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Building a Sustainable Research & HCD Eco-system: Case Study of Two Wireless Communication Eco Systems

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Abstract: The paper describes the organization and management of two wireless eco-systems in next generation wireless communications research and human capacity development. The developed eco-systems have been tested and presented at an international workshop organized by the council for science and industrial research and collaborating universities in South Africa. Furthermore, the possibility of extending such a framework to the regional context to improve wireless communications research, standards, human capacity development and technology innovation endeavours of emerging economies is presented. Finally the paper proposes a technology transfer and innovation framework to convert ideas and new technology solutions in the wireless eco-systems into small scale service and knowledge based industries.

Keywords: Emerging R&D and HCD Eco-systems, Innovation and Sustainable Economy, Broadband Wireless Communications..

1. Introduction

As wireless networks, devices and the useful services they deliver become more pervasive in Africa, there is a need to build a sustainable research and human capacity development eco system to address the demand for socio-economic development through innovative wireless technologies and services development. The paper argues that Africa's share of the return on investment in ICT infrastructure and wireless technologies has been limited due to absence of a sustainable research, development, innovation and human capital development (HCD) eco-system. With this in mind, the council for scientific and industrial research (CSIR), in collaboration with universities, the Department of Science and Technology (DST) and the National research foundation (NRF) have ventured to build two research and development (R&D) and HCD digital eco-systems which will be described in this paper.

The first eco-system is the so called "Smart radio technologies" (SRT): This is a project initiated by the CSIR R&D for collaborative research and capacity building with universities. The project aims to build a sustainable R&D and HCD collaboration in an African context, in the areas cognitive radio and opportunistic radio resource utilization for low cost next generation wireless broadband and future internet technologies.

The second digital eco-system described in the paper is the next generation wireless research infrastructure (NGWRI): This project was initiated by the wireless computing & Networking research group at CSIR as a National Research Foundation (NRF), research infrastructure support program (NRF-RISP). The aim was to create a sustainable eco-

system and accelerate research and development to sustainably address the wireless broadband connectivity of rural communities in Southern Africa.

The paper will describe the ways to sustain such wireless eco-systems of research, HCD and innovation for developing the next generation spectrum and energy efficient networks. Furthermore, it will argue that such networks are cost efficient with respect to implementation in rural areas, where energy supply are scarce and spectrum is abundantly available for wireless networks. The requirement of enabling policy and telecom regulation, and a long term vision from the wireless industry, will also be presented with the aim to allow flexible and dynamic spectrum allocation. Research in wireless network resource sharing and collaborative networking to improve energy and spectrum efficiency of deployed networks is a key issue. In the final analysis such Research and HCD eco-systems should be designed to promote sustainable socio-economic development, by converting the research outputs and expertise they generate into small scale service and knowledge based industries. The following sections describe 2 case studies of such wireless technology eco-systems and innovation schemes suitable for emerging and developing countries to achieve the technology policy and socio-economic development goals.

2. Related Work

Future internet research and experimentation test-beds have been solicited by the international telecommunications union (ITU), [6] described in many parts of the world and infrastructure eco-systems. European Union future internet research and experimentation (FIRE) test beds have been promoted in the EU future networks and mobile Summit, in Hamburg, Germany [11]. The PAERIP (http://www.paerip.org/) is an initiative to promote partnership between African & European Research Infrastructure sites and promote exchange of ideas.

3. Wireless Infrastructure Ecosystem

The next generation wireless research infrastructure (NGWRI) eco-system, is an attempt to build a research and human capacity eco-system. It is initiated by the national research foundation (NRF) of South Africa, the CSIR and seven South African Universities. The eco-system also includes linkages to research institutions and participation in standards organizations to learn from experiences of advances in the developed world through the establishment of a next generation wireless research infrastructure (NGWRI).

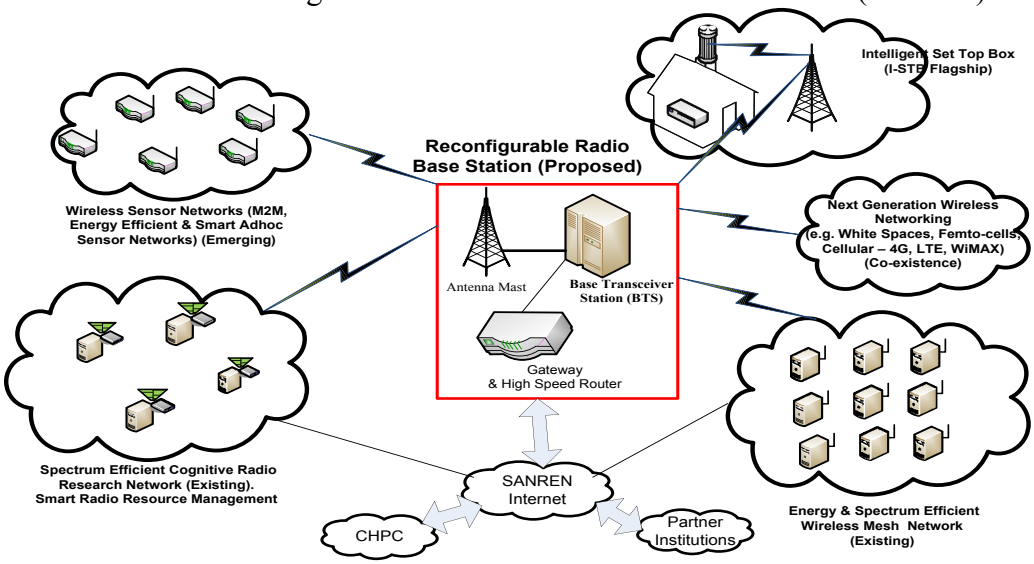

Figure 1: The Wireless Research & HCD Infrastructure Echo System

The project motto was Africa should rise and say "Yes we can" develop our research and HCD capacity and make a crucial impact on the future of science and technology development in Africa by creating a sustainable wireless R&D and HCD eco-system.

The NGWRI system described in figure 1, promotes collaboration and sharing state of the art wireless broadband research infrastructure, between research councils and universities in South Africa. It is envisaged to promote research and infrastructure co-sharing agreement with seven Southern African universities, government and industrial stakeholders, and research institutions in Africa, the US and Europe. The aim was to harness the explosive growth in wireless communications technology and services in emerging market African countries. The project is to be followed with research and development backup in emerging African countries to benefit from the wireless eco-system and catch up with the fastest growing wireless technology sector in the world [5,6]. The wireless industry is gearing up towards a model where people irrespective of their location and time should be able to access information and services through wireless devices and associated wireless communication technologies. At the same time, emerging economies of Africa, have large population of rural communities which are not connected to the broadband internet infrastructure. This requires spectrum and energy efficient broadband wireless communications research to contextually tailor the technology towards a cost efficient deployment. The proposed state of the art research eco-system and infrastructure in next generation wireless networking research, will allow emerging economies of Africa to benefit from the technological development, improved broadband connectivity, which is expected to result in knowledge based service industry creation and contribution to the research, human capacity building and socio-economic development of institutions and its population. The main purpose of the proposed wireless research and HCD infrastructure eco-system was:

(a) With such an eco-system of research and human capacity development, Africa will get new capability to perform research and development in energy & spectrum efficient algorithms and techniques using the new research equipment and resource sharing with partner institutions. This will improve our research capacity to address the challenges of throughput, coverage, low energy consumption and flexible spectrum utilization of new wireless broadband network deployments, and lead to the success of fulfilling the low cost broadband connectivity nationally and continentally.

(b) The national research foundation (NRF) has pioneered the research infrastructure support program that will provide researchers with the research capacity and access to collaborating institutions research infrastructure, to improve wireless research. Through utilizing the state of the art research facilities for simulation, testing and development of prototypes and technology demonstrators in next generation wireless networking.

(c) Postgraduate human capacity development (HCD) by research institutions will get revamped as the research infrastructure is upgraded with state-of-the art wireless radio research equipment. Research students get access to future internet research and experimental (FIRE) test-beds.

A number of emerging wireless technology research areas will get the necessary capacity to develop into a full-fledged research and development areas as shown in Figure 1. Such a wireless research infrastructure with reconfigurable base-station equipment as shown in figure 1 includes: (1) wireless ad-hoc and mesh networking laboratory, (2) wireless sensor network laboratory for designing bio-sensor based health applications, M2M and the Internet of Things, (3) wireless cognitive radio network laboratory for spectrum and energy efficient network development, (4) Future wireless cellular networking research with MIMO based LTE applications. The wireless mesh laboratory is

currently actively being used by the research group on a routine basis in order to demonstrate the performance of multi-hop routing protocols & metrics, energy efficiency and alternative energy powered networks for a rural community context. On the other hand, wireless sensor networking laboratory will allow real testing of multivariable sensing and collection of environmental data such as humidity, temperature & pressure [2].

Spectrum efficient cognitive radio networking laboratory will be available to perform research on spectrum monitoring, sensing, dynamic spectrum management and efficient network-management issues [1,9]. The research in this area is expected to support low cost wireless broadband technologies utilizing shared spectrum opportunistic TVWS network technologies [4]. An important feature of the proposed equipment is the reconfigurable radio frequency unit that supports long term evolution (LTE), WiMAX & Wi-Fi among other emerging radio-standards [2]. Another critical difference between the conventional base station equipments and the one being proposed here relates to the fact that, the new base station equipment will give researchers tools to experiment on alternative energy sourced network components, that result in less carbon emission and are suitable for rural communities with no or limited grid energy supply. Alignment of research and development and HCD activities with both the national & regional energy efficiency and green economy initiatives [4,7] are also addressed. The base station will intelligently monitor both spectrum & energy efficiency parameters through an intelligent network management system. The research infrastructure will also support several next generation network standards, including MIMO and smart antenna system research [8].

4. Smart Radio Technology R&D Ecosystem

The smart radio technology (SRT) research and postgraduate human capacity building eco-system was designed to alleviate the lack of expert human capacity in the wireless industry and government policy making in next generation smart radio technologies.

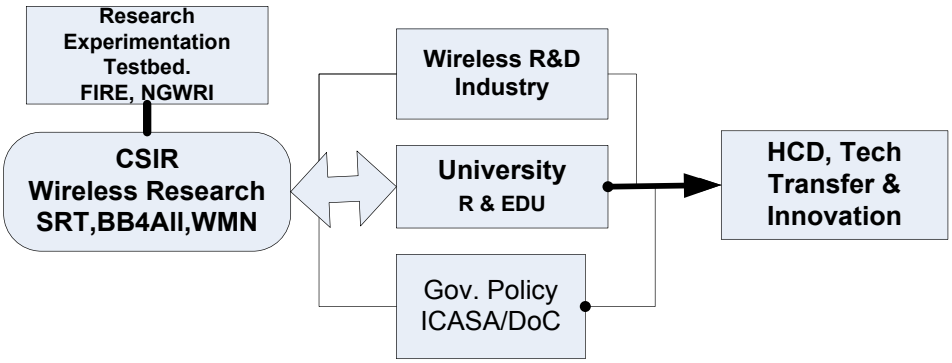

Figure 2: The Smart Radio technology R&D & HCD Eco-system

Smart radio technologies deal with spectrum and energy efficient networks of the future, research areas such as cognitive radio networks, dynamic spectrum access and energy efficient wireless communication protocols. Shannon's information theoretic perspective described in the equation:

$$R = \frac{1}{2}\log_2\left(1 + \frac{P}{B.N_0}\right) \quad (1)$$

Where R is the channel capacity in bits per second per Hertz, B is the system bandwidth in Hertz, P is the transmitter power and No is the noise or interference in the wireless system. Shannon's equation is used to motivate the design of spectrum and energy efficient networks. Cognitive radio networks will improve the channel capacity by using spectrum sensing and an intelligent choice of available channels and required bandwidth (R) for a specific application, while at the same time reduce the interference (N_0) to licensed and

adjacent channel users. Energy efficient network protocols and algorithms with reduction in N_0 due to cognitive networking will guarantee the energy efficiency requirement. The SRT research areas include but are not limited to cognitive radio, opportunistic TV White space spectrum technologies, intelligent/dynamic spectrum access techniques, energy efficient wireless sensor integration and convergent wireless service platforms.

Proper technological focus. enabling policy and incentives should be given to build a sustainable eco-system for increased innovation and creation of knowledge based industries and improving the competency and availability of expertise in government policy and regulatory bodies. The first phase of the SRT eco-system included collaborative research and postgraduate HCD projects with University of Johannesburg (UJ), Tshwane University of Technology (TUT), Independent Communications Authority of South Africa (ICASA) in South Africa and the University of California, Santa Barbara (UCSB), in the USA, and the Royal Institute of Technology KTH-Sweden.

A recent international workshop organized by the SRT research & HCD eco-system at the CSIR, has attracted representatives and stakeholders from wireless industry, government organizations, universities and research organizations [14]. The panel discussion on the wireless technology in the 2020s was led by the wireless industry vision of cognitive wireless technologies, utilizing ambient information for radio resource optimization and enabling seamless integration of the computing environment with naturally occurring processes to develop future services and applications impacting and improving the quality of life of people in motion, work, leisure and at home[13].

5. Technology Innovation & Digital Ecosystems

Connecting research and HCD eco-systems to technology transfer and innovation eco-systems is crucial to fulfil the socio-economic development demand and creation of knowledge-based services and industry of the future. In the 2020 vision for Africa's development, building science and technology supported small and medium enterprises (SME's) is identified as a crucial step [3,12]. Figure 3, shows one way to achieve this by building science and technology innovation eco-system in the vicinity of emerging research and HCD digital-eco-systems [9,10].

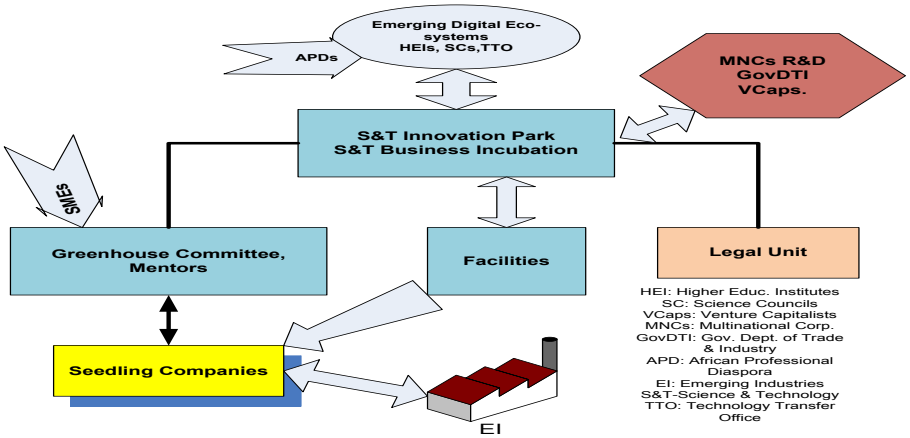

Figure 3: Functional diagram of technology transfer (TT) and innovation eco-system for Science and Technology.

As higher educational institutes and research organizations are driven by public mandate, integration of the scientifically agile research core and with innovation and technology transfer eco-systems for achieving socio-economic development outcomes are becoming crucial for the sustainability of socio-economic growth in Africa [10]. Figure 3 shows one such eco-system to achieve the future highly competitive knowledge economy where: technology transfer policy, conversion of new ideas and new technology research is

linked to tangible products and the development of emerging service and technological industry. This requires a close integration of the research and HCD eco-systems described in this paper with science and technology innovation parks, business incubation and development support. The full description of the innovation echo system and the technology transfer framework as shown in figure 3, is available in the references [9,10].

6. Initial Outcomes

Some of the initial outcomes of the digital wireless eco-systems described above can be classified into:

a) Postgraduate human capital development, where over 12 postgraduate projects are identified, in the areas of smart radio and network technologies.
b) Spin-offs from the postgraduate projects, have already impacted government regulatory bodies, in the form of building spectrum database in collaboration with the Independent Communications Authority of South Africa (ICASA).
c) Shared spectrum TV white space technology trials being carried out together with CSIR, ICASA and Google in the Cape Town area in South Africa [4].
d) Project DOLPHIN an EU-SA FP7 Future Internet Research & Experimental (FIRE) test-bed project between European research institutions and South Africa research institutions. This is a collaboration project on opportunistic shared spectrum networks (SSN) for improved wireless broadband connectivity and health portal applications [14].
e) Setting the standards for shared spectrum networks and TV white space technology testing and deployment, in Africa [4,5,11,12].
f) Building the capacity of local telecom regulatory bodies, in shared spectrum technologies and spectrum allocation [4]. This was achieved through co-organization of workshops and seminars and staff meetings with telecom regulators in Africa [1].

7. Conclusion

This paper proposes the acceleration of research and development in next generation broadband wireless technology, through research and experimental test-bed based eco-systems, as a crucial step to support a reliable and improved quality broadband connectivity of rural communities. The foresight study on Wireless Communications in the 2020, performed in one of the echo systems described in this paper [12], have shown that majority of the population in emerging markets will connect to the internet through heterogeneous wireless networks. And hence R&D in wireless broadband technologies that can convert part of the 6 billion cellular connections into mobile broadband internet connections is crucial to contribute to the socio-economic development of rural communities. According to the International Telecommunication Union (ITU) [6], the majority of people in the world do not have Internet access; the percentage of people on the Internet in 2010 was only 55.0% in the Americas, 21.0% in Asia and the Pacific, 24.9% in the Arab states, and least of all 9.6% in Africa. The numbers of people who have Internet access in their homes is even lower. These citizens are at a severe economic and educational disadvantage, as there is a clear link between Internet access, educational standards and enabling wealth creation. As the pace of the technological revolution increases, it is very often the case that the digital divide is exasperated unless measures are taken to improve the R&D echo systems in developing countries [13].

The eco-systems described above with wireless research infrastructure and the collaborative smart-radio technology projects will help us learn from experience and advances in the developed world. Through public and private industry research

collaboration and the standardization activities of next generation wireless technology, the described eco-systems will accelerate research and human capacity development with the aim of increasing innovation, technology transfer, and creation of knowledge based industries and improvement of expert human capital in government policy and regulatory bodies. It is expected that socio-economic development regionally and particularly in disadvantaged rural communities in emerging economies will improve through the wireless research, innovation and eco-systems described in the paper.

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