

Implementation of an Internet Access Cost Management System for Disadvantaged Communities

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Abstract—Rural Internet connectivity projects aimed at bridging the digital divide have sprouted up across many developing countries. After the initial deployment, economic sustainability remains one of the greatest challenges facing these projects. This paper presents the design and initial implementation of an Internet Cost Management System that will enable the exploration of suitable pricing models to generate revenue to make the infrastructure economically sustainable. An important goal of the exploration is the establishment of what would be regarded as equitable cost sharing in rural, marginalized communities in South Africa, such as the community in Dwesa on the Wild Coast.

Index Terms— Internet billing, ICT for development, rural, sustainability

I. INTRODUCTION

With developing nations rapidly realizing that the key to participation in the radically changing economy lies in possessing the right skills to access the right tools, it is likely that projects demonstrating that Internet can be deployed in marginalized communities are going to increase. The cost of Internet is however still high, when the ability to pay is low. The consequence is that the majority of rural areas are still unable to get connected to the Internet¹.

Since the 1980s, the South African Universal Service Agency has been searching for ways of providing ICTs within the reach of all citizens [1]. Community-driven wireless networking has emerged as a promising model for supporting universal access in disadvantaged and underserved communities [1]. These networks have sprouted up across South Africa, making it possible for rural areas to access cheaper Internet services. The solution is often implemented through some form of community access point for information and communications services, often known as a community telecentre or telekiosk [2]. In this model, Internet is delivered as a community resource that should be financially sustained by the community.

One of the main considerations in the implementation of development projects is to ensure long-term sustainability.

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This paper introduces an Internet Cost 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 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 cost of the network as well, at least for network generations higher than the first.

The Internet billing system is developed using Free and Open Source Software (FOSS) and non-profit business models. The system tries to appropriately reflect the perception of fairness held in the communities that use it. The system is transparent and easy to understand, runs customer-oriented billing plans and is designed to be flexible. The deployment and field-testing of this system is done in Dwesa, a community where a project is run jointly by the Universities of Fort Hare and Rhodes, 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. The novelty of our approach is its context sensitivity, which promotes active involvement and contribution on the part of the community to ensure sustainability.

The rest of the paper is articulated in six sections. Section II provides a review of work dealing with pricing Internet usage. Section III gives a brief description of the Dwesa / Cwebe region where the project is being implemented. Section IV describes the current network deployment in Dwesa. Section V outlines the Internet Cost Management System under development. Finally, sections VI and VII very briefly sketch future work and conclude.

II. RELATED WORK

There has been extensive research on the economics of the Internet and members of the technical, academic, and user communities have shown interest in the areas of charging and accounting for the Internet [2] [3]. An extensive account of work on charging and accounting, covering also customer care aspects, is given in [4]. Pricing the Internet is a complex and difficult task, due to the number of factors which have to be considered. These factors include the need for differentiated services, simplicity, socio-economic aspects and other issues like computational complexity and modelling. This has resulted in the formulation of many pricing models, some of which are presented in [5].

The Internet DEMand eXperiment (INDEX) project was started in order to investigate, amongst other things, the

user reaction to the different pricing schemes [6]. The research discovered that flat fee based schemes were favoured by users. However, the leaders of the project argue that this model in its purest form tend towards a waste of resources, unfairness amongst users and revenue loss for ISPs.

Best and Maclay discuss community Internet access in rural communities and argue that economic self-sustainability should be taken seriously if common failures associated with donor initiatives are to be avoided [2].

The Charging and Accounting Technologies for the Internet (CATI) project was set up to focus on the development of Internet protocols that support charging and accounting for existing and future networks and also demonstrate how these protocols can be used in real-world applications [7].

An important network usage accounting specification is the Internet Protocol Data Record – IPDR, which defines an XML-based model to collect usage information from the network and format it into usable records [8].

The Market Managed Multi-service Internet (M3I) project aims to design, implement and test a next-generation system that will allow Internet resource management through market forces, by enabling differential charging for multiple levels of service. The system will increase the value of Internet services to customers [9].

The essential motive behind all these endeavours is to design an efficient accounting architecture for collecting, storing, processing and communicating relevant technical information to the concerned parties.

III. DWESA / CWEBE

Dwesa / Cwebé is a remote rural area located in the Wild Coast of the former homeland of Transkei, in the Eastern Cape province of South Africa. Dwesa / Cwebé is in many ways a reflection of many rural realities in South Africa and Africa as a whole. It has a population of 15,000 people, who live in 2000 households. Its inhabitants are generally subsistence farmers. Dwesa is characterized by lack of infrastructure such as roads, electricity, sub-standard educational facilities and high levels of poverty [10].

This area was chosen as the settings of a research efforts run in cooperation by Fort Hare and Rhodes Universities, in which a complete, distributed and Internet-enabled computing system was deployed in early 2006. The aim is to explore the effect of ICT in a deep rural setting, as an enabler of economic growth and better quality of life.. Several meetings and discussions were held with the various community stake-holders to catalyse community buy-in, which now seems a reality. For example, some of the schools where computers were deployed have raised money to buy their own printers and photocopiers, and have started offering free basic computer training to the rest of the community.

IV. THE NETWORK AND COMPUTING INFRASTRUCTURE

There are a number of technical challenges in the provision of Internet connectivity in sparsely populated areas. This project uses a blend of various Internet connectivity technologies to overcome some of them. Internet was provided as a community resource and the deployment was centred on schools, which act as points of access for the at large. The network is a converged IP network consisting of both wired and wireless sections. In the setup, VSAT represents the backhaul connectivity to the Internet, while IEEE 802.16 (WiMAX) is the last-mile access to the various schools [10]. Currently, the points of presence are four schools: Mpume, Ngwane, Ntokwane and Nondobo, as shown in Figure 1.

Mpume (school A): This was the first point of presence for the project. Due to its strategic location and availability of electricity, it was chosen as the site for VSAT installation.

Ngwane (school B): This is in line of sight with Mpume and because of its location it was chosen as the site for the WIMAX base station installation.

Ntokwane and Nondobo (schools C and D): These schools are in line of sight with Ngwane, and this enabled the extension of the Internet to them.

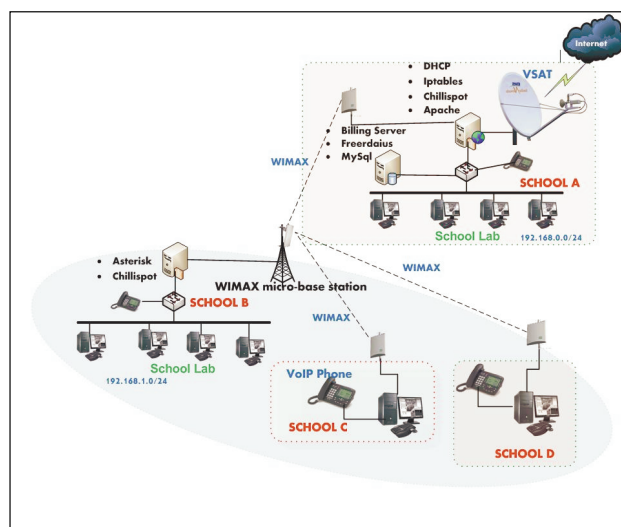


Figure 1. Deployed network infrastructure [14]

All the software used in this project is FOSS. The desktops run Edubuntu, a customized version of the Ubuntu Linux distribution designed for use in a school environment and suitable for young users. Edubuntu contains all software found in Ubuntu and more educational applications, such as TuxPaint, TuxTyping, GCompris, KDE Edutainment Suite, and Schooltool Calendar [10]. The use of FOSS can generate significant savings in hardware and software, thus FOSS has a relative advantage on proprietary solutions in the context of marginalized communities. Furthermore, the availability of source code and the right to modify and redistribute modifications gives the programmers the ability to understand the system better and adapt it to changing conditions. This also comes with all advantages associated with software development as a collaborative effort.

Our point of view on projects that bring an ICT infrastructure in a place where there was none can be understood using the analogy of nurturing a child. You give her life, teach her how to sit, walk, talk, send her to school, provide financial and social support just to mention a few things. But do you really want to do this until the child is a grandmother? Clearly, the answer is no. These projects are nurtured until they mature and can sustain themselves, and hopefully can also support other, upcoming projects. This can be achieved, in part, by implementing an Internet Cost Management System which allows the network to collect revenue that can be used first to cover operating costs, such as electricity, Internet connection and maintenance. All these costs will be shared among the different users of the infrastructure. Overtime, excess revenue will be used for the repayment of the initial capital costs and expansion.

V. THE INTERNET COST MANAGEMENT SYSTEM

1. Software

As mentioned earlier, this system is developed using FOSS running on Ubuntu. This operating system gives the programmer full access to the networking stack and can be used to provide and implement a wide range of networking functions on the system. The Chillispot package is used to handle access control and session management. The Remote Authentication Dial In User Service (RADIUS) is used to provide AAA (Authentication, Authorization and Accounting) functionality, using Freeradius [11].

2. Design Objectives.

- **Low cost:** This is a rather obvious objective, given the target users.
- **Flexibility:** The system should be flexible enough to be maintained and expanded. A set of adapters are used to interface with the rating engine, thus making it extensible and easy to experiment with various cost sharing ideas.
- **Supporting roaming:** There is a need for the users to be able to use the Internet from any point of presence within the network. Making use of a central shared database help us realise this goal.

The billing system collects information such as usage from the network, demographic data from users, and proceeds gained from the e-commerce system and uses these to create bills for clients. The key components of the system are presented in Figure 2.

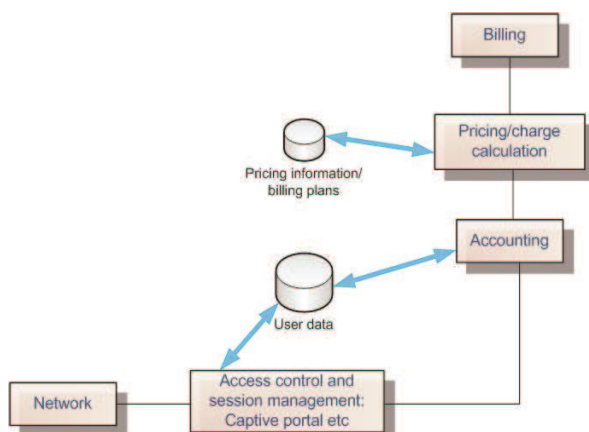


Figure 2. System Components

As on can see from the figure, the components are:

- **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.
- **BillingLayer:** Compiles all charges for a customer over a specific period

3. Authentication, Authorization and Accounting

Chillispot's Universal Access Method (UAM) was used for authentication. The access controller shown in Figure 3 has 3 network interfaces.

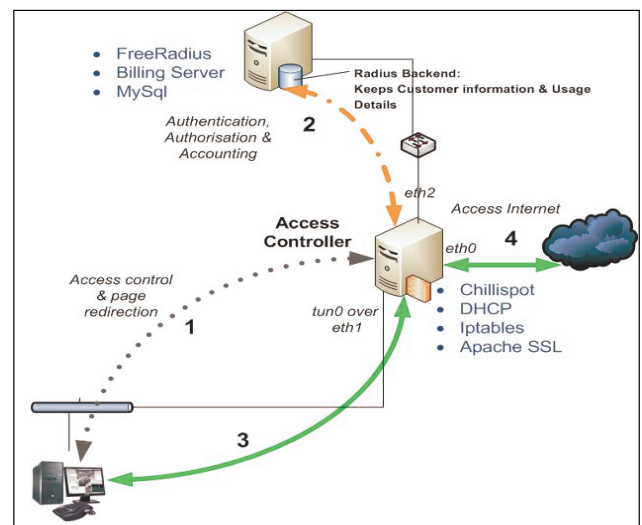


Figure 3. Access Controller

Chillispot uses eth0 as its uplink interface for forwarding packets to other networks, uses eth2 for authenticating clients against the RADIUS server and takes control of the internal interface eth1 using the vtun kernel module to bring up a virtual interface tun0. This interface accepts DHCP and ARP requests from clients. All clients connecting to this interface are dynamically allocated an IP address in the 192.168.1.0/24 network, or any other network specified in the configuration. To route packets from tun0 to eth0, masquerading (NAT) and ip_forward are enabled in the kernel [12].

A client can be in two states, unauthenticated and authenticated. An unauthenticated client trying to access the Internet will have its TCP connection intercepted by Chillispot and then redirected to a CGI or PHP script

served by Apache over SSL/TLS (captive portal web page), where it is prompted for username and password.

Upon submission, the password is encrypted and sent back to Chillispot, which sends an access-request message to the RADIUS server over the RADIUS protocol and using the CHAP-Challenge and CHAP-Password as specified by RFC 2865 [15]. The message attributes described in RFC 2548 [16] are used for channelling encryption keys from the RADIUS server to Chillispot. The RADIUS server determines if the user is valid, using schemes like PAP, CHAP or EAP. The backend could use any number of services such as LDAP, Active Directory, Kerberos, a database or Unix password files. In our case MySql and Unix password files are used. If the authentication is successful, the RADIUS server returns an access-accept message and a list of authorized resources. The client's state is changed to authenticated and is authorized to access the listed resource. The RADIUS server will also be notified when the session starts and stops, for billing purposes. The usage details are logged into the MySql database.

If the password does not match or if any attribute specified in the client's profile fails, the RADIUS server returns an access-rejected message and the connection is terminated [11] [12].

4. The billing/rating engine

The billing engine consists of a database management system, a database abstraction layer and modules for customer assessment, a rating engine, an adapter system and billing functions as depicted in Figure 4. These modules are developed using PHP.

The *billing engine* is responsible for assigning prices to records, to come up with costs. It gets its inputs from various sources as shown in Figure 5. Obvious inputs are, for example, the usage records generated by the RADIUS server. Less obvious inputs might be revenue gained through the system, or history of contributions made to the project.

These various inputs are fed through the *adapter system*, which allows the experimentation with various cost sharing ideas. The rating engine provides an interface which is implemented by a *rating class*. The adapter system provides a set of adapters which take the *rating class* and modify one or more of its methods to suit a particular pricing model.

Currently the system supports various standard types of

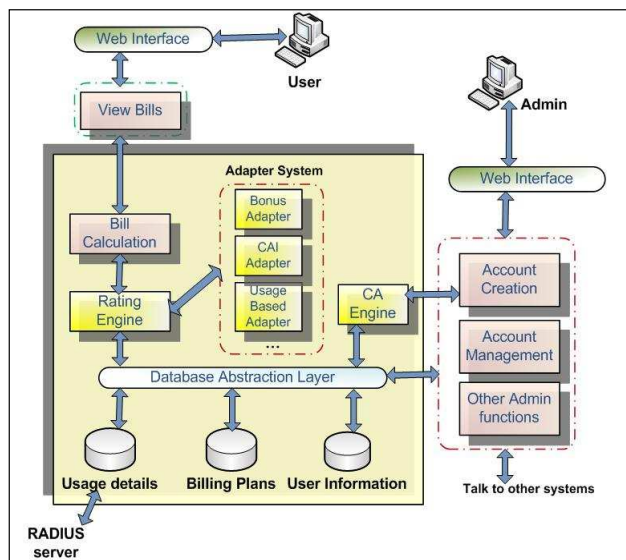


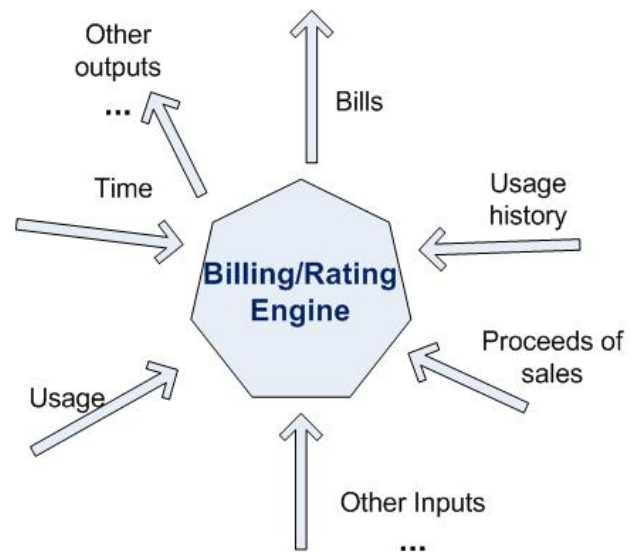
Figure 4. The Billing/Rating Engine

pricing models, including flat rate, usage based and time based. Accounts can be prepaid or postpaid and different models may have different usage restrictions, such as bandwidth usage or upload and download speed limits.

The system consists of a loader class, *EngineLoader*, which is executed first. This class consists of static functions which enable the system to dynamically load and configure its components and start the rating engine. For example *EngineLoader::loadClass('BillingPlan')* loads the billing plan after which we will be able to call its methods, like *BillingPlan::getBillingPlanName(\$id)*.

Using the method *EngineLoader::loadAdapters()* the rating engine loads all adapters stored in the *.adapters* directory. This means that after creating a new adapter, getting it to work simply means reloading the adapters using the *loadAdapters()* class and setting the appropriate configurations. This technique allows change of behaviour without programming. These adapters use the DAL API to

Figure 5. System inputs and outputs



access time, usage, sales and other information from the database. They do not execute *SQL* statements themselves. This indirection allows the database to evolve while keeping the system stable. This also helps us to separate the pricing logic and the application logic and makes it easy to introduce new rating methods and adapters. This will allow us to experiment with different ways of charging.

An adapter might build upon the *financial means test* and the South African Living Standards Measure (LSM) [13], to collect a range of information on the socio-economic condition of a client. This might include data on demographics, education, food and non-food expenditures, employment and income. This information can be used by the CA adapter to calculate the client's Customer Assessment Index (CAI) based on a point system. Ranges are used to collate various CAIs into groups. Each CAI

group might be given a certain discount and so is assigned to a specific discounted pricing plan (*AdapterCAI*).

Another adapter might implement the idea of getting a certain percentage from the user's selling proceeds (*AdapterSALES*).

Charging should not stifle Internet use, so there is a need to identify groups that, at a certain time, lack motivation to use the Internet and figure out to what incentives they respond to. This may be as simple as granting Internet for free to these groups. This functionality is handled by the bonus management adapter, which grants bonuses to subscribers (*AdapterBONUS*).

A mix of different adapters can be used, resulting in a tiered pricing structures. For example, certain users might pay a flat rate up to a certain limit, after which they will be charged based on time (*AdapterTIME*) or usage (*AdapterUSAGE*).

The *bill calculation* module is responsible for collecting the price events and compiling all charges for a customer over a specific period.

5. Front End Interface

The system makes use of a web based interfaces, which includes:

- a **control panel**, which is based on the *Phmymypprepaid* package. It contains a subscriber management panel used for activating and maintaining subscriber accounts and viewing transaction history, accounting history and user details. The account registration interface uses AJAX and PHP;

- a **billing plan management panel**, which is used to manage pricing plans;

- a **self care panel**, which is a web-based interface built to enable subscribers to view their usage summary and billing history.

VI. FUTURE WORK

After designing and implementing the billing framework, the obvious future work is the implementation of more adapters and, through them, the exploration of various billing options, to determine what is regarded as a fair way of charging by users in a rural community.

VII. CONCLUSION

This paper has described the design and implementation of an Internet Cost Management system to be deployed in the Dwesa /Cwebe community.

Most importantly, this paper outlines how the system tries to combine traditional billing methods with customer-oriented / communal-based methods to provide a larger pool of billing options which can be used for experimenting on ways of charging regarded as fair by the community hosting the system.

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