

An Applicable GSM Service Model for Rural Networking

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Abstract— Wide rural areas are often short of basic communication facilities and suffer from harsh geographic and climatic environments. Wireless networks which offer ease of operation and low maintenance cost appears to be a fast and feasible choice for service operators to install their individual networks.

We first propose a refined wireless networking method to foster communication construction in rural areas. A one-pipe-four-layer wireless simulation model, called Service Model, is highlighted in the paper to implement the network planning method. The Service Model collects raw data from given rural areas and abstracts these data by flowing them through four technical layers to form the predicted technical wireless network. Thereafter, a software simulation environment, *BrwsLi*, is coded in freeware Scilab to realize the Service Model for the sake of instantiation. This simulation environment is able to set up a specified rural network by constructing topology for the network on the depicted areas, simulate the network traffic, and evaluate network performance and economic efficiency. The Newcastle region in KwaZulu-Natal of South Africa is chosen as the sample of real-world cases to demonstrate how to practically apply Service Model and present how to operate *BrwsLi* properly.

Index Terms— Scilab, modeling, rural communications, wireless.

I. INTRODUCTION

Even though wireless telecommunication technologies have been showing considerable benefits for both urban and rural dwellers, it is more difficult to apply them technically and efficiently in telecommunications-raw rural areas than in urban areas with existing mature telecommunication infrastructures. Rural network planners therefore need a scientific rural-networks-modeling tool to make a blueprint of the communication networks for given rural areas.

A lot of substantial work has been done on rural communications to distribute appropriate services in unfavorable rural sites. Early in 1988, Nepal rural communication network was set up successfully by three

stages, which are reconnaissance on the spot, network parameters analysis, and network construction [1]. This project succeeded in building a rural communication system for low-level developing countries by choosing the appropriate system and using the self-defined decisive parameters to construct a wireless network. However, since the project did not forecast the network either in a model or in simulation environments, it risked a failure of being a full-functional network. The simulations were done in CRCnet project performed by WAND group at the University of Waikato, Australia, in which simulation tools of Open source Squid Report Generator (SRG) and Distributed Arpwatch (Darpwatch) served as proxy analyzer and monitor separately [2]. However, the network encountered difficulties in acquiring enough available bandwidth and capacity because only WiFi was used in order to save money.

The proposed Service model in this paper aims to provide network planners with a simple and easily understandable theoretical model as to fundamental rural wireless networking. In the model, the steps on how to quickly put up a wireless network in rural areas are shown, and the reasons for doing so are given at the same time. The model is made visible and operable via the realization of an appropriate simulation environment, *BrwsLi*. The purpose of developing this software simulation tool is to visualize a planned network on the basis of the model and evaluate the network in a scientific way. Moreover, both the Service Model and the simulation environment can be used widely among areas within GSM/GPRS coverage and are applicable to CDMA in theory.

The general benefits of and requirements on networking in rural areas are described in [3]. This paper gives an example of modeling rural networks using GSM. The model has also been presented at the South African Telecommunication Networks and Applications Conference 2005 as well [4]. This paper is organized as follows. The theory of the Service Model is firstly brought out in details in Section II, and its application in Newcastle is explained in Section III by analyzing real data. Thereafter, Section IV designs a prototype for the Service Model, which gets implemented in Scilab language in Section V. The conclusions of the Service Model are stated in Section VI.

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II. SERVICE MODEL

A one-pipe-four-layer model, namely Service Model, is designed to simulate service-modeling for universal access (basic voice access) in rural areas [5]. At the top of the hierarchy, an Application Layer defines high-level services to be supported by the network. These services are interpreted by sub-services at the Guideline Layer, and each sub-service functions independently. Following behind the Guideline Layer is the Network Layer. In the Network Layer, the overall architecture and communication strategies of the system, such as network nodes configuration, routing and rerouting, are defined by considering the constraints imposed by the Application Layer and the interfaces provided by the Physical Layer. The Physical Layer can be found at the end of the hierarchy where it is responsible for supplying equipment and labor. The Management Pipe manages the four layers throughout the entire process of modeling. The relationship of the above pipe and four layers can also be visualized as a distilling water system in Fig. 1:

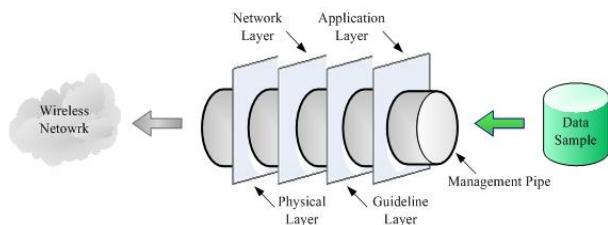


Fig. 1. Service model guide. First, one can conceive of the Management Layer as a pipe, the Application Layer, Guideline Layer, Network Layer, and Physic Layer then take their turns in this sequence, with each serving as a filter. After we have defined the input data and customer needs, data flows in the form of a stream through these filters one by one. In the end, we can get the “distillated running water”.

The five functional entities of the pipe and layers are explained as follows:

A. Management Pipe

Management Pipe manages the four layers throughout the entire process of modeling in terms of the four system management aspects, which are functional requirement, operating system, system administration, and database [6]. The pipe is supposed to supervise the data in all layers, coordinate compatible parameters for each layer, maintain the upgrade of operating systems and application software, and adopt modular design to ensure scalability.

B. Application Layer

The first layer of the Service Model aims to clarify the types and characteristics of services that the wireless network is supposed to provide to customers, and is therefore called the Application Layer. The Application Layer is designed to help understanding the service requirements of the five communication nodes throughout the value chain, including telecommunication carrier, service provider, equipment

manufacturer, information channel and end user [7]. A general relationship between them is depicted as Fig. 2:

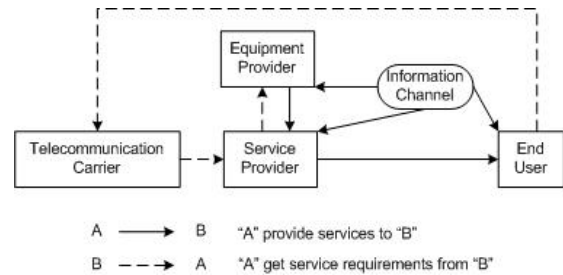


Fig. 2 Service chain in a communication network. There is an obvious relation of service-supply and service-demand between any two of the five communication nodes, so issues on service play a connective role in constructing a local network.

C. Guideline Layer

The Guideline Layer gives the criteria, for reference, as to resolving technical problems when constructing a rural wireless network. Thus, services in the Application Layer are specified in the Guideline Layer as detailed technical targets. For instance, the technical targets for constructing a rural wireless network include how to render a high-quality voice communication over long distance, or how to protect a network from natural interference. Two questions in the Guideline Layer are taken into main consideration:

1) *How can we choose an appropriate wireless technology according to rural situations?* Often high quality, large coverage, short rollout time, low initial and life-time cost, and strong social profits are used as threshold parameters for networking evaluation [8].

2) *What technical parameters need considering in a rural network construction?* The characters of Quality of Service (QoS), Bandwidth, Transmission Speed, Network Capacity and Signal Delay form the emphasis of technical problems in the Service Model in order to provide rural areas with universal wireless access [9][10].

D. Network Layer

Network topology in the Network Layer is used in conjunction with technology calibrations in the Guideline layer to build an ideal wireless network on paper. Ordinarily a network topology is characterized by 1) physical topology, representing the physical interconnection structure of a network graph, 2) routing algorithm, restricting the set of paths that signals or messages may follow, 3) switching strategy, prescribing how data traverses a route, by circuit switching or packet switching, 4) flow control mechanism, explaining when a message is allowed to traverse a route and what happens when traffic congestion is encountered.

E. Physical Layer

The Physical Layer forms a final physical platform that is responsible for setting up a wireless network. The apparatus

involved with most commonly-used wireless network nodes in GSM include local exchange, base station controller, base station, and subscriber terminal [11]. To link these apparatus that have multifarious network purposes, transmission media materials vary in terms of their working parts in the whole network, including backhaul, access, and last miles. These transmission media materials are twisted pair, cable, fiber, microwave link, and satellite. When considering the most appropriate equipment for network settings in rural areas, what is always taken into account is the network availability (long distance and resultant interference) and economic cost.

III. NEWCASTLE APPLICATION

According to [5], a technical Newcastle-service-model has been set up by applying the one-pipe-four-layer service modeling theory to the health system of Newcastle, South Africa, which is called Newcastle-Health-System (NHS). The real-world application is specially applied to a rural South African community because South Africa has a very low level of communication infrastructure in rural and remote areas [12] with a high demand for voice communications and a steadily growing demand for data communications [13]. An operable networking in rural South Africa can be expected in other rural areas with similar communication status.

A. Newcastle-service-model

First, a bird's-eye view of the Newcastle-service-model was drawn [5]. Overall, the model aimed to provide wholesome medical treatment services to customers (all patients in NHS), both in rural centers or commercial farms and along three main roads in Newcastle areas, as shown in Fig. 3(a). A compound management mechanism of Central Information Management (CIM) and Distributed Information Management (DIM) was proposed in NHS according to the different service requirements of different network nodes. Optimal technologies, such as Global System Mobile 400 (GSM400), Global System Mobile/General Packet Radio System Network In a Box (GSM/GPRS NIB), were chosen under the communication background of South Africa, and seven parameters were selected to evaluate network efficiency, including network traffic "A", probability of call blocking "B", bandwidth "Bs", average link delay "E[T]", average route delay "Ts", network capacity "Cnw" and network efficiency "E". Moreover, a self-contained network topology was selected as shown in Figure 3(b), coupled with a Distance Vector routing algorithm (DV), a Time Division Multiple Access (TDMA) packet switching strategy and a non-congestion flow control mechanism. Finally the three main physical network nodes - Gateway (GW), Base Station Switching Node (BSSN) and Base Station (BS), were entered in the model on the basis of the self-contained network topology and special rural Newcastle environments.

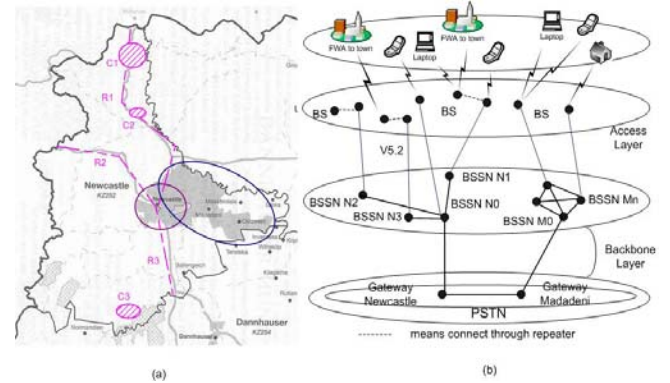


Fig. 3 Network topology of Newcastle-Health-System.

Furthermore, the formulae for calculating the A , the B , the B_s , the $E[T]$ and the T_s are listed as follows [14][15]:

$$A = S \cdot \lambda \quad (1)$$

$$B = \frac{A - A_0}{A} = \frac{\lambda - \lambda_0}{\lambda} \quad (2)$$

$$B_s = 40 \cdot \alpha \cdot \beta \cdot C \cdot L \cdot \frac{1 + (a-1) \cdot p_e \cdot L}{1 - p_e \cdot L} \quad (3)$$

$$E[T] = \frac{1}{\mu} \cdot \frac{1}{1 - \rho} \cdot \left(1 - \frac{\rho}{2} \left(1 - \frac{p_e \cdot L \cdot a^2}{(1 + (a-1) \cdot p_e \cdot L)^2} \right) \right) \quad (4)$$

$$T_s \leq 4 \cdot n_{av} \cdot \frac{L}{B_s} \cdot \frac{1 + (a-1) \cdot p_e \cdot L}{1 - p_e \cdot L} \quad (5)$$

Here A_0 is the successful incoming traffic in Erlang, S is the average occupying time of each call, λ is the number of calls per hour, λ_0 is the number of successful calls per hour, α is the fraction of the inter-node traffic, β is the traffic density (Erlang/km²), C is the coverage areas (km²), L is the number of bits for each signaling message, a is the window size of Go-Back-N (GBN) protocol [15] between messages, p_e is the bit error rate of the inter-connection links, μ is the processing rate of calls, ρ is the ratio of λ and μ , n_{av} is the average number of links for a successful path.

B. Network Capacity Estimation

After setting up the network, network capacity is chosen as the key parameter to evaluate network performance. A complex network capacity can be estimated in TABLE I and some assumptions to rural Newcastle will follow [5].

As is reported, there are 55,184 households in Newcastle area and each represents a user, and 56% of the Newcastle population lives in rural areas [16]. We assume that 80% of these rural people cluster around three rural centers: Hilda, Ingogo and Lookop, and travel along three main roads (refer to Figure 3(a)). The average user traffic at peak hour in rural Newcastle is supposed to be 0.015 Erlang, which is half of that over all areas in [17]. It is also assumed that Newcastle town and the three main rural centers hold most of the traffic in rural Newcastle. What is more, 2% of the traffic is assumed to be blocked at each BS. This is reasonable because it is in line with a requirement of Grade of Service (GoS), which is no

