

Adapter-based revenue management system for the exploration of non-conventional billing options in new markets for telecommunications

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Abstract - Rural Internet connectivity projects aimed at bridging the digital divide have mushroomed across many developing countries. Most of these projects are deployed as community centered projects. Usually, the initial deployment of these projects is funded by governments, multilateral institutions and non-governmental organizations. After the initial deployment, financial sustainability remains one of the greatest challenges facing these projects. In the light of this, externally funded ICT4D interventions should just be used for “bootstrapping” purposes. The communities should be “groomed” to take care of and sustain these projects, eliminating as soon as possible dependency on external funding. This paper presents the design and the implementation of a generic architecture for the management of the costs associated with running a computer network connected to the Internet. The proposed system, called the Network Revenue Management System, enables a network to generate revenue, by charging users for the utilization of network resources. The system provides a flexible architecture which allows the exploration of both conventional and non-conventional billing options.

Index Terms - Billing, ICT for development, rural, sustainability,

I. INTRODUCTION

Information and Communications Technology (ICT) for development has gained wide scholarly interest and support from governments, non-governmental organisations and private companies. ICTs are believed to play a crucial role in poverty alleviation and strengthening positive social dynamics, hence are viewed as enablers of community development [1]. As a result, there has been an increase in the number of projects that seeks to deploy ICT in rural hinterlands.

Over the last decade, the South African Universal Service Agency and other organizations have been searching for ways of providing ICTs within the reach of all citizens [2]. Over a period of time, community networks with wireless backbones, supported by wired networks, have proven to allow a more pervasive ICT penetration in marginalised communities. Such networks have sprouted up across South Africa making it possible for the rural hinterlands to be connected and enjoy the benefits of the information society [3].

As developing nations strive to bridge the digital divide, governments, multilateral institutions and non-governmental organizations, have taken the lead in sponsoring the deployment of ICT projects in marginalised communities [4-6]. Conceding the fact that infrastructure or start-up costs

have been footed by these organisations, very few of these deployed projects planned for long-term financial sustainability [7]. This, in many ways, has been the Achilles’ heel of ICT4D interventions. Most of these projects are characterised by financial short-sightedness and lack of measures and strategies to ensure long-term sustainability [3]

If a project is not financially sustainable, its economic and social benefits are unlikely to be realized. So, many projects promoting the use of ICTs in marginalized rural communities have failed in the past, partially due to economic sustainability problems [7].

Even though it sounds like an utopian goal in the light of many experiences, projects should aim for financial sustainability and hosting communities should be groomed to take care of and sustain these projects. This is crucial because it will earn the project self reliance and reduces its dependency on outside funding which often dries up. This process could be helped by identifying means and ways that can be used to raise revenue in these projects. The generated revenue will then be used to meet financial obligations.

Generally, ICT interventions need to be sustained in every sense; that is culturally, socially, technically and economically or financially. However, the focus of this paper is on financial sustainability. This paper introduces the Network Revenue Management System that will allow experimentation on ways of charging for the use of resources on the network. Initially, this might simply ensure that a deployed network will generate revenues to cover its operational costs, with the set-up costs absorbed by the government or a donor agency. The long term goal, however, is to recover the capital costs of the network, at least for network generations higher than the first .The system not only should allow experimenting with charging users on traditional billing metrics, such as bandwidth and time, but also incorporate contextualised billing mechanisms and attempt to integrate the community’s conceptualisation of fairness. The novelty of this approach is its context sensitivity, which promotes active involvement and contribution on the part of the community to sustainability.

II. RESEARCH CONTEXT

The deployment and testing of this system is done within the context of the Siyakhula project, which is undertaken in Dwesa. The Siyakhula project is an ICT4D project, initially

with the aim “to develop and field-test the prototype of a simple, cost-effective and robust, integrated e-commerce / telecommunications platform for marginalised communities in South Africa” [8]. It is run jointly by the University of Fort Hare (UFH) and Rhodes University (RU). This project has deployed a wireless network in Dwesa. The deployed network runs on an Open Source platform.

The current deployment in Dwesa is based in schools which are connected to a WiMAX backbone. VSAT forms part of the backhaul connectivity to the Internet. The schools were identified as the best locations to put the resources, but not necessarily the final locations. This is due to the fact of them having electricity and being learning centres. They act as central locations which serve communities in their vicinity.

For the past three years the project has been running with the financial support of the Centre of Excellence (UFH and RU) through the partnership with the industry. However, the philosophy of this specific project can be understood by using the analogy of nurturing a child, until he is able to provide for himself and then others. So this project is to be nurtured until it is mature and able to sustain itself, and hopefully can also support other, upcoming projects. This philosophy is similar to the ideology behind Innovation Hubs [9].

III. RELATED WORK

In South Africa, since the 1980s, the South African Universal Service Agency and other organizations have been searching for ways of providing ICTs within the reach of all citizens [2]. According to Benjamin [5], small, profit centred solutions have sometimes been successful, whilst none of the implemented donor funded solutions have shown a model that is sustainable. In the light of this reality, community-driven wireless networking has emerged as a promising model for supporting universal access in disadvantaged and underserved communities [6, 10]. The model is often implemented through some form of community access point for information and communications services, often known as a community telecentre or telekiosk [4-6]. Examples of ICT4D at work in South Africa include projects being run by the Council for Scientific and Industrial Research (CSIR) in South Africa [11].

For these projects to gain wide acceptance, they need to be sustainable. Sustainability is a complex and highly contested issue and there is considerable debate over its actual meaning. The term sustainability was popularised by the Bruntland Report [12]. In the context of development, this was articulated to mean “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. It is a property of the project’s capacity to cope with an uncertain future.

A study was conducted in the early phases of the Dwesa project to identify and explore factors promoting sustainability in rural ICT projects[13]. The preliminary investigation revealed that most researchers link the problem

of sustainability to financial sustainability. However, sustainability is not just about the financial side of projects but also encompasses the multiplicity of other issues such as cultural, social and political [14] factors. Sustainability for the Dwesa project was classified into social and cultural, institutional, economic/financial, political and technological sustainability [13, 14].

As highlighted in [15], projects aiming to bridge the digital divide have been implemented in different forms, most notably cybercafés and telecentres, or multipurpose community telecentres. Each of the different interventions may have different owners. The most common types of owners are NGOs, communities, aid agencies, universities, private companies and governments. It is obvious that a business telecentre should be financially sustainable [14].

It is noteworthy that the more an implementation is required to generate revenue in its initial stages, the less emphasis will be placed on supporting developmental goals, and hence this ultimately resembles a cybercafé. Hence, for developmental purposes, these projects need to be nurtured.

By ascertaining who benefits from the project, who pays for the costs and why, some researchers advocate for donors and /or governments to pay [16]. However, the majority believes that projects are managed better if the owners have some stake in them. They stress that the owners of the project should contribute towards its sustainability [5, 6, 17]. Hence, it is from this angle where this paper proposes a system which can be used to manage the revenue generated from the owners. This continues on research done and published at previous SATNAC conferences.

For obvious reasons of cost and affordability, commercial packages like Hotspot Pro, RAMADA, FirstSpot and Alepo RBS which could equal do the job were not considered.

Cost recovery mechanisms can be implemented through charging users for use of the Internet and other resources on the network. This means that a way to account, charge and bill users for their usage is needed.

Billing systems allow the generation of revenue for the network services provided. This means that such systems should provide functionality for service provision, tracking, billing plan selection, rating, discounting, invoice creation, payment management and customer management. These systems are the link between the network and the stakeholders [18].

IV. SYSTEM ARCHITECTURE

In this research, on account of time and human resources constraints and in line with current practice, we tried not to reinvent the wheel wherever possible. So, the system is derived from and designed to take advantage of currently available applications and technologies. Specifically, the system makes use of different open source applications to implement the functionality requirements of components where appropriate.

The fundamental components of any billing system can be categorised as follows.

- *Network Layer:* Captures, tracks and records usage of resources.
- *Access control layer:* Implements Authentication, Authorization and Accountability functionality on the network.
- *Accounting Layer:* Sorts the collected data into accounting records.
- *Charging / Pricing Layer:* Assigns prices to records to come up with costs of usage.
- *Billing Layer:* Compiles all charges for a customer over specific period

The diagram shown below depicts the architecture of the system under discussion.

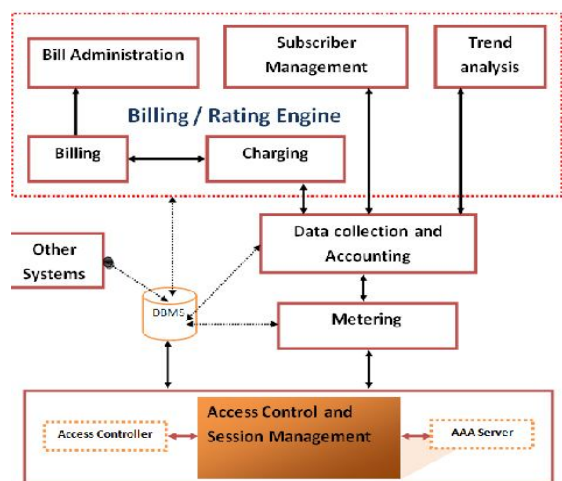


Figure 1: Conceptual architecture for the Network Revenue Management System

The architecture shown above highlights the two crucial components of the revenue management system; the access control and session management and the billing / rating engine.

1. Access control and session management

This component acts as a proxy that sits between the user and the Authentication, Authorisation and Accounting (AAA) server. It accepts the user credentials and forwards them to the AAA server which verifies them against a specific backend. Once the user's details have been verified, the AAA server returns information elaborating what the user is allowed to and not to do. At the end, when the user has finished using the resource for which is authorized, or his session has timed out, the session is ended.

2. Billing engine

This component abstracts the technical details and manipulates the data coming from other systems as well as generated by the system to display different kinds of reports to the user through a web interface. Its primary responsibility is to calculate and assign prices to records, based on different billing metrics or inputs. Some of the

rating engine's inputs are depicted in figure 2.

The engine gets its inputs from different places. The obvious inputs are the outputs of the data collection and accounting component, whilst the less obvious ones are the ones which have been specified as non-conventional billing options in the introduction section. These might include income, number of dependents, history of contributions, proceeds from sales and others.

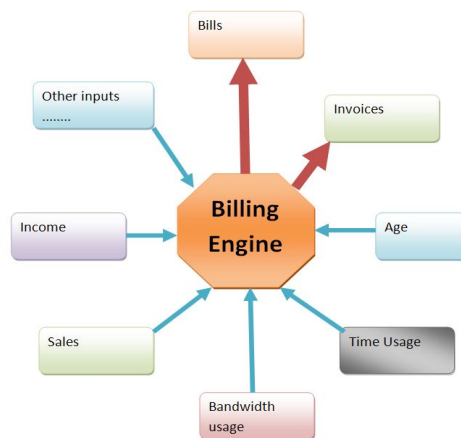


Figure 2: Billing engine

V. SYSTEM IMPLEMENTATION

As mentioned earlier, this system was implemented using Free and Open Source Software. The Chillispot package was used to handle access control and session management. The Remote Authentication Dial In User Service (RADIUS) was used to provide the AAA (Authentication, Authorization and Accounting) functionality on the system, and in this implementation, Freeradius was used as the RADIUS server.

The deployment diagram shown below depicts how the different components connect and interface with each other. It shows that the clients can run on any operating system, for example, Microsoft Windows, Linux, Mac or Symbian. The clients interact with the access controller via the TCP/IP protocol and with the service provider's web server via HTTPS. All communications concerning authentication are done over the Secure Sockets Layer. Finally, it is also highlighted that the RADIUS protocol is used for the communication between the Authentication manager and the Authentication server.

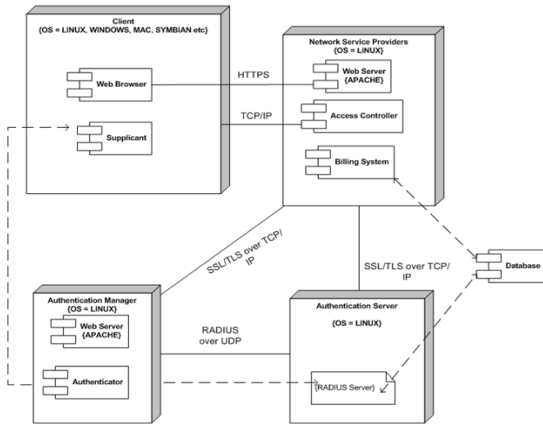


Figure 3: Network Revenue Management System Deployment Diagram

A. Billing System

As highlighted above, the captive portal forces users to authenticate before they are allowed to access the system. When they are authenticated, a session is started. FreeRADIUS, which is employed for AAA purposes, account for their usage, by logging their usage data into a MySQL database. After this, data is stored in the database; a way is needed to manipulate this data for billing purposes. In our case, we want to use this data in combination with other data from external sources to make billing decisions. A system for doing such operations was needed and for our prototype we chose Hotcakes.

1. Hotcakes Hotspot Manager

Hotcakes [19], is an Open Source, LAMP (Linux Apache Mysql PHP) hotspot management solution based on the CakePHP framework [20]. It features an interface which is used to manage subscribers, usage statistics and invoicing. It also supports bandwidth shaping through Chillispot. It offers traditional billing options, specifically data usage and time online, out-of-the box.

Some of Hotcakes' inherited advantages are: active, friendly community, integrated CRUD for database interaction, application scaffolding, built-in validation, email, cookie, security, session and request handling components, data sanitation, flexible view caching and it provides helper for features such AJAX, JavaScript and HTML forms [21].

Given its modularity and extensibility (it follows the Model View Controller architecture), it was easy to implement our non-conventional metrics in the billing processes without affecting the normal operation of the system. Its structure makes components reusable in new applications.

2. Tapping into Hotcakes Hotspot Manager

Hotcakes uses profiles to control how users should access the Internet. Profiles store information specifying:

- The maximum upload and download speeds.
- The allowed idle time for an account.
- The number of allowed simultaneous instances for the same username.

- Frequency in which accounting data will be updated for the accounts using that particular profile.
- The maximum data cap.
- Expiry date and other quality of service parameters.

A sample profile is shown in figure 4.

Attribute Name	Tool Tip Text	Check or Reply	Units
WISPr-Session-Terminate-Time	2008-06-09T19:00:00+00:00 (to terminate 09 June 2008 7PM)	Reply	Text String
WISPr-Bandwidth-Max-Up	Maximum transmit rate (b/s) - From Hotspot to Internet	Reply	Bits/Second
WISPr-Bandwidth-Max-Down	Maximum receive rate (b/s) - From Hotspot to Internet	Reply	Bits/Second
Idle-Timeout	(Try 900)- After switchoff => auto disconnect	Reply	Seconds
Simultaneous-Use	Limit the amount of machines / given time	Check	Text String
Acct-Interim-Interval	(Try 60) - The time in seconds which accounting data will be u	Reply	Seconds

Figure 4: Hotcakes profile attributes

After a profile has been created, user accounts can be created and then be associated with that profile. Billing plans are drawn and then used to generate invoices, normally based on the QoS parameters specified in the profile. The actual charging is performed by the Invoices Controller. Figure 5 gives the class diagram of the Invoices Controller.

Hotcakes provides two types of user accounts; permanent and prepaid. Permanent users are those users which are charged on a postpaid basis whilst prepaid users are charged on a prepaid basis (using prepaid cards).

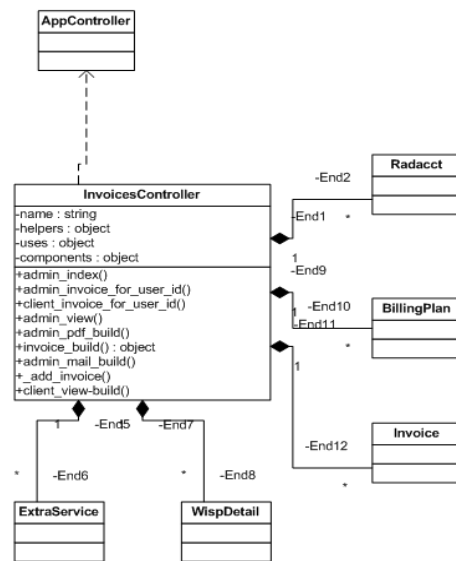


Figure 5: Authentication sequence diagram

The information that is generated by the *invoice_build* function and includes:

- Service provider details
- Invoice specific details such as invoice numbers
- User details
- Activity Details
- Billing plan details
- Extra services and
- The total amount to be paid.

What we wanted was the ability to include non-conventional billing options in our invoice calculations or to choose different billing options based on specified configurations or decisions.

To achieve this, we created new functions. The generic functions which perform common operations were placed in the *rating_manager*-controller class and adapter specific operations were placed in the specific Adapter. The *LoadAdapters* function is responsible for loading the adapters at startup. The structure and relationships of these classes are shown in figure 6.

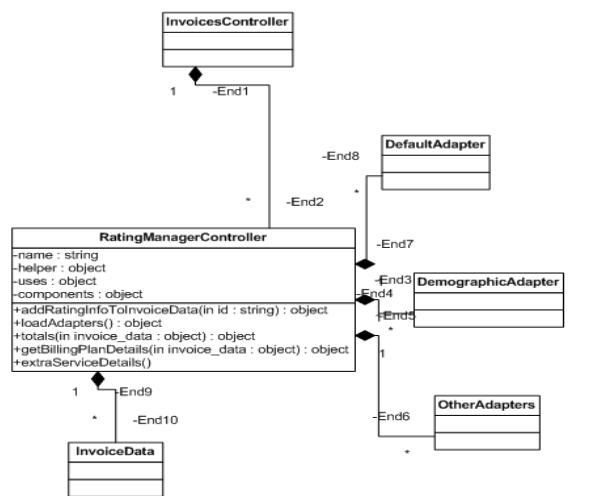


Figure 6: Rating Manager Controller

This implementation makes it possible to introduce new adapters or billing options without a need to change how the system was functioning. A bird's-eye-view into the billing engine can be given in Figure 7 shown below.

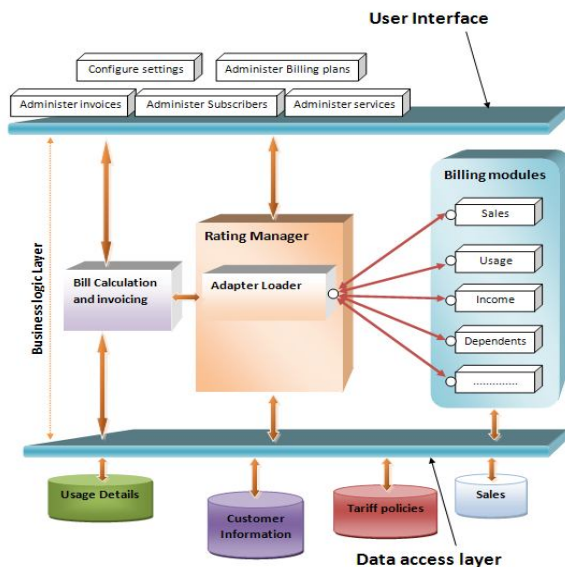


Figure 7: Conceptual architecture of the billing engine

The conceptual architecture of the billing engine shown in figure 7 highlights the application of the MVC architecture where the different application concerns are separated. The

different application layers collaborate to provide sufficient functionality for the Network Revenue Management System.

The *RatingManagerController* is responsible for adding rating information passed to it by the *InvoicesController* to the invoice data. This information includes billing plan details, extra services and other details. It also loads the adapters which are responsible for calculating charges based on different metrics. In other words, it acts as our central engine for making charging and pricing decisions. For example, by considering an adapter which classifies customers according to their level of income, it means that customers are charged according to the rules set for their income threshold. For instance, a rule might say if your income is less than the poverty datum line you get a certain discount on your charges. Or if you spend an amount more than X on the network over a period of time you will get promotional packages.

To implement the adapters we made use of CakePHP's 'components'. In the CakePHP framework, components are used to aid controllers in specific situations. Instead of extending Cake's core libraries, special functionality can be simply implemented in components. A component makes it possible to write a new class which can help controllers in specific situations. The advantage of using components lies in their shareability and reusability [20].

3. Data from other systems

A central requirement for the system was to get data from other systems and utilise it for billing. For example, the system should be able to extract and use the data obtained from the Dwesa e-commerce portal for billing purposes. To achieve this, a trigger might be written on the orders table of the e-commerce portal to replicate committed orders to the billing system's sales table.

The system also provides a way of recording money collected from other sources, for example, donations from the community or other donors.

All this information can be combined with the traditional billing metrics to come up with contextualised billing models. When charging for Internet usage in marginalised communities, we should not do it in a way that will deter users from using the technology. Rather, it should be done in way that will make the users feel that they are just contributing to the project's survival and foster the sense of ownership.

VI. CONCLUSION

This paper has described the design and implementation of a Network Revenue Management system for the sustainability of computer networks in marginalised communities.

The proposed architecture is based on the MVC architecture, making it possible to design well modularised and decoupled applications. We used FOSS as it is the most viable solution for poor and marginalised communities whose capacity to generate income is very low. The costs of

the network have to keep as minimal as possible. This means proprietary solutions are not an option since there will be the need to pay for licences.

Our generalised, flexible billing architecture enables us to design billing applications where billing information can be derived from all sorts of information repositories. This means that in addition to the traditional billing options, we are able to create custom and contextualised billing options. With a pool of billing options available, it is possible to experiment with different options and see their effects. This makes it possible to include different types of incentives aimed at motivating the community hosting the ICT facilities to use them and pay for them.

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