OPTIMIZING 3G SERVICE SITES IN RURAL AREA
A CASE STUDY IN CONTEXT TO BHUTAN

DAGO TSHERING

MASTER OF SCIENCE

IN

STRATEGIC MANAGEMENT INFORMATION SYSTEM

SCHOOL OF INFORMATION TECHNOLOGY

MAE FAH LUANG UNIVERSITY

2013

OPTIMIZING 3G SERVICE SITES IN RURAL AREA
A CASE STUDY IN CONTEXT TO BHUTAN

DAGO TSHERING

THIS THESIS IS A PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE
IN
STRATEGIC MANAGEMENT INFORMATION SYSTEM

SCHOOL OF INFORMATION TECHNOLOGY
MAE FAH LUANG UNIVERSITY
2013

OPTIMIZING 3G SERVICE SITES IN RURAL AREA
A CASE STUDY IN CONTEXT TO BHUTAN

DAGO TSHERING

THIS THESIS HAS BEEN APPROVED
TO BE A PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE
IN
STRATEGIC MANAGEMENT INFORMATION SYSTEM
2013

THESIS COMMITTEE

....CHAIRPERSON
(Dr. Surapong Uttama)

....ADVISOR
(Asst. Prof. Dr. Punnarumol Temdee)

....EXAMINER
(Asst. Prof. Dr. Roungsan Chaisricharoen)

....EXTERNAL EXAMINER
(Asst. Prof. Dr. Laor Boongasame)

ACKNOWLEDGEMENTS

I wish to express my sincere and heartfelt gratitude to my advisor, Assistant Professor Dr. Punnarumol Temdee, for her invaluable instructions, expert guidance, excellent suggestions and kindness shown to me which enabled me to complete my thesis on time.

My sincere thanks also go to Dr. Songsan Udomslip, for guiding and advising me on strategic management information system and Assistant Professor Dr. Rongsan for his special assistance in Mathlab program. I also wish to extend my heartfelt gratitude to Associate Professor Dr. Kosin, who has been instrumental in grooming me with my study and research and at the same time reviewing my thesis papers for the conference. My genuine appreciation goes to the staff of the School of Information Technology, Mae Fah Luang University for updating me and providing me timely information of all the events and schedules.

I take this opportunity to immensely thank Prof Dr. Vanchai Sirichana, President of Mae Fah Luang University, for granting me the scholarship to pursue further studies in the field of information technology, without which my research in Strategic Management Information System would not have been possible.

Finally I would like to specially thank and dedicate my achievement to my family, friends and CEO, Bhutan Telecom Limited, who have been a constant source of inspiration and encouragement during my entire research. Their unstinted and strong support will always be fondly remembered.

Dago Tshering

Independent Study Title Optimizing 3G Service Sites in Rural Area: A Case Study in Context to Bhutan

Author Dago Tshering

Degree Master of Science (Strategic Management Information System)

Advisor Asst. Prof. Dr. Punnarumol Temdee

Co-Advisor Asst. Prof. Dr. Roungsan Chaisricharoen

ABSTRACT

In developed countries, 3G services are common and usually provided by several private operators with almost 100% coverage. However, the situation is quite different in most developing countries. Majority of the people are considered to be under poverty. In most of these countries, telecommunication services are provided by state enterprise which cannot only make profit but have to support people as well. Therefore, compromise must be made in order to serve people within acceptable profit. In this thesis the problem of 3G service site installations in rural area has been modeled on the average income per active user, ratio of active users per potential user and the relationship between each component to solve the problem of installation of 3G sites in profitable areas whereby the input is done on the selected clusters of profitable customers. A framework is proposed in this thesis to solve the 3G service site optimization.

The proposed model considers both population coverage and expected income, which can be easily utilized by state telecommunication enterprise of any developing countries. In this paper, the optimization of 3G service sites in rural town is first modeled by famous linear programming and later the results are further explained by using the genetic algorithm which proves to be a good solution in providing a very small overlap area among sites. With flexible adjustment of parameters, the proposed technique provides tradeoff value to investment.

Keywords: Optimization/3G Service Sites/Rural/Flexible/Technique/Investment/ Genetic Algorithm/ Flexible Adjustment/Linear Programming/Tradeoff

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABBREVIATION AND SYMBOLS

$F(zi,Vi)$	The initial Voronoi region
zi	The initial point
Vi	The Voronoi tessellation (Voronoi Region)
ß	The pole capacity
$\int_{s\in Vi} s\rho(s)ds$	The centroid and new sets of points
$\rho(s)$	The user density
$s = (x, y)$	Represents the coordinates of a given point
SIR	Signal to Interference Ratio
λ	The orthogonal factor
α_{av}	The average intercell to intracell interference factor
Kpol	The Pole Capacity
BS	Base Station
MS	Mobile Station
DL	Downlink
UL	Uplink
GSM	Global System for Mobile Communications
RBS	Radio Base Station
UMTS	Universal Mobile Telecommunications System
RNC	Radio Network Controller
GPRS	General Packet Radio Services
EDGE	Enhanced Data Rates for GSM
WCDMA	Wideband Code Division Multiple Access
OVFS	Orthogonal Variable Spreading Factor
UE	User equipment
EU	End user

GA	Genetic Algorithm
LP	Linear Programming
2G	Second Generation
3G	Third Generation
COST231	Cooperation Scientific and Technical Research

CHAPTER 1

INTRODUCTION

1.1 Rationale

Due to rapid development in internet and information technology, the need of 3G services is often viewed as a necessity to every individual especially in improving the quality of life through high speed data transfer. This is because all end users' equipments these days provide built-in features that require high speed data. The built-in features are provided by mobile Operating Systems (OS) such as Android, iPhone, Blackberry and Windows phone and data is perquisite to use the features of the equipment. However, like in most developing countries, the 3G system is too expensive to be installed throughout the country. The digital divide (Wei, 2011; Wei-xian & Jun, 2012; Bristow, 2009; Joseph & Nath, 2012; Sukkar, 2004; Barry et al. , 2010; Meinrath, Losey & Lennett, 2011; Yates, Gulati & Tawileh, 2010), therefore, is seen as a primary concern especially in rural areas. Laying fiber optic cables is very difficult because of the rugged terrain and it often gets damaged due to natural calamities such as storms and winds. The maintenance is time consuming due to the geographical terrain of the country. The aerial cables, underground cables and drop wires do not support high speed data. Therefore, the existing resources must be divided effectively to deliver service to as many people as possible while at the same time acceptable profit in terms of money value and optimization of 3G services must be maintained.

This thesis seeks to discuss on how to optimize 3G service sites in rural areas where population is scattered. However, the optimization of 3G service sites in developing countries have some more criterions for consideration including profit, coverage areas, limited budget, average income per active user, ratio of active users per potential user and the capacity of the system. These criterions are used in this thesis for optimizing the number of required sites in the rural area particularly in the context of Bhutan.

1.2 Objectives

The objective of this thesis is to optimize 3G service sites in rural area. Optimize here means optimal use of the 3G system. Therefore to optimize 3G service sites in rural area, the following objectives should be met

1.2.1 to optimize the distribution of 3G service among rural towns

1.2.2 to optimize the distribution of 3G service in rural towns

The first and the second objectives are different in scopes and conditions of optimization.

1.3 Contribution

This thesis is based on the case study in context to Bhutan which is a developing country. The results or findings could be applied to any developing country as a reference to calculate the number of 3G sites required in the country according to its budget and average income. So far no research has been carried out separately using the proposed framework on optimizing 3G service sites in rural areas. The framework proposed could be used in any developing or developed country to easily locate potential places to install 3G services depending on revenue generated by any town considering traffic and population coverage while maintaining acceptable revenue.

1.4 Scope

The distribution will be among the rural towns. Among the rural towns, minimum number of 3G equipment will be provided to individual rural town. The minimum number of 3G equipment will be distributed in the respective rural town.

1.4.1 The first objective shows how much 3G sites are required to cover the rural area.

1.4.2 Whereas the second objective shows the distribution of 3G sites within the rural area. This can be shown in the table given below.

Table 1.1 Difference Between Objectives

Differences Between Objectives	
Objective 1	Objective 2
Shows number of 3G sites required	Shows where to install it.

CHAPTER 2

LITERATURE REVIEW

This chapter briefly explains the literature review on various methods in optimizing mobile networks. The proposed method used in this thesis is also explained in this chapter.

2.1 Previous Related Studies

Optimization in general means to make something function at its best or most effective, or use something to its best advantage. Optimization could be manipulated in many different ways in mobile communications network. Following are some methods of optimization.

Most literatures concerning the optimization of 3G systems are based on frequency management (Jiang & Hong, 2010; Song, Kim & Cheon, 2002; Ganesh, 1998; Veron, Beach & McGeehan, 2000), antenna design (Brunner & Flore, 2009), and broadcasting capability (Munaretto, Jurca & Widmer, 2010). Interestingly, there is a mathematical optimization approach for radio network planning of GSM/UMTS relevant to finding numbers of sites based on mathematical calculation (Al-Kanj, Dawy & Turkiyyah, 2009). However, they count only on number of 3G sites coverage, irrespective of whether the country can support installing the system or not. In addition, all assumptions are made on the cartographical information that would not be relevant to some of the developing countries.

2.1.1 Mathematical Method of Optimization

The mathematical method of optimization is the traditional method of optimization. The mathematical method consists of four main equations.

2.1.1.1 Minimize cost of deployment from Al-Kanj, Dawy and Turkiyyah (2009). This method aims to find new UMTS sites and reuse old GSM sites. The equation was defined as

$$C(n_1,n_2) = c_1 n_1 + c_2 n_2 \quad (2.1)$$

where n_1 represents new UMTS sites and n_2 represents reused sites.

2.1.1.2 Minimize GSM base station (BS) in existing GSM system from Al-Kanj, Dawy, and Turkiyyah (2009). This method aims to locate coordinates by choosing the optimal locations and dropping the unnecessary ones while guaranteeing capacity constraints. The equation was defined as

$$\min F(zi,Vi) = \sum_{i=1}^{No} \int_{s \in Vi} \rho(s) \, | s - zi |^2 \, ds \quad (2.2)$$

where zi is the initial point and

Vi is the Voronoi tessellation (known as Voronoi region).

$\int_{s \in Vi} s\rho(s)ds$ is the centroid and new set of points

This method is known as Lloyd method.

2.1.1.3 Optimization of finding new coordinates in existing GSM system using the ß% of the pole capacity. Here ß = 60% of pole capacity which is around 40 users found from Al-Kanj, Dawy, and Turkiyyah (2009). The equation is defined as under

$$while\left|\frac{1}{No}\sum_{i=1}^{No} Nu \bullet \int_{s\in Vi} \rho(s)ds - \beta K_{pole,}DL\right| \leq \varepsilon \; \{while \qquad (2.3)$$

average capacity per cell is not equal to ß% of the pole capacity} do 2.2.

This result gave new sets of points for UMTS site if centroid was resulted from the equations else the GSM site was selected to install new UMTS site. For this solution assumptions were made as follows

1. On geographical area described by cartographical information, and traffic demand derived from its topographical information.
2. user density distribution $\rho(s)$ where $s = (x, y)$ represents the coordinates of a given point within the area
3. ß% as 60%
4. Simulation area as 10 km x 10 km,
5. Number of user as 5000
6. *K*pol, DL as 67 with spreading factor of 128,
7. SIR_{MS} = 7 dB
8. λ =0.4
9. $\alpha_{av} = 0.55$

The advantage of mathematical optimization method is that new sets of point can be indicated for installation of GSM/UMTS. The disadvantages are as follows:

1. Cartographical information is not available for majority of the country. Therefore user density distribution cannot be taken into consideration.
2. These selected sites for installation of GSM/UMTS won't be feasible in a mountainous rural town. The selected points may fall in any mountain.
3. Simulation area is quite large and not feasible in a mountainous country where plain surface area is less.

This may cause unnecessary installation of 3G equipments from its new sets of point selected for installation. It will be costly to install the new site. Therefore, it is a new challenge to solve the optimization of 3G services in rural town where 2G are already installed and 3G will be installed along with 2G sites.

To cope with the optimization of 3G service sites in developing countries, some more criterions for consideration including profit, coverage areas, limited budget, average income per active user, ratio of active users per potential user and the capacity of the system are taken into consideration.

There is no previous work or studies on optimizing 3G service sites with respect to average income of the users, capacity of the system and number of active users. The adopted "Optimizing 3G service sites in rural area: a case study in context to Bhutan", not only reduces 3G sites and costs but also suggests installing services in profitable areas to generate revenue to the company.

2.2 Proposed Method

This thesis proposes two new methods in optimizing 3G services in rural area. The first part of the proposed method finds out the distribution of 3G services among rural towns which is modeled and optimized by the famous linear programming (LP). The proposed model considers both population coverage and expected income, which can be easily utilized by state telecommunication enterprise of any developing country. The example is made based on the case of three border towns of Bhutan. With flexible adjustment of parameters, the proposed technique provides tradeoff valued to investment.

The second part of the proposed method highlights the key area for the distribution of 3G services in rural town which is modeled by Genetic Algorithm (GA). Distribution of 3G service stations in rural towns is quite complex for a small developing country given its limited budget and government policy. This is also true to Bhutan where the state-run organization is responsible for 3G installation. As a part of the government, the organization must satisfy the needs of the people with adequate income ensuring its expansion and sustainability. Based on these constraints, Genetic Algorithm is used to suggest optimal distribution. The cost function is balanced between area coverage and expected traffic. The information for testing the proposed method is collected from Thimphu, where 3G is already installed that has resulted in quite a good solution providing very small overlap area among sites and acceptable generation of 3G traffic.

2.3 Linear Programming

A linear programming (Ferguson 1963; Dantzig, 1998; Chvatal, 1983; Sultan; Strayer, 2012) is a mathematical technique to solve the problem of maximizing or minimizing a linear function subject to linear constraints. The constraints may be equalities or inequalities.

None of the researcher has carried out the distribution of system or the optimization of 3G system in rural town. Therefore, it a big challenge to develop equation on optimization of 3G services in rural area by implementing linear programming method where the goal is to optimize the distribution of 3G services among rural town. The parameters of interest are the system capacity, rate of 3G users per existing 2G users, rate of income per 3G users, total investable stations and percentage of coverage. The goal is specified as growth rate of 3G users, which could be derived as a ratio of maximum capacity of the 3G equipment and expected user. The aim is to find the total number of stations and goal is to maximize the growth rate of the 3G users. With flexible adjustment of parameters, the proposed technique provides tradeoff valued to investment. This can be easily achieved my linear programming method. Therefore, in this thesis linear programming (LP) is deployed because it effectively solves the linear problems within a very short duration of time. It is much explained in chapter three.

2.4 Genetic Algorithm

Genetic algorithms (Fraser, 1957; Wolfgang, Peter, Robert & Frank, 1998; Melanie, 1999; Sastry, Goldberg & Kendall, 2005) are search methods based on principles of natural selection and genetics.

2.4.1 Maximum coverage

Maximizing coverage (Rahmani, Nematy, Rahmani & Hosseinzadeh, 2011) is defined as

$$X = 2r - distance(p1, p2) \tag{2.4}$$

where X is the overlap distance of two point p1 and p2.

r is the cell radius of points.

$$Total\_ideal\_coverage = n * (r * r * 3.14) \tag{2.5}$$

n is number of nodes in field.

$$Penalty(i) = (((X)^2) * 3.14) / 2) \tag{2.6}$$

X is the overlapping distance between the nodes or point P1 and P2

i is i^{th} cell of a node inside a voronoi cell

$Penalty(i)$ is the overlapping area.

$$Total\_penalty = \sum_{0}^{n} Penalty(i) \tag{2.7}$$

$$fitness = total\_ideal\_coverage - Total\_penalty \tag{2.8}$$

fitness is the value that is given to meet the requirement of the network. Here the fitness value is less to avoid cell overlap. When two nodes have overlap, their distance from each other is less than twice the radius.

The result of the above equation is that suitable places are allocated for maximizing the coverage area. Voronoi diagram is implemented for partitioning the sites for determining the wireless sensing network.

The advantage of this model is that the model is very simple to use and easy to locate node placement for maximum coverage. The disadvantage of this model is that in a complex environment the selected area will not be feasible for installation which means it cannot heal the coverage hole (Rahmani, Nematy, Rahmani & Hosseinzadeh, 2011). It is applicable for small wireless sensing network.

2.4.2 Optimize coverage

Optimize coverage (Yildirim, Kalayci & Ugur, 2008) is defined as

$$A_c = \sum_{i=0}^{width} \sum_{j=0}^{height} \begin{cases} 0, ifColor_{ij} isWhite \\ 1, else \end{cases} \tag{2.9}$$

$$F(C_i) = \begin{cases} -INFINITE, Q_0 \\ -(D_{cc} * N_{cc}), Q_1 \\ A_{c,} Q_2 \end{cases} \tag{2.10}$$

F(Ci) is the fitness of sensor which is represented in the form of chromosome.

where A_c is the coverage area of the site

Q_0 is not k-covered (not feasible)

Q_1 is k-covered not connected (not feasible)

Q_2 is covered, connected (feasible)

N_{cc} is product of number of connected components

D_{cc} is total of shortest distances between all connected components

$-INFINITE$ is if current individual does not satisfy k-coverage property

The result of the above equation gave optimal node distribution in a feasible time.

The advantage of the above method is that it is easy to conduct the feasibility of the node. However, the disadvantage is to find the minimum requirement of the node as mentioned as future study.

2.4.3 Optimize the Area Coverage

The optimization of area coverage in wireless sensor network (Xunbo & Zhenlin, 2011), was quite similar to (Rahmani, Nematy, Rahmani & Hosseinzadeh, 2011) which discussed on penalty value as fitness function.

The advantage of this method is that the battery life time power (Gil & Han, 2011) of the wireless sensing network improved by enhancing network coverage. The disadvantage is that more sites are required for area coverage.

So far the Optimization problem was based on maximizing area coverage by installing more sites, while at the same time maintaining the distance between the nodes in wireless sensing network. However, there are criterions in rural area while considering the optimization method. Criterion like income of the individual town and traffic of individual site and coverage area and services plays an important role in optimizing of 3G services within the city. This not only reduces the 3G sites but indicates wisely installation in profitable areas that generate income to the company thus providing tradeoff value to investment. For this reason genetic algorithm which is popular and flexible will be used in solving this problem. None of the above researchers have taken these criterions into consideration for optimal distribution of 3G sites in profitable 2G sites. The cost function will be implemented in this thesis.

Cost function here means the quantity of 3G sites required to cover the potential 2G sites which indicate the area covered by each 3G site with respect to the present 2G traffic. This can be simplified with the equation as given below.

$$goal = \frac{\sum_{i=1}^{n} E_i}{1 + \sum_{j,k \in N} \left(1 - \frac{d_{j,k}}{2r}\right) \left[\left(d_{j,k} < 2r\right) \wedge \left(j < k\right) \right]} \tag{2.11}$$

where “n” means the total number of installed stations

while “j” and

“k” present j^{th} and k^{th} installed stations.

Therefore, $d_{j,k}$ is the distance between any two installed stations. The numerator is the sum of average 2G transaction from selected sites based on Erlang unit.

where E_i is the average Erlang per specific duration of the i^{th} 2G station.

The distributions of 3G services in cities are different from distribution of 3G services among the cities. For this reason the genetic algorithm (GA) is used to reduce the intersected area of coverage. In this thesis, all goals and constraints in optimizing the 3G sites in rural towns of developing countries are presented in form of linear equations.

The above proposed models can be easily put to use by any state telecommunication enterprises of any developing country. The purpose of this thesis is ease the optimization problem of 3G services in rural towns by providing two methods of distribution which is much simpler as explained in latter chapters.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Research Methodology

This thesis proposes two new methods in optimizing 3G services in rural town. The first part of the proposed method finds out the distribution of 3G services among rural towns which is modeled and optimized by the famous linear programming (LP). The second part of the proposed method highlights the key area for the distribution of 3G services in rural town which is modeled by Genetic Algorithm (GA).

3.2 Linear Programming Model of the Distribution

As the goal is to optimize the distribution of 3G services among designed rural towns, the parameters of interest are capacity, rate of 3G users per existing 2G users, rate of income per 3G users, total investable stations, and percentage of coverage population. For these reasons a frame work is proposed in figure 3.1 illustrating the relationship between the different stages in the experimental process.

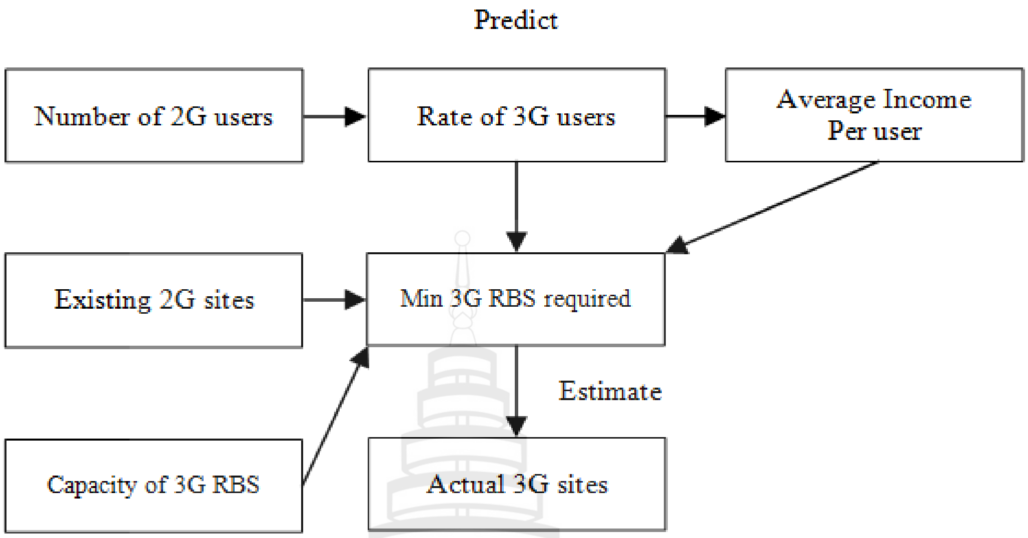


Figure 3.1 Prediction Framework of 3G sites

The prediction framework shown in figure 3.1 is self-explanatory. All constraints are mentioned in the framework. To find the minimum 3G service sites the radius of the cell is taken into account in the existing 2G network. The radius of the cell is 0.5 km according to Cooperation Scientific and Technical research (COST231) under cell classification that best fits to rural area (Ericsson, 2009). The Linear Programming (LP) has been used to find the feasibility of 3G sites. This will result in optimized solution to plan minimum number of sites with maximum profit while the goal is to serve several towns and cities.

From the above figure 3.1 it is assumed that 3G stations are installed in 2G sites and we know number of 2G users. The rate of 3G users are based on previously installed towns. Knowing the rate of 3G users, we can predict the 3G users. The average income per user of 3G is estimated from the previously installed towns. With the predicted 3G users we can predict the income too. However, the term capacity of 3G Radio Base Station (RBS) displays practical limitation. The capacity of one 3G RBS is 72 subscribers. With this value we can find number of 3G stations required from the total number of predicted 3G users from individual towns.

The relationship between each components of the prediction framework is as explained below:

3.2.1 Number of 2G users

This is the actual number of 2G subscribers.

3.2.2 Rate of 3G users

It is the ratio of 2G subscribers migrating to 3G. With this migration rate we can predict number of 3G users in existing 2G users. This rate presents ratio of the possible 3G users based on existing 2G users. The estimation of this rate is based on information from previously installed towns that are assumed equivalent to the target towns. This rate will be labeled as $R_{3/2}$.

3.2.3 Average Income Per Users

It is the estimated income from the existing 2G to 3G migration rate. This income rate can predict the potential of 3G subscribers. This rate, labeled as R_i, is also estimated from towns that are similar to the target towns. It presents rate of income in US$ per individual 3G subscriber in a month.

3.2.3.1 Potential Income

The overall monthly income of the whole project is roughly based on the use of $R_{3/2}$ and R_i along with 2G subscribers (G_{2i}) in each of n target towns.

$$income \cong \sum_{i=1}^{n} R_{3/2} R_i G_{2i} \tag{1}$$

However, this is the base income that can be expected according to current data which can be utilized to determine minimum number of installed station in each town (S_i). To effectively distribute service stations among towns, ability of growth of potential users is more important. The growth model is based on ratio of maximum capacity and expected number of users which is to be maximized.

$$growth \approx \sum_{i=1}^{n} \frac{S_i \times capacity}{R_{3/2} G_{2i}} \tag{2}$$

The term *capacity* displays practical limitation of each station.

3.2.4 Minimum 3G RBS Required

To optimize the 3G sites we require minimum 3G RBS sites. To have minimum sites it is a must to know the existing 2G sites and the capacity of the 3G RBS. With this information we can calculate the minimum 3G RBS required.

3.2.4.1 Existing 2G Sites

Existing 2G sites plays a crucial role in installing 3G sites. This is because all infrastructures required for 3G are already feasible in it.

3.2.4.2 Capacity of 3G RBS

Capacity here means the equipment capacity to cater 3G services to the subscribers. Knowing the capacity of the system, it is easy to find out number of equipments required to meet the subscriber demand 3G RBS is often known as "node b".

3.2.5 Actual 3G Sites

This is the estimated 3G sites from the mathematical calculation.

3.2.6 Total Service Stations

Within limited budget, the project can support a number of 3G service stations which must be distributed among *n* target towns as:

$$stations = \sum_{i=1}^{n} S_i \qquad (3)$$

where S_i is the number of stations to be installed in the i^{th} town.

3.2.7 Minimum Stations in Each Town

Each target town requires different number of minimum stations which must be able to support both estimated 3G users and percent of area coverage in each town indicated by the government (%area). Therefore, in combination, it is represented as:

$$\forall i \in [1..n]: S_i \geq \max\left\{ \left\lceil \frac{R_{3/2}G_{2i}}{capacity} \right\rceil, \left\lceil \frac{\%area \times size_i}{100} \right\rceil \right\} \qquad (4)$$

where $size_i$ is the town area of the i^{th} town. This can be easily solved by inserting the values in the equation shown below.

$$\forall i \in [1..n] : S_{Pling} \geq \max\left\{\left\lceil \frac{0.47x708}{72} \right\rceil, \left\lceil \frac{20 \times 19.68}{100} \right\rceil\right\}$$

Answer

5,4

From the above equation we can install five 3G sites in Pling town. Likewise we can use the same method with other towns too.

Suppose if you want to install 15 3G sites, then the equation would be as given under from equation (3).

$$15 = S_1 + S_2 + S_3$$

Here S_1 is town Pling

S_2 is town Gelephu

S_3 is town S.Jongkhar

The goal is to maximize the growth rate of the 3G users.

Maximize $growth = \frac{72}{333}S_1 + \frac{72}{102}S_2 + \frac{72}{97}S_3$ subject to $S_1 + S_2 + S_3 = 15$ where $S_1 \geq 5, S_2 \geq 2, S_3 \geq 8$

This result can be calculated by using linear calculator as shown in figure 3.2.

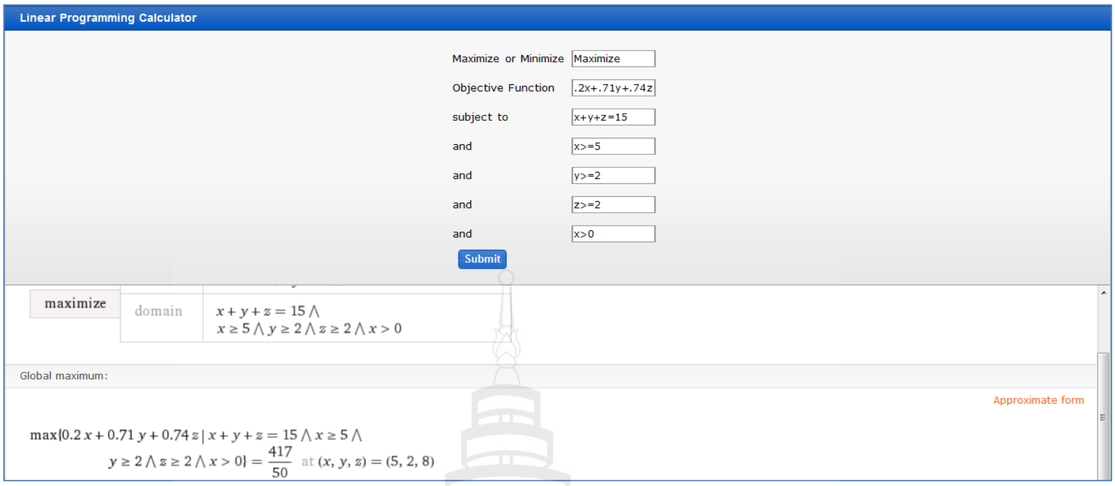


Figure 3.2 Linear Programming Calculator

The result is 5, 2, and 8 stations in the town of P.Ling, Gelephu, and S.Jongkhar respectively.

The process can be represented by a flow chart as show in figure 3.3. As the goal is to optimize the distribution of 3G services among designed rural towns, the parameters of interest are capacity, rate of 3G users per existing 2G users, rate of income per 3G users, total investable stations and percentage of coverage population. The first part is optimized by the famous linear programming method. The flowchart in figure 3.3 best describes the procedures in optimizing the 3G network by LP subjected to linear constraints.

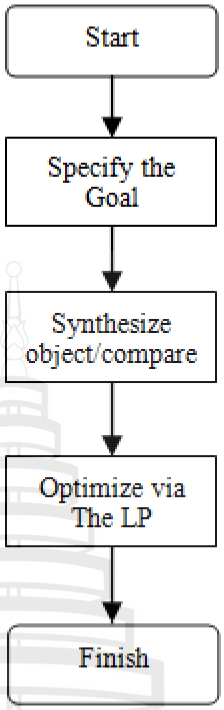


Figure 3.3 Flowchart to Maximize Growth Rate of 3G Users

From the explanation of the proposed framework and objective of the thesis, it is evident that growth rate of 3G users plays crucial role in generating income. Hence in the flowchart as shown above in figure 3.3 the goal is specified as growth rate of 3G users, which could be derived as ratio of maximum capacity of node b and expected user. The aim is to find the total number of 3G stations and the goal is to maximize the growth rate of the 3G users. By following the flowchart these results are as obtained in the above examples of 3 stations.

3.2.8 Total Investable Station

It is the actual selected stations for installation.

3.2.9 Percentage of Coverage Population

This is the actual mobile service coverage of the rural town, which is indicated by the government.

3.3 Genetic Algorithm Concept

Genetic algorithm (Fraser, 1957; Wolfgang, Peter, Robert & Frank, 1998; Melanie, 1998; Sastry, Goldberg & Kendall, 2005) is basically a natural selection technique in which a biological process of an individual is taken into consideration and strong individuals are selected. Here the individual stands for individual site within the city and the relationship between the sites/stations can be represented by a set of parameters like area coverage and traffic with coordinates of an individual. These parameters are the genes of a chromosome and can be arranged by a string of binary values. The positive values are known as fitness value which is used to reflect the degree of the goodness of the chromosome for solving the problem.

The advantage of GA is that it can easily develop solution without requiring detailed knowledge about the problem. It can search globally as well as it can adapt to the changing conditions in the problem. Though it is difficult to derive a solution for finding a better coverage by reducing the overlapping area to minimize cell sites for 3G network deployment as the space for all feasible solutions can be quite large, GA can efficiently be used to search an optimal solution to this problem as a powerful technique. Therefore the proposed method seeks to distribute the 3G services in rural towns depending on the present 2G network and its traffic.

Since the goal is to distribute the 3G service in rural towns, and the size of the town differs from place to place, the chromosome and cost function along with specific parameters will be used. The parameters like area and traffic play a crucial role in distribution of 3G network.

3.3.1 Chromosome

Chromosome here means individuality of the 2G Sites. These 2G sites are represented in binary form, i.e. in the form of 0s and 1s. This can further be explained by a simple diagram representing the site numbers from 1 to *n* stations as in figure 3.4 below.

1	.	.	.	.	n

Figure 3.4 Total *n* Station

Binary conversion method is as explained below.

Let there be *n* number of stations. These stations need to be converted into binary form or binary digits for machine to read it.

Here bit per station for *n* number of stations is represented as $\log_2 n$. This formula converts all *n* stations into binary form.

Suppose there are *m* selected stations. This can be converted to $m\log_2 n$. The figure 3.5 below shows a sample of chromosome of *m* selected stations.

0001 0010 0101 0110 ….

Figure 3.5 *m* Selected Stations

The length of the chromosome depends on number of 2G sites required for installing 3G service sites. If you need to select four 2G sites for installation of 3G services at a time due to budget constraints, you would have at least 16 bits representing the chromosome. This is because each site has 4 bits. Therefore when you increase sites, an addition of 4 bits adds to the chromosome each time you increase your size. Thus five sites would represent 20 bits.

In this thesis we have fourteen 2G sites from which we are going to select only four 3G sites. Therefore, four sites would have 16 bits representing the chromosome. A sample of 16 bits chromosome of stations 10, 9, 14 and 13 is as under.

1010 1001 1110 0011

Figure 3.6 Chromosomes of Stations 10, 9, 14 and 13

3.3.2 Cost Function

Cost function here means the quantity of 3G sites required to cover the potential 2G sites which indicate the area covered by each 3G site with respect to the present 2G traffic. This can be simplified with the equation as given below.

$$goal = \frac{\sum_{i=1}^{n} E_i}{1 + \sum_{j,k \in N} \left(1 - \frac{d_{j,k}}{2r}\right) \left[\left(d_{j,k} < 2r\right) \wedge \left(j < k\right) \right]} \qquad (5)$$

where "n" means the total number of installed stations

while "j" and

"k" present j^{th} and k^{th} installed stations.

Therefore, $d_{j,k}$ is the distance between any two installed stations. The numerator is the sum of average 2G transaction from selected sites based on Erlang unit.

E_i is the average Erlang per specific duration of the i^{th} 2G station.

Knowing the number of minimum 3G stations, where to install is as per the criterion and this is a must. A mathematical equation therefore is developed for this purpose.

Let us consider the radius of the cell as r. The separation between 2 cells would be $d_{j,k}$, which should be more than 2r or equal to 2r. If the distance between j^{th} and k^{th} stations is less than 2r, it means the cell is overlapping indicating overall reduced covered area.

The main idea of using this method is to arrange the sites according to the site relationship between the neighboring sites to eliminate the intersected sites to reduce the number of sites to be installed which as a result will save the investment. Such type of relationship between the cell sites could be considered as genetic relationship where each cell has its own neighboring cell with respect to distance.

This problem best describes the *genetic algorithm (GA)*. For this reason the *combinatorial optimization* method to find the best cell within the numerous cells would be implemented in cell selection problem. However, the result generated would be quite large in a complex 2G network which indicates more *feasible sites* for 3G installations. As a changing condition, the radius of the cell is taken into account in this proposed method. In addition to this, the traffic of individual cell could be used to reduce cell sites. This means that the cell with more traffic would definitely have more subscribers. With the entire problem as defined above, the GA can *efficiently* solve numerous complicated problems where site selection choices are put into constraints.

This can be simply illustrated as shown in figure 3.7. Assume that the mobile station lies in x and y axis.

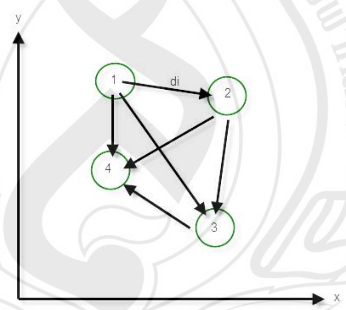


Figure 3.7 Sample of 2G Network

The pseudocode of cost functions is as shown below.

```
r= 500 m
station [1…n]
for j=  1 to n
        for k= 1 to n
        if j<k
                d=contour distance between j^th and k^th station
                if d<2r
                denom= denom + (1 - d/(2*r))
                erlsum= \sum_{i=1}^{n} erl_i
                cost= erlsum/denom
```

where r is the radius of the cell in meter

d is the distance between 2 stations

dnom is the denominator of the equation

erlsum is the total erlang sum of individual stations

cost is the cost function

Knowing required number of minimum 3G stations in a given town, it is also a must to know where to install them as per criterions. Therefore a mathematical equation is developed for the distribution of 3G services.

Let us consider the radius of the cell as *r* and the separation between 2 cells are distance *i*, which is more than 2*r* or equal to 2*r*. If the distance "*i*" is less, it means the cell is overlapping. Thus this cell would not be selected for installing 3G. Likewise if distance "*i*" is more than 2*r* it is selected.

$$\forall di \geq 2r \tag{6}$$

From the above sample, 2G network cell 1 can make 3 moves, cell 2 can make 2 moves and cell 3 can make 1 move. The condition for each cell is that the distance between each cell should be greater than twice the radius of the cell.

Suppose we are measuring distance between two coordinates on spherical earth, the distance of point on earth could be measured using Spherical Law of cosine since it gives the best result approximate to 1 meter. This formula is used for measuring the distance between each cell.

$$d = ACOS(SIN(lat1)xSIN(lat2) + COS(lat1)xCOS(lat2)xCOS(lon2 - lon1))x6371 \quad (7)$$

here "lat1" and "lat2" and "lon1 and lon2" are two latitude and longitude points of given site and mean radius is 6,371km (is the earth’s radius).

The pseudocode to measure the spherical distance on earth surface is as shown below.

erad = 6371000 m

$d = ACOS(SIN(lat1)xSIN(lat2) + COS(lat1)xCOS(lat2)xCOS(lon2 - lon1))x6371$

where erad is the mean radius of the earth

d distance is the between two points

lat,lon are the coordinates of the points

Note that angles are in radians to pass to trigonometry functions.

This would allow in finding the relationship between each component and solve the problem of installation of 3G sites in profitable areas and the input as the selected towns of profitable customers. The goal is to optimize 3G services to the profitable areas, at the same time minimize the digital divide by providing it to the revenue generating area.

3.3.3 Area

Area here means the actual area covered by the individual site. The radius r is equal to 500 meters according to Cooperation Scientific and Technical research (COST231) for rural area (Ericsson, 2009).

3.3.4 Traffic

Traffic is the actual record of the call information required for justifying the requirement of 3G network. This would also depend on type of area (dense urban, urban, suburban, rural and road) and referring to the topography of the country, urban best suits for designing 3G network in Thimphu, Bhutan. From my previous work, the number of 3G sites depend on the number of 2G users. This implies that more the 2G users, there are high chances of 3G users too. Here, approximate 3G users can be calculated using the rate of 3G users per existing 2G users multiplied by the number of 2G users.

Thus more traffic means more 2G users. More 2G users would imply potential 3G users. This indicates that there is the requirement of 3G stations provided that the objective is met.

Traffic therefore plays an important role in implementation of the 3G network.

3.3.5 Location of 2G Sites

The existing location of the 2G system plays a vital role in implementing 3G stations. Location here means the coordinates of the 2G sites. Coordinates of the 2G site is very important because all 3G sites are installed in 2G sites. With the coordinates one can install 3G in right location as per design result. The benefit here is that it saves time to locate site including overhead cost, transmission link, power, shelter and tower. The location of 2G sites can be plotted in x and y axis as shown in figure 3.8.

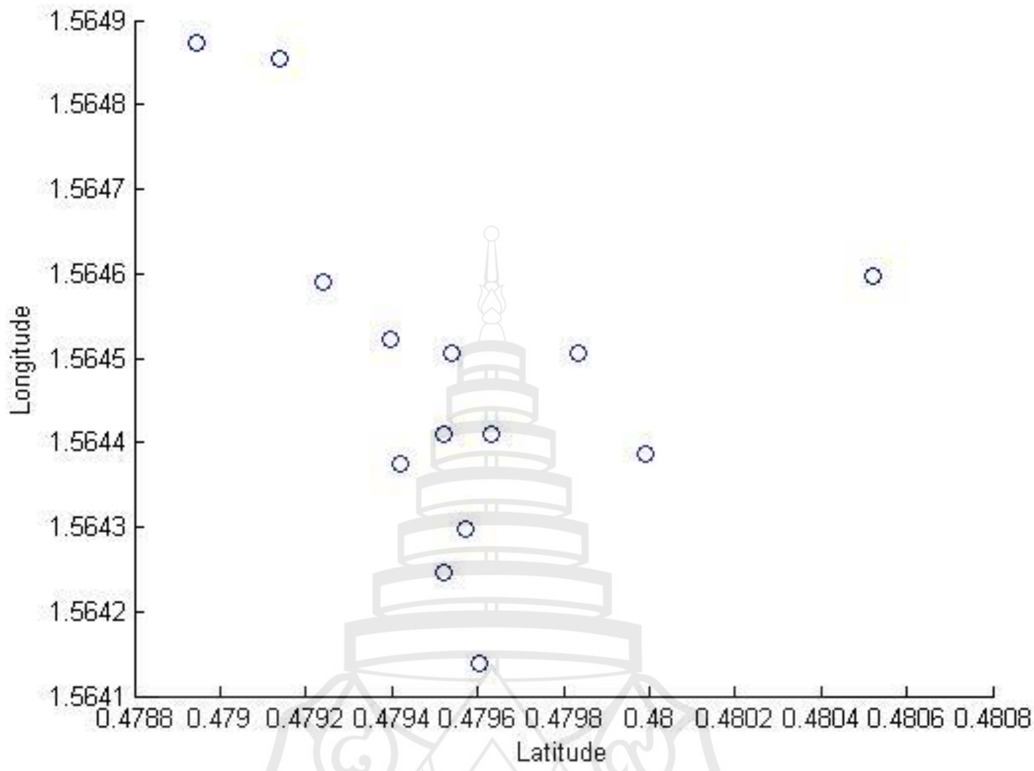


Figure 3.8 Location of 2G Sites

CHAPTER 4

ANALYSIS AND DISCUSSION

4.1 Design Example by Linear Programming Model

With the high end devices seeded in the market the need to challenge to provide 3G came to existence. The requirement of 3G Universal Mobile Telecommunications System (UMTS) was considered as the best solution to provide internet facilities to the people of Bhutan. Therefore 3G was considered as the most appropriate option in providing high speed data. However, 3G equipment being very expensive, the place to be installed needs to be optimized with reference to the revenue generated from the present GSM or 2G network. Therefore, Thimphu being the most revenue generating town with maximum users of mobile end user equipment, it was selected as the first town to install 3G

Trial installation of Radio Network Controller (RNC) and 14 3G node b began in 2008 and launched 3G, EDGE and GPRS on 5th May 2008. This project seems to capture more users. Based on the present 2G to 3G migration rate, following towns are marked as prospective places, particularly the southern belt bordering the Indian towns of Gauhati in the east, Dathgari in the central and Jaigong in the west. The reasons being that these places are the trading hubs for the Bhutanese Merchants. Also all the regional head offices are located in these areas, thus making it more reliable in terms of managerial and technical support for the survival of 3G network. This is because 3G network requires more technical people for maintenance of the system that is available in the regional head office. For this reason regional head offices are prime spots for 3G network.

Taking all the possible manpower and resources into consideration, proposed location for installation of 3G network has been narrowed down to three main border towns of Bhutan as shown in figure 4.1. These selected towns are P.Ling, Gelephu, and S. Jongkhar.

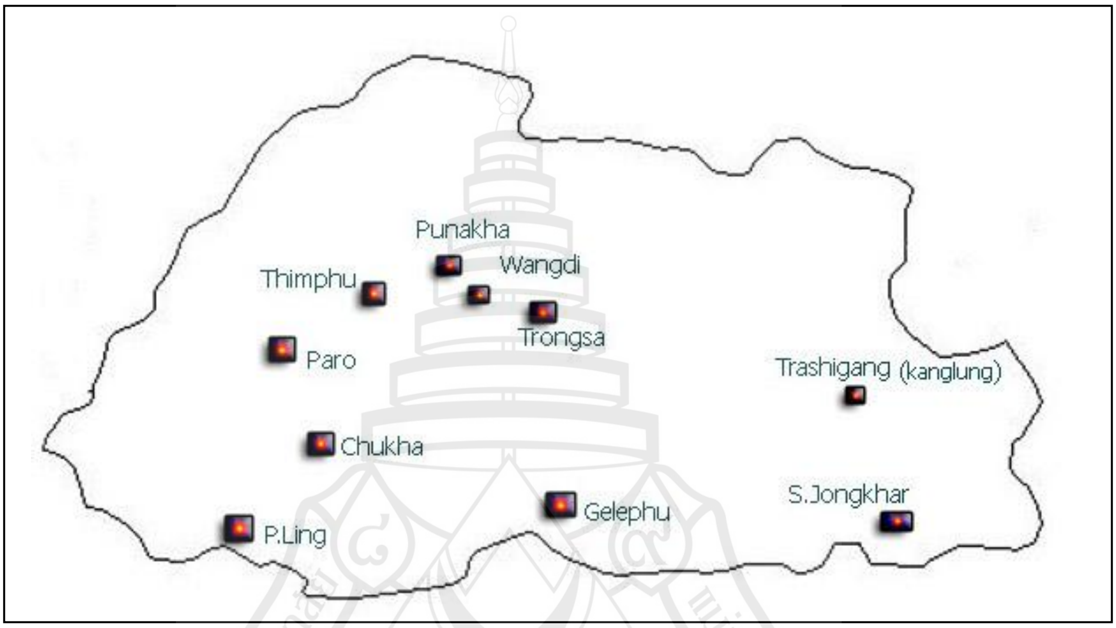


Figure 4.1 Sample Design of Three Border Towns of Bhutan

4.1.1 Constraint Estimation

In this subsection, important constraints and their components will be estimated based on practical information.

4.1.1.1 Rate of 3G User per existed 2G users

To estimate this migration rate, observed number of 3G and 2G users existed in the capital Thimphu is put to account which is resulted in $R_{3/2} = 0.47$.

4.1.1.2 Rate of income per 3G users

To estimate this value, collected monthly income based on the capital is divided within each month subscribers. Therefore, the estimated monthly R_i is \$2.1 per user.

4.1.1.3 Capacity

The 3G sites are often known as node b. The type of node b as of now is RBS 3418, 3206 and 6202 series. To guarantee quality of certain 3G services, the capacity of each node b is approximated at 72 users.

4.1.1.4 Service AreaThe standard used in our organization for urban town is defined at 0.78 km^2 per node b.

4.1.1.5 Total investable stations

Combining both budget from Universal Service Fund and Bhutan Telecom, the number of stations to be distributed among three selected bordered towns is approximately 9 stations.

4.1.2 Design Issues

Design issues collecting all constraints are listed in APPENDIX C based on the selected towns of P.Ling, Gelephu, and S.Jongkhar.

4.1.3 Goal Definition

To ensure future profit, the combined growth rate of 3G users in all towns must be maximized which can be modeled as

$$growth \cong \frac{5\times 72}{0.47\times 708}+\frac{2\times 72}{0.47\times 216}+\frac{2\times 72}{0.47\times 206}=4$$

S_1, S_2 and S_3 are the selected towns which represent P.Ling, Gelephu, and S.Jongkhar, respectively. Based on this example, solution space is based on three variable S1, S2 and S3 which yield one equality and six inequalities constraints. The result is 5, 2, and 2 stations in the town of P.Ling, Gelephu, and S.Jongkhar respectively.

4.1.4 Flexible Adjustment of Parameters by Linear Programming

The flexible adjustment simply means that the constraint values can be altered to meet the requirements of the company. For example the 2G user might grow with time and also the rate of income might increase with growth in 2G users. For this reason the word flexible is used. The proposed method has range of field setting to meet the requirements of any company. It is very simple yet effective in finding numbers of sites required. This method is suitable for surveying investment solutions as parameters can be adjusted to meet alternative policies.

Taking all the possible manpower and resources into consideration, proposed location for installation of 3G network has been narrowed down to three main border towns of Bhutan as shown in figure 4.1. However, the scope of the proposal is to provide 3G network throughout the country depending on the demand of the people and availability of budget with the company in the years to come.

A sample design, based on three border towns of Bhutan, is presented in this section. Constraints are listed in APPENDIC C with the objective to maximize overall income per month. To solve such equations, the famous linear programming method is utilized.

S_1, S_2 and S_3 are the towns that require minimum number of 3G sites. However, these towns have individual sites depending on the area and number of users. The number of stations should be greater than or equal to the capacity of the system.

4.1.4.1 Capacity of the system: The 3G sites are often known as node b. The type of node b as of now is RBS 3418, RBS 3206 and RBS 6202 series. To guarantee quality of certain 3G services, the capacity of each node b is approximated at 72 users.

The capacity of the system is the Capacity of Node B.

$$Total\_Capacity = 72 \qquad (1)$$

Here the capacity is the capacity of number of subscriber it can have. In 3G WCDMA UMTS node b, capacity depends on five things. The five things are as listed below.

1. Capacity: means the coverage area. If the subscriber is near the node b, it uses less power therefore increase the capacity. That means that more data rate can be transferred between user equipment and the node b because there is less noise. Hence larger area can reduce capacity.

2. Signal Quality: If the service quality requirements are high, the cell size decreases. Cell interference (including interference with cell, interference from other cells, and interference from other sources) also reduces capacity.

3. OVFS code: Orthogonal Variable Spreading Factor is a hard limit of 3G. Only adding the cell can increase the capacity. This means that code is equal to resource.

4. Channel Element: Baseband processor components. This is shared by all the cells of a node B. This means that all the cells use the same resources.

5. Iub bandwidth: This is the interface bandwidth from node b to radio network controller (RNC). License and limitations of equipments also play very important role in increasing the capacity of the network. However, the most important capacity constraint in WCDMA 3G technology is the code and power. Therefore, the user equipment far from the cell will experience poor data transfer rate compared to user equipment nearer to the cell.

The main idea of this proposal is to make good use of the 3G network by optimizing sites and providing it in a profitable area.

4.1.4.2 Number of 2G users: For installing 3G network we require 3G mobile users or user equipment (UE) or end user (EU), specified by different terminology. These users are actually the 2G users who migrate to use 3G network.

$$Total\_2G\_User = 3960 \quad (2)$$

Thimphu being the capital city with majority of high end mobile users, the 2G users of Thimphu is taken into account. As of March 2011, there were 3,960 2G subscriber and 1,875 3G users.

4.1.4.3 Average income of the users of a town: With average income of the users, we can approximate the income of 3G users with the formula. Total income divided by number of users. This could be done monthly or yearly depending on the availability of the data. The value below is in terms of US dollar.

$$Avg\_Income\_town\_per\_User = \frac{3944.60}{1875} = 2.10 \quad (3)$$

The average income as of March 2011 is $2.10 per month per user.

4.1.4.4 Rate of 3G user: It is the migration of 2G users to 3G users. It is the ratio of 3G to 2G.

$$Rate\_of\_3G\_Users = \frac{1875}{3960} = 0.47 \quad (4)$$

4.1.4.5 Income: The overall income per month as of March 2011 for the project is as given below in terms of US dollar. The details are listed in APPENDIX A and APPENDIX C.

$$income = 0.47 \times 2.10 \times 3960 = 3908.52 \quad (5)$$

The migration rate of 2G to 3G is 0.47 as calculated from 2, which is almost 50% migration. This shows the potential of 3G network which motivated in installing 3G Service sites.

4.1.4.6 Growth Rate of 3G user: The ability of growth of potential user is more important to generate income. Thus the growth rate could be derived as ratio of maximum capacity of node b and expected user.

$$growth \cong \frac{5 \times 72}{0.47 \times 708} + \frac{2 \times 72}{0.47 \times 216} + \frac{2 \times 72}{0.47 \times 206} = 4 \quad (6)$$

4.1.4.7 Minimum Stations in Each Town: Each target town requires different number of minimum stations which should be able to support both estimated 3G users and percent of area coverage in each town indicated by the government (%area). Therefore, in combination, it is represented as:

$$\forall i \in [1..n] : S_{Pling} \geq \max\left\{\left\lceil \frac{0.47x708}{72} \right\rceil, \left\lceil \frac{20 \times 19.68_i}{100} \right\rceil\right\} \quad (7)$$

Answer

5,4

$$\forall i \in [1..n] : S_{Gelephu} \geq \max\left\{\left\lceil \frac{0.47x216}{72} \right\rceil, \left\lceil \frac{20x5.85}{100} \right\rceil\right\}$$

Answer

2,2

$$\forall i \in [1..n] : S_{Sjongkhar} \geq \max\left\{\left\lceil \frac{0.47x206}{72} \right\rceil, \left\lceil \frac{20x1.94}{100} \right\rceil\right\}$$

Answer

2,1

where $size_i$ is the town area of the ith town.

For Pling town the results are 5 and 4. As per the equation the maximum value is selected. Thus in Phuntsholing we require five numbers of 3G service sites. Likewise for Gelephu and Sjongkhar two numbers of 3G service sites are required. This is much explained in "total service stations" as there is every chance of the growth of 2G users. With more 2G users, we require more 2G sites. This means that the more the 2G sites are, the more the 3G sites are likely to increase. The example below clearly explains the total number of 3G sites. The total number of 3G sites should not cross the capacity of the system too.

4.1.4.8 Total service stations: The total service station is the sum total of all towns which can be calculated as below.

Suppose the sum total of the town is 15 then the equation would be as under.

$$15 = S_1 + S_2 + S_3$$

The goal is to maximize the growth rate of the 3G user.

Maximize $growth = \frac{72}{333}S_1 + \frac{72}{102}S_2 + \frac{72}{97}S_3$ subject to $S_1 + S_2 + S_3 = 15$ where $S_1 \geq 5, S_2 \geq 2, S_3 \geq 8$

$$S_1 \geq 0, S_2 \geq 0, S_3 \geq 0$$

The above example shows solution space based on three variable S_1, S_2 and S_3 which yield one equality and six inequalities constraints.

4.1.5 The Results of Linear Programming

The result is 5, 2, and 8 stations in the town of P.Ling, Gelephu, and S.Jongkhar respectively. This model proves that linear programming can distribute 3G services among the rural towns. Comparison can be visually seen depending on the area of the individual town. The number of target towns indicates dimension of solution and number of constraints. The method is very suitable for surveying investment solutions as parameters can be adjusted to meet alternative policies.

However, the main aim and objective of this thesis is to optimize 3G service sites in rural area. The calculated results therefore need to be distributed in such a way as to give the optimum distribution. To obtain such results, the genetic algorithm (GA) is utilized.

4.2 Design Example by Genetic Algorithm

To show the effectiveness of our method, the already installed 3G sites in the capital Thimphu are virtually revised. In 2011, fourteen 3G sites were installed. Therefore, the outcome of installation is already known by now. Our problem is to optimally select four out of fourteen sites for installing 3G services. Based on the information on the locations of these fourteen sites and their average summary of 2G traffic for a quarter year of each site, the solution is evaluated with real 3G traffic generated in the year 2012. The results of the 2G traffic were taken from October to

December 2011. This is because all fourteen 3G sites were not commissioned until September 2011. Thus the quarterly result was taken as an experiment value.

4.2.1 City Background

Thimphu being the capital city of Bhutan has the highest population. From among many reasons, the most important is the rural urban migration. This is because of rapid socio economic activities and facilities like employment opportunities, easy mode of travel and transportation, town life, life style, living standard and access to amenities that are readily available in town areas as compared to rural areas. Thus Thimphu has the highest population. Taking into consideration the living standard and life style and also the present trend of technology with high end users, the requirement of 3G network has become a must in a town. However, 3G equipments being more expensive, the same needs to be installed in profit generating areas. Thimphu has thus been selected for installing the 3G network in Bhutan.

4.2.2 Location of Interested 2G Sites and Their Traffic

Location in this thesis means the coordinates of the individual sites in a town. The coordinates of fourteen 2G sites selected for installing 3G services are shown in APPENDIX D and their traffic in erlang are shown in APPENDIX E and F respectively. APPENDIX E shows the 2G traffic and APPENDIX F show the 3G traffic. The location of interested 2G sites can be plotted in x and y axis as shown in figure 3.8 of chapter 3.

4.2.3 GA Configuration

As we have to select four out of fourteen sites, the binary chromosome of the length 14 bits is implemented with restriction of only 4 bits per selected sites.

4.2.4 Solution

Based on several runs, only one solution is suggested by the proposed method which is composed of these sites.

4.2.4.1 Thimphu Town.

4.2.4.2 Thimphu Simtokha.

4.2.4.3 Thimphu Chang Gangkha.

4.2.4.4 Thimphu Chang Zamtok .

These four sites provide no overlap among them which will enable the maximization of 3G traffic. Out of fourteen 2G sites, four are graphically presented in figure 4.2.

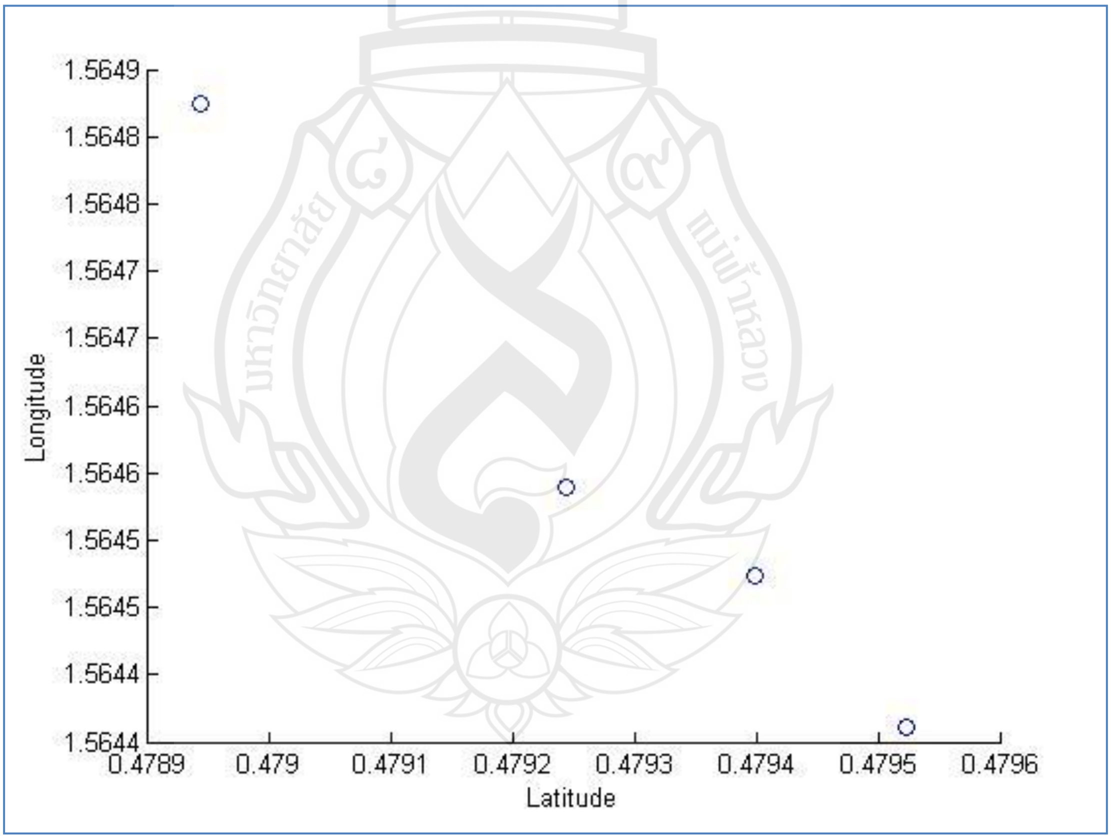


Figure 4.2 Selected 3G Service Sites for Installation

Compared to figure 3.8 in chapter 3, the figure 4.2 gives the maximum coverage base on four 3G service sites. This method eliminates overlapping cell and at the same time solves cell coverage area. This saves capital cost for the company and at the same time meets the service requirements of the people. However, 3G sites are installed depending on the capital budget for a fiscal year. Thus out of fourteen sites only four 2G sites are selected for installing 3G services at a time. The method of selection is based on the traffic of the existing 2G sites with respect to their coordinates provided these sites are within the radius of 2r or greater than 2r. This is as explained in the cost function.

The selected sites are plotted on Google Map for proper identification of the sites. The four selected sites are 14S, 13S, 2S and 3S. These four sites provide no overlap with highest traffic. The 3G traffic from January 2012 to June 2012 is as shown in APPENDIX E.

The average traffic generated by the existing fourteen 3G sites from January 2012 to June 2012 validates the proposed method and shows that the selected sites have more traffic compared to unselected sites.

Comparing the traffic results of fourteen 3G Sites, the four selected sites proved to be valid for considering this proposed method. The comparison table of the existing four selected 2G traffic and the known result of 3G sites is as shown below in table 4.1.

Table 4.1 Traffic Comparison Table of Selected 3G Sites

Sites	2G Traffic	3G Traffic	Remarks
14S	67,542.83	311.55	Selected
13S	50,896.27	366.99	Selected
2S	48,105.16	283.22	Selected
3S	46,497.80	381.14	Selected

The experimental results show that implemented genetic algorithm can provide optimal network distribution in the existing 2G network while taking care of traffic and overlapping cells. This algorithm can prioritize site for installation in a town or city when you have budget constraint and government policy to introduce 3G services.

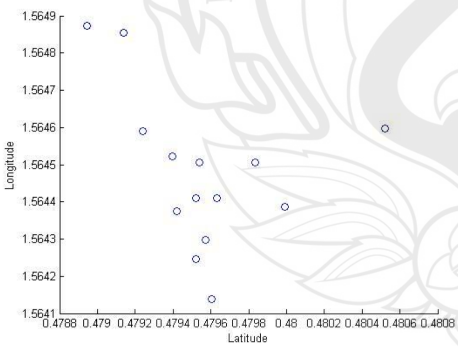
4.2.5 Experimental Results of Genetic Algorithm

From the experimental result of genetic algorithm the distribution of 3G services in the rural town can be optimized by using the genetic algorithm.

4.2.6 Scatter Chart on Existing 3G Services and Experimental Result

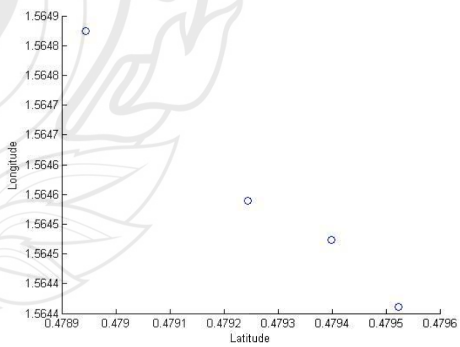
The figure 4.3 compares the existing 3G network and experimental result. The experimental result clearly shows that less 3G sites can achieve same coverage. The advantages and disadvantages of existing 3G services and experimental results are given in the tables 3.8 and 4.2. The figure 4.3 depicts the existing 3G network and experimental result after optimization.

Existing 3G Network System



Fourteen 3G sites

Experimental Result



Four 3G sites

Figure 4.3 Scatter Chart on Existing 3G Network and Experimental Result

The advantages and disadvantages of the existing 3G are shown in table 4.2.

Table 4.2 Existing 3G Network System

Advantages	Disadvantages
	1. Uneven distribution of network
1. Installed on as and where is basis	2. Uneven traffic
2. No calculation required	3. More sites required
3. Easy installation	4. More budget required
	5. Signal pollution

The experiment result of genetic algorithm is as shown in table 4.3.

Table 4.3 Experimental Result

Advantages	Disadvantages
1. Distribution of network maintained	1. Record individual 3G site traffic
2. Balance of 3G traffic	2. Record individual 3G site coordinate
3. Improved network quality	
4. Less 3G sites	
5. Less budget required	
6. More economic	
7. More cost saving	
8. Healthy environment	

4.2.7 Results of the Model

From the first part of the linear programming model, we can find out the distribution of 3G sites for network coverage. This method is suitable for surveying investment solutions as parameters can be adjusted to meet alternative policies.

The second part of the genetic algorithm experiment suggests optimal selection of installing site with very little overlap among stations and acceptable generated traffic. This method could be implemented in any wireless environment where the radius of the transmitter is maintained with the other transmitter for the same function. The advantages of implementing the genetic algorithm for distribution of 3G service sites are as listed below.

1. Easy to identify potential 3G service sites within the 2G sites.
2. Very fast to calculate budged required for 3G service sites.
3. Results can be made in pictographic form.
4. Handy for top level management to make immediate decision.
5. Forecast future expansion.
6. Time saving for any network expansion work.
7. Could be implemented in any wireless network.

CHAPTER 5

CONCLUSION

In developed countries, 3G services are common and are usually provided by several private operators with almost 100% coverage. However, the situation is quite different in most developing countries where the majority of the population lives under poverty. In these countries, telecommunication services are provided by state enterprises which cannot make profits but have to support people as well. Compromise is therefore made in order to serve people within acceptable profits. This paper presents the distribution of 3G services among rural towns in Bhutan modeled and optimized by the famous linear programming. The proposed model considers both population coverage and expected income which can be easily utilized by state telecommunication enterprise of any developing countries. The example is made based on the case of three border towns of Bhutan whereby with flexible adjustment of parameters and the proposed technique provides tradeoff valued to investment.

Distribution of 3G service stations in rural towns are quite complex for small developing countries since they are mostly based on limited budget and rigid government policies. This is also true to Bhutan where the state-run organization (Bhutan Telecom) is also responsible for 3G installation. As a part of government body, the organization must satisfy people with adequate income for its survival as well as for its expansion. For optimizing the distribution of 3G service sites in rural towns in Bhutan, combination of linear programming and genetic algorithm is proposed as it gives the best result in optimizing 3G service sites in rural towns. Genetic Algorithm is utilized to suggest optimal distribution. The cost function is balanced between area coverage and expected traffic. The information from installed station at Thimphu was collected and tested with the proposed method which resulted in providing very small overlap area among sites within acceptable 3G traffic.

The proposed framework seeks to maximize income for a state telecommunication enterprise while maintaining its duty to support people. The problem is modeled for the famous linear programming optimization where the number of target towns indicate dimension of solution and number of constraints. The method is very suitable for surveying investment solutions as parameters can be adjusted to meet alternative policies.

The cost function is balanced between predicted traffic and area coverage as the experiment information is based on the already existing 3G installation of the capital city, Thimphu. The solution suggests optimal selection of installing site with very little overlap among stations and acceptable generated traffic.

5.1 Recommendation

For a country like Bhutan the linear programming and genetic algorithm method of distribution of 3G services in rural towns is the best method for optimizing the 3G services. This method could be implemented in any wireless environment in the telecommunication system for the reason that the use of flexible adjustment of parameters as per design will result in providing tradeoff value to investment.

The linear programming model shows the total number of 3G sites required for network coverage in the country. This method is suitable for surveying investment solutions as parameters can be adjusted to meet alternative policies.

The genetic algorithm model suggests optimal selection of appropriate site for installation. This increases cell utility and ensures traffic balance in the network system.

5.1.1 The Advantages Are as Under.

5.1.1.1 Easy to identify potential 3G service sites within the 2G sites.

5.1.1.2 Very fast to calculate budget required for 3G service sites.

5.1.1.3 Results can be made pictographic, which is easy to understand.

5.1.1.4 Handy for top level management to make immediate decision.

5.1.1.5 Forecast future expansion.

5.1.1.6 Time saving for any expansion work.

5.1.1.7 Implement in any wireless network.

REFERENCES

REFERENCES

Sultan, A. (2012). *Linear Programming: An Introduction with Applications* (2 ed.). Retrieved August 03, 2012, from http://www.amazon.com/Linear-Programming-Introduction-Applications-Edition/dp/1463543670#reader_1463543670

Al-Kanj, L., Dawy, Z. & Turkiyyah, G. (2009). A Mathematical Optimization Approach for Radio Network Planning of GSM/UMTS Co-Siting. *Communications, 2009. ICC '09. IEEE International Conference* (pp. 1-5). Dresden: Germany.

Wolfgang, B., Peter, N., Robert, K. & Frank, F. (1998). Genetic Programming: *An Introduction. San Francisco*. CA: Morgan Kaufmann Publishers.

Barry, B., Barton, C., Chukwuma, V., Cottrell, L., Kalim, U., Petitdidier, M. & Rabiu, B. (2010). eGY-Africa: Better Internet connectivity to reduce the digital divide. *IST-Africa, 2010* (pp. 1-15). Durban: South Africa.

Bristow, P. (2009, October). The Digital Divide an age old question?. In *World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*, 2009(1), 2394-2397.

Brunner, C. & Flore, D. (2009). Generation of Pathloss and Interference Maps as SON Enabler in Deployed UMTS Networks. *Vehicular Technology Conference, 2009. VTC Spring 2009. IEEE 69th* (pp. 1-5). Barcelona: Spain

Chvatal, V. (1983). *Linear Programming.* New York: W.H. Freeman & Co.

Dantzig, G.B. (1998). *Linear Programming and Extensions*. 41 William Street, Princeton, New Jersey, USA: Princeton University Press.

Ericsson, (2009). *WCDMA RAN P7 Design*, Student Book LZT 123 8984 R2A.

Ferguson, T.(1963). UCLA Department of Mathematics. *LINEAR PROGRAMMING.* Retrieved August 03, 2012, from http://www.math.ucla.edu/~tom/LP.pdf

Fraser, AS. (1957). Simulation of genetic systems by automatic digital computers. I. Introduction. *Australian Journal of Biological Sciences*, *10*(4), 484-491.

Ganesh, R. (1998). Dual mode CDMA networks: capacity, planning and optimization. *Electro 98. Professional Program Proceedings* (pp. 221-239). Boston, MA: US.

Gil, J. & Han, Y. (2011). A Target Coverage Scheduling Scheme Based on Genetic Algorithms in Directional Sensor Networks. *Sensors 2011*, *11*(2), 1889-1906.

Jiang, Z., Hong , W., Tian, L., Xu, W. & Liu , J. (2010). Design of a triple-band scanner for TD-SCDMA network planning and optimization. *Communication Technology (ICCT), 2010 12th IEEE International Conference* (pp. 1220-1223). Nanjing: China.

Joseph, I.M. & Nath, A. (2012). Digital Divide: A comprehensive approach to Integrate State and community experiences into ICT Policy Framework from Indian perspective. *World Congress on Information and Communication Technologies* (pp. 383-388). Trivandrum: India.

Kezang, K. & Whalley, J. L. (2004). Telecommunications in the land of the thunder dragon: Recent developments in Bhutan. *Telecommunications Policy*, 28(11), 785-800.

Meinrath, S.D., Losey, J. & Lennett, B. (2011). A Growing Digital Divide: Internet Freedom and the Negative Impact of Command-and-Control Networking. *Internet Computing*, *15*(4), 75-79.

Melanie, M. (1999). *An Introduction to Genetic Algorithms* (5 eds.). London: A Bradford Book The MIT Press.

Munaretto, D., Jurca, D. & Widmer, J. (2010). Scalable video broadcast in cellular networks: impact on QoS and network resources. *Computers and Communications (ISCC), 2010 IEEE Symposium* (pp. 969-974). Riccione: Italy.

Rahmani, N., Nematy, F., Rahmani, A.M. & Hosseinzadeh, M. (2011). Node Placement for Maximum Coverage Based on Voronoi Diagram Using Genetic Algorithm in Wireless Sensor Networks. *Australian Journal of Basic and Applied Sciences,5*(12), 3221-3232.

Sastry, K., Goldberg, D. & Kendall, G. (2005). Genetic algorithms. *In Search Methodologies* (pp. 97-125). Springer: US.

Song, T., Kim, D. & Cheon, C. (2002). Optimization of sectorized antenna beam patterns for CDMA2000 systems. *3G Mobile Communication Technologies, 2002. Third International Conference on (Conf. Publ. No. 489)* (pp. 428-432). Hyundai Syscomm: Korea.

Strayer, JK. (2012). Linear Programming and Applications. *Springer-Verlag.*

Sukkar, N. (2004). The digital divide and development. Information and Communication Technologies: *From Theory to Applications, 2004. Proceedings. 2004 International Conference* (pp. 27-28). The Syrian Consulting Bur. for Dev. & Investment: Syria.

Vernon, AM, Beach, MA. & McGeehan, JP. (2000). Planning and optimisation of smart antenna base stations in 3G networks. *Capacity and Range Enhancement Techniques for the Third Generation Mobile Communications and Beyond (Ref. No. 2000/003), IEE Colloquium* (pp. 1 - 7). Savoy Place, London: UK.

Wei, L. (2011). Bridging the Digital Divide: China's Strategy. *International Conference on Information Management, Innovation Management and Industrial Engineering 1* (pp. 456 - 459). Shenzhen: China.

Wei-xian, X. & Jun, L. (2012). A study on measuring urbanization process drag from urban-rural digital divide in China. *International Conference on Management Science & Engineering (19 th)* (pp. 1794-1799). Dallas, TX: US.

Xunbo, L. & Zhenlin, W. (2011). Cellular Genetic Algorithms for Optimizing the Area Covering of Wireless Sensor Networks.*Chinese Journal of Electronics, 20*(2), 352-356.

Yates, D., Gulati, G. & Tawileh, A. (2010). Explaining the Global Digital Divide: The Impact of Public Policy Initiatives on Digital Opportunity and ICT Development. *System Sciences (HICSS), 2010 43rd Hawaii International Conference* (pp. 1-10). Koloa, Kauai, Hawaii: US.

Yildirim, K.S., Kalaychi, T.E. & Ugur, A. (2008). Optimizing Coverage in a K-Covered and Connected Sensor Network Using Genetic Algorithms. *9th WSEAS International Conference on EVOLUTIONARY COMPUTING (EC'08)* (pp. 21-26). Sofia: Bulgaria.

APPENDICES

APPENDIX A

SAMPLE OF MONTLY INCOME AS OF MARCH 2011 OF 2G AND 3G

Sl.	City	Mobile User	Amount $	Avg Income	User AvgIncome
1	Thimphu	3960	8,331.00	$2.10	$8,331.00
2	Gelephu	237	412.62	$1.74	$412.62
3	Samdrup Jongkhar	185	316.25	$1.71	$316.25
4	Phuntsholing	690	177.79	$0.26	$177.79

APPENDIX B

SAMPLE OF TOTAL NUMBER OF ACTIVE 3G USERS

Sl No.	3G Users	Total	Remarks
1	Active	332	16:20hrs
2	Attached	158	
3	Idle	1385	
4	Unstable	17	
	Total active 3G users(1+2+3)	1875	

APPENDIX C

SAMPLE OF DESIGN

Constraints	Specification		
Rate of 3G users per existed 2G users	0.47		
Rate of income per 3G user	$2.10		
Capacity	72		
Service area (km^2)	0.78		
Target Towns	P.Ling	Gelephu	S.Jongkhar
Area (km^2)	19.68	5.85	1.94
Existed 2G users	708	216	206
percent of area coverage in each town (%)	20		
Total investable stations	9		

APPENDIX D

SAMPLE OF 2G TOWNS WITH COORDINATES

StationID	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**
Latitude	0.479541	0.479521	0.479242	0.480519	0.479992	0.479634	0.479834
Longitude	1.564505	1.564411	1.564589	1.564598	1.564386	1.564409	1.564507

StationID	**S8**	**S9**	**S10**	**S11**	**S12**	**S13**	**S14**
Latitude	0.479572	0.479519	0.479603	0.479418	0.479137	0.478943	0.479397
Longitude	1.564298	1.564247	1.564138	1.564376	1.564854	1.564874	1.564523

APPENDIX E

SAMPLE OF TRAFFIC OF 2G IN ERLANG

Month	1S	2S	3S	4S	5S	6S	7S
Jan	12,797.74	54,591.30	50,091.84	27,464.39	28,038.43	42,684.96	11,269.83
Feb	20,990.26	42,677.56	43,114.38	25,518.23	25,614.42	31,023.51	10,477.37
Mar	23,975.60	47,046.63	46,287.17	25,476.51	22,996.08	34,556.83	14,007.93
Total	57,763.60	144,315.49	139,493.39	78,459.13	76,648.93	108,265.30	35,755.13
Avg Erl	19,254.53	48,105.16	46,497.80	26,153.04	25,549.64	36,088.43	11,918.38

Month	8S	9S	10S	11S	12S	13S	14S
Jan	10,713.77	19,514.86	18,470.41	20,603.99	18,158.89	54,787.94	73,115.36
Feb	15,470.12	17,891.14	17,586.49	17,120.33	30,662.96	46,000.83	65,084.88
Mar	6,670.91	12,113.46	21,074.48	18,802.88	13,240.71	51,900.05	64,428.26
Total	32,854.80	49,519.46	57,131.38	56,527.20	62,062.56	152,688.82	202,628.50
Avg Erl	10,951.60	16,506.49	19,043.79	18,842.40	20,687.52	50,896.27	67,542.83

APPENDIX F

SAMPLE OF TRAFFIC OF 3G IN ERLANG

Month	1S	2S	3S	4S	5S	6S	7S
Jan	350.69	336.25	450.67	83.09	345.08	308.67	322.57
Feb	106.18	105.91	134.05	22.91	113.55	110.26	104.34
Mar	394.74	302.22	444.09	68.74	315.82	372.82	292.93
Apr	353.3	283.82	373.67	69.57	279.86	350.88	290.83
May	409.57	338.13	467.86	73.43	350.58	417.28	336.59
Jun	371.34	332.99	416.52	93.88	299.97	335.62	315.3
Total	1,985.82	1,699.32	2,286.86	411.62	1,704.86	1,895.53	1,662.56
Avg Erl	330.97	283.22	381.14	68.6	284.14	315.92	277.09

Month	8S	9S	10S	11S	12S	13S	14S
Jan	461.89	343.69	244.88	258.68	367.77	408.15	315
Feb	145.55	118.41	92.24	121.65	122.1	137.61	103.75
Mar	460.63	355.58	253.37	354.18	407.75	381.06	389.64
Apr	394.4	332.76	230.98	326.97	361.67	383.32	326.66
May	418.72	406.59	275.96	383.22	431.91	437.99	398.11
Jun	107.55	386.3	244.7	310.86	415.57	453.8	336.11
Total	1,988.74	1,943.33	1,342.13	1,755.56	2,106.77	2,201.93	1,869.27
Avg Erl	331.46	323.89	223.69	292.59	351.13	366.99	311.55

APPENDIX G

ASSESSMENT OF INCOME OF PREVIOUS YEARS

Year	2008	2009	2010
Sale of vouchers	$15,423,376.19	$18,417,038.99	$21,249,546.51
Post paid Mobile	$803,369.55	$1,123,317.49	$1,685,298.25
E-load	$0.00	$72,792.45	$384,183.20
Total Revenue	$16,226,745.74	$19,613,148.93	$23,319,027.96
Active users	229,000	262,052	312,316
Mobile broadband		11,886	84,458
Avg. Rev per Sub	$70.86	$74.84	$74.66

CURRICULUM VITAE

CURRICULUM VITAE

NAME	Mr. Dago Tshering
DATE OF BIRTH	03 August 1973
ADDRESS	Yangchenphu Thimphu District, Thimphu, Bhutan Thimphu 11001

EDUCATIONAL BACKGROUND

1995	Diploma in Electrical Engineering Electrical Engineer Royal Bhutan Polytechnic, Deothang Bhutan
2010	Bachelor of Science Management in Information Technology Mae Fah Luang University, Thailand

WORK EXPERIENCE

2004-Present	Officiating Manager RAN, B-Mobile, Bhutan Telecom Limited, Thimphu Bhutan
2000-2004	Technical Officer Bhutan Telecom Limited, Trongsa Bhutan
1999-2000	Incharge Department of Telecommunication, Ministry of Communication, Gedu Bhutan
1995-1999	Section Officer Department of Telecommunication, Phuntsholing Bhutan

TRAININGS

1997	Training on Measuring Instruments by SingTel, in Singapore funded by UNDP. From 17th November to 12th December 1997
2002	Training on Understanding Telecommunications Conducted by Singaporean Government, Ministry of Foreign Affairs on 25th February to 8th March 2002
2003	In country Training on Telecom Integrated Information Management System. Thimphu, Bhutan on 26th August to 30th August 2003
2004	Course completed on GSM BTS O & M conducted by Bharat Sanchar Nigam Limited (A Govt. of India Enterprises) Ghaziabad ISO 9001: 2000. From 20th December 24th December 2004
2005	Course on Management in GSM conducted by JICA in Yokosuka Research Park, Japan. From 18th October to 26th October 2005
2010	In-house training on “Mid Level Management” conducted by ACU TECH in Phuntsholing, Bhutan. From 3rd May to 7th May 2010
2010	EUGAP (Ericsson User Group Asia Pacific) Meeting No 24. Langkawi, Malaysia. From 17th May to 19th May 2010
2010	NGOP (National Graduate Orientation Programme). Thimphu, Bhutan From 6th October to 14th October 2010

2011	Certificate of recognition for outstanding work as trainer staff of Chiang Rai Vocational College Communicative English Winter Camp 2011 awarded on 20th February 2011
2011	In-house training on "WCDMA RAN P7 Optimization" conducted by Bhutan Telecom, Thimphu, Corporate Head office Training Unit. From 14th April to 16th April 2011
2011	In-house training on "WCDMA RAN P7 Design" conducted by Bhutan Telecom, Thimphu, Corporate Head office Training Unit. From 14th April to 16th April 2011
2012	Panel Member for the validation of the Diploma in Electronics and Communication Engineering Programme at Jigme Namgyel Polytechnic, Deothang Bhutan. From 25th - 27th November 2012
2012	EUGAP (Ericsson User Group Asia Pacific) Meeting No 29. Langham Place, Mongkok, Hong Kong. From 26th November to 28th November 2012
2013	Certificate on WCDMA RAN W12 Performance Management & Optimization. Ericsson Academy, Cyberjaya, 63000, Malaysia. From 29th July 2013 to 2nd August 2013

PUBLICATIONS

Tshering, D., Chaisricharoen, R. & Temdee, P. (2012). Distribution of 3G services in rural town: Case study of Bhutan. *ICT and Knowledge Engineering (ICT & Knowledge Engineering), 2012 10th International Conference* (pp. 135-139). Siam University, Bangkok: Thailand.

Tshering, D., Chaisricharoen, R. & Temdee, P. (2013). Distribution of 3G Services Among Rural Towns: Case Study of Bhutan. *Wireless Personal Communications: An International Journal*, *69*(3), 1047-1054.