A CONCEPTUAL MODEL OF AN ACCESS-TECHNOLOGY-AGNOSTIC DELIVERY MECHANISM FOR ICT4D SERVICES

By

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DECLARATION:

In accordance with Rule G4.6.3, I hereby declare that the above-mentioned dissertation is my own work and that it has not previously been submitted for assessment to another university or for another qualification.

SIGNATURE: ____

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Abstract

Information and Communication Technology for Development (ICT4D) is an emerging research area that is concerned with the beneficial applications of Information and Communications Technology (ICT) to achieve developmental goals. ICT4D is thus concerned with designing and developing innovative technologies for resource-constrained environments for applications in key areas of social development such as health, agriculture and education. The ICT4D initiatives, therefore, are driving three main tasks, namely developing the required infrastructure (connectivity, electricity and computing devices) sustainably, building the required ICT human capacity, and providing access to digital content and services. Each of these three main thrusts necessitates innovation.

This study addresses the evident lack of delivery mechanisms to facilitate access to digital content and services to end-users through the technologies that these end-users already possess. This lack of innovative delivery mechanisms is both an impediment to achieving equitable access to digital content and service and an opportunity to innovate.

Therefore, drawing from the theoretical background of ICT4D, this study develops a set of technical and socio-technical requirements that the missing delivery mechanisms should satisfy. The study also explores the Service Delivery Platform (SDP) concept as a technically viable basis for the required delivery mechanisms. The study then develops a conceptual model of an Access-Technology-Agnostic Delivery Mechanism as a possible delivery mechanism that facilitates equitable access to digital content and services within an ICT4D context. The relevance of the conceptual model is established and, through a prototype implementation, the technical feasibility and utility of the conceptual model is demonstrated. The conceptual model is demonstrated through a proof of concept implementation using standards-based open source technologies. The proof of concept clearly demonstrates that the access-technology-agnostic delivery of digital content and services is achievable, thus making the same service accessible through different

access technologies. In developing the Access-Technology-Agnostic Delivery Mechanism, this study contributes through innovation to providing access to digital content and services in an access-technology-agnostic manner.

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Chapter 1
Introduction

The individual researcher's decision to carry out a research project is motivated by a number of factors. One of these factors is the realisation that there exists a research warrant within a particular field of study. This realisation eventually culminates in the rationale for conducting research. There is a pleasing relationship between the rationale for conducting the research and the background to the research. The relationship is one in which the latter informs the former. The background of the research study serves to demonstrate the relevance of the intended research relative to the extant literature, and the rationale expresses what the researcher has identified as key realisations, ultimately informing his decision to commit to a full research exercise.

With the above in mind, the researcher's realisations, which are informed by the explored literature, are outlined.

It is observed that *people may already own or have access to technologies that they can afford and use*. Research shows that mobile cellular technology has penetrated developing countries much faster than any other technology (Botha, Makitla, Fogwill & Tolmay, 2011). Mobile technology has become the personal technology in which users in least developed regions have, in the words of Heeks (2008), "invested with their wallets". According to Botha, Batchelor, van der Berg and Islas (2008), the impact of mobile technology access is in empowering mobile technology users with new possibilities, and affording them the capacity to participate in the information age both as contributors and as users. Botha *et al.* (2011) further emphasise that where no other means of access are available, mobile cellular technology offers a viable connectivity alternative.

In view of the realisation that people may already have access to some sort of technology, the need to capitalise on such available technological capabilities becomes a key driving force. Batchelor, Evangelista, Hearn, Pierce, Sugden and Webb (2003:82) express the view that existing technologies such as telephone, radio and television can offer inexpensive information distribution alternatives to a larger number of people in developing regions than can new technologies. This informs the realisation that *there is a need to capitalise on existing technological capabilities of target communities*.

Botha (2009) coined the term digital difference to reflect this paradigm-shifting realisation. The primary tenet of digital difference is providing access to contextually meaningful digital content and services, and enabling participation in the information society through technologies that have already penetrated user communities. The primary realisation embedded in the digital difference paradigm shift is that users already have access to, or own, some technology, be it television, radio, personal computer, mobile telephone, fixed-line telephone or other personal communication and entertainment gadgetry. Botha and Herselman (2011) contest the prevailing concept of a digital divide by arguing that users have different technologies with different capabilities and that this difference in capabilities creates more of a digital difference amongst users rather than a digital divide.

In accordance with the digital difference perspective, the key challenge, and the essence of the direction of this study, is to bridge this "digital difference" by finding those mechanisms that can facilitate delivery of meaningful digital content and services, and that can also enable participation in the information society through whatever technologies the target communities have access to and use. Such mechanisms will have the potential of ensuring equitable access to digital content and services by focusing critically on being access-technology-agnostic.

In terms of the researcher's decision to commit to a full research project, the need to bridge the digital difference, as discussed above, motivates the research.

This chapter sets the context of the study; Section 1.1 provides the context of the study, leading to the identification and motivation of the research problem in Section 1.2. The objective of the research, which is inferred from the researcher’s decision to conduct research, is discussed in Section 1.4, followed by Section 1.3, which presents and elaborates on the research questions. The delineations and assumptions are explicitly stated in Section 1.5. Finally, Section 1.6 presents an overview of the structure of this dissertation with a synopsis of each chapter.

1.1 CONTEXT

Information and Communication Technology for Development (ICT4D) is an emerging research area that is concerned with addressing the Millennium Development Goals (MDGs) as well as designing technologies for resource-constrained environments through innovations in the areas of healthcare, agriculture and education, among others (Sambasivan, Rangaswamy, Cutrell & Nardi, 2009: 156). The eight millennium development goals set to be achieved by 2015 are:

1. To eradicate extreme poverty and hunger
2. To achieve universal primary education
3. To promote gender equality and empower women
4. To reduce child mortality
5. To improve maternal health
6. To combat HIV/AIDS, malaria and other diseases
7. To ensure environmental sustainability
8. To develop a global partnership for development.

According to Dias and Brewer (2009:75), the MDGs have infused new energy into world development efforts and helped to focus these development efforts on concrete objectives such as poverty eradication, improving health, universal primary education and so forth. In his Development Informatics literature synthesis, Johanson (2011:3-4) submits a summary definition of Development Informatics in which he refers to Development Informatics as a field of study which aims to maximise the beneficial application of ICTs to improve the quality of lives of individuals and the collective. In the case of this study, the development of new technologies, methods and processes is geared towards facilitating such beneficial applications of ICTs.

According to Toyama and Dias (2008: 22-23), innovation within the ICT4D space occurs in different areas; this is a result of the multi-disciplinary and multi-stakeholder nature of the ICT4D space (Donner, Gandhi, Javid, Medhi, Ratan, Toyama and Veeraraghavan, 2008:34). Accordingly, the 4C Framework presented by Tongia and Subrahmanian (2006) indicates that innovation in the ICT4D domain has several components; it incorporates *Computers* (devices); *Connectivity* (infrastructure); and *Content* and *Capacity*. Figure 1-1 depicts the components of ICT4D innovation.

Figure 1-1: Areas of innovation within ICT4D (adapted from Tongia and Subrahmanian, 2006)

Each area of innovation in Figure 1-1 addresses the challenges that are within its scope. This is because the set of challenges that ICT4D initiatives seek to address, through innovation in these key areas, differ significantly as a result of context-specific conditions and constraints. Pitula, Dysart-Gale and Radhakrishnan (2010) as well as Pitula and Radhakrishnan (2011:325) noted that ICT4D initiatives have three main thrusts:

- Developing the required infrastructure (power, connectivity and devices) in a sustainable manner.

- Building the ICT capacity, the skills and the competencies required to manage and maintain and use the technology effectively.
- Providing access to digital content and services.

These thrusts map directly to the areas of innovation within ICT4D shown in Figure 1-1, and these mappings are shown explicitly in Table 1-1 below.

Table 1-1: Mapping the main thrusts of ICT4D to areas of innovation.

Main Thrust of ICT4D Initiatives	Areas of Innovation (4C Framework)
Developing the required infrastructure in a sustainable manner	• Connectivity • Computers (or computing)
Building the ICT capacity	• Capacity
Providing access to digital content and services	• Content and services

In view of the mappings as shown in Table 1-1, delivering ICT functionality within an ICT4D context is accomplished through innovations in the key areas that Tongia and Subrahmanian (2006) refer to as the 4C Framework (Figure 1-1).

Of the four key areas of innovation (Table 1-1), this study focuses on the area of innovation pertaining to content and service delivery, and will contribute towards innovative mechanisms of providing access to, and facilitating delivery of, digital content and services with an ICT4D context.

In this study, the focus on ICT4D in terms of addressing the global developmental challenges is based on the moral imperative of applying innovative technological solutions such as ICTs for the benefit of the world's poor. This imperative has also been recognised by Heeks (2008) and Unwin (2009).

The decision to focus on the delivery of digital content and services on the other hand is supported by the critical *importance of access to information and* *knowledge* as expressed by a number of scholars such as Harande (2009), Jacobs and Herselman (2006a), Garai and Shadrach (2006). According to Harande (2009), the ability to acquire, produce, access and use information is critical for the development of nations. In view of this, advances in ICT to which this study hopes to contribute, provide tools that enable and facilitate the production, acquisition, access and exchange of information.

The decision is also informed by the awareness that not much has been done in this area of innovation within the ICT4D context, especially with regard to bridging the digital difference. This awareness is based on the review of prior efforts that attempted the delivery of digital content and services within the ICT4D context.

Prior efforts to address the delivery of digital content and services include the proposals of community information systems as outlined by Bieber, McFall, Rice and Gurstein (2007). Their deliberations, however, do not address the issue of access-technology-agnostic delivery of information. Access-technology-agnostic delivery of information is the delivery of the same information through different access channels.

Many of the proposed content distribution models involved a single specific access-technology (e.g. Shazel & Abdulla, 2005) or specific areas, points or nodes of access within a community such as:

- ICT hubs (Jacobs & Herselman, 2006b).
- Cyber cafés and multi-purpose community centres (Akinsola, Herselman & Jacobs, 2005).
- Public internet terminals (Lavhengwa, 2007).
- Village kiosks (Patel, Bataveljic, Lisboa, Hawkins & Rajan, 2006).
- Small and Medium Enterprises (SMEs) (Mvelase, Dlodlo, Mathaba, Krause & Kabanda, 2009).
- The use of community radio technology (Kwapong, 2007).

Further to this has been the delivery of content in specific formats, for instance through:

- Web-based interactive text (Agarwal *et al.*, 2009),
- Voice (Patel *et al.*, 2006), or
- Audio-visuals (e.g. Faulkner & McClelland, 2002).

As a direct consequence of the content delivery models discussed above, information (digital content) and services are distributed only over a specific physical network. Furthermore, digital content and services are accessible only from specific places (points of access) and presented only in a specific format. This approach places strict requirements on the part of the end-user to be able to reach specific places to gain access and to be in possession of a device that can connect through specific access networks and can be able to process content in the format in which the content is being presented. In view of this shortcoming, a gap still exists.

1.2 PROBLEM STATEMENT

One of the main thrusts of ICT4D is the delivery of digital content and services (Pitula *et al*., 2010). However, there is little evidence of delivery mechanisms that deliver digital content and services through any access-technologies and devices available to end-users. This lack of access-technology-agnostic delivery mechanisms impacts negatively on inclusive and equitable access to digital content and services. Consequently, a model for a delivery mechanism that enables inclusive and equitable access to digital content and services remains a challenge.

1.3 RESEARCH OBJECTIVE

The primary objective of this study is to develop an Access-Technology-Agnostic Delivery Model to facilitate the access-technology-agnostic delivery of digital content and services within an ICT4D context.

It is essential to follow a well-founded research methodology and research design which are appropriate to achieve the above research objective. Chapter 2 will discuss this study's research methodology in more detail.

1.4 RESEARCH QUESTION

In order to achieve the objective of developing and describing a model that would facilitate access-technology-agnostic delivery of digital content and services to resource-constrained communities, one main research question was identified:

> What are the elements of a model that facilitates access-technology-agnostic delivery of, and access to, digital content and services in resource-constrained communities?

To answer the above question adequately, it is necessary to elaborate on the following investigative question (IQ-1):

- What requirements does an ICT4D context impose on the mechanisms by which digital content and services are delivered, and which the proposed model must address?

The purpose of this investigative question is to establish, through literature review, what are typical ICT4D challenges and the requirements imposed by these challenges on technological solutions aimed at facilitating equitable access to digital content and services within an ICT4D context. Chapter 3 of this dissertation addresses this investigative question: it presents literature on ICT4D, discussing the challenges within the ICT4D domain and the impact that these challenges have had on previous ICT4D initiatives, culminating in the list of requirements for a possible solution that would address such challenges.

Based on the set of requirements for a solution as developed through the investigative question above, the second investigative question (IQ-2) is:

- On what architecture should the proposed Access-Technology-Agnostic Delivery Model be based?

This investigative research question explores an existing technical architecture which may serve as the basis for the solution proposed by this study with regard to the delivery of digital content and services, as well as facilitating equitable access to content and services. The choice of the base architecture is informed by the set of requirements and the researcher's own awareness of existing architectures that deal specifically with the delivery of service.

Based on selected technical architecture, the third investigative question (IQ-3) is:

- What should be the basic elements, the relationships and the functionalities of these elements in order to realise the proposed Access-Technology-Agnostic Delivery Model?

The third investigative question (IQ-3) pertains to the high-level view of the proposed solution to understand its conceptual principles in terms of the basic elements (see main research question), the functional principles with respect to the set of requirements imposed by the environment on these elements (see IQ-1), and the relationship between these elements which constitute the solution architecture (see IQ-2).

- Which technologies, if any, are available to implement an Access-Technology-Agnostic Delivery Model as described conceptually in IQ-3 and based on the selected architecture (IQ-2)?

The fourth investigative question pertains to the reference implementation of the proposed solution. It will explore available technologies that may facilitate the implementation of the proposed solution; it will also explore technological challenges when implementing an Access-Technology-Agnostic Delivery Model.

1.5 DELINEATION AND ASSUMPTIONS

Delivering ICT functionality within an ICT4D context is done through developing the required infrastructure, delivering digital content and services, and building the required ICT capacity (see Figure 1-1). These are the main thrusts of ICT4D and are equally important. Focusing on one aspect of these main thrusts is limiting.

Furthermore, the delivery of digital content and service to any community, which is the focus of this study, requires a good understanding of the nature of content that the target community will consider relevant and useful. It also entails understanding the capabilities available within the community to support delivery of digital content. To achieve this understanding, descriptive qualitative studies can be undertaken to assess information needs and state of communications infrastructure in target communities. This is, however, outside the scope of this study; the researcher aims for the outcomes of this research to inspire other researchers to carry out the kind of research (e.g. case studies) needed to implement the developed model in specific communities.

Since this study focuses only on the digital content and services component of ICT functionality, and because this is a technical study that does not involve fieldwork, it makes assumptions regarding the deployment or implementation environment.

This study assumes the availability of basic information and communication infrastructure. It also assumes that community members (as potential end-users) own or have access to some form of electronic communication or entertainment gadgetry. This assumption is inherent in the *digital difference* paradigm.

1.6 CHAPTER OUTLINE

The work done in this research project will systematically be reported on in seven chapters as follows:

Chapter 1: Sets the context of the study: it presents the background to the study, identifies and motivates the research problem, and presents research questions, research objectives and scope of the research.

Chapter 2 Discusses the research methodology and the research framework followed during the course of this research.

Chapter 3: Presents a literature review of ICT4D, specifically the challenges within the ICT4D domain. This chapter will identify specific requirements that ICT4D context imposes on the proposed model, describing potential use case for the model within the ICT4D context.

Chapter 4: Explores the technical architecture which can serve as the technical basis for the proposed solution. This chapter forms part of the design phase of the research process (*cf.* Chapter 2).

Chapter 5: Extracts key concepts derived from the literature (Chapter 3 and Chapter 4), and maps these key concepts to the objectives or requirements of a solution, leading to the identification of basic components of the conceptual model. This chapter then discusses the components of the proposed model in detail, justifying the inclusion of each component and detailing the nature of relationships between these components. It will also argue, with reference to the requirements of the solution, that the conceptual model has beneficial characteristics.

Chapter 6: This chapter discusses the experimental instantiation of the conceptual model to support the argument that the model has beneficial characteristics, and furthermore that the model is technically feasible. This chapter therefore represents a proof of concept.

Chapter 7: Summarises and concludes the research; it revisits the research problem, research questions and the methodological aspects of the study; it also highlights the contribution of the study. Finally, this chapter also gives some recommendations for further research.

Chapter 2

Research Methodology

Research involves applying various techniques and methods to create scientifically obtained knowledge (Welman & Kruger, 2004:2). Research methodology defines how the research is carried out in terms of research design, how research effort is measured and what constitutes success. Research design ensures that the evidence obtained through the research process enables the researcher to adequately answer the research questions as unambiguously as possible. Therefore, selecting an appropriate research approach is a critical aspect of sound research.

2.1 SELECTING A RESEARCH APPROACH

Scientifically obtained knowledge, to which Welman and Kruger (2004:2) refer, rests on the researchers' epistemological assumptions in terms of the nature of knowledge, how it may be represented and the perceived appropriateness of the methodologies applied in obtaining such knowledge. Becker and Niehaves (2007) analyse such underlying epistemological assumptions of research paradigms and methods in Information Systems (IS). According to Becker and Niehaves (2007:205), the methodological aspects of epistemology concern the modes of acquiring knowledge. Knowledge can be acquired *inductively* by extending individual cases into a generalised universal case (Becker & Niehaves, 2007:205) or universal law (Becker & Niehaves, 2007:205). Another mode of acquiring knowledge is through the use of a *deductive* method (Becker & Niehaves, 2007:206). Deduction can be understood as the opposite of inductive in the sense that deduction derives the individual from the universal through the use of logical reasoning as in mathematical axioms.

The researcher's belief as to what constitutes knowledge and how such knowledge may be reliably acquired informs the choice of a research approach as either positivistic or anti-positivistic (interpretivistic). Positivistic approaches attempt to generalise from the specific, whereas anti-positivistic approaches attempt to interpret the specific (Opie, 2004:8). This study takes a positivistic stance, and will therefore adopt a positivistic research approach.

According to March & Smith (1995) research approaches in Information Technology (IT) can be categorised into two: *natural* (*behavioural) science* and *design science*. These two research approaches differ fundamentally in terms of research objectives. The key distinction between natural science and design science research, according to March and Smith (1995:253), is that natural science attempts to understand reality, whereas design science concerns itself with creating artefacts that serve human purpose. These two research paradigms are also discernible as complementing each other, where natural science strives to understand problems, whereas design science attempts to solve such problems (Adikari, McDonald & Campbell, 2009).

March & Smith (1995:252) further drew distinctions between research approaches by what they call the scientific interests in IT research, namely *descriptive* and *prescriptive*. The descriptive interests relate to the nature of IT artefacts, how they affect or are affected by their environment. The descriptive interests, therefore, correspond to natural (behavioural) science. Peffers, Tuunanen, Rothenberger and Chatterjee (2007: 47) lament that most research activities in Information Systems (IS) tend to be more descriptive with limited applicability to addressing real-world human problems and purposes. The prescriptive interests, on the other hand, relate to the implementation of intelligence and knowledge-using activities that correspond to the engineering-inclined design science research.

The purpose of this study is to address the evident lack of an access-technology-agnostic delivery mechanism for digital content and services within an ICT4D context by prescribing and developing an *Access-Technology-Agnostic Delivery Model*. A design science research paradigm was adopted in this study because of the prescriptive nature of the study, and also because the development, design and building of the model as an output adheres more to design science research than to any other type of research strategy.

A methodology for design science research, according to Peffers *et al.* (2007:49), comprises three key elements, namely *conceptual principles* that define what constitutes design science research (Section 2.2 and Section 2.3), *practice rules* of how to carry out acceptable design science research (Section 2.4), and a *process* for carrying out and presenting design science research (Section 2.5). The next section discusses the conceptual principles of design science research.

2.2 CONCEPTUAL PRINCIPLES OF DESIGN SCIENCE RESEARCH

Design science research is understood by March and Smith (1995:253) as being about developing artefacts to attain specific goals. In keeping with this view, and through literature synthesis, Peffers *et al*. (2007:49) and Carlsson, Henningsson, Hrastinski and Keller (2011:126) note that the definition of design science research includes any designed object that embeds a solution to an understood research problem. Reeves (2006:52) views design science research as seeking to investigate the development of solutions that target practical problems which culminate in the identification of design patterns or re-usable design principles. In this sense, design science research may also be about applying the design patterns and principles from a different domain (for example, reusing concepts from building architectures in computer systems architectures). In this study, concepts from the telecommunications domain will be investigated for applicability in defining a viable architecture of an access-technology-agnostic delivery model for digital content and services within the ICT4D domain.

Venable (2006:1), on the other hand, defines design science research as a creative, problem-solving activity that is rooted firmly in engineering and other applied sciences. Peffers *et al.* (2007: 47) concur, noting that design is accepted as a valid and valuable research methodology in engineering because of the value placed by engineering research on incrementally effective solutions to problems.

Epistemologically, design science research is seen by its proponents to be based on pragmatism as its philosophical orientation (Iivari, 2007). The underlying belief of design scientists is that knowledge and better understanding of design problems and their solutions can be established through building and applying purposeful artefacts (Hevner, March, Park & Ram, 2004). The researcher embraces this belief for the purpose of this research and contends that the development of an access-technology-agnostic delivery model and its ultimate instantiation would contribute to knowledge, firstly by contributing design product (practical utility), and secondly by expanding the application domain of the foundation on which the study is grounded.

Although design science research is rooted firmly in engineering (Iivari, 2007), there is general consensus among IS researchers that effective research in IT requires both engineering-inclined design science research and natural (behavioural) science research activities. March and Smith (1995) argue that both design science and natural science research activities are needed to make IT research relevant and effective. Gregor and Jones (2007) support this argument, stating that design science research in Information Systems (IS) should not only be concerned with prescriptions for designing technological products, but should also focus on designing methodologies. Carlsson *et al.* (2011) emphasise that IS should be viewed as a socio-technical system and not merely as an IT artefact. Furthermore, Baskerville, Pries-Heje and Venable (2007), Carlsson (2010), McKay and Marshall (2008) are of the view that design science research in IS should be underpinned by a socio-technical perspective. To this end, Carlsson *et al.* (2011) suggest a socio-technical approach to design science research in IS. This socio-technical approach points to the reciprocal relationship between the two disciplines, namely engineering-inclined design science and socially-inclined natural sciences. Furthermore, Donner *et al.* (2008:34) consider ICT4D as a multidisciplinary domain that facilitates collaboration between engineers and social scientists to develop innovative solutions to challenges faced by communities in resource-constrained environments. This too supports the view of the need for both engineering-inclined design science and social science research activities. *In recognition of this, and also because of the socio-technical nature of the ICT4D domain, this study has developed a set of socio-technical requirements which the proposed solutions must satisfy* (*cf.* Section 3.4, Table 3-1 and Table 3-2).

As discussed in the conceptual principles above, design science research requires both interpretivist (behavioural) science research and positivist (engineering-inclined) research activities, but it must still be done according to a well-defined research framework.

For such a research framework, Hevner (2007), with expressed acknowledgement of theses from Iivari (2007), provides a three-cycle view of the design science research framework, according to which the research activities within design science research are understood in terms of the *Relevance Cycle*, the *Design Cycle* and the *Rigor Cycle*. Additionally, March and Smith (1995) in Figure 2-2 provide a two-dimensional framework based on research outputs (*construct*, *model*, *process*, *instantiations*) and research activities (*build*, *evaluate*, *theorise*, *justify*) of design science research, which may be interpreted as making up the *design cycle* (build and evaluate) in the three-cycle view of design science research (see Section 2.3).

2.3 FRAMEWORK FOR DESIGN SCIENCE RESEARCH

This section discusses the research framework for design science research and specifies how this study implements the framework.

Figure 2-1 below depicts the three-cycle view of design science research adapted from Hevner (2007).

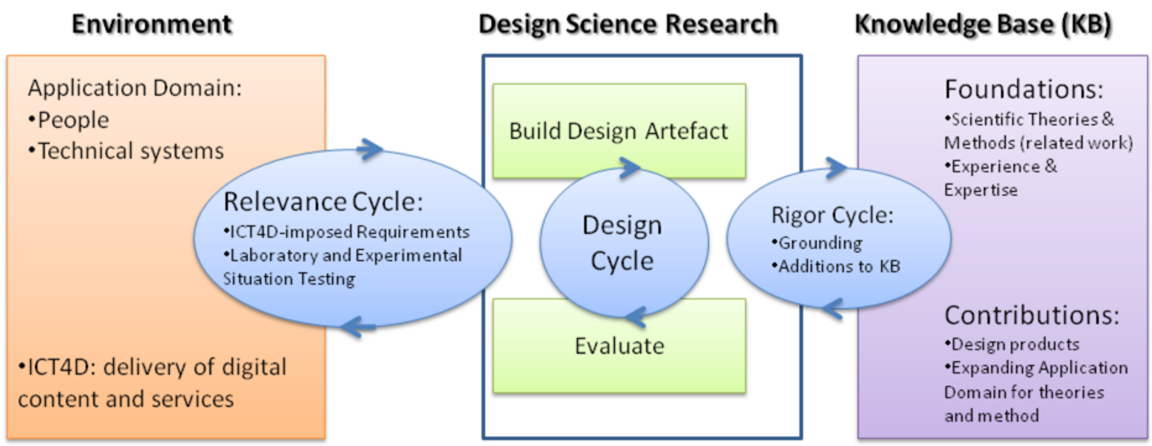

Figure 2-1: The three-cycle view of design science (adapted from Hevner, 2007)

2.3.1 Relevance cycle

The *relevance cycle* is aligned to the relevance of the research problem, where the contextual environment provides inputs into the research. Context provides both requirements as well as the application environment for the design artefacts and processes.

In accordance with the *relevance cycle* of the three-cycle view of DS, this study will be informed by literature on ICT4D to identify a potential research problem. In this sense, ICT4D represents the environment in which the study is located, and automatically serves as a testing ground for the design artefacts. The environment further presents opportunities and challenges in the research. These opportunities and challenges will culminate in sets of requirements which the desirable artefact would meet. In this study, the set of such requirements will be developed from a detailed discussion on ICT4D literature in Chapter 3. ICT4D context therefore serves as an environment whose practical challenges and opportunities represent the problem relevant to this research.

In order to address the practical challenges to be identified from the ICT4D context, the proposed solution should then satisfy the ICT4D-context-imposed requirements. These requirements provide input into the research in two ways. Firstly, they dictate what a desirable artefact would look like in terms of its beneficial characteristics. Secondly, these requirements serve as evaluation criteria for the developed artefact; both the model and its instantiation. The artefact to be developed as part of this research will be evaluated against this set of requirements.

2.3.2 Design cycle

The *design cycle* pertains to the building and evaluation of design artefacts and processes in solving the problem, and such design activities are informed or grounded on established scientific theories and methods; they may also rely on existing experience and expertise such as technological advances. The *design cycle* therefore applies theories, methods, experiences and expertise found in the knowledge base.

In this study, the *design cycle* involves the building and evaluation an *Access-Technology-Agnostic Delivery Model* for digital content and services within the ICT4D context. In terms of the two-dimensional framework, the intended research outputs and research activities that apply to this study are checked accordingly in Figure 2-2.

Research Activities

Research Output	Build	Evaluate	Theorize	Justify
Construct				
Model	✓	✓		
Method				
Instantiation	✓	✓		

Figure 2-2: Design cycle as a two-dimensional framework (adapted from March & Smith, 1995)

In Figure 2-2, the first dimension shows the research output based on design science research, namely *construct*, *model*, *method* and *instantiation*. The second dimension represents research activities for both design science-intended research as well as natural science-intended research. Design science research activities involve building and evaluating IT artefacts, whereas natural science research activities involve *theorising* and *justifying* theories (March & Storey, 2008:725). The desirability of theories as outputs of design science research has been recognised (Venable, 2006).

The “build” and “evaluate” research activities have been identified by March and Smith (1995) as the two main design science research processes. This study therefore adopts the two-dimensional framework as a view for its *design cycle* in accordance with the three-cycle view of design science research.

Building is the act of constructing the actual artefact (construct, model, method or instantiation) to address a well-understood problem. This construction is aided by the existing body of scientific knowledge in terms of theories and methods. It is also aided by experiences and expertise within the problem domain. Once the artefact is built, it needs to be evaluated against a set of evaluation metrics or criteria.

Evaluation is a research activity within design science research aimed at developing criteria by which artefacts may be assessed (March & Smith, 1995:258). As such, the contributions of artefacts such as new models and methods are evaluated in terms of the improvements they introduce in the development and use of information systems (March & Storey, 2008:726). The instantiations of these artefacts, according to March and Storey (2008:726), demonstrate their feasibility and utility for a given task. The evaluation approach adopted in this study is discussed in Section 2.5.5.

2.3.3 Rigor cycle

The last of the three cycles in the three-cycle view of design science research is the Rigor Cycle and pertains to the contribution to, and the use of, existing established scientific theories and methods, and the use of existing experience and expertise in the knowledge base (Hevner, 2007). The Design Cycle, which applies theories, methods, experiences and expertise found in the knowledge base, can also contribute to the knowledge base by adding new design products and processes and also expanding the application potential of the existing theories and methods. The proponents of design science research assert that it is this scientific rigor, and contribution to the knowledge base, that distinguishes design science research from routine building of IT artefacts (Iivari, 2007; Hevner *et al.*, 2004).

This study uses the 4C Framework (Tongia & Subrahmanian, 2006) as its theoretical basis towards a set of components of delivering ICT functionality within the ICT4D context. Furthermore, the researcher's solution approach is also informed by the theoretical perspectives on technology and development (*see* Section 3.2). The researcher further employs his practitioner's knowledge in the area of communications services delivery to develop the desired artefact.

In terms of contribution or addition to the knowledge base, this study will contribute an *Access-Technology-Agnostic Delivery Model* as a design product. The study will also contribute to knowledge by expanding the application domain for the theories and methods used for grounding this research.

In addition to a well-defined research framework for conducting design science research, it is also important that design science research be conducted in accordance with a well-defined protocol or set of practise rules. For such a set of practise rules for conducting design science research, Hevner *et al.* (2004) offer seven guidelines for conducting design science research, for which Venable (2010) provides a detailed review of the level of consensus within the research community. Section 2.4 discusses the seven guidelines and highlights how this study adheres to each of the guidelines.

2.4 PRACTISE RULES FOR DOING DESIGN SCIENCE RESEARCH

In order for the research execution to qualify as design science research instead of a mere routine design task, it needs to comply with the practise rules for conducting design science research. To aid in this regard, Hevner *et al.* (2004: 82–90) present seven guidelines for conducting design science research. These guidelines are to be used when evaluating the actual research process to ascertain that this study has followed a proper research process in the development of the proposed artefact.

2.4.1 Design as an artefact

The creation of innovative and purposeful artefacts is the fundamental expectation of design science research. This is evident from Peffers *et al.* (2007:49), who singled out this guideline as the most important expectation for design science research, namely that it must produce an artefact to address a problem. For its part, this study develops an access-technology-agnostic delivery mechanism to deliver digital content and services to resource-constrained communities in a manner that is independent of the access technologies used to access them.

2.4.2 Problem relevance

The researcher has to indicate that the problem he is trying to solve is significant and relevant as a measure of the value of his research. The problem statement and significance of the study as discussed in Chapter 1 addressed this point. Furthermore, the relevance cycle of the adopted research framework clearly indicates how this guideline has been adhered to (*cf.* Figure 2-1 and Section 2.3.1).

2.4.3 Design evaluation

Because the researcher makes claims that his model bears characteristics that make it better suited to address the problem, the artefact must be thoroughly tested and evaluated against specific criteria or metrics (*cf.* Section 2.5.5), specifically to ascertain that it does indeed have beneficial characteristics enabling it to address the problem adequately.

2.4.4 Research contribution

In light of the researcher's argument on the significance of his research, the developed artefact must provide a clear contribution in the form of a solution to a previously unsolved problem. For this the research must demonstrate, for instance, through critical literature review, that all previous efforts were either directed elsewhere or did not address the problem sufficiently in a manner that the new artefact would.

In terms of research contributions, the design science research literature (Hevner *et al.*, 2004:81; Ellis & Levy, 2010; Oates, 2006) warns specifically with regard to design science research that there must be a clear differentiation between a routine system development and design research. Hevner *et al.* (2004:81) submit that the key difference between routine system development and design research is the clear articulation of a contribution to the body of knowledge. This guideline therefore emphasises the need for rigor in design science research, and the rigor cycle of the research framework adheres to this important guideline.

2.4.5 Research rigor

This guideline pertains to methodological soundness in the development and evaluation of the artefact, and is about grounding the design activities on established scientific theories and methods. The rigor cycle of the adopted research framework (*cf.* Figure 2-1 and Section 2.3.3) adheres to this guideline.

2.4.6 Design as a search process

The process of developing an artefact, such as a model in the case of this study, involves using available means within the confines of the problem domain in the best way to reach the desired end, which is to solve a specific problem. This study started by reviewing ICT4D literature, and searching for any access-technology-agnostic delivery mechanism which is being used to facilitate equitable access to digital content and services. This search started a quest for such an access-technology-agnostic delivery mechanism and culminated in the proposal to develop a conceptual model of what an access-technology-agnostic delivery mechanism would look like, and instantiating it (see the adopted research process in Section 2.5).

2.4.7 Communicating research outcomes

The research process, the outcomes and lessons learned during the design cycle must be communicated effectively to various interested audiences, which may include non-technical or scientific stakeholders. In the case of this study, the research will be communicated in a form of a written dissertation supported by a number of peer-reviewed conference papers.

Whereas the seven guidelines allow the researcher, as objectively as possible, to determine if what he/she did is “good” design science research, there is also a need to follow a proper research process that adheres to the above guidelines. To aid in this regard, Peffers *et al.* (2007) provide a process model for conducting design science research (*cf.* Figure 2-3). The next section discusses such a process model and how this study follows the prescribed process.

2.5 DESIGN SCIENCE RESEARCH PROCESS

Figure 2-3 below depicts a design science research process model. The process model indicates the possible research entry points that may necessitate or encourage research. The nominal process sequence indicates possible starting points in the process interaction based on each entry point. In keeping with this view, a problem-centred solution would begin the sequence by identifying and motivating and showing the significance of such a problem (see Figure 2-3 below).

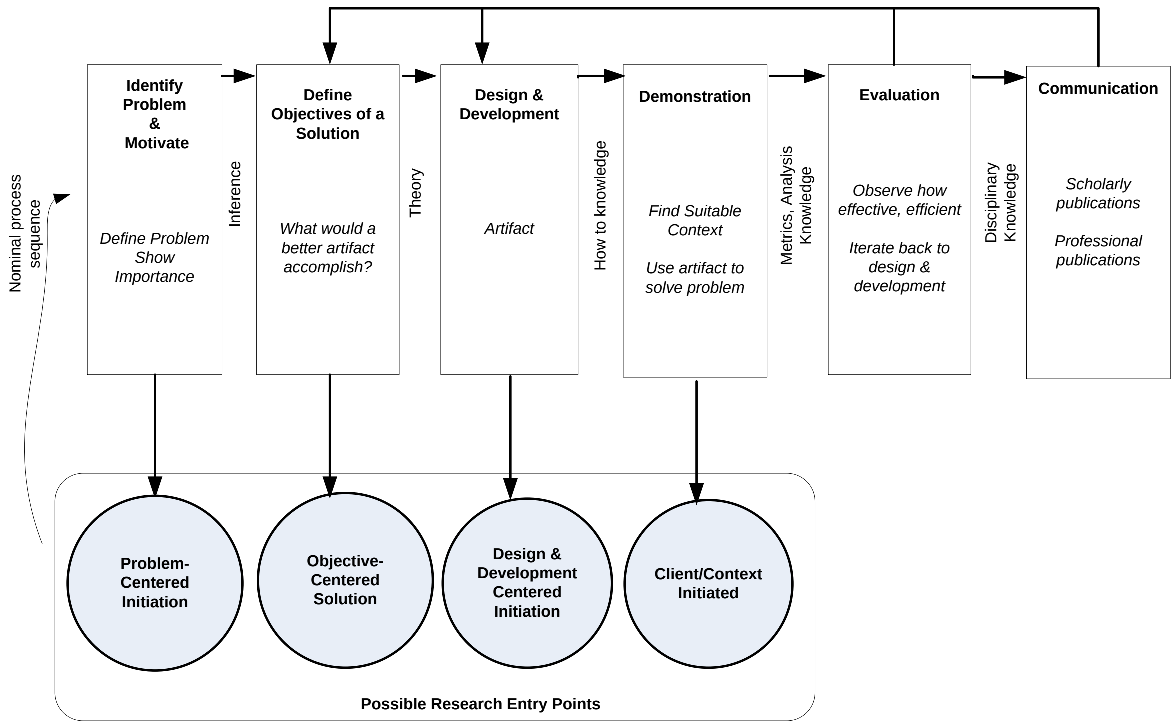

Figure 2-3: Design science research process model (Peffers *et al.*, 2007:54)

This study followed the design science research process model outlined in Figure 2-3 in the manner as explained in Sections 2.5.1 - 2.5.6).

2.5.1 Identify and motivate

This activity corresponds to the Relevance Cycle according to Hevner (2007) and the "awareness" phase according to the five-step interactive process proposed by Oates (2006). In this activity, the researcher identifies a problem within the domain, motivates the significance of the problem and thus the value of its solution.

After having identified the problem, the researcher also needs to set clear objectives of the solution (what a desirable artefact would accomplish), and this can be done through defining a finite set of requirements that the proposed solution must satisfy.

2.5.2 Defining objectives of the solution

In this activity, the researcher articulates a clear and finite set of objectives or requirements which a desirable artefact must satisfy to be developed. The identification of these requirements is informed by the context or environment which, according to the *relevance cycle* (*cf.* Figure 2-1), provides inputs into the research.

The clear articulation of the requirements of a solution is important in that it already provides the researcher with the evaluation metrics since he can evaluate the design artefact in terms of whether it meets these requirements and refine it accordingly during design and development activities of the iterative *design cycle* (*cf.* Figure 2-1).

2.5.3 Design and development

During this activity, the researcher creates the artefact according to the requirements of the solution to purposefully address the identified problem. Potential design artefacts for design science research are *constructs*, *models*, *methods* and *instantiations* (Ayanso, Lertwachara & Vachon, 2011).

For the purpose of this study, this activity entails defining the conceptual model and instantiating such a model. The conceptual model embeds the design principles and the architecture on which the artefact will be based. Both the adopted design principles and the underlying architecture must be chosen purposefully to satisfy the requirements of the solution.

From the design and development perspective, the requirements of the solution pertain to the intended functionality of the final design product once the model is instantiated. The instantiation of the conceptual model therefore pertains to the concrete implementation of the conceptual model to satisfy the functional requirements inferred from the list of requirements for a solution. To ascertain that the instantiation of the model meets the functional requirements, the researcher has to demonstrate the use of the artefact to address the identified problem.

2.5.4 Demonstrate

After having developed a concrete implementation of the conceptual model, in this activity the researcher demonstrates the use of the artefact to address the problem in a suitable experimental situation. For the purpose of this study, the researcher will experiment with the access-technology-agnostic delivery of a typical ICT4D service as a proof of concept. This will involve creating a suitable use case which highlights the important aspects of the identified problem and the expected behaviour of the design artefact which would constitute a success. It is therefore possible that an evaluation may be done through a proof-of-concept *demonstration* where the main evaluation metrics not only consider the functional aspects of the design artefact, but also include non-functional characteristics of the design.

Chapter 6 of this dissertation will report on this experimentation.

2.5.5 Evaluation

Since the instantiation of the model, which was demonstrated above (*cf.* Section 2.5.4), is based on the conceptual model, which in turn is informed by the requirements of the solution, the researcher now observes and measures how effectively or efficiently the design artefact addresses the problem. This evaluation is done according to a set of evaluation metrics which are informed by the objectives of the solution (see Section 2.5.2).

Evaluation metrics define exactly what the research is trying to accomplish. The lack of such evaluation metrics, as March & Smith (1995) warn, make it impossible to effectively judge the research effort. 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 set of requirements developed in Chapter 3 provides criteria by which both the conceptual model and its reference implementations are evaluated. The model is thus evaluated in terms of how effectively it addresses the problem, and also how well it meets the set requirements developed in Chapter 3 (*cf.* Table 3-1 and Table 3-2).

Olivier (2004:12) submits that research studies with technical goals, such as this study, apply creative research methods intended to devise new mechanisms to be used in computing. These creative research methods are what Iivari (2007) refers to as constructive research methods. The quality of such creative or constructive research methods is measured in terms of attributes of the creation such as its utility (March & Smith, 1995; Olivier, 2004:12).

For the purpose of this study, the black-box testing technique (Krichen & Tripakis, 2004) was adopted for the functional evaluation of the model's instantiation; this technique hides the complexities of the system components and only focuses on the system view from the end-user perspective. This technique has been chosen because the interest is only in the functionality of the artefact, that is, the ability to deliver digital content and services to the end user regardless of the technology the end user uses to access the said digital content and services.

2.5.6 Communication

In this study, communicating the research will take the form of a written dissertation with conclusions and recommendations for further research (see Section 2.4.7).

2.6 CONCLUSION

Whereas behavioural science (natural science) is more descriptive, attempting to explain, justify and theorise why or how things are, design science is more prescriptive and attempts to provide utilities to solving problems and attaining goals. The research objectives set for this study clearly qualify it as design science research, prescribing how access-technology-agnostic delivery of digital content and services could be realised to solve the identified research problem.

This chapter presented an overview of the design science research paradigm and the research framework, the practise rules and the process model for conducting design science research. It then described how the design science research paradigm has been adopted for the purposes of this study, namely the three-cycle view of design science research *(cf.* Figure 2-1). Table 2-1 summarises the research methodology in terms of the research questions, research activities and the cycles within which these activities fall, along with the chapters in this dissertation where each question is addressed.

Table 2-1: Mapping of research question, activities, cycles and chapters

Research Question	Activity	Cycle	Chapter
What requirements does an ICT4D context impose on the mechanisms by which digital content and services are delivered, and which the proposed model must address?	Set the context of the study; identify and motivate the research problem, infer the objectives of the study, and develop requirements of the solution to address the identified problem.	**Relevance**	1 & 3
On what architecture should the proposed access-technology-agnostic delivery model be based?	A literature review to establish which existing technical architecture for digital content and services delivery should serve as the basis for the proposed model (artefact).	**Rigor**	4
What is the conceptual view of an access-technology-agnostic delivery model?	Based on the identified set of requirements for a solution, and the explicitly selected technical architecture, *develop a conceptual model and clearly elaborates on its beneficial characteristics*. Finally, *provide reference implementation of the model to further support the claims for its beneficial characteristics*.	**Design**	5 & 6

In accordance with the adopted research framework (*cf.* Section 2.3) as well as the mapping tabulated in Table 2-1 above, the next chapter forms part of the relevance cycle of this research project and presents literature review on ICT4D.

Chapter 3

ICT4D: Information and Communication Technology for Development

This chapter introduces the context for the proposed Access-Technology-Agnostic Delivery Model. Drawing on the ICT4D literature, this chapter identifies challenges within ICT4D, and specifically enumerates the requirements and constraints that these challenges impose on the proposed model. Based on these requirements, a critical review of previous attempts at delivery of digital content and services within the ICT4D context is presented.

The remainder of this chapter is structured as follows: Section 3.1 presents a general overview of ICT4D and covers aspects of applying ICT in and for development. The section also discusses the main focus areas and the goals of ICT4D research in Sections 3.1.3. and 3.1.2 respectively. Perspectives on technology and development are discussed in Section 3.2, and are followed in Section 3.3 by a discussion about perspectives on innovation and context. Having discussed the issues of context and innovation, Section 3.4 discusses the challenges within ICT4D along with the requirements and constraints that are imposed by these challenges. Finally, Section 3.5 summarises and concludes the chapter.

3.1 GENERAL OVERVIEW OF ICT4D

ICT4D is an emerging multi-disciplinary research area that is concerned with addressing the Millennium Development Goals (MDGs) by designing innovative technologies for resource-constrained environments (Sambasivan et al., 2009: 156). According to Heeks (2008) the idea behind ICT4D is to look at ways in which

ICTs can be used to enhance developmental initiatives aimed at improving the living standards of poor communities.

Heeks (2008) sees ICT4D as an amalgamation of three key domains, namely *computer science*, *information systems (IS)* and *development studies*. These domains, in their individual contribution towards effecting development, ask domain-specific questions (Heeks, 2008:32): The computer science domain seeks to establish what is possible with technology, while the IS domain concerns itself with what is feasible with technology. The development studies domain in turn seeks to determine what is desirable with technology to effect development. The nature of this study's contribution to ICT4D falls within the computer science and IS domains, as it demonstrates what is possible and technically feasible with digital technology.

3.1.1 Research landscape around ICT4D

Walsham and Sahay (2005) observed that the main focal area of ICT4D entails the key challenges confronting practitioners when deploying ICTs in developing countries. Research in this focus area seeks to establish how deployment of ICT impacts on development, how issues of context (for instance tradition, culture, politics and available infrastructure) impact on ICT deployment, and looks at ways of adapting technology to these local conditions. Heeks (2008:28) uses Figure 3-1 to illustrate the changing research themes in ICT4D over time.

The earlier stages, labelled ICT4D 1.0 in Figure 3-1, focused on strengthening the *digital readiness* of developing countries by making available computers, telecommunication infrastructure and Internet service providers in response to the "digital divide" challenge (Roman & Colle, 2003).

Early researchers in ICT4D thus focused on assessing awareness of ICT capabilities, the state of available infrastructure, and understanding the digital divide. This allows researchers to guide policy development in the application of ICT for sustainable development.

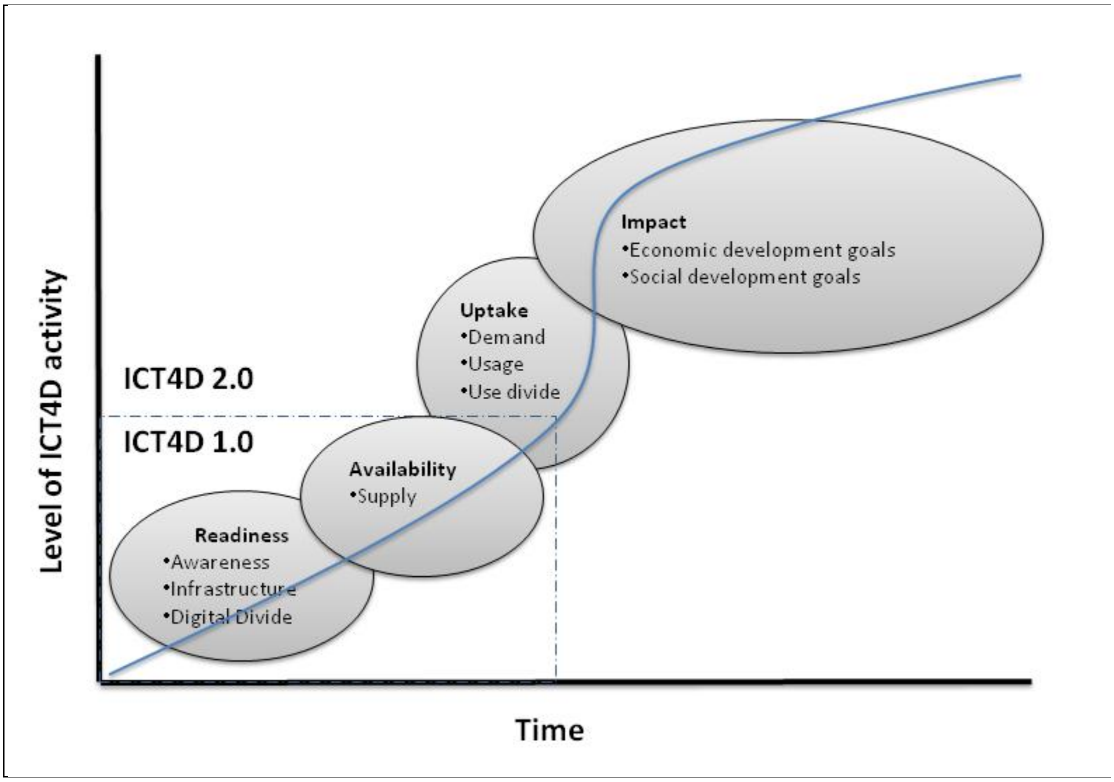

Figure 3-1: Changing ICT4D focus issues over time (Heeks, 2008:28)

A further focus within ICT4D 1.0 was on developing and supplying the infrastructure necessary for the use of ICTs in remote rural areas. Telecentres (Sey, 2008) and multi-purpose community centres (Islam & Hasan, 2009; Akinsola, Herselman & Jacobs, 2005) as possible realisations of shared computing and a connectivity model in developing regions, provided the archetype for these early efforts (Heeks, 2008:27). The shared computing and connectivity models thus represented the supply mechanism to ensure availability of required computing and connectivity infrastructure.

Lessons learned from ICT4D 1.0 in terms of *sustainability*, *scalability* (reach) and *evaluation* (metrics) led to reappraisal of priorities, processes and purposes towards ICT4D 2.0 (Heeks, 2008:27). According to Heeks (2008), this shift meant innovations in *hardware*, *new applications*, *new innovation models* and *new worldviews or perspectives on ICT and development*.

In terms of ICT4D 2.0, once infrastructure has been developed, the focus shifts to the social dynamics, issues of context become more important as researchers try to assess the uptake of technologies in terms of demand, and current *use divide* signifies the distribution of access and usage of ICTs within a population. Furthermore, the focus tends to be less on technology per se, and more on its integration into societies for socio-economic development goals, and hence renewed perspectives on technology, society and development are paramount. Furthermore, the *impact* of ICT applications for development is assessed in terms of the *social and economic development goals* they were purported to support.

The contribution that this study makes is in facilitating usage, and it therefore falls within the uptake activities according to Figure 3-1. Against the background of ICT4D research foci above, Section 3.1.2 discusses the goals of ICT4D research.

3.1.2 Goals of ICT4D research

Heeks (2008) discusses the three imperatives that he believes are the driving force behind giving priority to ICT applications for the poor in developing countries. There is a moral imperative – the ethical importance of the potential benefits of applying ICT to the world's biggest challenges (poverty, illiteracy, etc.) as compared to boosting productivity of the super-rich. Second is the enlightened self-interest imperative – the understanding that problems at the bottom of the pyramid today can later become problems of those at the top of the pyramid due to the converging nature of a globalised world, refugees, migrations and disease epidemics among other things. Furthermore, the economic, social and political life in the 21st century is becoming increasingly digital and connected, and will potentially exclude those without access to the necessary ICTs (Heeks, 2008:26). The exclusion of those without access to ICTs may result in inequalities of opportunities.

In view of the ethical importance of applying ICTs to combat the world's serious challenges, poverty alleviation is a key focus of ICT4D research efforts. Poverty is defined by making reference to powerlessness, voicelessness and vulnerability (Harris, 2004:7). Therefore, to aid in alleviating poverty, ICTs, as a set of tools, must give voice to the voiceless and empower the exploited and neglected sections of society. The European Commission (European Commission, 2001) suggests that the definition of poverty should also include any form of deprivation of basic capabilities, lack of access to natural resources such as land, lack of access to health care and education, denial of right to political participation and lack of access to necessary basic infrastructure.

What becomes clear from the versions of definitions of poverty is that they each highlight areas of possible improvements that individual ICT-supported developmental efforts can focus on. For example, by improving and promoting access to education and health care, and by facilitating equitable access to information for equal opportunities, ICTs become powerful tools to support existing on-going developmental efforts. As Pade-Khene (2010:19) advised, ICTs should not be seen as creating change but rather as being enablers for change that complement on-going developmental initiatives.

For each of the possible areas of applications, the use of ICTs resulted in acronyms such as ICT4E (education), and a more general ICT4D (development).

Pade, Mallison and Sewry (2006:7) identified the uses of ICT as an enabler for rural development. These uses include:

- Enabling rural communities to have access to timely market information, thereby promoting entrepreneurial activities in these communities.
- Supporting health initiatives by supporting communications, monitoring and controlling of disease outbreaks, and promoting healthy lifestyle by disseminating valuable health and nutritional information.
- Enhancing transparency of government and promoting active participation by the public and thus strengthening the voice of the voiceless.
- Using advanced ICTs for earth observation and environmental monitoring activities which are key to preserving natural resources.
- Promoting new social structures through extended community networks, connecting rural communities to their urban counterparts, which eventually results in exchange of information, ideas and knowledge, all of which, according to Harande (2009), are important to development.

In terms of the use of ICT as an enabler for rural development as discussed above, the intention of this study is therefore to provide a possible access-technology-agnostic mechanism that facilitates the delivery of ICT functionality in support of on-going developmental initiatives.

After gaining some clarity on poverty as a major focus for development, it is necessary to understand the relationships between development, information/knowledge and ICTs. Information is understood as being central to key social and economic activities, which are a greater part of the development process. Therefore ICT, as a means of exchanging such information, is also critical (Harris, 2004:10).

Harris (2004) is of the view that the application of ICT in development should be based on a development strategy. Once the development strategy is clearly articulated, it becomes clearer as to what information resources are prerequisites for development. Information strategy is about determining information resources that are necessary to actualise the development strategy. ICT, and specifically its information manipulation, processing and delivery capabilities, forms part of the technology strategy aimed at developing technologies to deliver the information resources required to achieve the development strategy.

The proposed access-technology-agnostic delivery model, as a possible information resource and in taking advantage of ICT capabilities, will facilitate the delivery of, and access to, the required information services in support of the development strategy. This is because it is possible that the strategic thinking about ways in which technology can enhance the effectiveness of developmental initiatives may be duly influenced by the appreciation of the capabilities of ICTs. These same capabilities also inform the general goals and dimensions of ICT4D.

The general goals and dimensions of ICT4D are summarised in Figure 3-2.

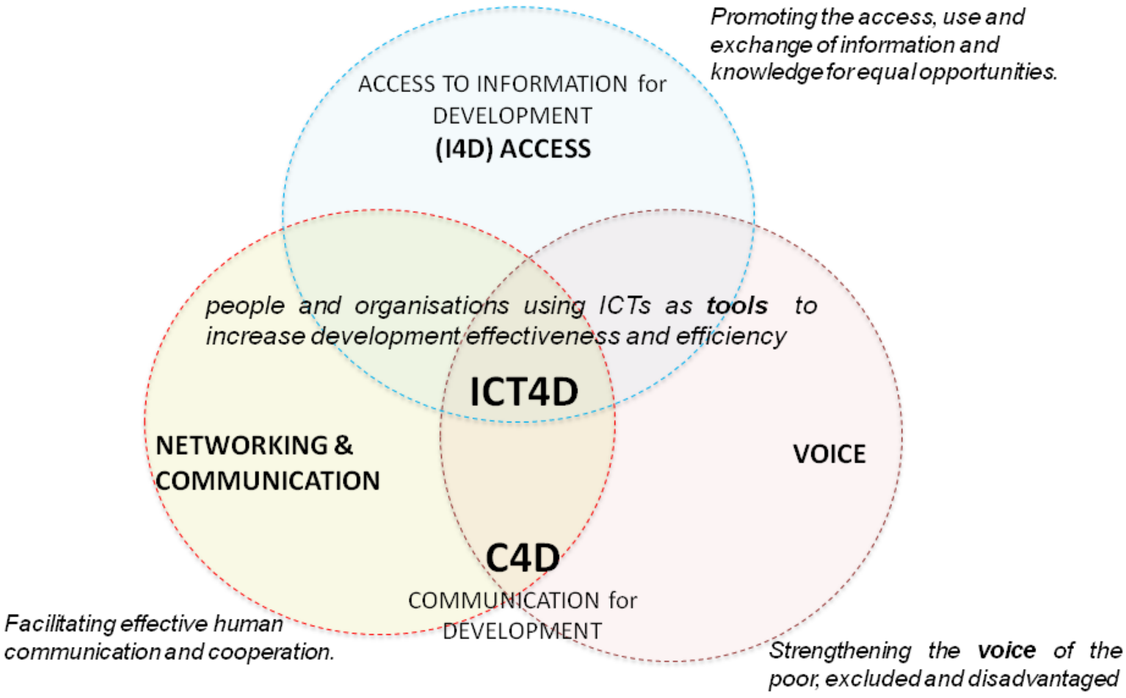

Figure 3-2: Goals and dimensions of ICT4D (adapted from Weigel, 2004)

As shown in Figure 3-2, ICT4D involves using ICTs as tools to support developmental initiatives and has a number of dimensions. The first dimension is Information Access for Development (I4D ACCESS), which is about promoting access to, and the exchange of, information and knowledge. In view of the role that knowledge plays in human development as recognised by Garai and Shadrach (2006), ICT promotes the use and exchange of information and knowledge for equal opportunities. By promoting equitable access to information, ICT can help to eradicate deprivation of access to information which Gebremichael and Jackson (2006) labelled as "information poverty". In terms of the Communication for Development (C4D) dimension, the *networking* and *communication* capabilities of ICTs facilitate effective human communication and collaboration, and present platforms through which the poor, excluded and disadvantaged can find their *voices*. The proposed Access-Technology-Agnostic Delivery Model is envisaged to facilitate the delivery of digital content and services for the purpose of promoting equitable access to, and the use and exchange of information. Therefore, in terms of the general goals and dimensions of ICT4D, the proposed Access-Technology-Agnostic Delivery Model leans towards the I4D ACCESS dimension, while taking advantage of the networking and communication capabilities of ICTs in the C4D dimension to facilitate access-technology-agnostic delivery of services.

The efforts within ICT4D are inspired by the belief that ICT has the potential to contribute to the improvement of various aspects of life, including poverty alleviation and strengthening the democratic polity (Avgerou, 2010). ICT also has the potential to strengthen the voice of the poor and marginalised by providing a platform for citizen-centred government service delivery mechanisms. This belief in the developmental potential of ICTs is informed by the researchers' and practitioners' perspectives on the relations between development and technology. Therefore, the next two sections draw on published literature and discuss perspectives on technology and development (Section 3.2), as well as perspectives on the issues of context and innovation within the ICT4D space (Section 3.3).

3.2 PERSPECTIVES ON ICT AND DEVELOPMENT

The review of discourses on ICT and development (Avgerou, 2010) indicates that there are two perspectives of ICT-enabled development, namely the *progressive transformation* perspective and the *disruptive transformation* perspective. The progressive transformation perspective reflects the understanding of ICT as a tool for socio-economic development by enabling competitive participation in the global free market (Avgerou, 2010:11).

The disruptive transformation perspective on development considers any development, including ICT-enabled interventions, as having unequal effects on different categories of population, often maintaining or worsening the current uneven distribution of wealth and privilege and leading eventually to uneven development (Avgerou, 2010:7). In his critical discourse analysis of ICT, power and development, Thompson (2004:3) submits that the operations of power within ICT in developmental discourse is not inherently "top-down" but rather lie in their mediation of what becomes visible and real. This suggests that operations of power within ICT tend to impose certain world views within developing countries.

In furtherance of his argument, Thompson (2004) warns of the potential danger of ICTs leading to uneven development, maintaining or worsening the systematic exploitation of the poor by those already privileged by the current social arrangements.

For the purpose of this study the perspective of progressive transformation to ICT and development is supported.

The next section discusses perspectives on innovation and context as they apply to ICT4D discourse. These perspectives are particularly relevant as they inform the researcher's decision to conduct this specific nature of study.

3.3 PERSPECTIVES ON INNOVATION AND CONTEXT

Avgerou (2010:3) states that there are two orientations toward addressing the issue of context; the *universalist* and *situated* research streams of ICT4D. The universalist perspective elaborates on the values of ICT and information, and also on Information Systems (IS) innovation processes to unlock such ICT potential without regard to the circumstances of the social actors involved (Avgerou, 2010:3). It addresses the issues of context through *transfer* and *diffusion*. According to this perspective, ICT innovations in developing countries are the results of diffusion of knowledge from advanced economies which are then adapted to local conditions of individual developing countries (Avgerou, 2008:135). The transfer and diffusion perspective takes a reductionist view of technology. As far as this view is concerned, the core of technology is culturally neutral and as such reduces cultural factors merely to user interface design considerations (Pitula *et al*., 2010: 82).

The *situated* research orientation, on the other hand, considers IS innovation as enacted by social actors and places more emphasis on meaning-making within the local context (Avgerou, 2008:140). This orientation is understood to address the issues of context through *socially embedded processes*. The social embeddedness perspective views the purpose of ICT innovation as emerging from what is locally meaningful (local problematisation), and as shaped by the local actors' understanding of its value in their lives (Avgerou, 2002). Castells (2005:3) state categorically that technology is shaped by society according to the needs, values and interest of the people using the technology. As such the social embeddedness perspective views the transfers and diffusion perspective as overly simplified and misleading (Avgerou, 2010:4). Similarly, Pitula *et al*., (2010:81-82) also argue that the reductionist view of technology manifested by the transfers and diffusion perspective neglects the deep cultural nuances and only considers "surface-level aspects" such as languages, currency and symbols conventions.

In support of the socially embedded view, Krishna and Walshman (2005:126) argue that IT implementation projects are not disconnected from the circumstances or context (historical, cultural, organisational and economic) from which they emerge. Dias and Brewer (2009:75-76) further argue that in the case of ICT4D, interdisciplinary collaboration between computer scientists, engineers, sociologists, ethnographers and anthropologists is a critical requirement for success. This is because such collaboration provides valuable information regarding cultural practices, traditions, beliefs, livelihoods and so forth about the communities intended to benefit from ICT4D (Dias & Brewer, 2009:76).

Another dimension to the socially embedded approach is the "use-up" approach discussed by Heeks (2009). This approach challenges the invention-down approach that tends to follow the transfer and diffusion approach to ICT4D. The use-up approach considers what is actually being used within poor communities; it considers those technologies where these poor communities have already "voted with their wallets" (Heeks, 2008:28). This "use-up" approach is compatible with the digital difference paradigm shift advocated by Botha (2009). The digital difference paradigm shift encourages innovations that capitalise on the technological capabilities of target communities, however limited these capabilities may be.

In terms of the perspectives on innovation and context discussed above, this study leans towards a middle ground between the two discourses, namely (1) ICT and development as socio-economic improvement *through transfer and diffusion* and (2) ICT and development as a socio-economic improvement *through locally situated action*. The question of technology appropriateness here establishes whether the proposed ICTs (architectures, mechanisms or products) are appropriate for the tasks (such as universal access to information and knowledge) needed to be done for development in resource-constrained settings. This will further inform design decisions taken to come up with technological innovations to address specific development needs and challenges in resource-constrained communities.

Furthermore, these perspectives (Section 3.2 and Section 3.3) also influence the objectives and the approach that the said researchers adopt in applying ICT to achieve development goals. To this end, Unwin (2009:371) presents two broad classifications of ICT4D initiatives, namely those that are market led, focusing mostly on economic growth, and those socially led initiatives that concern themselves with achieving *equality of access*. As already indicated in Chapter 1, the product of this research is intended to be of use to this latter category of ICT4D initiatives (i.e. socially led).

Against these perspectives on innovation and the context as discussed above, the next section discusses the peculiarities of the ICT4D context that impose certain requirements on socially led technological solutions.

The next section discusses ICT4D challenges and their implications for technological innovation within ICT4D which culminate in a set of requirements imposed by the ICT4D challenges on the proposed model.

3.4 REQUIREMENTS IMPOSED BY CHALLENGES IN ICT4D

Brewer (2005) noted that ICT4D projects operate in vastly different cultural, social and economic contexts than conventional enterprise software development projects. Accordingly, Pitula *et al*. (2010:78) advise that these socio-cultural differences should be key considerations when developing ICT4D applications.

The issues of context highlight the perspectives on innovation and context in ICT4D. A *social-embeddedness* perspective is favourable as it pays attention to the context and duly appreciates the constraints and specific requirements that the ICT4D context imposes on potential technological solution approaches. The discussion in this section explores ICT4D challenges and their implications for technological innovation within ICT4D.

In its 2009 report on ICT4D, the World Bank expressed the view that ICT has the potential to enable socio-economic development. The use of ICTs in the public sector promises greater improvements in the state's ability to provide effective, efficient and more citizen-centred government services (Farelo & Morris, 2006). However, most of the initiatives and projects aimed at introducing and providing access to ICTs to developing countries often fail, either completely or partially (Heeks, 2002).

The challenges that ICT4D projects have to confront may be broadly categorised into two main categories:

1. *Socio-technical challenges*: the combination of general development challenges (mainly social, political and economic) as well as hindrances to development, deployment and optimal use of ICTs which are mainly technical and are of interest to this study.
2. *Project management- and execution-related issues* pertaining to the management of ICT4D projects under conditions vastly different from typical IT projects.

Unwin (2009), as well as Tongia and Subrahmanian (2006), have identified some of the reasons for the failures of many ICT4D projects to bring sustainable benefits to the communities beyond the prototype stages. These reasons can be thought of as project management and execution issues, and are summarised by Pitula *et al*. (2010:80) as follows:

- Multiple stakeholders have vague objectives that do not converge; each of them has his/her own ideas and expectations of the ICT4D project.
- Limited or no participation by the ultimate beneficiaries, leading to their being unable or unmotivated to make use of the technology.
- Incomplete and unarticulated project objectives and therefore a lack of clear metrics for evaluating project success.
- Usability requirements and evaluations are not adequately reported.

- Economic sustainability requirements are not considered, resulting in projects not surviving beyond the prototype stage.

In addition to these sustainability-related issues, there are also socio-technical challenges that pertain specifically to the development, deployment and optimal usage of ICTs. Rolling out ICTs such as infrastructure for rural connectivity requires contending with a number of these socio-technical challenges. Some have been captured by various authors such as Johnson and Roux (2008:17); Ntlatlapa (2007:2); Akinsola, Herselman & Jacobs (2005:21); Ngcobo & Herselman (2007:713 -714) and are summarised below:

- Great distance to travel between service centres such as clinics and schools.
- Difficulties in getting line of sight due to terrain and severe climatic conditions.
- Single low-bandwidth gateways to the Internet.
- High cost of Internet connectivity coupled with low per capita income.
- Lack of proper roads and supporting infrastructure.
- Lack of reliable connectivity and power supply.
- Lack of required local technical personnel.
- Generally low literacy levels.

Non-technical challenges also include issues of theft, vandalism and equity of access. A serious social challenge which is faced when introducing ICTs in rural communities is ensuring equitable access to digital services (Azam, 2008:488). These serious constraints, combined with other socio-economic factors, call for innovative techniques to provide adequate ICT functionality to users in resource-constrained communities. Therefore, the first requirements imposed upon the proposed model would be to facilitate equitable access to digital content and services.

The literature abounds with possible causes of ICT4D project failures attributed to the socio-technical challenges. In reviewing the successes and failures of ICT4D initiatives, Heeks (2002) coined the term “design reality gap”. Design reality gap results from the mismatch between the assumptions that are built into the pro poor innovation approach, and the on-the-ground realities of poor communities (Heeks, 2002). This also relates to the neglect of the demand-side dimension of ICTs, which has already been identified by Wade (2002) as one of the weaknesses of ICT4D approaches. The concept of design reality gap informs this study to pay particular attention to the ICT4D context and the specific constraints that it imposes on ICT4D projects.

Failures of ICT4D initiatives have also been attributed to the use or choice of inappropriate technologies (Van Reijswoud, 2009). From the design frameworks point of view, Van Reijswoud (2009:2) points out that not much attention has been paid to the general design frameworks to improve the success and impact of ICT4Ds in developing countries. There is therefore a need, as advised by Cecchini and Scott (2003:77), to focus ICT4D research efforts on poor-user techniques that duly consider the specific requirements imposed by the target user communities' conditions. This leads to the second and third requirements imposed by the ICT4D context upon the proposed model, which are to *focus on poor-user techniques*, and *the choice and use of appropriate technology (*Mvelase *et al.,* 2009*) with regard to appreciating the prevailing resource-constrained context*.

On the issue of infrastructure and capacity, Heeks (2002:102) states that practical reasons such as lack of technical infrastructure and human capacity in developing countries support the idea that failure rates of community-based information systems are much higher in developing countries than in developed countries. Azam (2008: 488) further states that the problem of inadequate ICT infrastructure is compounded by market absence of technical infrastructure and the sub-optimal usage of whatever infrastructure is available. Hence, this study advocates the need to capitalise on the available technological capabilities through access-technology-agnostic delivery of ICT4D services. The implications in terms of requirements are that the proposed model should possess the ability to *capitalise on available technological capabilities* of target communities, that the model should be able to *scale in accordance with the increase in user population and technological capabilities*. Furthermore, the model should *support end-user device neutrality* in order to facilitate equitable access to information services regardless of the devices used to access these services. Finally, the model should also *facilitate access-technology-agnostic access to, and delivery of, digital content and services* so that users can access the same digital content and services regardless of the access networks and the devices they use.

The set of requirements as developed in the preceding sections is summarised as socio-technical requirements (Table 3-1) and as purely technical requirements (Table 3-2).

Table 3-1: Summary of ICT4D context-imposed socio-technical requirements

Requirement	Description
Choice of appropriate technologies	One of the causes of ICT4D project failures has been attributed to the choice of inappropriate technologies (Van Reijswoud, 2009). Technology appropriateness in this study pertains to sensitivity to environmental constraints (low literacy, low income, inadequate infrastructure and prevalence of older technologies). Appropriate technologies in the ICT4D context are those technologies tailored for resource-constrained environments.
Focus on poor-user techniques	Focusing ICT4D efforts on technologies that are optimised for resource-constrained contexts has been advocated by Cecchini and Scott (2003).
Capitalise on available technological capabilities	This requirement has been identified by Heeks (2008; 2009) as one of the key approaches of ICT4D 2.0 and emphasises the need to optimally utilise whatever technological capabilities are available to the communities to make a difference. It also necessitates the use of even older technologies (such as radios and basic mobile phones) to deliver meaningful value-adding services to end-users.
Facilitate equitable access to information services	Azam (2008:488) stated that when introducing ICTs in rural communities, ensuring equitable access to digital services is one of the most serious social challenges. Digital services should be made equally accessible even to users with low literacy levels (e.g. Agarwan *et al.*, 2010; Ford & Leinonen, 2009).

The requirements summarised in Table 3-1 above are regarded as socio-technical in the sense that they are informed by social realities of ICT4D beneficiaries, and also have technical implications in terms of solution design to work around such social realities.

Table 3-2 below presents a summary of technical requirements that are important for the development of a technically viable solution. These requirements are regarded as purely technical because, although they have been developed through exploration of the ICT4D literature, they are not only applicable to the ICT4D environment but to other application domains as well.

Table 3-2: ICT4D context-imposed technical requirements

Requirement	Description
Scalability	The proposed model should support up-scaling in order to adapt to changing technological capabilities, and increasing requests or usage volumes of user communities.
Client Device Neutrality	Client Device Neutrality pertains to the delivery of content and services to any device connected through whatever access technology that the said device supports.
Access-technology-agnostic	This entails the support for information and service delivery media convergence so that digital content and services are accessible and delivered to end-users regardless of the access technologies used by the end-users to access these services.

The next section presents a summary of, and reflections on this chapter.

3.5 SUMMARY

This chapter presented a literature review of ICT4D from which key challenges within ICT4D emerged as well as areas of innovation in delivering ICT functionality within the ICT4D context. These areas of innovation relate to the three main thrusts of ICT4D initiatives, which are concerned with developing connectivity and computing infrastructure, delivering content and services as well as building capacity. The chapter then highlighted the ICT4D-specific requirements and constraints which are imposed by the particular context under which ICT4D projects operate. These requirements are considered important in delivering ICT functionality to resource-constrained communities within the ICT4D context and were summarised in Table 3-1 and Table 3-2.

This chapter, and more specifically the requirements it developed (see Table 3-1 and Table 3-2), inform this study in terms of what is desirable and relevant in the ICT4D domain. The next chapter, Chapter 4, will consider what is technically possible in terms of applicable technical architecture on which to base the solution. It will thus make the case that it is possible to learn from and even adopt concepts and frameworks from a different domain to address challenges within the ICT4D context.

Chapter 4
Service Delivery Platform

This chapter marks the beginning of the design and development phase (design cycle) in the research process of this study (see Figure 2-1). The purpose of this chapter is to explore the technical architecture on which the proposed artefact (access-technology-agnostic delivery model) may be based.

The qualifying criteria for such a technical architecture is that it must address business or research problems in its domain which can be juxtaposed or aligned with the research problem identified in this study (*cf.* Section 1.2). Furthermore, such a technical architecture must be able to address the requirements which are imposed on the proposed solution of this study by the ICT4D context (*cf.* Section 3.4, also Table 3-1 and Table 3-2).

The remainder of this chapter explores the conceptual principles of such a technical architecture. Firstly, Section 4.1 considers the motivations that spurred the development and adoption of the Service Delivery Platform (SDP) concept within the telecommunications domain. These motivations are discussed in relation to the requirements (see Table 3-1 and Table 3-2) for a delivery mechanism for digital content and services within the ICT4D context. Section 4.2 demonstrates how the SDP addresses telecommunication operators' requirements; it discusses the service delivery patterns and presents a typical application of the SDP in delivering converged multimedia services. The conceptual principles of the SDP, its definitions and key concepts are discussed in Section 4.3. Section 4.4 discusses the architecture of the SDP, first its basic architecture (4.4.1) and then the evolved next-generation architecture of the SDP (4.4.2). Furthermore, the SDP concept is discussed in this chapter as it provides a technical basis for realising the access-technology-agnostic delivery for digital content and services in the context of ICT4D.

4.1 MOTIVATION FOR SDP ADOPTION

The traditional vertical service platforms which were the norm within the telecommunication domain meant that operators needed dedicated infrastructure resources for each service such as voice and data service networks (Mani & Crespi, 2008:4). Each service needs its own signalling, management, provisioning and control protocols. Figure 4-1 below shows a simplified vertical service platform.

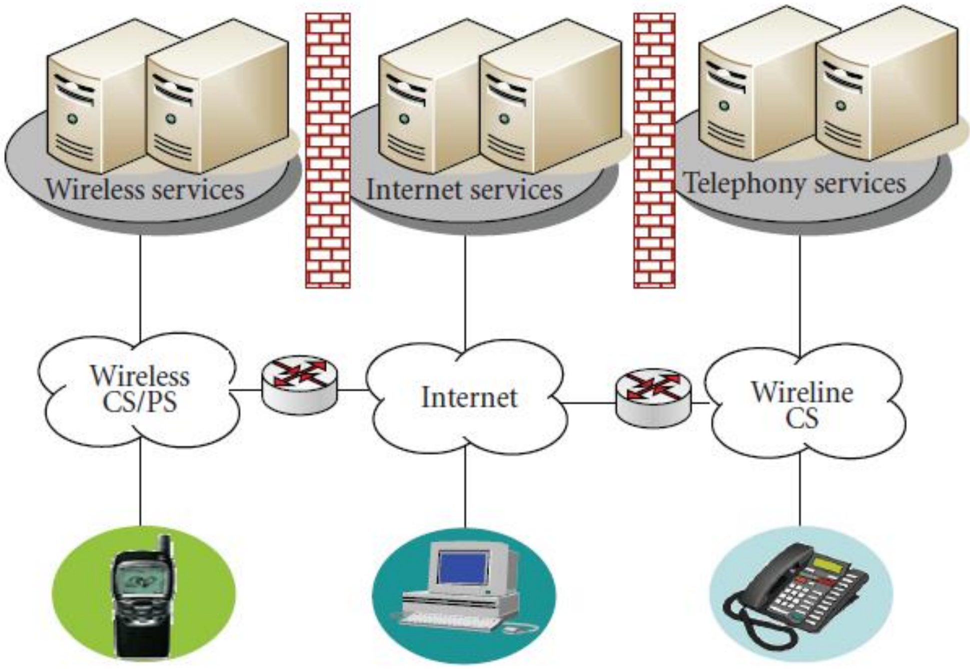

Figure 4-1: Traditional vertical service platform (source: Mani & Crespi, 2008)

The vertical service platform architecture further leads to services being developed around a particular network technology (Lofthouse, Yates & Stretch, 2004:81). The end result is service silos where services in one domain (e.g. mobile) are inaccessible to other access networks (e.g. telephony). Even when these service networks are owned by a single service provider, additional equipment is needed to serve as "bridges" to other service domains – this involves cost in both installation and maintenance. The service architecture in which each service requires its own infrastructure and functional systems is often referred to as the stovepipe architecture (Magedanz, Blum & Dutkowski, 2007:46-47). This stove-pipe analogy of the architecture also holds true for ICT4D projects that deliver ICT functionality around specific technologies, making content and services accessible only in specific formats, devices and access technologies.

Furthermore, mergers and acquisitions within the telecommunication industry often meant that the two operator networks had to be maintained as one logical network belonging to the new organisational entity emerging from the merger or acquisition. Because of lack of compatibility and interoperability of service networks, this requirement often presents technical challenges. From a business point of view, it becomes imperative to be able to continue providing seamless access to services as one logical service provider regardless of the actual access networks through which these services are being accessed. The requirement for seamless service delivery relates to the access-technology-agnostic property which has been identified as one of the requirements for the proposed delivery model for digital content and services within ICT4D.

The financial investments that telecommunication operators have placed in their legacy infrastructures do not favour immediate discontinuation of these infrastructures (Open Cloud, 2007:3). Telecommunication operators needed some return on investment. They also needed to be able to use their new and legacy infrastructure to achieve their business objectives, namely to retain their old customers and attract new customers, thereby increasing their Average Revenue Per User (ARPU) (Schulke, Abbadessa & Winkler, 2006). To retain old customers, the telecommunication operators needed a way to make it easier for their customers to move over to their new, more attractive service offerings. To attract new customers, they needed to provide attractive services at competitive prices, and they had to do so at regular intervals, which necessitates reduced time-to-market. This requirement relates to scalability and adaptation, both of which were identified (Section 3.4, Table 3-2) as important properties of an appropriate ICT4D technology.

Moreover, because telecommunication operators provide the technical infrastructure for data transmission, they need to avoid commoditisation of their infrastructure, which may result from them being reduced to transport-only providers (Falcarin & Venezia, 2008:60). One way of doing so is through some means of exposing their communication infrastructure capabilities to external developers along with attractive business models/revenue to attract developers (Mekens, 2010). The exposure of network infrastructure to third parties enables development of rich services for operators' networks by third parties (Open Cloud, 2007:4), and also presents new revenue streams for telecommunication operators (Burger, Rajasekar & Lundiqvist, 2007).

Finally, telecom operators needed a converged and open infrastructure that offers support for new services without vendor lock-in (Maes, 2007). The traditional vertical, vendor-locked and often non-standardised telecom architectures were not ready to support the emerging business requirements (Open Cloud, 2007). This was a motivation for an architecture that could enable rapid and cost-effective development, deployment and delivery of value-added customer services. The *architecture that could run such valued-added customer services was needed*. Such an architecture had to glue together the heterogeneous networks (e.g. mobile and fixed networks) to provide seamless multimedia services to customers. By gluing together heterogeneous networks as a single logical service network, and for the purpose of this study, such an architecture will facilitate *client device neutrality* and *access-technology-agnostic delivery* of services hosted in the heterogeneous networks that are converging into one logical service network.

To address the above business imperatives, telecommunication operators needed to design and develop service networks that would constitute their content and service delivery infrastructure. Jain (2007) noted that in trying to deal with the needs for content and service delivery in the evolving telecommunication service networks, the network operators use a combination of service delivery design patterns.

4.2 SERVICE DELIVERY PATTERNS

Jain (2007) discusses the three main service delivery design patterns, namely access-agnostic service delivery, seamless service delivery and Service Delivery Platform (SDP). The *access-agnostic* and *seamless* service delivery approaches are used to define how services are delivered in the network, whereas the *Service*

Delivery Platform deals with how services are developed, deployed, provisioned and managed in the network (Jain, 2007).

Access-agnostic service delivery can be accomplished by separating the service layer from the network or transport layer following the SDP conceptual model (Christian & Hanrahan, 2007) or any technology-specific implementation of the SDP.

The Internet Protocol Multimedia Subsystem (IMS) is commonly used to accomplish seamless access to roaming users through the concept of home and visiting networks using functional components of the IMS core network, namely the Proxy-Call Session Control Function (P-CSCF) and the Service-Call Session Control Function (S-CSCF) (Jain, 2007). An overview of these components of the IMS core is presented by Magedanz and De Gouveia (2006:272-273).

The Service Delivery Platform (SDP) approach incorporates both the access-agnostic and seamless service delivery patterns. The architecture of the SDP (Figure 4-4 and Figure 4-6) indicates how the SDP may achieve access-agnostic delivery through network abstraction and the layered architecture approach. In terms of seamless service delivery, Sakurai, Tange and Sekine (2009), Lu, Zheng and Sun (2009), as well as Cho and Lee (2009) discuss the use of IMS as an implementation of the SDP for seamless delivery of multimedia services.

To address the vertical, stove-pipe architecture, the use of a SDP introduces a horizontal service delivery approach as depicted in Figure 4-2.

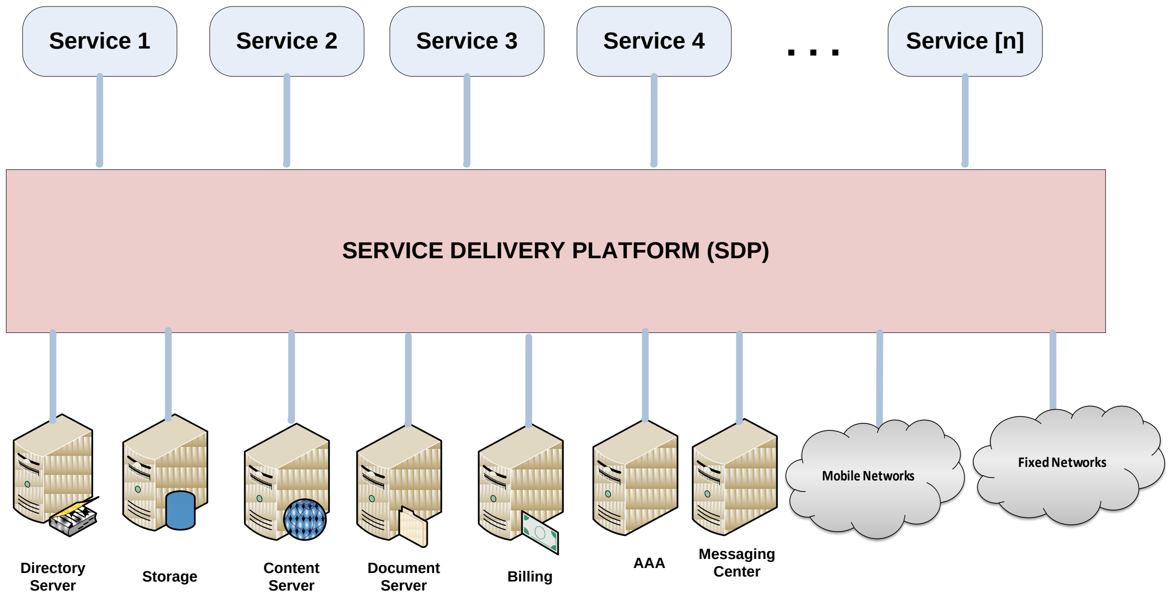

Figure 4-2: Addressing operator challenges using the SDP (adapted from DEVOTEAM, 2007)

In the horizontal service delivery approach, the SDP glues together the underlying access networks, session management and control functions, the operator's back-end business processes and the end-user applications.

Figure 4-3 demonstrates the operational implications of the SDP of addressing the need to glue together the heterogeneous access networks, to exploit additional revenue streams, to expose operators' communication capabilities to external application developers, and to capitalise on both legacy and new infrastructure.

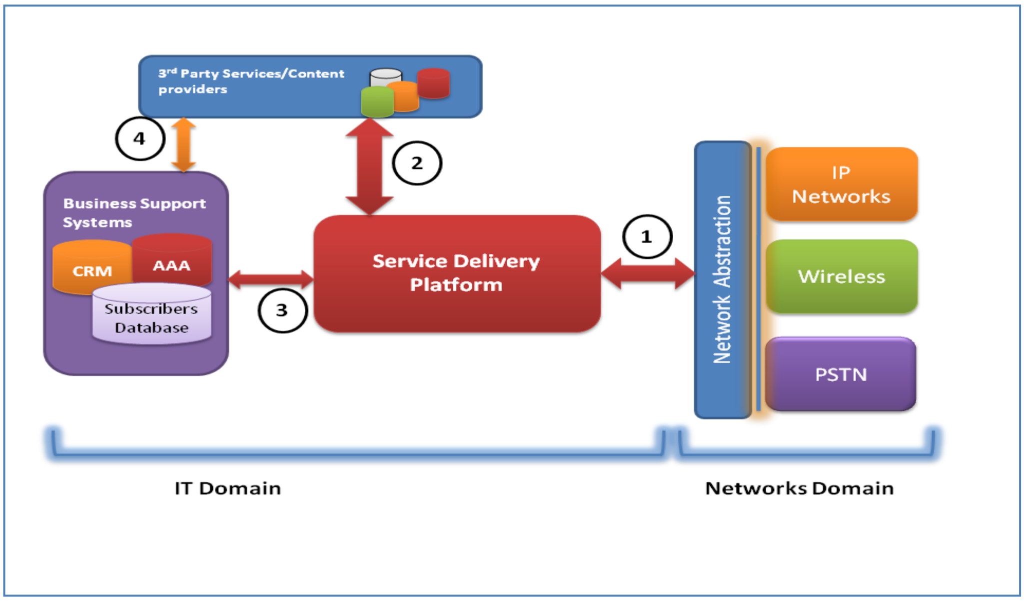

Figure 4-3: The SDP within converged IT-Telecom space (adapted from Maes, 2007:2886)

Starting from the network domain, (1) the SDP defines standardised interfaces that abstracts the underlying technology-specific networking functions exposed to it by network operators. This helps achieve access-agnostic service delivery. This also helps the operators to capitalise on both legacy and new access network infrastructures.

Secondly, (2) the SDP exposes the abstracted telecommunications capabilities such as Short Message Service (SMS) as standard Service Oriented Architecture (SOA) compliant interfaces to third parties, and in turn the third parties themselves make rich content available to traditional telecommunication networks. This presents operators with an additional revenue stream.

Thirdly, (3) the SDP uses IT enterprise-provided resource APIs to access back-end systems such as Business Support Systems (BSS) and subscriber management systems. These systems provide functionalities such as billing as well as authentication, authorisation and accounting (AAA).

Lastly, (4) where the business model allows it, the charging architecture has to allow sharing of revenue resulting from access to content or service usage.

The above discussion highlighted the practical implications of the SDP, which should still be considered when developing delivery mechanisms for digital content and services within the ICT4D context. The practical implications of the SDP should be considered by looking at how the delivery mechanism for ICT4D (which is based on the SDP) would relate to the overall pre-existing community technical infrastructure, technological capabilities and services.

4.3 SDP DEFINITIONS AND CONCEPTS

This section discusses the conceptual principles of the SDP in terms of its definitions, characteristics and architecture. Specifically, the SDP concept is explored to establish how it may be applied to address the requirements that were developed and discussed in Section 4.1.

According to The Moriana Group (2010), the SDP provides *sets of technology components for (1) rapid development, provisioning, execution, management and billing for value-added customer services*, supports (2) *network and device-independent delivery of multimedia (voice, video and data) services*, (3) aggregates *different networking capabilities into re-usable services which are then exposed to external service developers in a standardised manner*.

Jain (2007) describes the SDP as an open and standards-based framework that helps service providers (CSPs) to simply, quickly and cost effectively *create*, *deploy* and *deliver* new *services* and applications. The SDP therefore provides a service creation and execution environment as well as an abstraction layer that hides the complexities of the underlying communication networks (Jain, 2007). On the other hand, Menkens (2010) notes that SDPs define the use of telecommunication infrastructure, the Internet and Web technologies to provide *a service delivery architecture* that allows the service providers (CSPs) to *create services*, and to expose such services to external partners. As such, SDPs should provide support for session control and standardised protocols. Christian and Hanrahan (2007) define the SDP as a distributed IT platform that uses telecommunication infrastructure capabilities to aid in the development and delivery of customer services.

Maes (2007:2887) adds that the SDP is a horizontal platform for the service layer that follows the SOA principles, that provides an extensible set of multimedia (video, voice, data) functions and abstracts the underlying network resources. Lu, Zheng and Sun (2008) as well as Zheng, Lu, and Sun (2008) refer to the SDP as an enabling platform for efficient *creation, deployment, execution, orchestration* and *management* of telecommunication *services* that has the flexibility to integrate with legacy systems easily. These requirements of an SDP, as Maes (2007:2887) puts them, are summarised later in this chapter when discussing Next Generation SDP (NGSDP).

By literature synthesis and for the purpose of this study, the SDP is understood as follows:

- A Service Delivery Platform defines a set of standards-based concepts and technologies that ensure support for rapid service creation, deployment and delivery.

- The SDP provides service life cycle management for deployed services. It also supports integration with third party service providers and service developers through exposure of secured and standardised service interfaces.

- Furthermore, the SDP allows for integration with heterogeneous networks, including legacy systems. The complexities of these underlying networking technologies and protocols are abstracted from the service delivery core by packaging the networking capabilities into re-usable service components which service developers (even non-telecom developers) can use when creating their services.

- Most importantly, the SDP architecture should be technology-neutral to support interoperability across any *SDP-compliant* implementations.

The service delivery platform approach incorporates both the access-agnostic and seamless service delivery concepts through network abstraction and the service layers. Below are the elements of a typical service delivery platform for telecommunication infrastructure. The elements described below appeared consistently in the literature consulted on SDPs and Next Generation Networks (NGNs).

4.4 ELEMENTS OF THE SDP ARCHITECTURE

This section looks at the architecture of the SDP in relation to how each of the requirements identified above is met. The architecture of the SDP is particularly relevant to this study because it highlights key components that comprise a typical SDP, and these components may be adapted for application within the ICT4D space and help to identify elements of a model that facilitates access-technology-agnostic delivery of ICT4D content and services to resource-constrained communities.

The next section presents the basic architecture of the SDP.

4.4.1 Basic SDP architecture

Whereas the IMS core components are standardised as P-CSCF, I-CSCF, S-CSCF and HSS (Reichl, Bessler, Fabini, Pailer & Zeiss, 2006; Magedanz & De Gouveia, 2006:272-273), there is no consensus on the core elements that an SDP should be composed of (Lu, Zheng & Sun, 2008). Literature on the requirements of SDP architecture, however, indicates predominance of the following elements in the description of a *generic* SDP architecture:

- Service Creation Environment (SCE)
- Service Exposure
- Service Management Platform
- Service Execution Environment
- Content Delivery
- Network Abstraction

Service Creation Environment – this is made up of service creation frameworks and developer tools that simplify rapid service creation and deployment. *Service* *creation environment* is responsible for the rapid creation of services and is hosted within an IT enterprise ecosystem. It is supported by tools such as Integrated Development Environments (IDEs) which significantly ease programming tasks by supplying features such as source code highlighting and numerous libraries, plug-ins and Application Programmer Interfaces (APIs).

Service Exposure – provides simplified and secure interfaces to the SDP service capabilities for external third party developers. Service exposure can be accomplished through the use of Web Services standards such as Service Oriented Architecture (SOA) (Makitla & Fogwill, 2011:61).

The *Service Management Platform* – provides facilities for management and provisioning of services within the SDP. The Service Management Platform comprises Operational Support System/Business Support System (OSS/BSS) and Authentication, Authorisation and Accounting (AAA) systems which provide support for service charging and management of provisioned user data such as subscriber profiles.

The *Service Execution Environment* provides the run-time environment and support for services components within the platform. The service execution environments are based on standards such as Java API for Intelligent Network Service Logic Execution Environment (JSLEE, 2005).

Content Delivery – this component is responsible for providing application-level access to content. In a deployment scenario where the SDP integrates with the content delivery platform, the content delivery component makes it possible to enrich traditional telecommunication service offerings with multimedia content (e-mail, calendar, portals, etc).

Network Abstraction – abstracts the complexities of the underlying network technologies by providing common points of access to the underlying heterogeneous network capabilities. The abstraction hides the telecom infrastructure complexities from the service execution environment; they provide vendor and technology-independent interfaces to the underlying network resources and capabilities. This means they package the underlying telecommunication capabilities into re-usable service components which can be used by upper-layer components.

Figure 4-4 below depicts a typical SDP block diagram that shows the components described above.

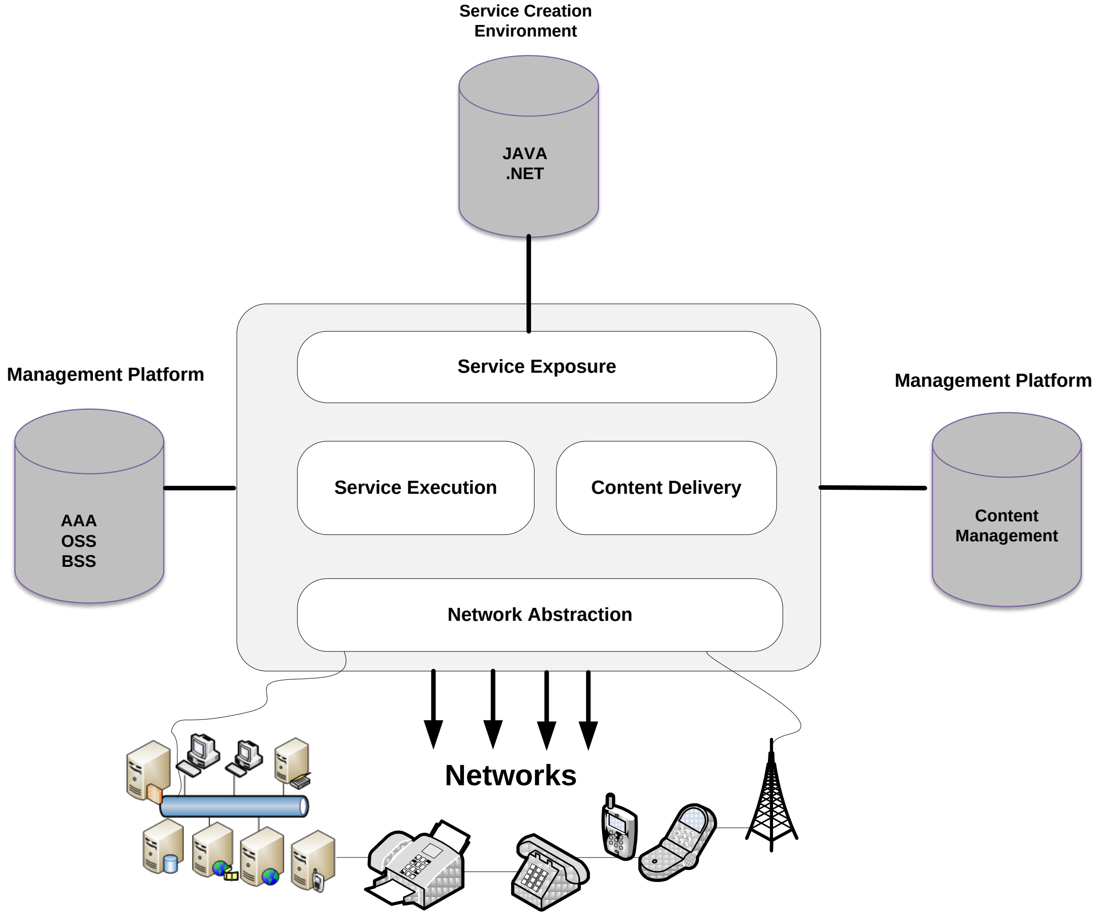

Figure 4-4: Generic SDP architecture (adapted from Christian & Hanrahan, 2007)

Christian and Hanrahan (2007) further presented Figure 4-5 as a technology-independent conceptual model of the SDP.

The SDP conceptual model shown in Figure 4-5 illustrates an SDP as a layered architecture made up of five planes. Each plane represents a collection of services of the SDP depending on the functions they provide.

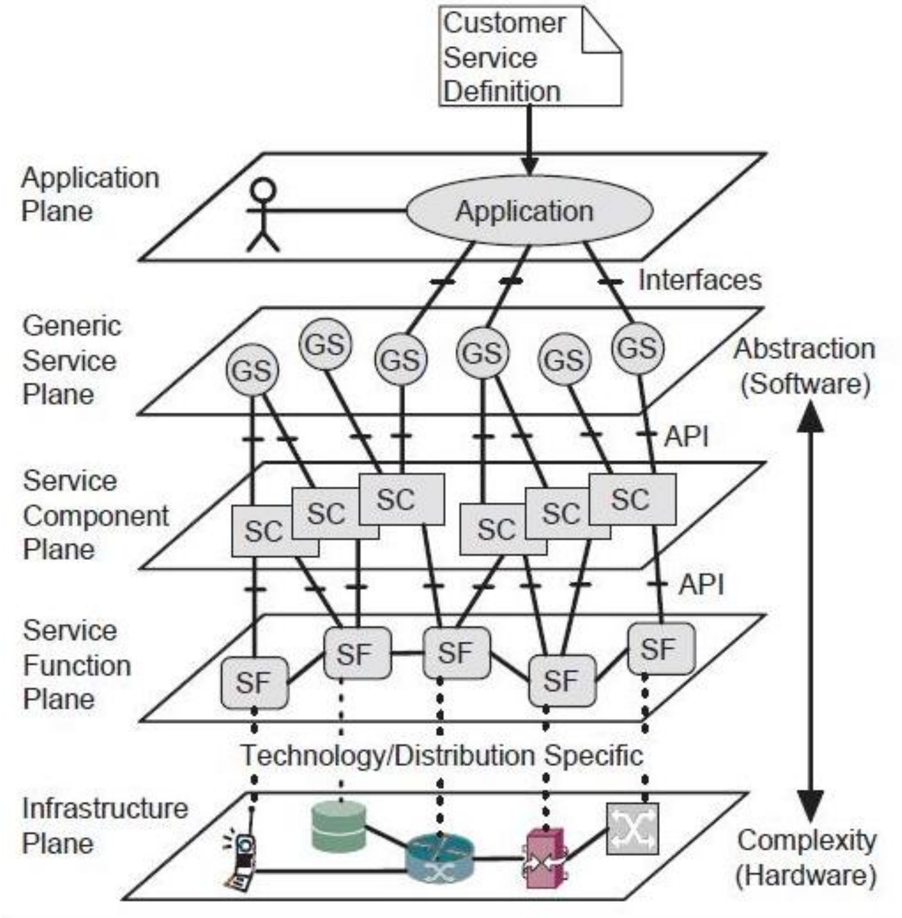

Figure 4-5: SDP conceptual model (source: Christian & Hanrahan, 2007)

Starting from the Application Plane, customer services are defined by integrating re-usable functions exposed by the Generic Service Plane through the GS implementation-independent interfaces. The Service Component Plane abstracts the complexity of the underlying telecommunication infrastructure into re-usable software-based components representing the telecommunication capabilities of the network. These components are exposed to the Generic Service Plane in the form of APIs. The Service Function Plane is aware of the underlying telecommunication infrastructure and technologies; it represents the abstraction of complex telecommunication functions. The abstracted telecom capabilities are exposed through APIs to the Service Component Plane, and in doing so the Service Function Plane enables technology and network-independent access to telecommunications functions. The Infrastructure Plane hosts the physical networking equipments such as network routers, Internet gateways, and so forth.

The Infrastructure Plane enables these vendor and technology-specific functions to be accessible to and used by the Service Function Plane.

Beyond the most basic SDP conceptual model discussed above, The Moriana Group (2010) presents a next generation SDP model that incorporates new features and technologies. The next section presents the architecture of a next generation SDP.

4.4.2 Next Generation SDP architecture

The Next Generation SDP or NGSDP (Lu, Zheng and Sun, 2008) is based on the principles of Service Oriented Architecture (SOA) which is an established Web Services standard. Figure 4-6 depicts the Third Generation SDP architecture model.

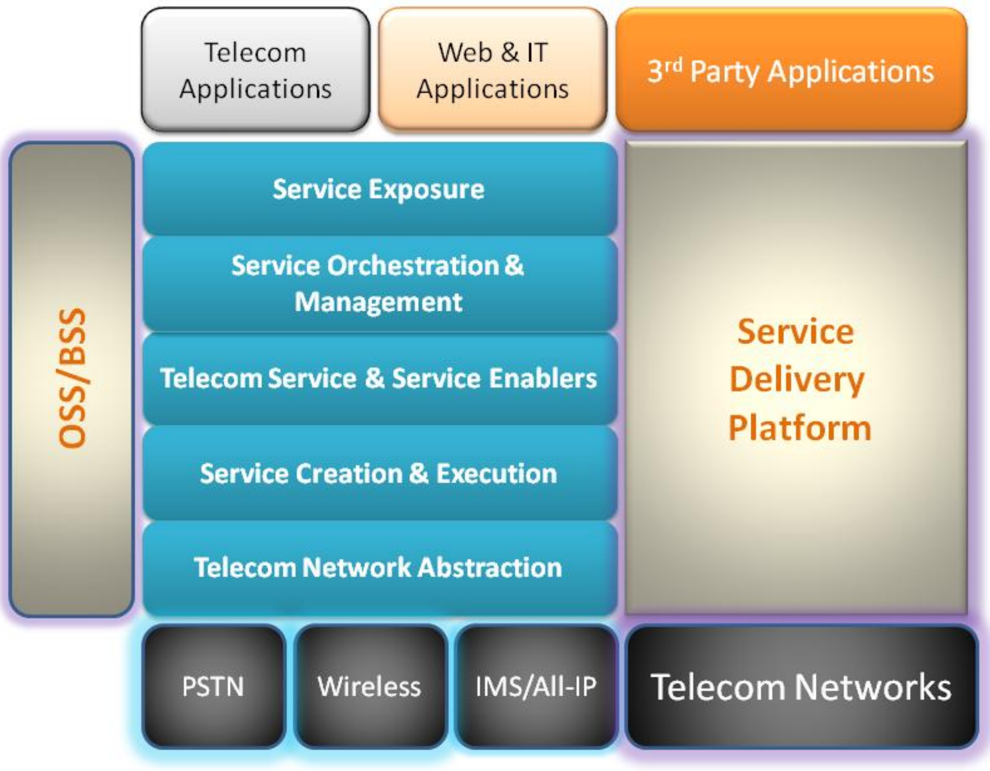

Figure 4-6: Third Generation SDP architecture (source: The Moriana Group, 2010)

In addition to the components of a typical SDP described earlier in this section, the evolved SDP architecture follows the layered architecture and comprises all the key elements of the generic SDP and additionally includes the SOA-based Service Orchestration and Management Layer (The Moriana Group, 2010). The SDP architecture (Figure 4-6) shows the following layers (The Moriana Group, 2010):

- Service Exposure Layer
- Service Orchestration and Management layer
- Telecom Services and Service Enablers Layer
- Service Creation and Execution Layer
- Telecom Network Abstraction Layer.

Lu, Zheng and Sun (2008) suggested that to incorporate new features the NGSDPs have to satisfy a number of new requirements. The requirements are that the NGSDPs must:

- Provide mechanisms to integrate with IMS and support the necessary standards
- Be built following the principles of SOA to support service orchestration and management
- Provide open APIs to support integration with Web 2.0 – these standardised and secured interfaces should be exposed to third party organisations (as per the requirements of the SDP).

Truly, the NGSDP seeks to bring the Web 2.0 and telecommunication worlds much closer: it provides for the convergence of Web and telecom through Telecommunication Web Services (Burger, Rajasekar & Lundiqvist, 2007) by applying Web 2.0 paradigms to the communications sphere, for instance through Com 2.0 (Labrogere, 2008).

NGSDPs are also envisaged to be central concepts within the NGN space through integration with IMS core networks. Magedanz and De Gouveia (2006) illustrated how IMS and the SDP can be incorporated into next generation service networks.

4.5 SUMMARY

Section 4.1 presented motivations for the adoption and evolution of the SDP within the telecommunication domain. Each of these motivations was matched against a corresponding ICT4D requirement from the set of requirements which were developed in Chapter 3 (see Section 3.4), and summarised in Table 3-1 and Table 3-2.

Having aligned the requirements from the two distant domains, namely telecoms and ICT4D, it is also helpful to consider how the telecom domain has attempted to address these issues, especially as they pertain to delivery of digital content and services. In the case of ICT4D, however, Chapter 1 already indicated the evident lack of such delivery mechanisms within ICT4D as a key motivation for this research. In the case of the telecommunication domain, however, Jain (2007) has presented three of the delivery design patterns which telecom operators use in developing their service delivery infrastructure. These patterns were discussed in Section 4.2 of this chapter.

The SDP is one of the patterns discussed, and it incorporates both access-agnostic and seamless service delivery approaches, both of which are concerned with how services are delivered on telecommunication networks. Based on its conceptual principles (see Section 4.3) and its architecture (see Sections 4.4.1 and 4.4.2), the SDP presents a viable technical architecture for an access-technology-agnostic delivery mechanism for digital content and services within the ICT4D context.

Table 4-1 captures the mapping of SDP capabilities to the ICT4D context-imposed socio-technical requirements for the solution in this study.

Table 4-1: SDP capabilities and the ICT4D context-imposed socio-technical requirements

ICT4D context-imposed socio-technical requirements	Description of ICT4D context-imposed requirements	SDP capabilities
Choice of appropriate technology	One of the causes of ICT4D project failures has been attributed to the choice of inappropriate technologies (Van Reijswoud, 2009). Technology appropriateness in this study pertains to sensitivity to environmental constraints (low literacy, low income, inadequate infrastructure, and prevalence of older technologies). Appropriate technologies in the ICT4D context are those technologies tailored to resource-constrained environments.	Technology appropriateness in this study pertains to sensitivity to environmental constraints such as the prevalence of older technologies. The SDP incorporates new and older technologies by abstracting complexities of these technologies from the actual content and services. By converging both old and new technologies, the SDP allows telecom operators to deliver content and services to their customers through technologies that are appropriate for a particular user population in terms of technologies that have penetrated this user market. Therefore the technologies used to implement the SDP as a delivery pattern are appropriate.
Focus on poor-user techniques	Focusing ICT4D efforts on technologies that are optimised for resource-constrained contexts has been advocated by Cecchini and Scott (2003).	One of the key requirements for telecom operators has been to ensure return on investments in older technology infrastructures. The SDP, through the network abstraction, enables the telecom operators to continue providing services on these older technologies, making the SDP a technically viable poor-user technique.

ICT4D context-imposed socio-technical requirements	**Description of ICT4D context-imposed requirements**	**SDP capabilities**
Capitalise on available technological capabilities	This requirement has been identified by Heeks (2008; 2009) as one of the key approaches of ICT4D 2.0 and emphasises the need to optimally utilise whatever technological capabilities are available to the communities to make a difference. It also necessitates the use of even older technologies (such as radios and basic mobile phones) to deliver meaningful value-adding services to end-users.	The SDP helps telecom operators to avoid commoditisation of their legacy infrastructure (mainly for voice services), thus enabling the operators to capitalise on the legacy infrastructures to ensure return on infrastructure investment.
Facilitate equitable access to information services	Azam (2008:488) stated that when introducing ICTs in rural communities, ensuring equitable access to digital services is one of the most serious social challenges. Digital services should be made equally accessible even to users with low literacy levels (e.g. Agarwal *et al*., 2009; Ford & Leinonen, 2009).	The SDP allows telecom operators to continue providing services to customers that are still connected through the legacy infrastructure, and attracting new customers by tapping into newer and more attractive converged service offerings through multimedia service networks. This way the operators are able to increase average revenue generated per user by providing equitable access to services to both old and new customers.

The mapping of SDP capabilities to the ICT4D context-imposed technical requirements is presented in Table 4-2.

Table 4-2: SDP capabilities and ICT4D context-imposed technical requirements

ICT4D context-imposed technical requirements	Description of ICT4D context-imposed requirements	SDP capabilities
Scalability	The proposed model should support up-scaling in order to adapt to changing technological capabilities, and increasing requests or usage volumes of user communities.	The SDP meets the scalability requirement because through the network abstraction element, additional access networks can be attached to the SDP, allowing telecom operators to tap into new user populations connecting through those access networks.
Access-Technology Agnostic	This entails the support for information and service delivery media convergence so that digital content and services are accessible and delivered to end-users regardless of the access technologies used by the end-users to access these services.	Through the layered architecture, and specifically the Network Abstraction layer, Telecom Services Layer and Service Enablers Layer, the SDP links together heterogeneous networks (all IP-networks, PSTN, wireless), hiding the complexities of these networks and thus making the upper layers of the SDP, which are most concerned with service logic, to be agnostic of the underlying access networks.

In view of the discussion in Sections 4.2, 4.3 and 4.4 and summarised in Table 4-1, this chapter contributes towards addressing the investigative research question that sought to establish which technical architecture an access-technology-agnostic delivery mechanism for ICT4D digital content and services may be based on.

The next chapter, Chapter 5, discusses the selective adaptation of the SDP concept to develop a conceptual model of an Access-Technology-Agnostic Delivery Mechanism for digital content and services within the ICT4D context.

Chapter 5

Conceptual Model

In Section 1.2, this study identified the research problem as being the evident lack of delivery mechanisms that can facilitate equitable access to digital content and services within an ICT4D context. Furthermore, peer-reviewed sources from the ICT4D literature that also hinted at the problem and its significance were cited. The lack of these delivery mechanisms exists despite the delivery of digital content and service being one of the main thrusts of ICT4D. In this chapter, an Access-Technology-Agnostic Delivery Model will be developed by re-using the concepts from both the synthesised ICT4D literature (Chapter 3) and the SDP literature (Chapter 4).

This chapter is structured as follows. Section 5.1 revisits the concepts from the ICT4D literature as discussed in Chapter 3 and extracts the key elements of delivering ICT functionality within an ICT4D context. Section 5.3 then re-uses the concepts from the SDP discussion in Chapter 4, and explores how the SDP capabilities, which have already been aligned to the ICT4D context-imposed requirements (see Table 4-1), may be used to link together the components of providing ICT functionality and thus forming a delivery mechanism for digital content and services within an ICT4D context. This adaptation of the SDP concept into an ICT4D context necessitates the reappraisal of telecommunication-specific SDP terminology to fit the ICT4D context by redefining key elements of the SDP architecture in terms of a typical community setting. Following the reappraisal of the SDP concepts for use within an ICT4D context, Section 5.3 assembles the key elements that constitute the proposed Access-Technology-Agnostic Delivery Model. Section 5.4 discusses the advantages of the proposed model in terms of how the configuration of the model addresses the requirements imposed by the ICT4D context.

5.1 ELEMENTS OF DELIVERING ICT FUNCTIONALITY

In discussing the role of ICT to support developmental initiatives, Weigel (2004) identified the following as general dimensions and goals of ICT4D:

- *Access to information for development*: Promoting the use and exchange of information and knowledge.
- *Communication for development*: Strengthening the voice of the poor, excluded and disadvantaged.
- *Networking and communication*: Facilitating effective human interaction and cooperation.
- Using ICTs as *tools* to increase development effectiveness and efficiency.

Based on these general goals as identified by Wiegel (2004) above, this study views the three main thrusts of ICT4D presented by Pitula *et al*. (2010) as narrowing the goals and dimension of ICT4D into the three main focal areas:

- Developing the *required infrastructure* (electricity, connectivity and devices) in a sustainable manner.
- Building the *ICT capacity*: the skills and competencies required to manage and maintain and use the technology effectively.
- Providing access to *digital content and services.*

Relating to the above focal areas, the primary components of ICT functionality which were discussed in Section 1.1 and referred to as the 4C Framework (i.e. *Connectivity*, *Computing*, *Content* and *Capacity*), are represented within an ICT4D context in the following manner:

Connectivity – this pertains to the overall telecommunication infrastructure; the community as a whole has supporting physical infrastructure such as road networks, electricity, community local networks and telecommunication infrastructure. The connectivity component is addressed through development of the required communications infrastructure to facilitate human interaction and cooperation, and to provide access to digital content and services.

Computing – this pertains to personal and shared ICT devices whereby individuals within the community each own and have access to some shared technological or computing devices which they use to access the digital content and services that are accessible through the available community connectivity infrastructure. The computing component is addressed by both the first and second thrusts of ICT4D initiatives, namely developing the required infrastructure (both public access ICTs and personal ICT devices), as well as building human technical capability (in this case the ability to use technological gadgets effectively).

Content – this component pertains to the digital content and services which are delivered over the available connectivity infrastructure and which the end-user accesses using the personal or shared ICT devices (see *Computing* component). This is addressed by the third thrust of the ICT4D initiatives, namely, providing access to digital content and services.

Capacity – this component relates to human capacity, including the technical know-how needed to maintain and manage the community-owned ICT infrastructure (computing and connectivity), the ability to understand the available digital content and services as well as the ability to use available personal or shared ICT devices to retrieve information. By developing human capacity as one of the three main thrusts of ICT4D initiatives, individuals within a community acquire some working knowledge which enables them to operate the personal or shared ICT devices to access available digital content and services through the available community infrastructure. Individuals within a community also acquire the technical know-how needed to maintain and manage community-owned ICT infrastructure.

Derived from the 4C Framework represented above, there needs to be a component that links together the elements of delivering ICT functionality to facilitate the ultimate delivery of, and access to, digital content and services. This study refers to the required component as a Digital Content and Service Delivery Mechanism.

Incorporating the *Digital Content and Service Delivery Mechanism* component into the 4C Framework results in the representation in Figure 5-1.

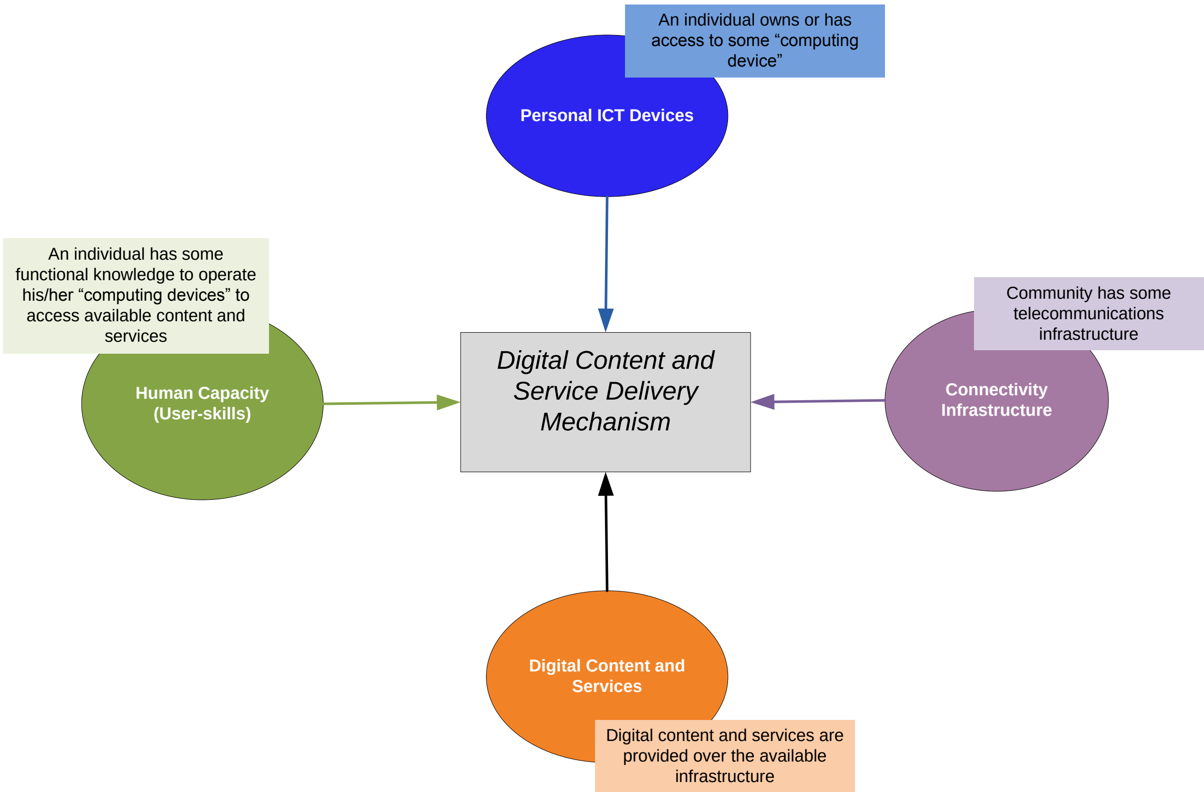

Figure 5-1: Digital Content and Service Delivery Mechanism and the 4C Framework components

Figure 5-1 places the *Digital Content and Service Delivery Mechanism* component in the centre with all other components connecting to it. This serves to indicate the central role that this component plays. The relationship between the *Digital Content and Service Delivery Mechanism* and the components of the 4C Framework can be represented as in Figure 5-2.

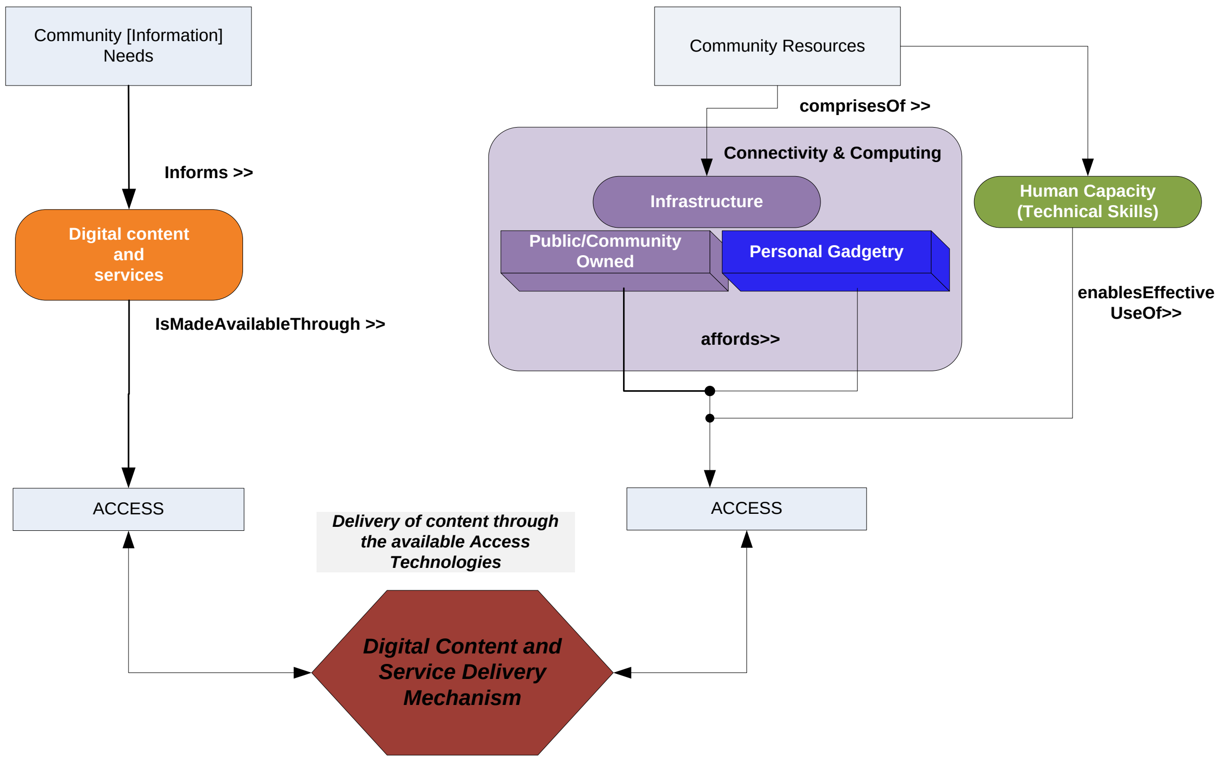

Figure 5-2: Relationships between components of the framework

The *community information needs* inform the nature of digital content and services to be delivered to the end-user through whatever delivery mechanism is available to the community. The Information Needs Assessment Model (INAM) proposed by Dhingra and Misra (2004) may be used in identifying the information needs of rural communities.

Community ICT resources comprise human capacity (e.g. technical know-how), the supporting physical infrastructure (e.g. buildings, transport, electricity and water) and information infrastructure (e.g. tele*communication networks, computers, telephones)*. The information infrastructure further comprises community-owned or public infrastructure such as community wireless mesh networks (Makitla, Makan, Roux, 2010). The information infrastructure also comprises the private or personal *end-user communications and entertainment devices* (gadgetry); this is a collection of electronic devices owned by private individuals (e.g. FM radios, mobile phones, televisions, music players, and laptop and desktop computers).

The community infrastructure, the personal computing infrastructure and the technical know-how together constitute the community's technological capabilities. The community's technological capabilities afford community access to digital content and services which are being delivered through the delivery mechanism. Additionally, the technical know-how enables the community to make effective use of the personal or community-owned ICT devices and communications networks to access digital content and services.

The *digital content and services* are made available to communities through whatever connectivity and computing infrastructure they may have as part of the overall technological capabilities.

The delivery of digital content and services to the community is ultimately the responsibility of the *Digital Content and Service Delivery Mechanism* which, as was mentioned in Section 1.2, is currently lacking within an ICT4D context.

Based on the preceding discussion, the main components of the proposed Access-Technology-Agnostic Delivery Conceptual Model can be outlined as follows:

- Community information needs
- Communication networks
- Digital content and services
- Digital Content and Services Delivery Mechanism
- End-user communication and entertainment devices
- End-user capacity.

As depicted in Figure 5-1, the *Digital Content and Service Delivery Mechanism* component interacts with all the components that deliver ICT functionality to ensure the delivery of digital content and services. The objectives of the *Digital Content and Service Delivery Mechanism* component are dictated by the ICT4D context-imposed requirements which were developed and described in Section 3.4. This study re-uses the telecommunications concept of the SDP to realise the

Digital Content and Service Delivery Mechanism component. Chapter 4 argued that it is sensible to adopt the SDP concept based on the alignment of SDP capabilities and the requirements imposed by the ICT4D context.

5.2 RE-USING THE SDP CONCEPT WITHIN AN ICT4D CONTEXT

Chapter 4 has already demonstrated that the SDP represents the technical basis of a delivery mechanism needed to ensure the actual delivery of digital content and services to target communities using whatever technologies (e.g. network connectivity and computing devices) are available to these communities. The concepts of network abstraction and layered service architecture are central to the SDP approach and present a re-usable design pattern to realise the Digital Content and Service Delivery Mechanism component (see Figure 5-2). However, to re-use the SDP concept in an ICT4D context necessitates the reappraisal of telecommunication-specific SDP terminology to fit the ICT4D context by redefining key elements of the SDP architecture in terms of a typical community setting.

From Section 4.4 the key components of the SDP architecture can be outlined as:

- *Service* – set of electronic functionality being provided to end-users (e.g. weather information, instant messaging, video conferencing, and voice call)
- *Service Creation Environment* – set of tools for creating the actual services
- *Service Exposure and Enablers*– making services accessible to external developers, content providers and end-users who may not have sufficient resources to maintain the actual service infrastructure
- *Service Execution Environment* – the computational environment where deployed services are being executed
- *Network Abstraction* – hiding the complexities of the underlying telecommunications infrastructure from the service execution environment and the actual service
- *Telecommunications Network* – the physical network infrastructure

- *End-user devices* – electronic gadgets that end-users use to connect to the available network infrastructure (e.g. desktop computers, laptops, mobile phones, etc.).

Within an ICT4D context the above components of the SDP may be understood as those components that represent the actual ICT functionality being provided (*Service*), the mechanisms by which such ICT functionality is provided (*Service Creation Environment*, *Service Exposure and Enablers*, *Service Execution Environment* and *Network Abstraction*), the physical connectivity infrastructure that represents the channels through which a beneficiary community may access the ICT functionality (*Telecommunication networks*), and lastly the electronic gadgets (*end-user devices*) in possession of the community which it uses to access the available ICT functionality in terms of digital content.

5.3 ACCESS-TECHNOLOGY-AGNOSTIC DELIVERY MODEL

Following the reappraisal of the SDP concepts for use within an ICT4D context, this section assembles the key components that constitute the proposed Access-Technology-Agnostic Delivery Model.

Ensuring equitable access to digital content and services is one of the requirements imposed by the ICT4D context on the proposed solution (see Table 3-1). Furthermore, the need to ensure equitable access to digital content and services for equal opportunities is also one of the general goals and dimensions of ICT4D. This study argues that for equitable access to digital content and services to be possible, the delivery mechanism has to be access-technology-agnostic. That is, it has to ensure access to and delivery of digital content and services to all users within a community regardless of the access infrastructure the users connect through or the computing devices being used. Meeting this access-agnostic requirement necessitates the separation of the ICT functionality and the underlying access technologies. Therefore the layered architecture employed by the SDP is re-used in this study to separate the ICT4D information service logic, the content presentation format, the end-user devices and the underlying access network. The conceptual model that follows this layered approach is presented next along with the accompanying description and discussion.

To ensure access-technology-agnostic delivery of digital content and services to resource-constrained communities, the *Digital Content and Service Delivery Mechanism* is conceptually modelled as shown in Figure 5-3.

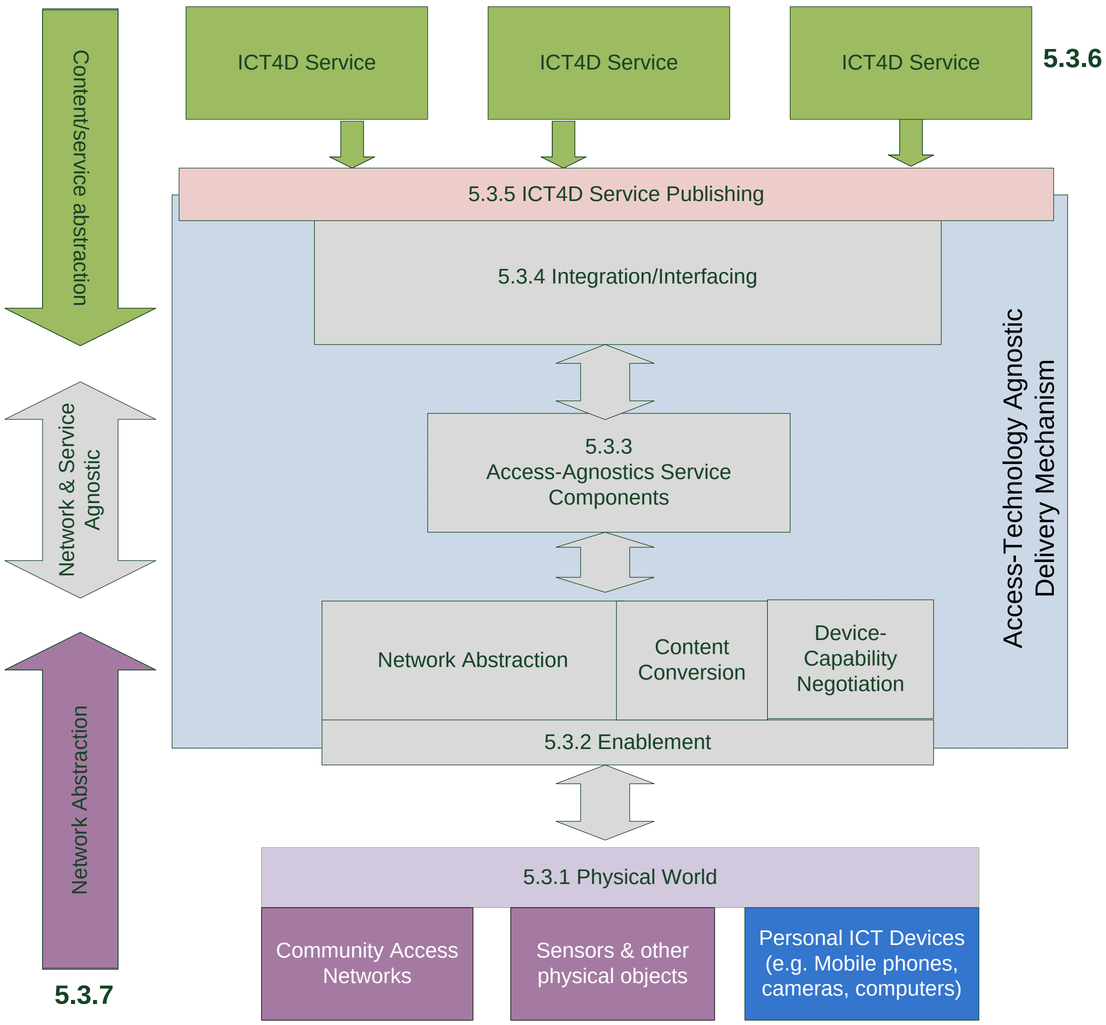

Figure 5-3: Conceptual Access-Technology-Agnostic Delivery Model

5.3.1 Physical world

The personal ICT *Devices* used to access the ICT4D services and the 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 delivery mechanism.

5.3.2 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. The Enablement layer is composed of three functions, namely *Device Capability Negotiation*, *Content Conversion* and *Network Abstraction*.

The *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 to render multimedia content to the connected end-user device. For example, rendering a video service on a dial-up access network would require some adaptive streaming techniques (Hillestad, Perkis, Genc, Murphy & Murphy, 2006). However, when considering the actual device, even the display has to be adjusted to give the user a good service experience. Device capability negotiation can be accomplished through the capability exchange mechanism described by Rosenberg, Schulzrinne and Kyzivat (2004), in which a SIP user agent indicates its capabilities and characteristics to other user agents on the call chain.

The *Content Conversion* function is also part of the Enablement layer. This function is responsible for content-device capability matching. Since a service may produce output that needs to be presented at the end-user device, this function adapts the content to the format understandable to the device. This makes it possible to deliver the same content in different formats (e.g. audio and text) depending on the device's capabilities.

The *Network Abstraction* function is adopted from the SDP basic and next generation architecture (see Section 4.4) and abstracts the complexities of the underlying access technology from the platform. It represents the connected client and the underlying networking capabilities to the platform (this is the enablement).

5.3.3 Access-Agnostic Service Components layer

The *Access-Agnostic Service Components* layer has no knowledge of the network connectivity resources. It receives requests from the *Enablement* layer (already in a form understandable within its access-agnostic environment). The Access-Agnostic Service Components layer then has the logic or algorithm to ensure that these requests do reach their intended services. As far as the Access-Agnostic Service Components layer is concerned, it knows only that it has to forward these requests to the Integration/Interfacing layer which "subscribed" to be notified of such requests. Therefore the Access-Agnostic Service Components layer is not aware of the application specifics such as the actual service functionality being provided; only the Integration/Interfacing function needs to worry about application specifics.

5.3.4 Integration/Interfacing layer

The *Integration*/*Interfacing* layer is fully aware of what services lie outside of the delivery mechanism (i.e. the platform). When a request is received from within the delivery mechanism for one of the ICT4D services, it is the responsibility of the Integration/Interfacing layer to invoke the appropriate service logic on the requested ICT4D service itself. The Integration/Interfacing layer must therefore have all the knowledge it needs to correctly invoke these services. This way, the Integration/Interfacing layer represents the ICT4D services to other components in the lower layers of the delivery mechanism. As far as the Integration/Interfacing layer is concerned, both the Access-Agnostic Service Components layer and the Enablement layer represent the underlying communication capabilities, including any knowledge of the user agents and devices. For example, the application data is simply pushed down to these two layers and they have enough knowledge about the requesting user to deliver the data in a format understandable and acceptable to the end-user device.

5.3.5 ICT4D Service Publishing layer

The *ICT4D Service Publishing* layer is shown as a layer for ease of description, but is logically part of the Integration/Interfacing layer. ICT4D services inform the delivery mechanism of their presence by publishing/advertising themselves.

Through these advertisements, they provide sufficient information necessary to invoke the advertised service logic. The Integration/Interfacing layer, which is responsible for the invocation of these external services, subscribes to be notified as and when services become available. The ways in which the ICT4D services are published and discovered are open to different implementations.

5.3.6 ICT4D services

The *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. Through the ICT4D *Service Publishing* layer and the *Integration/Interfacing* layer of the delivery mechanism, the ICT4D services developer can make his/her services access-agnostic. Chapter 6 discusses the reference implementation of the proposed model and will demonstrate how a pre-existing service can be plugged into the access-agnostic delivery mechanism and be made accessible through additional access technologies and presented in different formats.

5.3.7 Levels of abstractions

The conceptual model in Figure 5-3 depicts two levels of abstractions. The first abstraction is the network abstraction which hides the complexities of the underlying physical networking infrastructure and its technologies. These complexities are hidden from the access-agnostic layer component (see Section 5.3.3) which is the core of the delivery mechanism.

The second level of abstraction is the service/content abstraction which hides the service functionality-specific concerns from the core of the delivery mechanism. Therefore, whereas the lower layers and their functions are more specific to access technologies, the uppermost layers are more specific to the service functionality of each service to be delivered.

This study refers to the proposed configuration in Figure 5-3 as access-technology-agnostic because it allows information to be delivered to the end-user independent of his or her access technology. This configuration was adopted because it promises inclusivity, extended reach and equitable access to digital content and services. The advantages of this access-technology-agnostic delivery approach and the ICT4D context-imposed requirements that this approach satisfies are discussed next in Section 5.4.

5.4 ADVANTAGES OF THE PROPOSED DELIVERY MECHANISM

The proposed model of a delivery mechanism depicted in Figure 5-3 has been developed in response to the evident lack of such mechanisms within an ICT4D context. Therefore, the proposed delivery mechanism has to address the ICT4D context-imposed technical and socio-technical requirements. This section describes how the proposed configuration as depicted in Figure 5-3 addresses the ICT4D context-imposed requirements (see Table 3-1 and Table 3-2 in Chapter 3).

5.4.1 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 therefore any service available through the 3G networks is inaccessible to these devices, and also to their owners or users.

Therefore by being access-technology independent, the conceptual model facilitates equitable access to information services (ICT4D services). It also capitalises on available technologies by allowing users with low-end devices, and who are connecting through older access technologies supported by these devices, to use the same devices to access digital content and services.

5.4.2 Extendibility and scalability

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, and it is also possible to support new and advanced devices as users upgrade their handsets. Therefore, by scaling horizontally through additional access technologies and end-users whose devices can support these additional access technologies, the conceptual model addresses the scalability requirement as imposed by the ICT4D context on the delivery mechanism for digital content and services.

5.4.3 Content format independence

The decoupling of service logic, service access and content presentation makes 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. This allows the proposed delivery model to address the end-user device neutrality requirement imposed by the ICT4D context.

5.4.4 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.

The proposed configuration of the Access-Technology-Agnostic Delivery Model addresses the ICT4D context-imposed technical and socio-technical requirement as follows:

- 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.

- The digital 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 actual services can be re-used, because their published interfaces enable other developers to rapidly create composite services by re-using some of the functionalities provided by these services.

5.5 SUMMARY

This chapter synthesised the ICT4D literature to derive components for delivering ICT functionality to resource-constrained communities. These components were essentially the 4C Framework, with an additional component (the *Digital Content and Service Delivery Mechanism*) specifically purported to facilitate the actual delivery of digital content and services. It was argued that this delivery mechanism should be configured in a specific manner to be access-technology-agnostic in order to facilitate equitable access to digital content and services. The service delivery platform approach was therefore adopted. Specifically, the layered architecture and network abstraction aspects were adopted and re-used to realise the *Digital Content and Service Delivery Mechanism* component. The responsibility of the *Digital Content and Service Delivery Mechanism* component is to facilitate delivery of digital content and services through interaction with components of ICT functionality (i.e. connectivity, content, computing and capacity).

The resulting conceptual model thus developed was described in more detail in Section 5.3 and the beneficial characteristics of the conceptual model were presented in Section 5.4. However, this conceptual model would require functional verification to further reaffirm the beneficial characteristics claimed in Section 5.4, and the theoretical assumptions underpinning the model. Therefore the instantiation of the conceptual model is required.

The next chapter presents a reference implementation of the conceptual access-technology-agnostic delivery mechanism.

Chapter 6

Reference Implementation

Hevner *et al.* (2004:79) stated that instantiations of artefacts serve to demonstrate feasibility and to show that artefacts of design science can be implemented in reality. According to the three-cycle view of DSR (Hevner, 2007), instantiation of artefacts is discernible as part of the design cycle which is concerned with the iterative building and evaluating of design artefacts. Furthermore, because the design artefacts are built to address hitherto unsolved problems, these design artefacts are to be evaluated with respect to the utility they provide in addressing those problems (Hevner *et al.*, 2004:78).

Accordingly, the purpose of this chapter is to demonstrate that the proposed Access-Technology-Agnostic Delivery Model (developed and discussed in Chapter 5) is feasible and can be implemented in reality. This chapter therefore discusses a proof of concept implementation of the model to demonstrate how a pre-existing service (online weather service), which is traditionally accessible only through a Web browser (using HTTP), can be made accessible through multiple channels and in multiple formats (e.g. text and voice). This proof of concept implementation will serve to illustrate the utility in terms of the ability to make digital content (weather information) accessible and the technical viability in terms of the possibility of implementing the model using available open source technologies.

The remainder of this chapter, which draws on Makitla and Fogwill (2011), is structured as follows: an illustrative scenario is presented in Section 6.1 to express the practical dimension of the research problem within an ICT4D context; it sets the scene for experimentation. Section 6.2 presents the scope of the experiment to indicate what the experiment will cover. Section 6.3 discusses the technologies and standards on which the experiment is based, specifically those standards and technologies relating to the Service Execution Environment (Section 6.3.1) and its open source implementation (Section 6.3.2). The choice of an experimentation technology is discussed in Section 6.3.3. Based on the chosen experimentation technology, the experimental delivery platform is discussed in Section 6.4 in terms of the key elements of the conceptual Access-Technology-Agnostic Delivery Model. Section 6.5 describes an access-technology-agnostic weather service delivery experiment to demonstrate how typical ICT4D services could be delivered to facilitate equitable access to digital content and services. Section 6.6 then discusses how the experimental delivery platform addresses the requirements imposed by the ICT4D context. Finally, a chapter summary and conclusions are given in Section 6.7.

6.1 ILLUSTRATIVE SCENARIO

The illustrative scenario discussed here is also captured in a live demonstration video which is included in the accompanying materials (see Appendix B).

Scenario: Makitla and Fogwill (2011:65) consider an imaginary rural farming community that has basic communications infrastructure. Individual residents in such a community are assumed to have personal computing devices of various technological capabilities, from very powerful Smartphone to very basic SMS-Call-Only phones, while others have computers with Internet access (Makitla & Fogwill, 2011).

From the above scenario, Makitla and Fogwill (2011:65) infer the potential access technologies that are supported by the collective technological capabilities as:

- SMS
- USSD
- IM (e.g. MXit)
- Voice-Calls (VoIP-based Interactive Voice Response)
- Web (HTTP).

Information Needs Category: Daily News
Information Service: Weather Service

Purpose: an imaginary community would like to get on-time, up-to-date weather information in order to plan their farming activities.

Typical challenge: The weather service is available free online from (www.rsweather.com). However, the devices (e.g. mobile phones) that do not have Internet browsing capabilities cannot access weather information through this service. *How might the same weather service be made accessible through all other access technologies supported by other personal computing devices within the community?*

Solution approach: delivering the weather service through the access-agnostic delivery mechanism.

To address the practical problem described above, the solution approach, which is based on the experimental implementation of the Access-Technology-Agnostic Delivery Model, is discussed in this chapter. The next section, Section 6.2, discusses the scope of the experimental implementation of the model in terms of the elements of the Access-Technology-Agnostic Conceptual Model that have been implemented for proof of concept.

6.2 SCOPE OF THE EXPERIMENTAL IMPLEMENTATION

The main aim of this reference implementation is to demonstrate the ability to deliver digital content (weather information) through multiple-access technologies (SMS/USSD/IM/Web) and thus to devices supporting those access technologies. Therefore it is not absolutely necessary to provide reference implementations for all other components of the conceptual model (Figure 5-3). Only the following layers and functions have been implemented as part of this experiment:

- Access-Agnostic service components
- Integration/Interfacing layer
- ICT4D services
- Network abstraction
- Content conversion function.

The next section, Section 6.3, discusses the technology and standards that have been instrumental in the development and evolution of the SDP. This discussion of technologies and standards for the SDP is necessitated by the fact that the conceptual model itself is derived from the Service Delivery Platform (SDP) concept. This means that the reference implementation of the conceptual model would be realised using such standards and technologies.

6.3 IMPLEMENTATION: TECHNOLOGIES AND STANDARDS

From the conceptual model of the SDP architecture as discussed in Sections 4.4.1 and 4.4.2, and which was depicted in Figure 4-4 and Figure 4-6, a Service Execution Environment was presented as one of the main components of the SDP architecture; the Service Execution Environment represents the run-time environment purported to ensure delivery of telecommunication services. Therefore the experimental implementation of the Access-Technology-Agnostic Conceptual Model focuses on this component of the SDP. Specifically, this section discusses the Service Execution Environment component of the SDP from the telecommunication domain in terms of its supporting standards and technologies.

Standardisation bodies such as the Open Mobile Alliance (OMA), TeleManagement Forum (TMForum), Third Generation Partnership Project (3GPP), Internet Engineering Task Force (IETF), Parlay Group, Java Community Process (JCP), and Session Initialization Protocol (SIP) Forum are among those that have contributed to the evolution of the SDP. These bodies focused on specific elements of the SDP (e.g. service enablers, signalling protocols, execution models, policy management, service exposure and orchestration) and not on the architecture of the SDP in its entirety.

The evolution of SDPs has been attributed to the contributions and impact made by the following standards and technologies within converged Web and telecommunication domains: SIP, SIP Servlets, Internet Multimedia Subsystem (IMS), Open Service Access (OSA)/Parlay APIs, Java APIs for Integrated Networks Service Logic Execution Environment (JAIN SLEE), Parlay X, OMA Policy Evaluation, Enforcement and Management (PEEM), OMA Open Service Environment (OSE), TeleManagement Forum’s Service Delivery Framework (SDF), Service Oriented Architectures (SOA), Web Services and Web 2.0, among others. Literature references to the role of these standards and technologies include: (Blum, Magedanz & Schreiner, 2009; Stecca, Maresca & Baglietto, 2009;

Chen & Zhang, 2004; Camarillo & Carcia-Martin, 2008; Magedanz & De Gouveia, 2006; Magedanz, Blum & Dutkowski, 2007:46-50; Griffin & Pesch, 2007:28-35; Lofthouse, Yates & Stretch, 2004:83).

However, because the experimental implementation presented in this chapter focuses on the delivery of services, the next section discusses standards and technologies relating to the Service Execution Environment which is ultimately responsible for the delivery of services. The discussion will therefore focus on theJAIN SLEE Java-based standard.

6.3.1 THE SERVICE LOGIC EXECUTION ENVIRONMENT (SLEE)

The JAIN community (a number of participating communications companies) carries out the JAIN initiative aimed at the development of JAIN specifications in conformance to the Java Community Process (JCP) and the Java Specification Participation Agreement (JSPA). The objectives of the JAIN initiative are to define APIs for application-level development to support service portability and also a set of protocol-level APIs for signalling to support convergence (De Keijzer, Tait & Goedman, 2000). The JAIN initiative therefore aims to ensure the following (Devoteam, 2007:21; De Keijzer, Tait & Goedman, 2000; Ogunleye, Makitla, Botha, Tomay, Fogwill, Seetharam & Geldenhuys, 2011):

- *Service portability* – to allow services to run on any JAIN-compliant environment.
- *Network independence* – to provide APIs that abstract the complexity of the underlying network infrastructure from the service logic.
- *Open development* – to provide Java industry standards to transform telecommunication systems into open environment away from too many incompatible proprietary systems.

The JAIN initiative's API specification development led to JAIN Service Logic Execution Environment, abbreviated as JAIN SLEE or JSLEE (Yelmo, Del Álamo, Trapero, & Martín, 2011). For this, the JAIN's Java API specification covered two areas (Ogunleye *et al.*, 2011):

- Specification for container interfaces which specifies APIs for Service Execution Environment that can support low-latency and high throughput and other stringent requirements of the telecommunication domain.
- Specification for service development APIs for distributed communication applications.

Service Logic Execution Environment (SLEE) provides the run-time environment for services; it allows the services to be deployed, controlled, activated and managed, and to interwork with other services on the service network. The challenge of ensuring interoperability, according to Ogunleye *et al.* (2011), necessitated making a SLEE into a standardised execution environment that can host services from different vendors and even those services developed using completely different technologies that comply with such a SLEE standard. SLEE standardisation would also ensure and promote service portability and interoperability across compliant platforms (Ogunleye *et al.*, 2011).

The Devoteam SDP Workgroup's White Paper (Devoteam, 2007:21), as discussed by Makitla and Fogwill (2011:57), lists the following as key features that a SLEE should have in order to support interoperability:

- Service portability over different SLEE vendors that support the standard, through standardised APIs, objects and methods.
- Independence from operating systems (OS), hardware, platforms and network architecture.
- Common framework providing the generic services or facilities of a SLEE (timers, statistics, fault tolerance, etc.).
- Modular architecture, allowing interoperability with legacy, state-of-the-art and next generation service networks

The JAIN SLEE meets these requirements (Devoteam, 2007:21; OpenCloud, 2008). JAIN SLEE provides a high-throughput, event-processing environment for distributed communications applications written in Java programming language (Deruelle, 2008; Maretzke, 2008; Van Den Bossche, De Turck, Dhoedt, Pollet, Van Vlerken, Moreels, Janssens, Demeester, & Colle, 2005). It also provides tools for building a service execution framework (Makitla & Fogwill, 2011:57). According to JAIN SLEE Specification 1.1 (JSLEE, 2005), JAIN SLEE brings service portability, convergence and secure network access to telephony and data networks.

The JAIN SLEE Specification 1.1 document further identifies some of the goals of the JAIN SLEE architecture as follows (JSLEE, 2005:4; Makitla & Fogwill, 2011:57):

- Defining the standard component architecture for building distributed object-oriented communication applications using the Java programming language.
- Allowing the development of these distributed communication applications by combining different components from different vendors, developed using different tools.
- Adopting the "Write Once, Run Anywhere" philosophy of Java to support portability of service components.
- Defining interfaces that enable communication applications from multiple vendors to interoperate.

6.3.2 JAIN SLEE and Mobicents

JAIN SLEE is an event-oriented communications application middleware standard of which Mobicents is an open source implementation (Ivanov, 2006). Any vendor-specific implementation of JAIN SLEE must comply with the JAIN SLEE specification in order to be certified. As of this writing, Mobicents JAIN SLEE is the only open source implementation certified JAIN SLEE 1.1 compliance.

Mobicents JAIN SLEE is given as an example to demonstrate how the JAIN SLEE architecture addresses the SLEE requirements. Figure 6-1 depicts the Mobicents JAIN SLEE architecture.

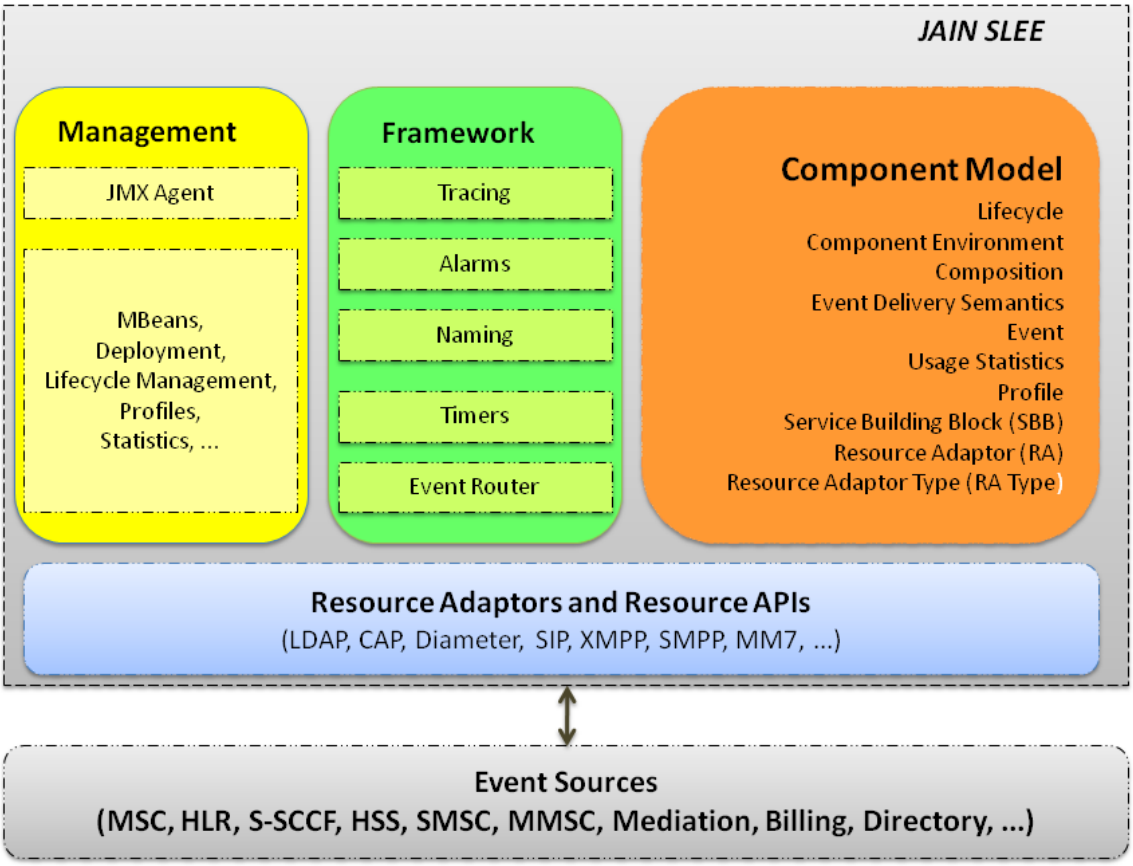

Figure 6-1: JAIN SLEE service platform (source: Open Cloud, 2008)

Network abstraction is achieved through resource adaptor and resource API architecture. Resource adaptors (RAs) are the bridges that connect the component model and the underlying event infrastructure (Ivanov, 2006). The purpose of resource adaptors is essentially to deliver network-specific signals from the underlying networks to the JAIN SLEE service platform. These even sources can be protocol stacks of underlying networks such as SIP on IP-based networks.

Events received through the RAs need to be routed to all previously registered Service Building Blocks (SBBs) within the component model. Thus the RA converts incoming protocol-specific messages into events understandable by the SLEE (Van den Bossche *et al*., 2005). The event router is responsible for routing incoming and newly created typed events to previously registered SBBs and resources (Ivanov, 2006).

The JAIN SLEE *component model* allows composition of services from Service Building Blocks (SBBs). JSLEE uses the Subscribe-Notify event delivery model (Van den Bossche *et al.*, 2005); it defines events as well as event delivery semantics. RAs are event sources and SBBs are event consumers/sinks. To receive events from the event router, the SBBs subscribe (register) such events as events of interest to them – when any of these events are observed, the event router will notify all registered SBBs. The SBB developers must therefore provide the necessary programming logic to process events of interest. The JAIN SLEE implementation also enables binding of SBBs to underlying RAs using the SBB's configuration descriptor files.

The *JAIN SLEE facilities framework* provides generic services and features that are available to the component model. These include timer, naming, tracing or logging facilities, and the event router as shown in Figure 6-1. It is the responsibility of the SBB developer to make use of these facilities, for instance the timer facility may be used to check weather information at certain time intervals to provide the most up-to-date information. Another example could be credit control applications for duration-based charging for services where interim service usage reports are sent at certain time intervals.

For the management of deployed services, JAIN SLEE uses the Java Management Extensions (JMX) Agent, it allows starting and stopping of services and the management of service lifecycle.

6.3.3 Experimental service delivery platform using Mobicents

The technical implementation of the experimental service delivery platform is based on Mobicents[1] JAIN SLEE application server which, as stated in Section 6.3.2 above, is an implementation of the JAIN SLEE standard. Mobicents was chosen because it is the only open source implementation of JAIN SLEE that is certified for compliance with the JAIN SLEE specification. Furthermore, because of the need to modify some of the components of the Mobicents platform, it is necessary to use an open source implementation in order to gain unrestricted

[1] http://www.mobicents.org/slee/intro.html

access to the source code. The availability of free technical support and guidance within the Mobicents developer community also encouraged the use of Mobicents for this experiment. Furthermore, in terms of the socio-technical requirements imposed by the ICT4D context, the use of free and open source technologies, as opposed to expensive and proprietary technologies, is further motivated by the need to focus on poor-user techniques (see Table 3-1).

The next section, Section 6.4, discusses the implementation of an experimental delivery platform which is based on Mobicents JAIN SLEE. The section draws on Makitla and Fogwill (2011) Makitla, Herselman, Botha and van Greunen (2012) as well as Makitla & Botha (2012) to represent Mobicents JAIN SLEE in terms of the elements of the Access-Technology-Agnostic Delivery Model. Table 6-1 presents the mapping of the components of a Mobicents-based experimental delivery platform (Figure 6-2) and the elements of the Access-Technology-Agnostic Delivery Model (Figure 5-3). Finally, Figure 6-3 depicts the implementation architecture that describes how the experimental delivery platform was implemented in order to realise access-technology-agnostic delivery of a sample ICT4D service, namely a weather service.

6.4 IMPLEMENTING THE ELEMENTS OF THE ACCESS-TECHNOLOGY-AGNOSTIC DELIVERY MODEL

The elements that constitute an Access-Technology-Agnostic Delivery Model were presented in Section 5.3. The elements are the *physical world*, *enablement layer*, *access-agnostic service components layer*, *integration/interfacing layer*, *publishing layer* and the *ICT4D services layer*. This section describes how these elements and their functions were realised as part of the proof of concept implementation of the Access-Technology-Agnostic Delivery Model.

Figure 6-2 depicts a simplified block diagram of the Mobicents JAIN SLEE-based experimental delivery platform. The components of this delivery platform are subsequently discussed in relation to the Access-Technology-Agnostic Delivery Model.

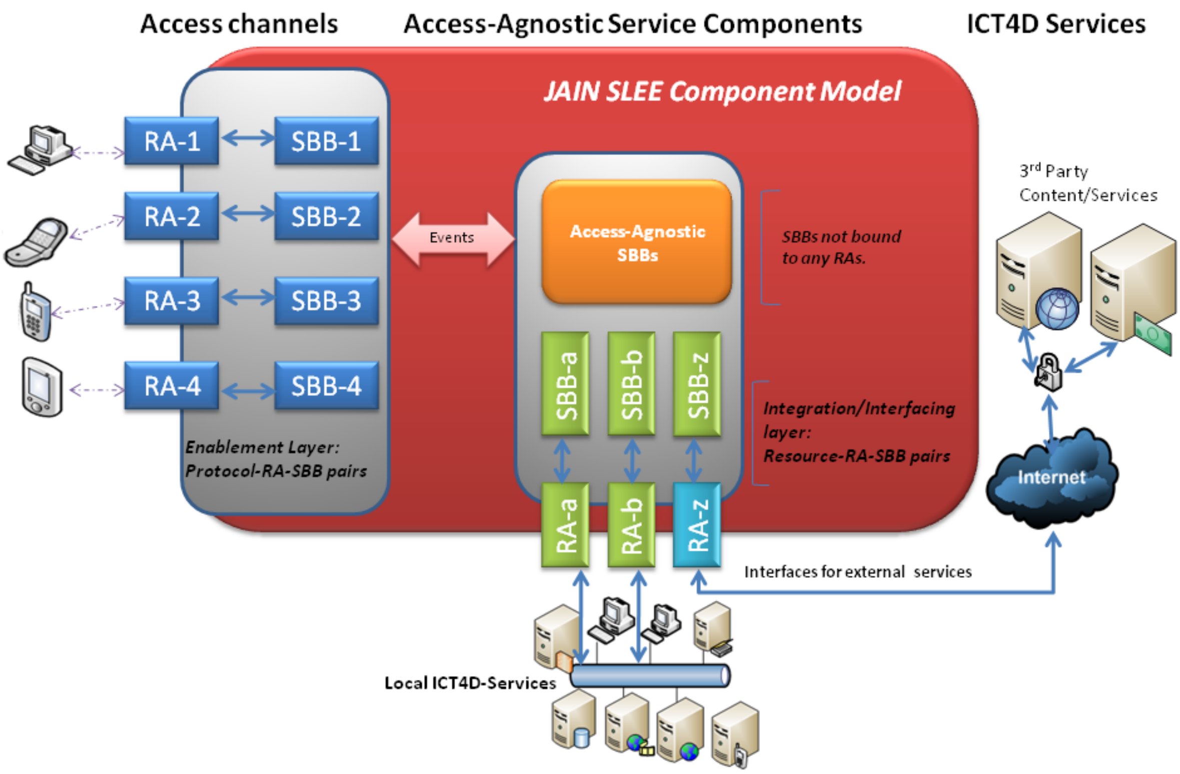

Figure 6-2: JAIN SLEE-based access-technology-agnostic delivery platform (adapted from Makitla & Fogwill, 2011)

6.4.1 Physical world

The physical world is comprised of physical artefacts such as buildings, roads, telecommunication infrastructure, users and personal electronic gadgets such as laptops, tablets, mobile phones, television and radios. The physical world represents the available technological capabilities within a beneficiary community. In the experiment, the physical world comprises test users, electronic gadgets and the telecommunication facilities that the test users are using to connect to the experimental delivery mechanism.

6.4.2 Enablement layer: Protocol-RA-SBB pairs

These are access-technology-specific RA-SBB pairs made up of the protocol RAs and SBBs bound to these protocol-RAs to realise network abstraction. The bindings between a protocol RA and SBB is defined in the SBB's descriptor file named sbb-jar.xml as shown in the accompanying source code in Appendix B.

The protocol-RA-SBB pairs also perform content conversion when they pass content back to the end-users. For instance, the SSMI protocol-RA-SBB pair sends out SMS text messages because it receives SMS from the recipient – and the recipient would probably support SMS sending and receiving. A Text-to-Speech (TTS) helper service could receive requests from within the delivery platform to convert textual content to speech (audio) in order to accommodate textually illiterate or blind users. These requests can originate from the Protocol-RA-SBB pairs or from access-agnostic SBBs.

The following protocol-RA-SBB pairs were used for the experiment:

1. SSMI-RA and SSMI SBB handle both USSD and SMS incoming requests from basic mobile phone users.
2. SIP-RA and SBB (SIP-IVR) handle VoIP voice calls from SIP-enabled devices.
3. HTTP-Servlet-RA and SBB handle incoming Web-based (HTTP) requests mainly from desktop and laptop users.
4. MXitGateway-RA and SBB handle incoming Mxit chats (instant messages) from smartphone users.
5. XMPP-RA and SBB to handle XMPP chat (instant messages) from GTalk used by smartphone users.

6.4.3 Access-Agnostic Service Components layer: Access-agnostic SBBs

SBBs that are not bound with any RAs can be understood as service-independent blocks and constitute the access-agnostic layer. The SBBs are independent of the actual service functionality, the underlying access network, and resources. An example of an access-agnostic SBB would be a "calculator SBB" that accepts calculation parameters and returns values to the requesting services, which may be access-technology specific (e.g. SMS-based calculator service). Because the service logic of access-agnostic SBB is independent of the actual service functionality, they may be chained together to build complex service functionalities.

Access-agnostic SBBs access external resources via the resource–API RA-SBB pairs discussed in Section 6.4.3 above. This makes it possible, for instance, to enable the weather service component to use HTTP-client-RA and the SBB pair to retrieve weather information from external sources using HTTP Web service calls. By doing so, access-agnostic SBBs make the external resources (weather service) access-technology-agnostic. This is what the demonstrator sought to prove!

The *Weather-Service-SBB* receives weather requests from any underlying access technology represented by the Protocol-RA-SBB pairs (see Section 6.4.2). Once it retrieves the weather information from the service provider through the Integration/Interfacing layer (see Section 6.4.4), it sends the response back to the requesting Protocol-RA-SBB pair. The presentation of the content to the actual user device is the responsibility of the Protocol-RA-SBB pair through its content conversion function (see Section 54.3.2).

6.4.4 Integration/Interfacing layer: Resource-API-RA-SBB pairs

The resource–API RA-SBB pairs are the pairs of RAs (resource-API RAs) and SBBs (bound to the resource-API RAs). They abstract details of the APIs for accessing resources within the community facility's IT network and external parties. This way, resource–API RA-SBB pairs enable the delivery platform to access internal and external systems, content and services. Examples of internal business systems include directory services such as Lightweight Directory Access Protocol (LDAP) servers, Operations Support Systems/Business Support Systems (OSS/BSS), billing systems and Customer Relationships Management (CRM) systems.

For the purpose of the experiment, only one resource–API RA-SBB pair was implemented:

HTTP-client-RA and SBB pair – used for invoking Web service requests for external content and services.

In the case of accessing external content and services, the HTTP-client-RA and SBB pair sends HTTP requests (GET) to remote Web-based services on behalf of access-agnostic services. This is true for the experimental weather service, which is provided by a third party organisation and not hosted within the experimental delivery platform itself. These services are accessible to the experimental delivery platform through the Service Publishing layer (see Section 6.4.5).

6.4.5 Service Publishing layer

A service provider who owns and provides the online weather service (www.rssweather.com), exposes an interface for external developers and users to access these services. Service Oriented Architecture (SOA) standard technologies such as Representation State Transfer (REST) Web Service interface was used as a possible implementation of the ICT4D Service Publishing layer of the conceptual model (*cf.* Section 5.3.5). In this instance, components of the experimental delivery platform's Integration/Interfacing layer, notably the HTTP-client-RA-SBB pair, act as Web service consumers.

6.4.6 ICT4D services

The actual ICT4D services can be hosted within the platform as one of the internal resources (see local ICT4D Service in Figure 6-2) or they can be hosted elsewhere (e.g. different community facilities or service providers). The service chosen for this experiment is the online weather service, available from (www.rssweather.com). This service is provided by an external service provider and is independent of the experimental delivery platform.

The elements of the Access-Technology-Agnostic Delivery Model which were implemented as part of the proof of concept are tabulated below in Table 6-1.

Table 6-1: Mapping experimental platform architecture to conceptual model

Conceptual Model (layers & functions)	Experimental platform architecture
5.3.1 Physical world	Physical networks, people and devices
5.3.2 Enablement layer Network abstraction and Content Conversion functions	Access channels of the experimental delivery platform realises the enablement layer of the conceptual model (see Protocol-RA-SBB pairs)
5.3.3 Access-Agnostic Service Components layer	Agnostic-SBBs – the SBBs that are not bound to any protocol-RAs or resource-API RAs.
5.3.4 Integration/Interfacing layer	Resource-API RA-SBB pairs that connect the platform to internal and external systems within the IT enterprise domain (see Section 6.4.4). These RA-SBB pairs also connect to third party services (through HTTP-Client-RA, may also use other Web service technologies).
5.3.5 Service Publishing	This is mostly done by third parties to make their services available for integration with other external systems following SOA principles. In the case of this experimental delivery platform, the weather service is exposed by the third party at www.rssweather.com.
5.3.6 ICT4D Services	The demonstrator service chosen for this experiment is the weather information service available at www.rssweather.com.

Figure 6-3 depicts the mapping, summarised in Table 6-1, in the form of a solution implementation architecture that indicates the connections between components of the experimental delivery platform.

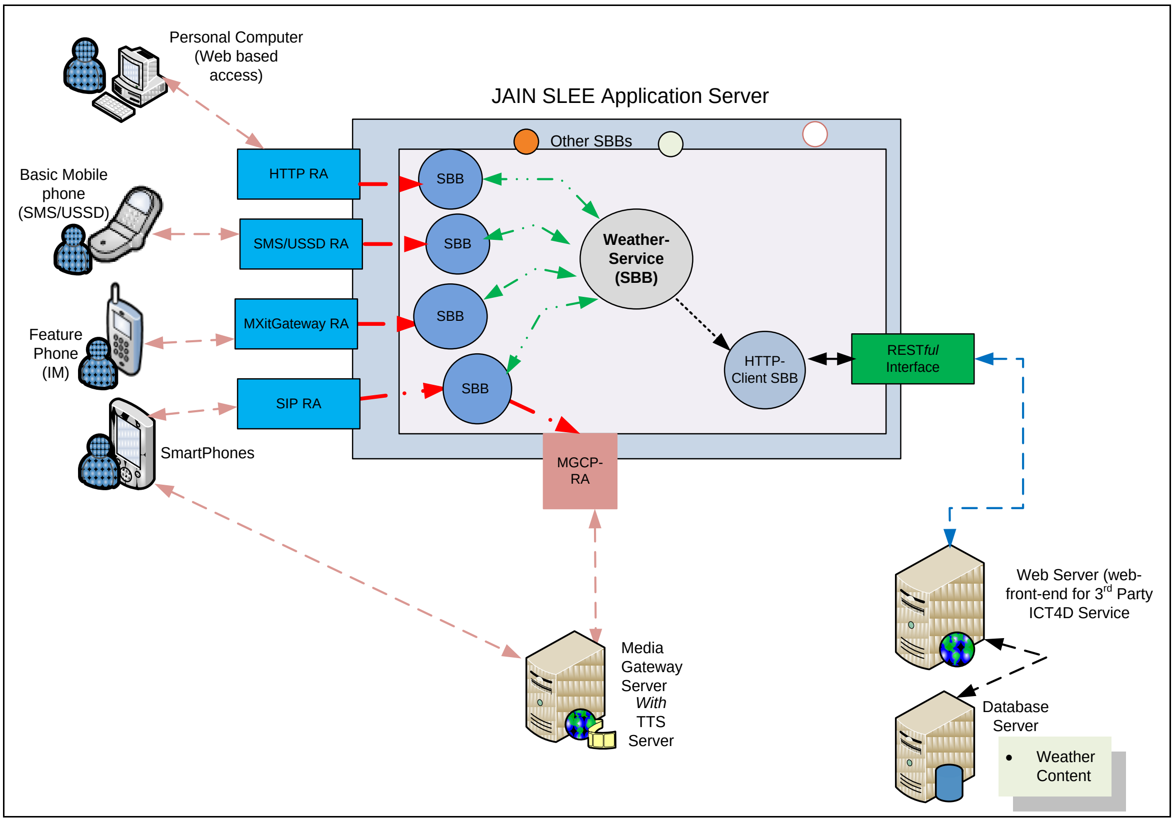

Figure 6-3: Implementation architecture (adapted from Makitla & Fogwill, 2011))

Personal computing devices of different capabilities (PCs, basic mobile phones, feature phones and smartphones) represent the physical elements of the experimental delivery platform. These devices connect through the protocol-RA-SBB pairs that provide enablement for access technologies supported by these devices (e.g. SMS, USSD, IM and HTTP). The protocol-RA-SBB pairs simply forward the requests for weather service to the Weather-Service SBB. The Weather-Service SBB, which is part of the Access-Agnostic Service Components layer, makes use of the HTTP-client-SBB in the Integration/Interfacing layer to pass the request for weather information to the external weather service provider. When the weather information is received from the external service provider, the Weather-Service SBB then sends the response (i.e. weather information) to the protocol-RA-SBB pair that requested it. The protocol-RA-SBB pair renders the weather information in accordance with the capabilities of the end-user device that originated the request for weather information. At this point, the user now receives the weather information on his/her device. Figure 6-4 illustrates this flow of events.

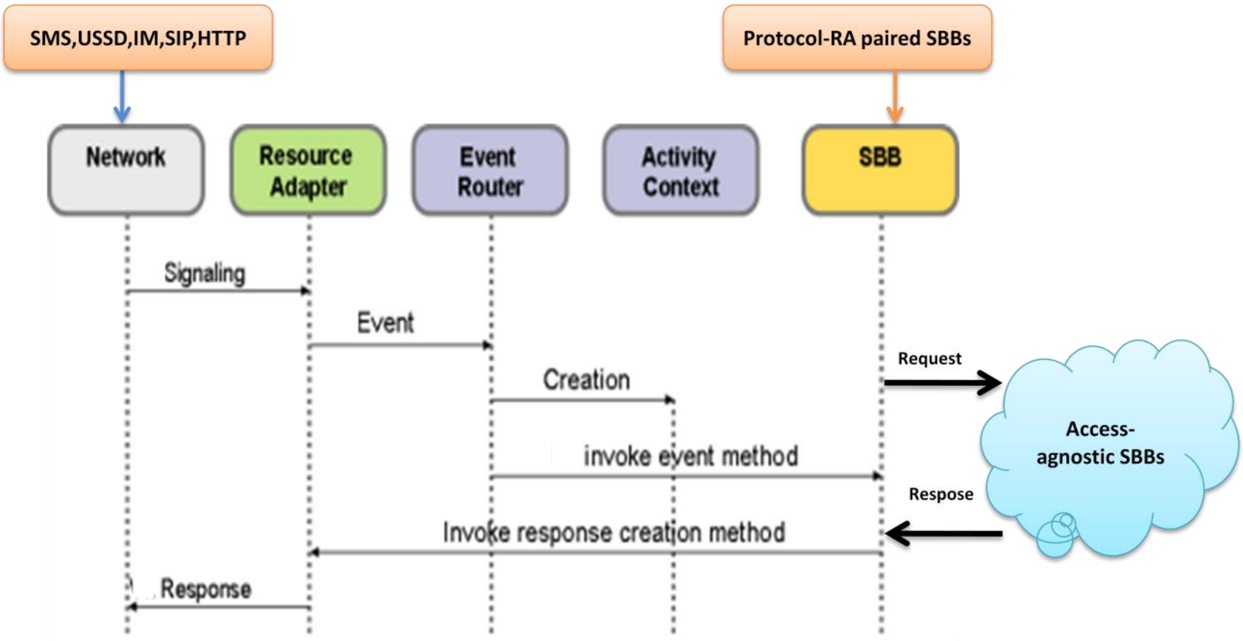

Figure 6-4: JAIN SLEE flow of events (adapted from Makitla & Fogwill, 2011:66)

Makitla and Fogwill (2011:66-67) capture the flow of events depicted in Figure 6-4 as follows. When a user sends a request using SMS, USSD, Instant Messenger (MXit/XMPP), voice call (SIP) or a Web browser client (HTTP), access-technology-specific signalling begins. The protocol-RA for the specific access network receives the request; it then generates a JAIN SLEE-typed event and hands it over to the event router. The event router follows the event delivery semantics to invoke event processing logic on the SBBs (these SBBs are bound to the protocol-RAs in a form of protocol-RA-SBB pair). The event processing logic invoked on these SBBs involves creating access-technology-agnostic request events and sending these requests to access-agnostic SBBs.

The access-agnostic SBBs handle the request and send back responses to the requesting SBBs in the protocol-RA-SBB pairs. These SBBs invoke response creation methods on their bound protocol-RAs; invoking such response creation methods is achieved using a Resource-Adaptor-SBB-Interface Java Interface class as defined by the JAIN SLEE specification. The RAs in turn render the response back to the original event sources in the physical world, that is, the end-user devices. Appendix B provides the source code listings for the operations described above.

The next section presents a full description of how the access-agnostic delivery of weather information was achieved using the experimental delivery platform. Further details are provided in the accompanying materials (see Appendix B).

6.5 ACCESS-AGNOSTIC WEATHER SERVICE DELIVERY EXPERIMENT

The experimental delivery of a weather service is presented in this section and demonstrates how the same weather service is accessible through SMS (Section 6.5.1), USSD (Section 6.5.2), MXit instant messaging service (Section 6.5.3), XMPP (GTalk) instant messaging service (Section 6.5.4), and also through the traditional web-based channel HTTP (Section 6.5.5).

6.5.1 SMS access channel

When using SMS as an access channel, the user sends the word “weather” to 31623. The experimental delivery platform, henceforth system, responds with an SMS that lists the number of cities for which the experimental weather service can be provided. The user replies by sending the number corresponding to the desired city for which the user would like to retrieve weather information. The system responds by sending the weather information as an SMS. The SMS use case is captured in Figure 6-5.

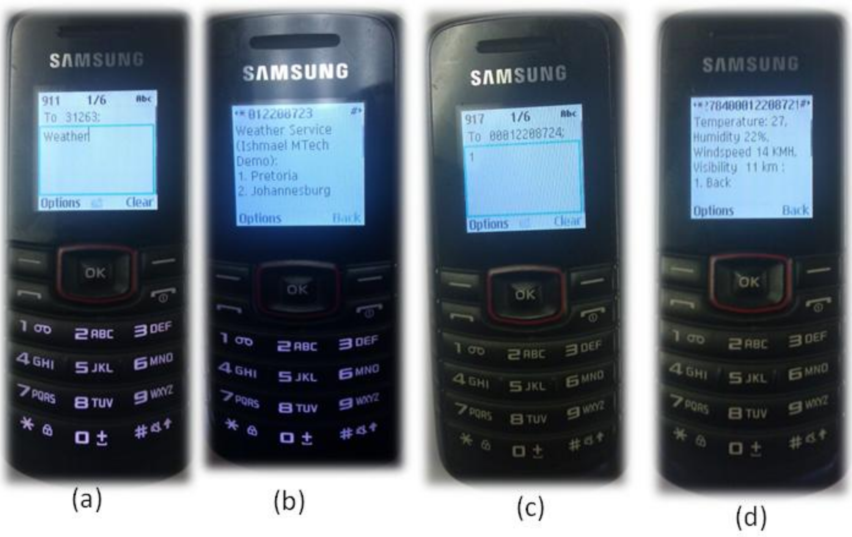

Figure 6-5: Weather service access through SMS

6.5.2 USSD access channel

When using USSD as an access channel, the user dials ***120*2747*79#**. The system responds with a USSD list of options that contains the list of cities for which the experimental weather service can be provided. The user replies by sending the number corresponding to the desired city for which the user would like to retrieve weather information. The system retrieves the weather information and renders it to the user on a USSD screen. The USSD use case is captured in Figure 6-6.

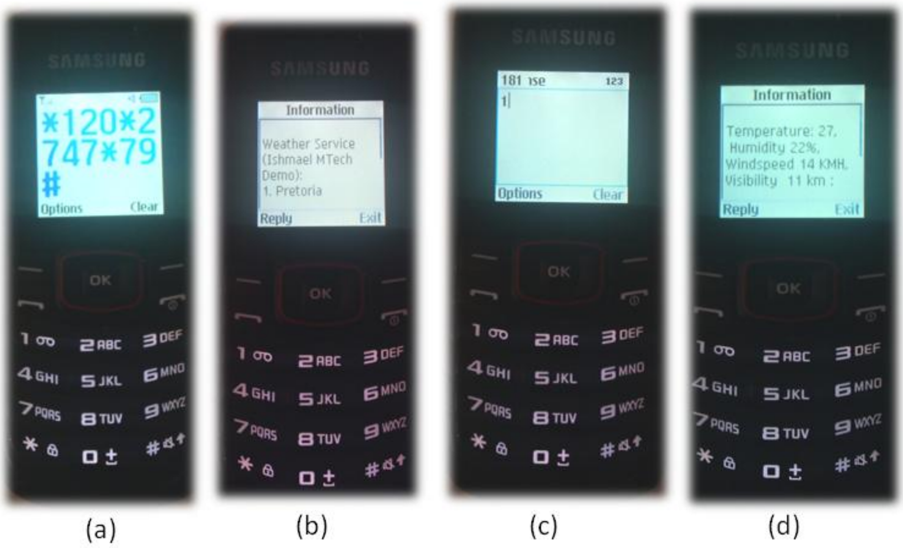

Figure 6-6: Weather service access through USSD

For instant messaging (IM), the end-user needs to add the delivery platform's instant messaging account (contact) into his or her contact list before he or she can send or receive instant messages, including presence information, from the delivery platform. The IM use cases (Sections 6.5.3 and 6.5.4) assume that this step has already been completed.

6.5.3 MXit access channel

When using MXit as an access channel, the user sends the word "weather" as an instant message to the contact named "***9a65844d-c874-418c-877d-597dbed14314***". The system responds with an instant message containing a numbered list of cities for which the experimental weather service can be provided. The user replies by sending the number corresponding to the desired city for which the user would like to retrieve weather information. The system retrieves the weather information and renders it to the user as a MXit instant message. The Mxit use case is captured in Figure 6-7.

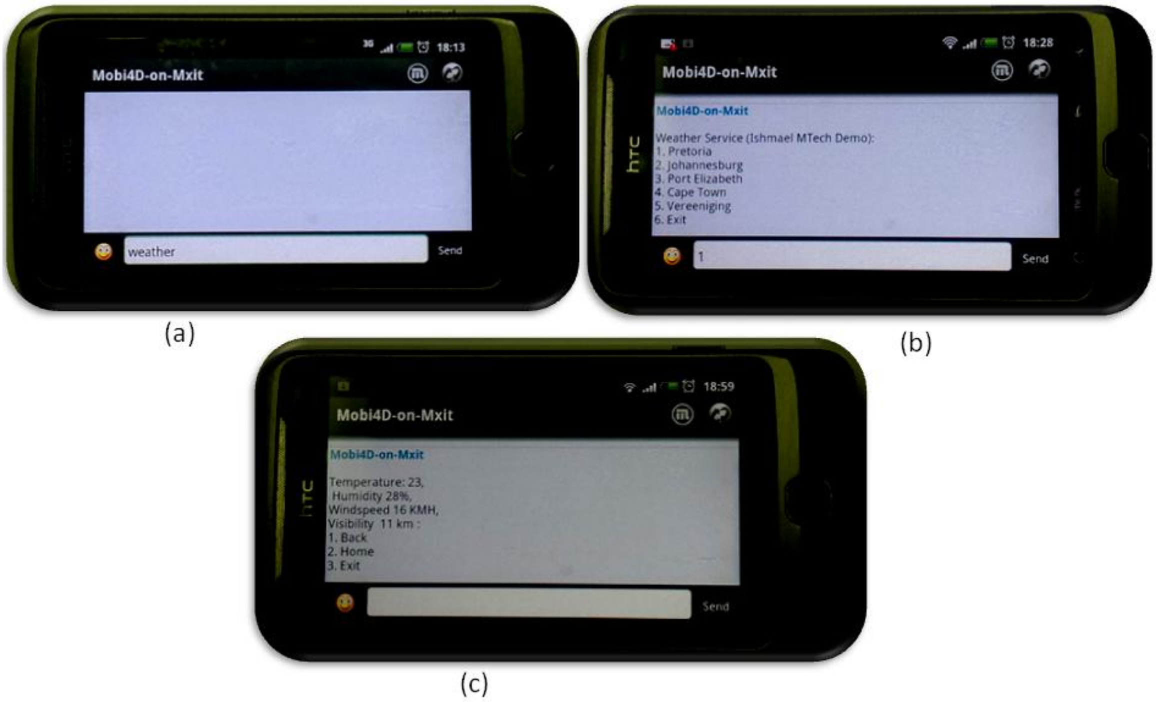

Figure 6-7: Weather service access through MXit (IM)

6.5.4 GTalk (XMPP) access channel

When using GTalk (XMPP) as an access channel, the user sends the word "weather" as an instant message to the contact named "mobi4d.xmpp@gmail.com". The system responds with an instant message containing a numbered list of cities for which the experimental weather service can be provided. The user replies by sending the number corresponding to the desired city for which the user would like to retrieve weather information. The system retrieves the weather information and renders it to the user as a GTalk (XMPP) instant message. The GTalk (XMPP) use case is captured in Figure 6-8.

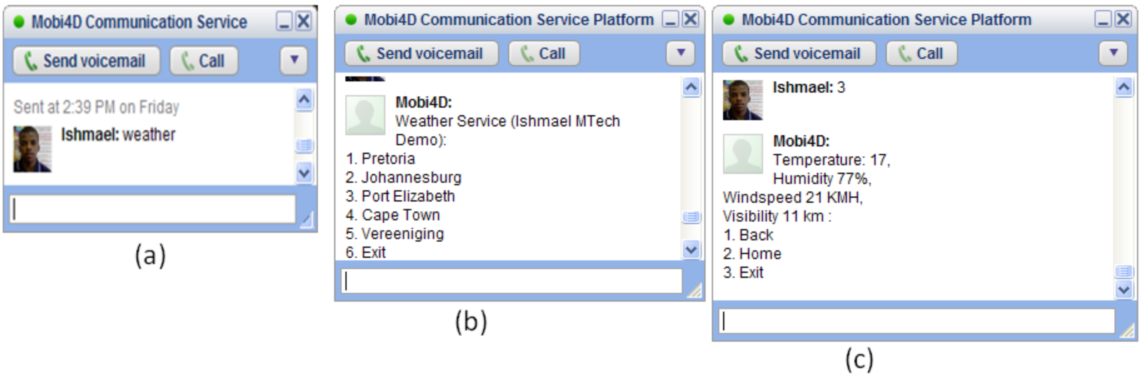

Figure 6-8: Weather service access through XMPP (Gtalk)

6.5.5 HTTP (web) – original access mechanism

When accessing the weather information in its traditional online access channel, the user opens the browser and points it to the Web address http://www.rssweather.co.za. This is the original access mechanism and is captured in Figure 6-9.

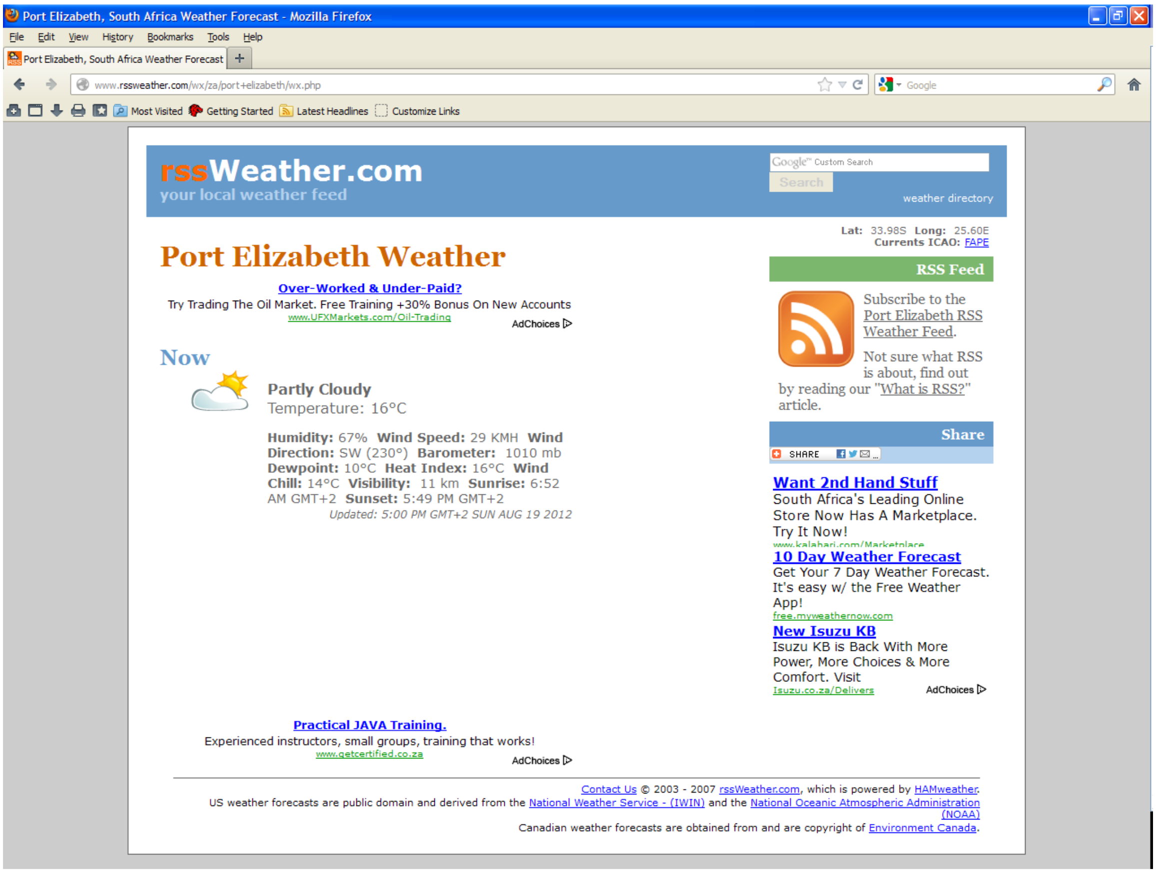

Figure 6-9: Weather service access through the Web (HTTP)

6.6 ADDRESSING THE REQUIREMENTS IMPOSED BY THE ICT4D CONTEXT

In Chapter 3, Section 3.4 discussed the requirements for a delivery mechanism to facilitate equitable access to digital content and services, and which are imposed by the prevailing ICT4D context. These requirements were also summarised in Table 3-1 and Table 3-2. These are the same requirements that the experimental delivery mechanism, which is a proof of concept implementation of the conceptual model (see Section 5.3), needs to satisfy within the accepted scope mentioned in Section 6.2.

The design considerations are discussed below in terms of how they help to address the requirements for an access-technology-agnostic delivery mechanism.

6.6.1 Access-technology-agnostic

The access-technology-agnostic requirement refers to ensuring that digital content and services are accessible and delivered to end-users regardless of the access technologies through which users access the digital content and services.

The experimental delivery platform addresses this requirement by defining the sets of SBBs that are bound with Protocol-RAs (protocol-RA-SBB pairs), those that are bound with resource-API RA (resource-RA-SBB pairs) and those that are not bound with any RA (access-agnostic service components). This design pattern enables the delivery platform to support re-usability and loose coupling of underlying networks and the actual service functionality. It is because of this design consideration that it is possible to access the same service (e.g. weather service) from any access technology (e.g. SMS, USSD and Instant Messaging). According to this design, the weather-SBB (Figure 6-3) resides in the Access-Agnostic Service Components layer.

6.6.2 Facilitate equitable access to information services

The access-technology-agnostic delivery design pattern, as discussed in Section 6.6.1, ensures that the access network, abstracted by the protocol-RA-SBB pairs, is separated from the Weather-SBB, which contains the weather service logic.

Therefore, a user device (e.g. mobile phone) can be connected to any access network and access the weather service through one of the implemented protocol-RA-SBB pairs. Users of low-end mobile phones, which only support SMS and USSD without any Internet browsing capabilities, may not be able to access the weather service through its traditional Web-based access mechanism. However, because the same weather service is also accessible through basic technologies such as SMS and USSD, users of low-end devices are now able to access the service. In doing so the experimental delivery platform facilitates inclusive and equitable access to the weather service.

6.6.3 Capitalise on available technological capabilities

This requirement pertains to the necessity to use older or most basic technologies (such as radios and basic mobile phones) to deliver meaningful value-adding services to end-users. The experimental delivery platform, in supporting both SMS and USSD for basic mobile phones, and while also supporting Instant Messaging for technologically advanced mobile phones, meets this requirement. Therefore in accordance with the illustrative scenario, the experimental delivery platform capitalises on available technologies by introducing protocol-RA-SBB pairs for even older and more basic communication technologies such as SMS and USSD. The screen shots (Figure 6-5 and Figure 6-6) depict how the weather information is presented to a user through SMS and USSD protocol-RA-SBB pairs.

When other access technologies become available within a community, the protocol-RA-SBB pairs for such technologies can be added to the delivery platform without having to change the actual service logic.

6.6.4 Scalability

This requirement is meant to ensure that the resulting delivery mechanism, such as the experimental delivery platform described in this chapter, supports up-scaling in order to adapt to changing technological capabilities and high usage volumes. In terms of the actual architecture of the experimental delivery platform, this requirement is best addressed by the actual JAIN SLEE architecture itself.

As discussed in Section 6.3.1, the JAIN SLEE API specification was developed expressly to enable support for low latency and high throughput and other stringent performance requirements of the telecommunication domain. Therefore, by basing the experimental delivery platform on the JAIN SLEE specification and using its compliant open source implementation, Mobicents, this requirement has been satisfied. Furthermore, the ability to add new protocol-RA-SBB pairs to represent additional access channels means that the experimental delivery platform can scale horizontally. This further enables the experimental delivery platform to support new and advanced devices as users upgrade their devices.

6.6.5 Client device neutrality

As demonstrated in this chapter (Section 6.5), by plugging the weather service as a typical ICT4D service into the access-agnostic delivery mechanism, it can be accessible through any access technology and can be presented in any formats supported by the end-user devices (e.g. SMS, USSD and Instant Messaging). The network abstraction function, which hides the complexities of the access technology and the device used, ensures that the Weather-Service SBB processes the weather information request without any knowledge of the actual device that originates the request. By doing so, the experimental delivery mechanism supports client device neutrality.

6.6.6 Focus on poor-user techniques

This requirement pertains to the need to focus on technologies that are tailored for a resource-constrained environment. Resource constraints in the case of this experiment refer to limited technological features of end-user devices. The client device neutrality feature of the experimental delivery platform as discussed above also addresses this requirement. Furthermore, the use of open source technologies in the implementation of the experimental delivery platform is informed by this requirement.

6.6.7 Choice of appropriate technologies

The technology used to implement the experimental delivery platform is based on open standards, notably the JAIN SLEE specification. Furthermore, the only certified open source implementation of the JAIN SLEE standard, Mobicents, was used as opposed to non-standard compliant implementation. Open source technology was used instead of expensive proprietary technologies; this also afforded the researcher the possibility of modifying the source code provided by the open source developer community.

6.7 SUMMARY

The reference implementation discussed in this chapter shows how a pre-existing service, traditionally accessible online through a website (HTTP) can be made accessible through multiple channels and in multiple formats (text/voice). By applying the principles of access-technology-agnostic delivery, it has been shown that it is possible to deliver a traditionally web-based service through multiple access technologies such as SMS, IM, USSD and VoIP. The *network abstraction* function, which is made up of protocol-RA-SBB pairs, adapts the request to a standard format (typed JAIN SLEE event) understandable to the Weather-Service SBB in the Access-Agnostic Service Components layer. When the weather information is rendered back to the requesting end-user, the *format conversion* and the *device capability negotiation* functions handle the presentation of information on the end-user devices such as mobile phones.

The reference implementation has supported the claim that the proposed access-technology-agnostic delivery mechanism has the potential to facilitate equitable access to information. By introducing additional access channels (e.g. SMS, IM, USSD, and VoIP), a new community of users that previously had no access to the weather information can now be served. The experimental delivery platform has also demonstrated scalability, with the ability to add more access channels (protocol-RA-SBB pairs) to handle emerging access technologies. Furthermore, network independence is achieved through the use of Resource Adaptors (RAs), which hide the complexities of the underlying communication infrastructure that serves as event sources. Section 6.6 described how the experimental delivery platform addresses the set of requirements imposed by the ICT4D context.

The next chapter presents reflections on the preceding discussions and draws reasoned conclusions. The chapter also gives recommendations for future research work.

Chapter 7

Conclusion

This chapter concludes the research and reflects on key aspects of the research, such as the research problem, the guiding research questions and research objectives. The chapter reflects on the methodological aspects of the study specifically to qualify this study as a proper design science research and not a routine development exercise. The chapter also gives recommendations for future research.

This chapter is structured as follows: Section 7.1 discusses how the research problem and the objective of the research have been met. Section 7.2 revisits the research questions and details how each of the questions was addressed, including how the objectives of the study and those of the proposed solution were satisfied. The contributions of this study are then highlighted in Section 7.3. The methodological aspects of this study are reviewed in Section 7.4 to ascertain that a proper research process was followed in conducting the study. Necessarily, Section 7.4.1 discusses how the research guidelines for Design Science (DS) research were followed and Section 7.4.2 discusses how the DS research process model was adhered to. At the same time, Sections 7.4.1 and 7.4.1 will also review what each chapter in the dissertation has discussed in relation to both the research guidelines and the research process model. Section 7.5 presents a reflection on this study and highlights recommendations for future research that may subsequently be carried out to address the identified limitations of the current study.

7.1 ADDRESSING THE RESEARCH PROBLEM AND RESEARCH OBJECTIVE

One of the three main thrusts of ICT4D has been the delivery of digital content and services to resource-constrained communities. As stated in Section 1.2, the study identified the absence of access-technology-agnostic delivery mechanisms as a serious impediment to the ability to realise equitable access to digital content and services or, more generally, information services. As such, the primary objective of this research, as stated in Section 1.3, was to develop an Access-Technology-Agnostic Delivery Model in order to facilitate the access-technology-agnostic delivery of digital content and services within an ICT4D context. This objective has been met: the Access-Technology-Agnostic Delivery Model has been developed (see Chapter 5) and its technical viability and utility have been demonstrated through a reference implementation (see Chapter 6).

In addressing the research problem and the objectives of the research, this study was guided by the main research question and four supporting investigative questions. The next section, Section 7.2, describes how the main research question and the investigative questions were addressed.

7.2 ADDRESSING THE RESEARCH QUESTIONS

The main research question, as mentioned in Section 1.4, is as follows:

What are the elements of a model that facilitates access-technology-agnostic delivery of, and access to, digital content and services in resource-constrained communities?

The objective of this main research question was to establish the key elements that constitute an access-technology-agnostic delivery model. In order to describe how the main research question was answered, the subsequent discussion starts by first examining how each of the investigative questions was answered. These investigative questions were intended to help in addressing the main research question.

To answer the main research question adequately, it was also necessary to elaborate on the following investigative question (**IQ-1**) that supports the main research question:

- *What requirements does an ICT4D context impose on the mechanisms by which digital content and services are delivered, and which the proposed model must address?*

The purpose of this investigative question, as mentioned in Section 1.4, was to establish what requirements are imposed by the peculiarities of the ICT4D context on a technological solution aimed at facilitating equitable access to digital content and services. The requirements imposed by the ICT4D context were developed through a review of ICT4D literature. Chapter 3, and specifically Section 3.4, developed a set of socio-technical and purely technical requirements. These requirements were summarised in Table 3-1 and Table 3-2 respectively.

The second investigative question (**IQ-2**), which also supported the main research question, was:

- *On what architecture should the proposed Access-Technology-Agnostic Delivery Model be based?*

This investigative research question sought to explore an existing technical architecture which may serve as the basis for the proposed Access-Technology-Agnostic Delivery Model. Chapter 4 addressed this question through exploration of the SDP literature. The technical and business imperatives that led to the development and evolution of SDP were found to be closely aligned to the set of ICT4D-imposed requirements that prompted this research to search for an access-technology-agnostic delivery mechanism. Furthermore, the SDP architecture (*cf.* Section 4.4) was found to be technically viable to readily facilitate access-technology-agnostic delivery of digital content and services. Specifically, through the access-agnostic service delivery pattern (see Section 4.2), which is made possible by the SDP's network abstract capabilities and the layered architecture, the SDP provides an ideal architecture on which to base the proposed Access-Technology-Agnostic Delivery Model.

Building on the preceding investigative question (**IQ-2**), the third investigative question (**IQ-3**) was:

- *What should be the basic elements, the relationships and the functionalities of these elements in order to realise the proposed Access-Technology-Agnostic Delivery Model?*

This investigative question pertains to conceptual principles of the proposed Access-Technology-Agnostic Delivery Model with regard to the basic elements. The functional principles of each of these basic elements had to be established with respect to the requirements imposed by the environment on these elements (see **IQ-1**). Furthermore, the relationships between these basic elements had to be expressed in accordance with the chosen architecture (see **IQ-2**). The conceptual model of the proposed Access-Technology-Agnostic Delivery Model was developed and presented in Chapter 5. Section 5.1 specifically discussed the elements of the model and their functionalities. The conceptual model is depicted in Figure 5-3 and is described in detail in Section 5.3. The conceptual model expresses the relationship between the elements of the model as well as the logical flow of computational activities between them. Section 5.4 presented the advantages of the conceptual model in its current form.

The fourth and final investigative question (**IQ-4**) was:

> Which technologies, if any, are available to implement an Access-Technology-Agnostic Delivery Model as described conceptually in (**IQ-3**) and based on the selected architecture (**IQ-2**)?

The fourth investigative question pertains to the reference implementation of the proposed solution and sought to explore available technologies that could be used to provide a proof-of-concept implementation to the solution.

After having developed a conceptual model based on the Service Delivery Platform (SDP) architecture, Chapter 6 presented a reference implementation. The reference implementation was based on Mobicents' JAIN SLEE application server. Mobicents was chosen because it is the only open source implementation certified for the JAIN SLEE standard specification. In response to (**IQ-4**), Section 6.4 presented details of how each of the elements of the conceptual model was implemented. Section 6.6 then described how the reference implementation addresses the set of requirements developed through (**IQ-2**), and the experiment in Section 6.5 confirmed the functional principles expressed by the conceptual model (**IQ-3**).

Having discussed all the investigative questions (**IQ-1** – **IQ-4**), a discussion follows next on how the main research question was addressed.

The answer to (**IQ-1**) provided a list of requirements that the final model had to satisfy. These requirements determined what the model should accomplish. However, in order to address the identified requirements, the elements of the model should have specific structural characteristics and functions. The SDP architecture was chosen in response to (**IQ-2**), and was informed by what the final model had to accomplish in terms of requirements. The conceptual model, which was based on adapting the SDP concept, was developed as an answer to (**IQ-3**). The conceptual model captures the list of key elements that are necessary to meet the requirements. Furthermore, to confirm that the conceptual model is technically viable, the model was instantiated based on the technologies chosen in response to (**IQ-4**). The successful proof of concept indicated that the conceptual model is functionally possible. This also reaffirms that the identified elements that constituted the conceptual model are useful in meeting the requirements. The answer to the main research question is therefore the list of these elements. In this regard, Chapter 5 presented the conceptual model. The key elements of the proposed Access-Technology-Agnostic Delivery Model were developed and outlined in Section 5.1 as follows:

- Community Information Needs
- Communications Networks
- Digital Content and Services,
- Digital Content and Services Delivery Mechanism
- End-User Communication and Entertainment Devices
- End-User Capacity.

These elements, their intended functions and the logical relationships between them were discussed in Section 5.1 and depicted in Figure 5-1 as well as in Figure 5-2.

7.3 RESEARCH CONTRIBUTIONS

The delivery of digital content and services to end-users in an access-technology-agnostic manner has the potential to promote equitable access. Therefore, owing to the lack of evidence of any digital content and services delivery approaches that facilitate access-technology-agnostic delivery of digital content and services within an ICT4D context, this study developed and demonstrated a technically viable Access-Technology-Agnostic Delivery Model. Therefore, in terms of contributions, this research contributes the Access-Technology-Agnostic Delivery Model as a design product.

It is worth mentioning that answers to the investigative questions (especially IQ-1 and IQ-2) may also be viewed as contributions. For instance, in answering (IQ-2), it was shown that the concept of SDP can be adapted and applied within the ICT4D context. As of this writing, this has not been done before in any other study. The set of ICT4D-imposed socio-technical and purely technical requirements, though not exhaustive, provides a good starting point for technologists to begin developing technologies for typical ICT4D use cases.

The next section discusses the methodological aspects of this research to ascertain that a proper research process was followed in addressing the research questions, the research problem and research objectives as discussed in the preceding sections.

7.4 METHODOLOGICAL ASPECTS

In this section the methodological aspects of this study are reviewed in terms of the seven guidelines for conducting design science research (*cf.* Section 7.4.1) as well as the design science research process model (*cf.* Section7.4.2).

7.4.1 Conformance to the seven guidelines for conducting DS research

Hevner *et al.* 2004 developed a set of seven (7) guidelines for conducting design science research. Since this study followed a design science research approach, it is important to evaluate the research process against this set of guidelines.

Design as an artefact

As mentioned in Section 2.4.1, the fundamental expectation for design science research is the creation of artefacts that address the identified research problems. In accordance with this guideline, this study built an Access-Technology-Agnostic Delivery Model to facilitate access-technology-agnostic delivery of digital content and services.

Problem relevance

This guideline was adhered to when discussing the problem statement and significance of the study in Section 1.2. The discussion of the relevance cycle (Section 2.3.1) further supports the relevance of the identified research problem which is informed by the ICT4D literature.

Design evaluation

The created artefact, the Access-Technology-Agnostic Delivery Model, was evaluated against the set of requirements summarised in Table 3-1 and Table 3-2. The evaluation was further supported in Chapter 6 by the instantiation of the artefact through a proof-of-concept implementation. The proof of concept demonstrated that the artefact does indeed address the identified set of requirements. The use of black-box testing technique meant that only the functional aspects of a proof-of-concept implementation were considered to ascertain that the implementation does work.

Research contribution

The clear articulation of the research contribution is particularly important for design science research as it distinguishes design science research from a routine system development exercise. The contribution of this study is discussed in Section 7.3.

Research rigor

This guideline advocates for methodological soundness in conducting design science research, as well as the use of, and contributions to, the body of knowledge. The rigor cycle of this study was adopted from the three-cycle view of design science research and was discussed in Section 2.3.3 to address this guideline. This study was founded on the sound theoretical basis of the 4C Framework from the ICT4D domain, the SDP concept from the telecommunication domain, and the standards-based technologies used for reference implementation.

Design as a search process

The design of an artefact entails a search for the best possible means by which the identified problem can be addressed through design. Furthermore, in accordance with the need for rigor in the search process, this also entails the use of existing scientific theories and methods. The search process in this research involved the exploration of both the ICT4D literature and the SDP literature, and applying the researcher's practitioner experience. This was covered in the rigor cycle discussion in Section 2.3.3.

Communicating research outcomes

This guideline urges that the research outcomes be communicated effectively to both technical and non-technical audiences. This guideline is equivalent to the *communication* research activity according to the design science research process model. Among other things, Section 7.4.2 describes how the outcomes of this research were communicated.

7.4.2 Conformance to the DS Research Process Model

This section reviews the research process followed in this study. The research process is evaluated against the adopted design science research process model (Peffers *et al*., 2007).

Identify and motivate

This study had to identify a research problem and the problem had to be significant to warrant a search for a solution. In Chapter 3, after conducting a literature review in ICT4D, the researcher identified the lack of an access-technology-agnostic delivery mechanism as a significant problem that severely impacts on the ability to facilitate equitable access to meaningful ICT services for resource-constrained communities within an ICT4D context. Supported by peer-reviewed sources from the ICT4D literature, the researcher motivated the significance of the identified problem (*cf.* Section 1.2) and thus established the significance of this study and the potential contribution of the proposed solution. Furthermore, the ICT4D literature constituted the relevance cycle of this study in terms of the three-cycle view of design science research proposed by Hevner (2007).

Defining objectives of the solution

In this study the researcher investigated the challenges within ICT4D (see Section 3.4) and developed a list of socio-technical requirements (see Table 3-1 and Table 3-2). These socio-technical requirements constitute the objectives of the proposed solution. In this case, the objective of the Access-Technology-Agnostic Delivery Model was then to satisfy these socio-technical requirements. Section 5.4 discussed the advantages of the conceptual model and how it addresses the requirements. Chapter 6 then demonstrated how an experimental delivery platform, which is based on the conceptual model, also addresses these requirements.

Design and development

In terms of the design and development activities, the requirements or objectives of the solution discussed above pertain to the intended functionality of the final design product once the artefact is instantiated.

The design and development activities in this research involved the development, in Chapter 5, of the conceptual model called the Access-Technology-Agnostic Delivery Model (see Section 5.3 and Figure 5-3). This conceptual model embeds the design principles and patterns necessary to address the identified research problem. The design and development activities had to ensure that the proposed Access-Technology-Agnostic Delivery Model has advantageous properties that make it specifically suited to address the identified research problem and objectives of the solution in the best possible way. These advantageous properties of the Access-Technology-Agnostic Delivery Model were discussed in Section 5.4.

Furthermore, the design and development activities also included the reference implementation of the conceptual model in Chapter 6, which served to verify the technical viability of the conceptual model as well as its utility in addressing the identified research problem.

Demonstrate

In accordance with the design science research process model, this study was expected to demonstrate that the proposed Access-Technology-Agnostic Delivery Model is technically viable. To this end, Chapter 6 presented the reference implementation of the model and demonstrated that it is possible to implement the key elements of the conceptual model with the chosen technologies. Furthermore, Section 6.5 demonstrated that it is functionally possible to deliver a weather service, as a typical ICT4D service, in an access-technology-agnostic manner, thereby facilitating equitable access to digital content and services. Necessarily, Section 6.1 described the experimental situation against which the model instantiation was verified, and Section 6.5 outlined the use cases for the demonstration.

Evaluation

As mentioned in Section 2.5.5, artefacts of design science must be evaluated with respect to utility. The evaluation metrics are defined in order to assess what the research is trying to accomplish. For this study, the set of technical and socio-technical requirements (Table 3-1 and Table 3-2) were developed in Section 3.4. These requirements provided the criteria by which the design Access-Technology-Agnostic Delivery Model and its reference implementation were evaluated. The objective of this research was to develop an Access-Technology-Agnostic Delivery Model to facilitate the access-technology-agnostic delivery of digital content and services within an ICT4D context. This objective also served as an evaluation criterion. Chapter 5 developed the Access-Technology-Agnostic Delivery Model and argued, in Section 5.4.1, that the model has beneficial characteristics that enable it to facilitate access-technology-agnostic delivery of ICT4D services. Chapter 6 supported this argument by demonstrating the access-technology-agnostic delivery of a weather service.

Communication

As with the seven guidelines for conducting design science research, the design science research process model also requires that the outcomes of the research be communicated effectively to a variety of audiences.

This study communicated the outcomes of this research through conference papers, posters, a technology demonstrator as well as a full dissertation (this report). Appendix A provides a list of papers and posters, which communicated different aspects of the research. Appendix B provides a list of materials that accompany this dissertation, which include a live video demonstrator as well as the Java application source code developed for proof of concept.

The next section presents recommendations for further research.

7.5 RECOMMENDATIONS FOR FURTHER RESEARCH

The recommendation section covers areas of possible future research to address some of the issues that this study did not address, or to address issues that have arisen from this study. It also presents recommendations on how the ideas and knowledge generated through this study can be applied in real life.

7.5.1 Recommendations for ICT4D researchers and practitioners

This section presents recommendations for researchers who may want to implement the proposed Access-Technology-Agnostic Delivery Model within a specific community context, or who may want to address ICT services delivery issues within an existing ICT4D project or other community ICT initiatives. In order for the communities to benefit from this research, the following recommendations are made to ICT4D researchers and practitioners.

The researchers may, using the Information Needs Assessment Model (INAM) for instance, conduct case study research to establish community information needs. The findings from such case study research will then inform the nature of the digital content and services to be delivered to the beneficiary community through community information systems. The community information systems must then be based on the principles of access-technology-agnostic delivery of digital content and services.

The researchers may also conduct a state-of-infrastructure survey to understand what access technologies are available within the specific community. The findings from this data collection exercise will inform the researchers about the technological capabilities available within the community and will further dictate the nature of access technologies that the delivery mechanism (e.g. community information system) will need to enable.

More specifically, the reference implementation presented in Chapter 6 should be carried out in a real community setting, where the digital content and services to be delivered are informed by real community needs as expressed by community members. The enablement layer, which was realised through protocol-RA-SBB pairs (see Section 6.4.2) in the reference implementation, should consist of those access technologies supported by the community's collective technological capabilities. Technological capabilities are to be deduced from the quantitative data collected by the researchers in those communities.

7.5.2 Comparative performance analysis for access-technology-agnostic delivery patterns

JAIN SLEE architecture provides in-container multi-protocol support through the Resource Adaptor (RA) and is critical for the realisation of access-technology-agnostic service delivery as demonstrated in Chapter 6. However, as Maretzke, (2008:3) as well as Makitla and Fogwill (2011: 64) acknowledge, the tight coupling between the protocol-to-Java object mapping and the SBB has the potential to limit the portability of the SBBs. Researchers should look into container design options that promote service portability by loosening the tight coupling between the SBBs and protocol-to-Java object mappings (i.e. RAs).

The experimental delivery platform described in Chapter 6 demonstrated a possible approach to address the tight coupling between the SBBs and protocol-to-Java object mappings. The experimental delivery platform defined the protocol-RA-SBB pairs that handle protocol-specific signalling (protocol-to-Java object mapping at the RA level) and the protocol-specific Java event objects (at the SBB level). These protocol-RA-SBB pairs transform protocol-specific events into access-agnostic events understood by the SBBs within the Access-Agnostic Service Components layer (see Section 5.3.3). The access-agnostic SBBs within the Access-Agnostic Service Components layer are independent of both the protocols and service functionalities and are highly re-usable and portable across services and even JAIN SLEE containers. Comparative performance analysis should be conducted to establish if there is no major performance drop as a result of additional events being fired by the protocol-RA SBB pairs to access-agnostic SBB, as opposed to these events being fired directly from the RAs and not the SBBs bound to these RAs. If the performance is unacceptable, better-performing alternative approaches should be investigated.

7.6 FINAL WORD

This study adopted a socio-technical approach to ICT4D research. This approach pays equal attention to the perspectives on social development in terms of what is desirable for development, whereas the technical aspect concentrates on what is technically feasible to support the desired social development. In view of this socio-technical approach, understanding the challenges to which ICT4D has to respond and the implications of these challenges to technological development ushers in a slightly different way of conducting ICT4D research – a more prescriptive approach that unearths domain problems, and directs technological advances. As a possible effect of this study, the researcher expresses the hope of seeing more of this kind of approach to ICT4D research in the future. The researcher also hopes that the recommendations for future research will be acted on.

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Appendix A - List of papers

Local Conference Paper

1

MAKITLA, I. & FOGWILL, T. 2011. Exploring hybrid communications with a Mobi4d platform – the use of web services and the role of SOA in telecommunications. In: *Proceedings of the 13th Annual Conference on World Wide Web Applications, Johannesburg, South Africa, 14-16 September 2011*. ISBN: 978-0-620-51918-2.

Contribution

Our paper contributes to the conference deliberations in two ways:

- Firstly, it provides an overview of the evolution of Service Oriented Architectures (SOA) in telecommunications and the use of Web Services to enrich communication services.
- Secondly, the paper presented some real-life implementations where Representation State Transfer (REST) Web Service technology is used to achieve access-technology-agnostic value-added service delivery to service consumers.

Posters at Local Symposia

2.

MAKITLA, I., HERSELMAN, M. & VAN GREUNEN, D. 2010. *Toward an architectural framework for ICT4D service delivery platform*. In**:** *SAICSIT 2010 Postgraduate Symposium, Bela Bela, South Africa, 11-13 October 2010*. This poster won a prize for the best poster.

Contribution: This poster was developed at an early stage of the research and mainly outlines the need or case for architecture for an ICT4D service delivery platform.

3.

MAKITLA, I., HERSELMAN, M. & VAN GREUNEN, D. 2011. An Access-Technology Agnostic Delivery Model for ICT4D Services. In**:** *SAICSIT 2011 Postgraduate Symposium, Cape Town, South Africa, 3-5 October 2011*.

Contribution: This poster was a continuation, at a different stage of research, and presents an access-technology-agnostic service delivery mechanism to address the need identified in the first poster (see **2.** above).

International Conference Papers

4

MAKITLA, I. & FOGWILL, T. 2011b. Mobi4D: Mobile Value-Adding Service Delivery Platform. In: PARK, J.J., ARABNIA, H., CHANG, H.-B. & SHON, T. (Eds.) *IT Convergence and Services, Lecture Notes in Electrical Engineering, 107.* Netherlands: Springer, pp. 55-68.

Paper presented at the *3rd International Conference on Information Technology Convergence and Services (ITCS-11)*, 20-22 October 2011, Gwangju, South Korea. The article was published by Springer and is available at: http://www.springerlink.com/content/rh7l5245884l7245/

Contribution: This paper presented technical details of the Mobi4D platform as a technical realisation of *access-technology-agnostic service delivery*. It contributed to the conference discussions by presenting a delivery platform for converged communications services (the conference was on convergence and services).

5

MAKITLA, I., HERSELMAN, M., BOTHA, A. & VAN GREUNEN, D. 2012. Access-Technology-Agnostic Conceptual Model. In: KUMAR, V. & SVENSSON, J (Eds.) *Proceedings of 3rd International Conference on Mobile Communication for Development (M4D2012), New Delhi, India, 28-29 February 2012.*

Contribution: This paper presented the case for an access-technology delivery mechanism for ICT4D services to realise equitable access to digital content and services. The paper then proposed and presented a conceptual Access-Technology-Agnostic Delivery Model and detailed a prototype implementation.

6

MAKITLA, I. & BOTHA, R.A. 2012. Open Source Implementation of an Access-Technology-Agnostic Conceptual Model. In: CUNNINGHAM, P. & CUNNINGHAM, M. (Eds.) *Proceedings of IST-Africa 2012 Conference, Dar es Salaam, Tanzania, 8-11 May*.

Contribution: This paper discussed the use of open source technology to implement the Access-Technology-Agnostic Conceptual Model. It contributes by listing the lessons learned in the implementation and drawing attention to some of the technical challenges in realising access-technology-agnostic delivery of services. In many respects, Chapter 6 of the dissertation is an extension of this paper.

Appendix B - Accompanying Materials

The following additional support materials are supplied with the CD accompanying this dissertation:

A live demonstration video is provided in the folder called "**Live Demo**". This video shows a live demo of the experimental delivery platform. The video also includes voice-over narration by the researcher. Also in Live Demo folder is a file called "**Demonstration-Notes.pdf**" which details how the researcher-hosted live demonstrator service can be accessed by potential end users or testers.

Extra technical notes and further design details of the experimental delivery platform are provided in the file called "**Extra-Technical-Notes.pdf**" which is in the folder called "**Technical Extras**". The file includes details which the researcher deems useful to technical readers interested in the technical aspects, especially of JAIN SLEE as used in the reference implementation of the Access-Technology-Agnostic Delivery Model (Chapter 6 of the dissertation). Furthermore, because the discussion of technical details makes reference to the source code, the source code is provided in the folder called "Source Code".

Source code is provided in the Java programming language for the components of the experimental delivery platform. The source code is in the folder called "**Source Code**". Extra information in this regard is provided in the file called "**Source-Code-Notes.pdf**".