and water quality monitoring. This will in turn accelerate development of smart community societal ICT services, and facilitate the sustainability of the RDEs' business models. The future scaling up of the project will benefit from the proof of concept intervention involving the four pilot rural communities and the lessons learned from them. With support from UNDP, this is expected to be rolled out to all the nine provinces in South Africa by 2022.

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