Access-technology Agnostic Conceptual Model

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Abstract: The delivery of digital content and services to end users in an access-technology agnostic manner has the potential to promote equitable access. Components of relevant Information and Communication Technology (ICT) functionality comprise of computing, connectivity, content and capacity. These functionalities are extended to include the delivery mechanism. The delivery mechanism is responsible for the actual delivery of digital content and services to communities or individual end users. The purpose of this study is describing a content delivery mechanism that provides access-technology agnostic delivery of digital content and services to resource-constrained communities. The proposed delivery mechanism adopts the conceptual service delivery architecture of the telecommunications service delivery platforms. It reuses the concepts of network abstraction and access agnostic delivery pattern to ensure equitable access to digital content and services. Such a delivery mechanism would be able to capitalize on available technological capabilities of resource-constrained communities. This paper overviews the proposed access-technology agnostic delivery model and details a prototype implementation.

Keywords: Digital content and services, Delivery mechanism, Access-technology agnostic.

1. Introduction

A main thrust of ICT4D has been the delivery of digital content and services to resource constrained communities (Pitula, Dysart-Gale & Radhakrishnan, 2010). Despite efforts there is little evidence of delivery mechanisms that facilitate relevant content and service delivered to end-users through any access-technologies and devices available to the end-users. Consequently a delivery framework to enable inclusive and equitable access to digital content and services remains a challenge.

Preceding efforts to address this challenge are the proposals on community information systems outlined by Bieber, Mcfall, Rice, and Gurstein (2007). Their deliberations, however, do not address the issue of access-technology agnostic delivery of information. Furthermore, many of the proposed content distribution models involved a single access-technology or a specific areas, points or nodes of access within a community (Jacobs & Herselman, 2006; Akinsola, Herselman & Jacobs, 2005; Lavhengwa, 2007; Mvelase *et al*, 2009). Further to this has been the use of specific content delivery formats (Agarwal *et al*, 2009; Patel *et al*, 2006).

Subsequently, digital content and services are distributed only through a specific physical network, and available only from isolated nodes of access that cater for a specific format. This shift in focus, Botha (Botha, Makitla, Ford, *et al*., 2010) terms a *digital difference*. Where a digital divide focuses on the provision of technology to access services and content, a digital difference shifts the focus towards provision of content and services through technology that is available. In order to address this paradigm shift in community information provision, this paper describes an access-technology agnostic delivery approach. The following section outlines the Methodology used followed by a deliberation of the components of such a delivery approach to enable ICT functionality to resource-constrained communities.

2. Methodology

According to Olivier (2004:12), research studies with technical goals, such as this study, apply creative research methods intended to device new mechanisms to be used in computing. The quality of such creative methods is measured in terms of attributes of the creation such as its utility (Olivier, 2004:12). Design-science research approach (March & Smith, 1995:253) lends itself naturally for this nature of study.

A model is one of the artifacts that are developed through design-science research (March & Smith, 1995). In order to develop the proposed model, this study followed the seven guidelines of doing design-science research outlined by Hevner *et al* (2004). This study further conformed to the five-step interactive process of design and creation research methodology (Oates, 2006). Furthermore, because this study makes certain claims that the proposed *Access-technology Agnostic conceptual model* developed bears characteristics that make it better suited to address the problem, the model is tested and evaluated, specifically to ascertain that it does indeed have beneficial characteristics enabling it to address the problem of the delivery of digital content and services to resource constrained communities sufficiently.

Evaluation of the *Access-technology Agnostic conceptual model* in this case, is one of the guidelines in the seven-guideline list of doing design-science research (Hevner *et al*, 2004:85). Evaluation is a research activity within the design-science research aimed at developing criteria by which artifacts may be assessed (March & Smith, 1995:258). Furthermore, because purposeful artifacts are built to address hitherto unsolved problems, these artifacts are to be evaluated with respect to the utility they provide in addressing those problems (Hevner *et al*, 2004: 78). Evaluation metrics define exactly what the research is trying to accomplish (March & Smith, 1995). In the case of this study, being able to deliver same digital content (service) to end-user devices that are connected to different access-networks and that support different content formats (access-technology) is a key evaluation criterion.

The approach adopted for evaluation in this study is an initial proof of concept. The concluding expectation for this study is to demonstrate that the proposed *Access-technology Agnostic conceptual model* is practical and can be implemented. The "Black Box Testing Technique" (Krichen & Tripakis, 2004) was adopted; this technique hides the complexities of the system components and only focuses on the system functionality as viewed from the end-user perspective in accordance to the expectation.

The *Access-technology Agnostic conceptual model* is outlined as a possible configuration of a Digital Content Delivery Mechanism to achieve access-technology agnostic delivery of digital content.

3. Delivering ICT functionality

ICT4D concerns itself with promoting the use of ICTs to enhance developmental initiatives which can be discernible as the realization towards the Millennium Development Goals (Sambasivan *et al*, 2009: 156; Dias & Brewer, 2009:75). Heeks (2008:26) argues that the prioritisation of ICT application in developmental initiatives relate to the economic, social and political life in the 21st century. He anticipates that future participation in such structures will be increasingly digital, and will potentially exclude communities and individuals without access to ICTs. Therefore Heeks (2008) and Unwin (2009) propagate addressing the uneven diffusion of access and participation in the information society as a critical developmental mission.

To this end, ICT4D is driven by three main thrusts (Pitula, Dysart-Gale & Radhakrishnan, 2010):

- the development of the necessary technical infrastructure in a sustainable manner,
- the delivery of digital content (information), as well as
- building the human capacity to effectively use, maintain and manage the available ICTs.

ICT4D can achieve this through innovation in four key areas colloquially referred to as the 4C Framework (Tongia & Subrahmanian, 2006): *connectivity*, *computing*, *content*, and *capacity*. The next section describes how the 4C Framework has been adopted to define an access-technology agnostic approach to delivering digital content and services to communities.

3.1 Components of delivering ICT functionality

The 4C Framework is adopted as appropriate primary components for delivering ICT functionality to resource-constrained communities. Figure 1 depicts these components. Each of the components in Figure 1 is briefly outlined below:

3.1.1 Connectivity:

Firstly, the community has a whole has supporting physical infrastructure such as road networks, electricity, community local networks and telecommunication infrastructure. The connectivity element is addressed through development of the required communications infrastructure to facilitate human interaction and cooperation.

3.1.2 Personal ICT devices:

Secondly, individuals within the community each owns and has access to some technological or computing devices which they use to access the digital content and services that are accessible through the available community infrastructure. This is addressed by the both the first and second thrusts of ICT4D initiatives, namely, developing the required infrastructure as well as building human technical capability (ability to use technological gadgets effectively in this case).

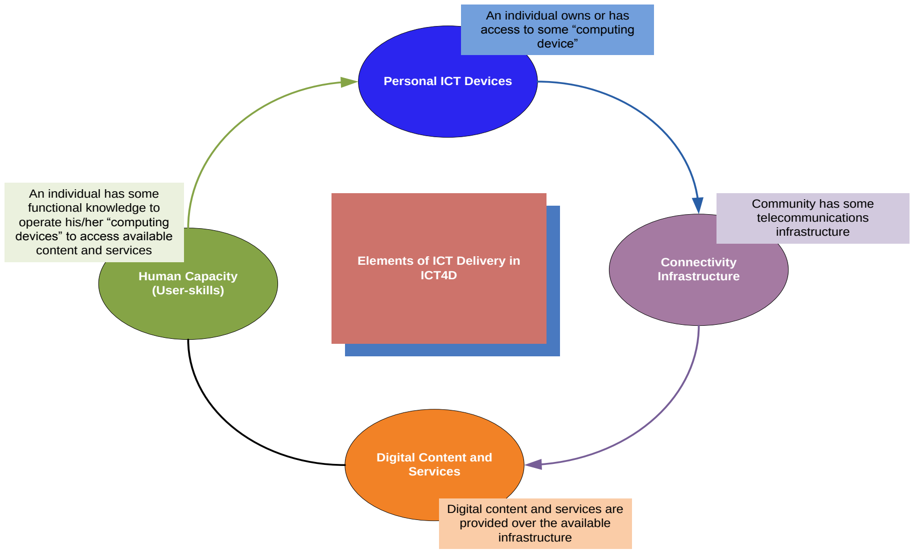

Figure 1: Components of ICT functionality adapted from Tongia & Subrahmanian (2006)

3.1.3 Digital content (information) and services (information systems)

Digital content (information) and services (information systems) are delivered through the available infrastructure. This is addressed by the third thrust of ICT4D initiatives, namely, providing access to digital content and services.

3.1.4 Human Capacity:

Individuals within the community have some working knowledge to be able to operate their personal ICT devices to access relevant content and services through the available community infrastructure. This also means the technical know-how needed to maintain and manage community owned ICT infrastructure, the ability to understand the available information as well as how to use the information systems to retrieve it.

Incorporating *Delivery Mechanism* as the fifth component facilitates the need to represent the crucial delivery of digital content/services to end-user communities. Figure 2 below illustrates the relationship between the four components from Tongia and Subrahmanian's (2006) 4C Framework and the additional component, the Delivery Mechanism.

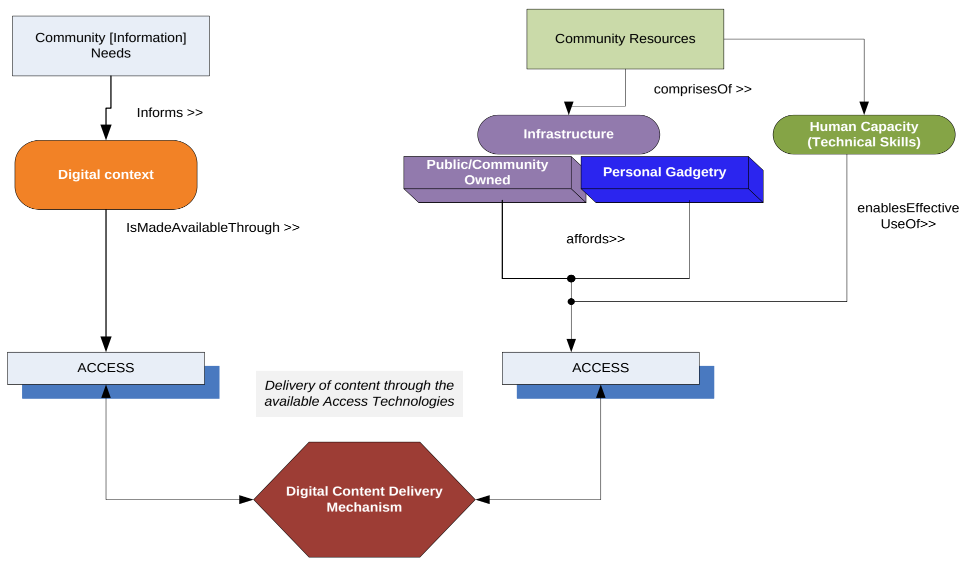

Figure 2: Components of access-technology agnostic delivery model

The information needs of the community (Dutta, 2009; Dhingra & Misra, 2004) inform the nature of digital content to be delivered to the end-user through some delivery mechanism. The digital content is made available to end-user communities through whatever access they may have to the delivery mechanism.

Community ICT resources comprise of *human skills* (technical know-how) and the supporting *physical and information infrastructures*. The communications or information infrastructure further comprises of community-owned or public infrastructure and the private or personal communications and entertainment gadgetry. This gadgetry can be described as a collection of electronic devices owned by private individuals or end-users. Together the *community infrastructure*, the *personal computing infrastructure* and *technical know-how* constitute the community's technological capabilities. These community technological capabilities afford community members access to digital content and services that are available through the delivery mechanism.

The *technical know-how* additionally enables users to make effective use of their devices and access networks. This effective use of available technologies further enables users to acquire value from access to the information infrastructure.

The delivery of digital content and services to end-users in the community is ultimately enabled by the Digital Content Delivery Mechanism which interacts with all components associated with the effective delivery of ICT functionality.

We argue that for equitable access to digital content and services, the delivery mechanism has to ensure access-technology agnostic delivery. The delivery mechanism has to ensure the needed participation mechanisms for delivery of content and interaction with services to all users regardless of the access infrastructure they connect through or the computing devices they use. This will require separation of the service logic, the content presentation format and the underlying access network. The separation of concerns among components of the proposed model proves to be a very promising approach to achieving universal information delivery – to deliver content (information) through any access technology (connectivity) and to any potential end-user device.

4. Access-technology agnostic delivery model

To ensure access-technology agnostic delivery of digital content and services to resource-constrained communities, the delivery mechanism is presented and discussed in the following section.

4.1 Conceptual model

Figure 3 represents the *Access-technology Agnostic conceptual model* developed, and is briefly outlined.

4.1.1 Physical world

The Personal ICT Devices used to access the ICT4D services, underlying Sensors and Access Networks through which the user is accessing services are all tangible objects in the physical world; they form part of the physical layer of the access-technology agnostic conceptual model.

4.1.2 Enablement layer

The Enablement layer defines the platform's explicit support for an access technology (communication protocol, device and content format). Specifically it adapts the delivery mechanism to the physical world, and represents the physical world to the internal components of the delivery mechanism.

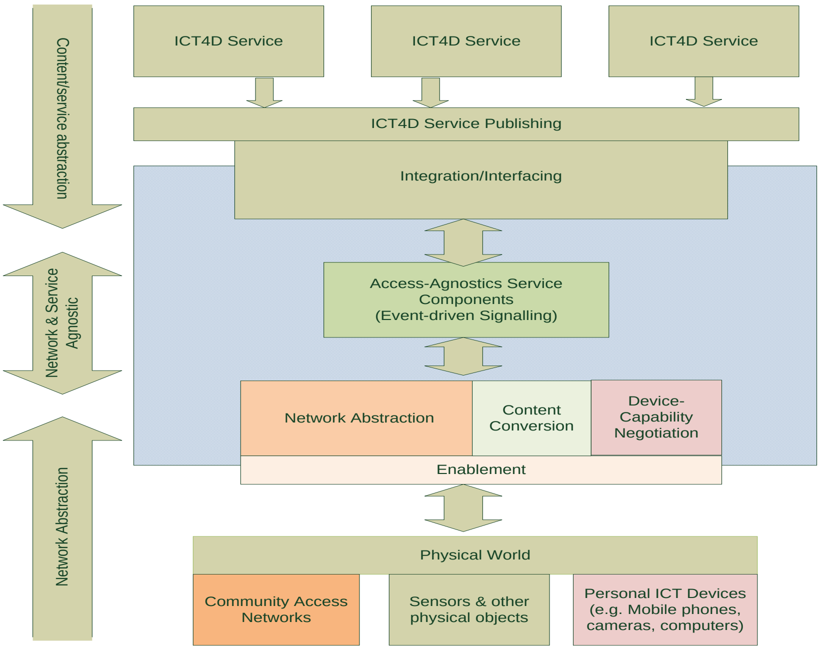

Figure 3: Access-technology Agnostic Conceptual Model

Device Capability Negotiation function is part of the Enablement layer, this function is envisaged to collect information about the capabilities and features of the end-user device (e.g. display size, CPU processing speed and direct download limit) and uses this information in rendering multimedia content to the connected end-user device.

Content conversion function is also part of the Enablement layer, this function is responsible for content-device capabilities matching. Since a service may produce outputs that need to be presented at the end-user device, this function adapts the content to the format understandable to the device.

The *Network Abstraction function* is adopted from the service delivery platform (SDP) conceptual model (Christian & Hanrahan, 2007) and abstracts the complexities of the underlying access-technology from the platform.

4.1.3 Access-agnostic layer

The access-agnostic layer has no knowledge of the network resources, it receives requests from the Enablement layer (already in a form understandable within its environment) and it has the logic or algorithm to ensure that these requests do reach their intended services. As far as the access-agnostic layer is concerned, it knows only that it has to forward these requests to the interfacing layer which “subscribed” to be notified of such requests. It is not aware of the application-specifics; it is only the Interfacing function that needs to worry about application-specifics.

4.1.4 Integration/Interfacing layer

The Integration/Interfacing layer is fully aware of what services lie outside of the platform. When a request is received from within the platform for one of the ICT4D services, it is the responsibility of the interfacing layer to invoke the appropriate service logic on the requested ICT4D service itself. The Interfacing layer therefore must have all the knowledge it needs in order to correctly invoke these services. The Interface layer represents the ICT4D services to other components in the lower layers of the platform.

4.1.5 Services publishing layer

The Publishing layer is shown as a layer for ease of description but is logically part of the Interfacing function. ICT4D services inform the platform of their presence by publishing/advertising themselves. Through these advertisements, they provide sufficient information necessary to invoke the advertised service logic. The Interfacing layer, which is responsible for the invocation of these external services, subscribes to be notified as and when services become available.

4.1.6 ICT4D services

ICT4D services are the actual digital content and services that are to be delivered through the available community access infrastructure. They are domain specific and are developed by or on behalf of ICT4D practitioners to address specific community needs. Examples of these services include eHealth, mHealth, mLearning, and weather services.

The proposed configuration presented in Figure 3 draws its inspiration from the Service Delivery Platform model and related concepts in telecommunications (Jain, 2007; Maes, 2007; Christian & Hanrahan, 2007; The Moriana Group, 2010). This study refers to this configuration as access-technology agnostic because it allows delivering information to the end-user independent of his or her technology of access. This configuration was adopted because it promises inclusivity, extended reach and equitable access to information.

4.2 Advantages of this approach for mobile phone users

With the proliferation of mobile devices as the most prevalent personally owned ICT the following four advantages associated with the *Access-technology Agnostic conceptual model* can be outlined:

4.2.1 Access-technology independence

Because the access network is separated from the core service logic, a user-device can be connected to any access-network and still be able to access the service. The significance of "access-network" is that only a specific set of devices can support certain access networks (technologies). For instance, low-end mobile phones (e.g. Samsung GT-E1080i) may not be able to connect to the 3G networks, and as such any service available through the 3G networks is inaccessible to these devices, and by extension, to their owners or users.

4.2.2 Future-proof and scalable

Underlying access network complexities are hidden from the service logic and execution environment, this makes it possible for new access technologies to be added to the enablement layer, it is also possible to support new and advanced devices as user's upgrade their handsets.

4.2.3 Content format independence

The decoupling of service logic, service access and content presentation make it possible to present the same content (e.g. information about farming) in multiple formats (Webpage, mobile phone text message, or audio) depending on the requesting user-device capabilities.

4.2.4 Delivery of ICT4D services to all

By plugging ICT4D services into the access-agnostic delivery mechanism, these services can be accessible through any access-technology and can be presented in any formats supported by the end-user devices. This is the enabling power of the proposed access-agnostic delivery mechanism.

This study argues that when configured as described in above, the delivery mechanism is able to deliver content (ICT4D services) to any device with the help of the device-capability negotiation and content conversion functions. The device can be connected to any underlying access-network, because the network abstraction function hides these details from the service logic execution environment. Content can also be presented in any format (text or audio) supported by the end-user device because the content conversion function is aware of both the content type and device capabilities.

The next section discusses the initial proof of concept implementation used to validate the *Access-technology Agnostic conceptual model*.

5. Reference implementation

Instantiations of design-science artifacts serve to demonstrate feasibility and to show that artefacts of design science can be implemented in reality (Hevner *et al*, 2004:79). Therefore the final expectation for this study was to demonstrate that the proposed *Access-technology Agnostic conceptual model* is practical and can be implemented.

The initial implementation of the *Access-technology Agnostic conceptual model* demonstrated how a pre-existing service (online weather service), traditionally accessible through a website (www.rssweather.com) could be made accessible through multiple channels and in multiple formats (text/voice). The proof of concept was demonstrated using the Mobi4D communications service delivery platform (Botha *et al*, 2010). It was necessary to develop additional access network abstractions components to enable access-technology agnostic delivery of the weather service. The Figure below shows components that were developed to demonstrate access-technology agnostic properties of the proposed *Access-technology Agnostic conceptual model*.

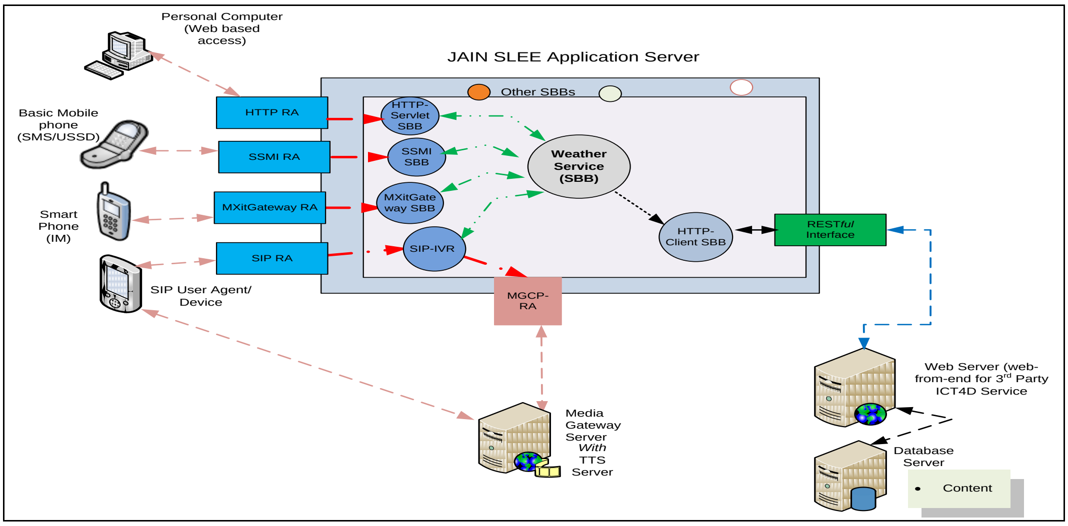

Figure 4: A reference implementation of access-technology agnostic delivery

The weather-service component receives weather requests from any underlying access network represented by the network abstraction components (HTTP RA, SSMI RA, MXitGateway RA and SIP RA). After retrieving the weather information from the service provider, the weather-service component sends the response back to the requesting network abstraction components. Formatting and presentation of the weather information is the responsibility of the network abstraction components since each has knowledge about the capabilities of the access-technologies they abstract. The reference implementation successfully made the weather information available through multiple access-technologies and formats. This demonstrated the utility and technical viability of the proposed *Access-technology Agnostic conceptual model*.

6. Conclusion

Ensuring equitable access to information is important both in terms of the importance of knowledge for development, and addressing global inequalities of opportunities. ICT4D has the potential to assist in this regard through its three main areas of concern, namely development of required ICT infrastructure, development of human capacity, and through the delivery of digital content and services.

Owing to the lack of delivery mechanisms in place to realize the equitable access to information, this paper presented an *Access-technology Agnostic conceptual model*, it also presented an initial proof of concept implementation of this model. The initial proof of concept implementation successfully demonstrated that relevant services and content could be made accessible through a diversity of technology commonly associated with resources constrained communities.

7. References

Agarwal, S., Kumar, A., Nanavati, A. A. & Rajput, N. (2009) Content creation and dissemination by-and-for users in rural areas. *Proceedings of the International Conference on Information and Communication Technologies and Development (ICTD).*

Akinsola, O., Herselman, M. & Jacobs, S. (2005) ICT provision to disadvantaged urban communities: A study in South Africa and Nigeria. *International Journal of Education and Development using ICT*, vol. 1.

Bieber, M., Mcfall, B. S., Rice, R. E. & Gurstein, M. (2007) Towards systems design for supporting enabling communities. *The Journal of Community Informatics*, vol. 3.

Botha, A., Makitla, I., Ford, M., Fogwill, T., Seetharam, D., Abouchabki, C., et al. (2010). *The mobile phone in Africa: Providing services to the masses*. Paper presented at the CSIR Science real and relevant conference 2010., Pretoria, South Africa.

Botha, A., Makitla, I., Tolmay, J., Ford, M., Seetharam, D., Butgereit, L., et al. (2010). *Mobile4D Platform.* Paper presented at the IST Africa Durban, South Africa.

Christian, R. & Hanrahan, H. (2007). Defining a Service Delivery Platform Architecture by Reusing Intelligent Network Concepts. *Proceedings of Southern African Telecommunications Networks and Applications Conference (SATNAC)2007.*

Dhingra, A. & Misra, A. D. C. (2004) Information Needs Assessment Model (INAM) for Identifying the Information Needs of Rural Communities. *Journal of Information Technologies and International Development,* vol. 2. Pp 77 - 78.

Dias, B. & Brewer, E. (2009) How Computer Science Serves the DevelopingWorld. *Communications of the ACM, vol.* 52. Pp 74–80.

Dutta, R. (2009) Information needs and information-seeking behavior in developing countries: A review of the research. *The International Information & Library Review,* vol. 41**.** Pp 44 - 51.

Garai, A. & Shadrach, B. (2006) Taking ICT to every Indian village: opportunities and challenges. *One World South Asia*.

Gebremichael, M. D. & Jackson, J. W. (2006) Bridging the gap in Sub-Saharan Africa: A holistic look at information poverty and the region's digital divide. *Government Information Quarterly, vol.* 23**.** Pp 267 - 280.

Harande, Y. I. (2009) Information Services for Rural Community Development in Nigeria. *Library Philosophy and Practice*.

Heeks, R. (2008) ICT4D 2.0: the next phase of applying ICT for International Development. *Computer,* vol. 41**.** Pp 26 - 33.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in information systems research. *Management Information Systems Quarterly, vol. 28, No.* 1. Pp 75-106.

Jacobs, S. J. & Herselman, M. E. (2006) Information Access for Development: A Case Study at a Rural Community Centre in South Africa. *Issues in Informing Science and Information Technology*, vol. 3. Pp 295 - 306.

Jain, A. 2007. Telecom Service Delivery Design Patterns. *Proceedings of the 14th Conference on Pattern Languages of Programs*, ACM.

Krichen, M. & Tripakis, S. (2004) Black-box conformance testing for real-time systems. *Model Checking Software***.** Pp 109 - 126.

Lavhengwa, T. (2007) Public Internet Terminals supporting accessibility to information in rural areas. *Faculty of Information and Communication Technology*. Pretoria, Tshwane University of Technology.

Maes, S. H. 2007. Service delivery platforms as IT Realization of OMA service environment: service oriented architectures for telecommunications. In: *proceedings of the Wireless Communications and Networking Conference. WCNC 2007*. 11-15 March 2007,Redwood Shores, CA.

March, S. T. & Smith, G. F. (1995) Design and natural science research on information technology. *Decision support systems,* vol. 15**,**. Pp 251 - 266.

Mvelase, P. S., Dlodlo, N., Mathaba, S. U., Krause, C. & Kabanda, S. K. (2009) Theoretical framework for government information service delivery to deep rural communities in South Africa. *Proceedings of the 3rd International IDIA Development Informatics Conference.* Kruger National Park, South Africa.

Nnadi, N. & Gurstein, M. (2007) Towards supporting community information seeking and use. *The Journal of Community Informatics,* vol. 3.

Oates, B. J. (2006) Researching information systems and computing, Sage Publications Ltd.

Olivier, M. S. (2004) *Information technology research: A practical guide for computer science and informatics.2nd ed. Pretoria: Van Schaik,* Pretoria, van Schaik Publishers.

Patel, S., Bataveljic, O., Lisboa, P., Hawkins, C. & Rajan, R. (2006) iShakti--Crossing the digital divide in rural India. *Proceedings of the 2006 IEEE/WIC/ACM International Conference on Web Intelligence*. IEEE Computer Society.

Pitula, K., Dysart-Gale, D. & Radhakrishnan, T. (2010) Expanding Theories of HCI: a case study in requirements engineering for ICT4D. *Information Technologies & International Development,* vol. 6.

Sambasivan, N., Rangaswamy, N. Cutrell, E. & Nardi, B. (2009) UbiComp4D: infrastructure and interaction for international development—the case of urban Indian slums. *Umbicomp 2009.* Orlando, Florida, USA, ACM.

The Moriana Group. (2010) *Service Delivery Platforms – Thought Leadership Papers*. Available from: http://www.morianagroup.com [Accessed: 10 August 2010].

Unwin, T. (2009) *ICT4D: Information and communication technology for development,* Cambridge, Cambridge University Press.