

## CHAPTER III RESEARCH METHODOLOGY

### 3.1 Overview

This chapter explains the research methodology adopted for this thesis. The research methodology adopted consists of the following steps:

- i. Formulate pricing schemes for multiple service networks and multiple class QoS networks.
- ii. Solve the optimization problems using LINGO 11.0.
- iii. Draw conclusions from the results.
- iv. Finally, propose the pricing schemes for multiple service networks and multiple class QoS networks.

### 3.2 Multi Service Networks and Multi QoS Networks

The internet pricing in multiservice network architecture that is proposed can be described based on the brief illustration adopted from Kung et al. (1999) in which the network is set up to control telephone calls, provide the applications and services of the network as shown in Figure 7. Based on that network architecture, the research then focuses on pricing scheme in multiservice network as shown in Figure 8 which is adapted originally from Niran (2004) and pricing scheme in multi class QoS network as shown in Figure 9.

FIGURE 7: The Proposed Multiservice Networks

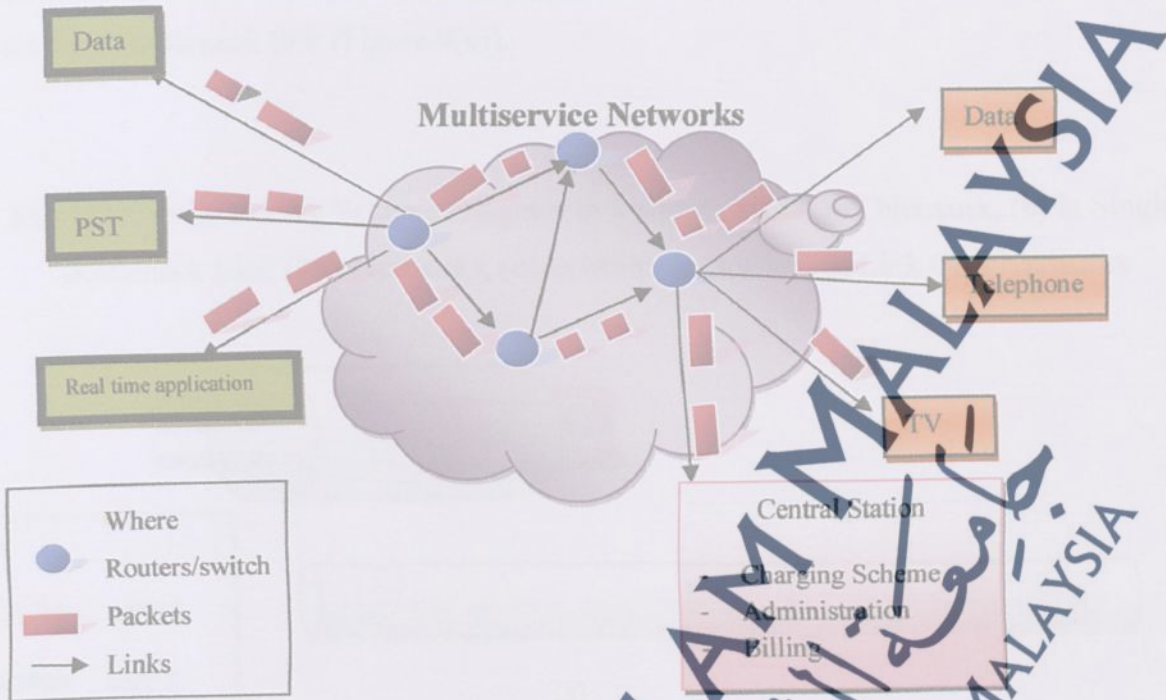


FIGURE 8: (a) Pricing Scheme Diagram of Multiservice Networks, (b) in Single Bottleneck Links and (c) in Multiple Bottleneck Links

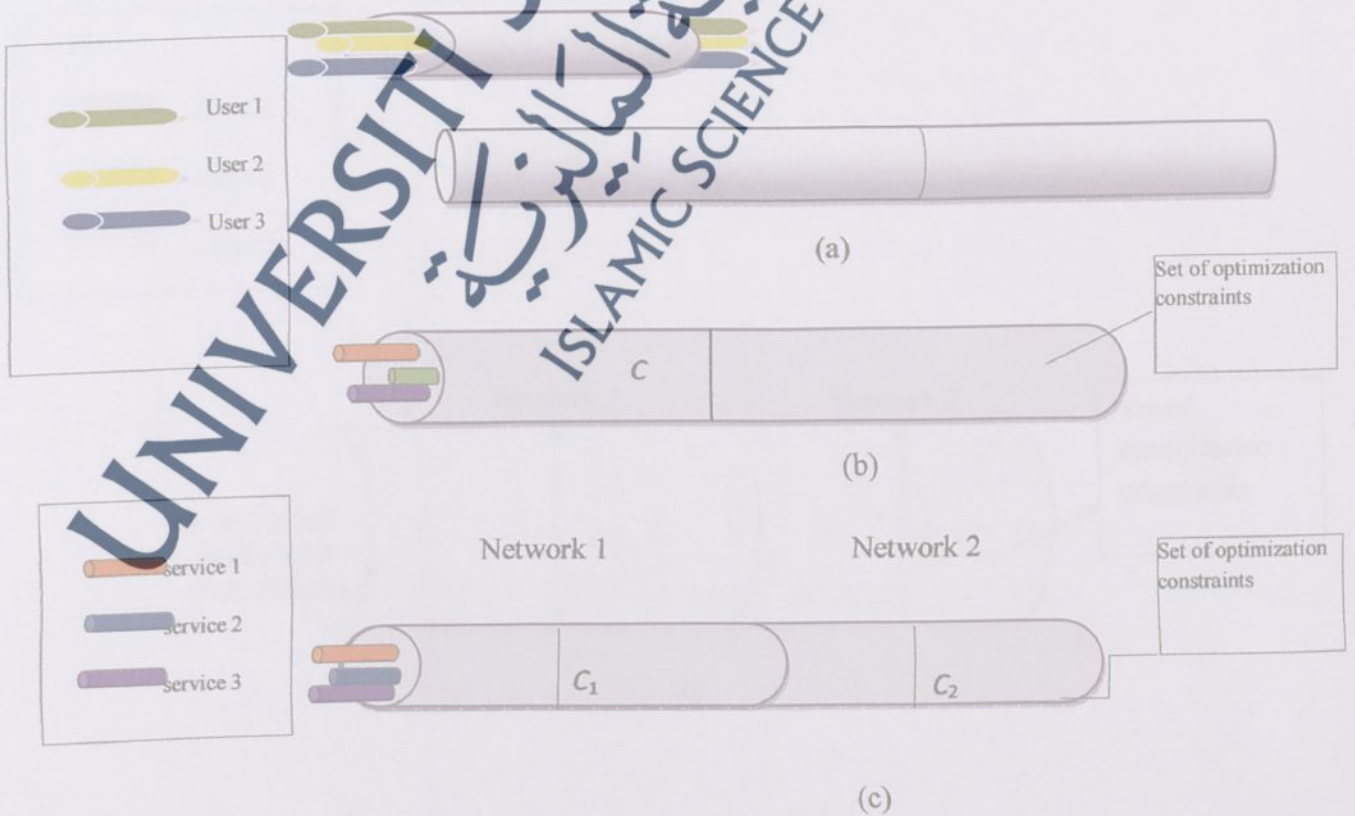
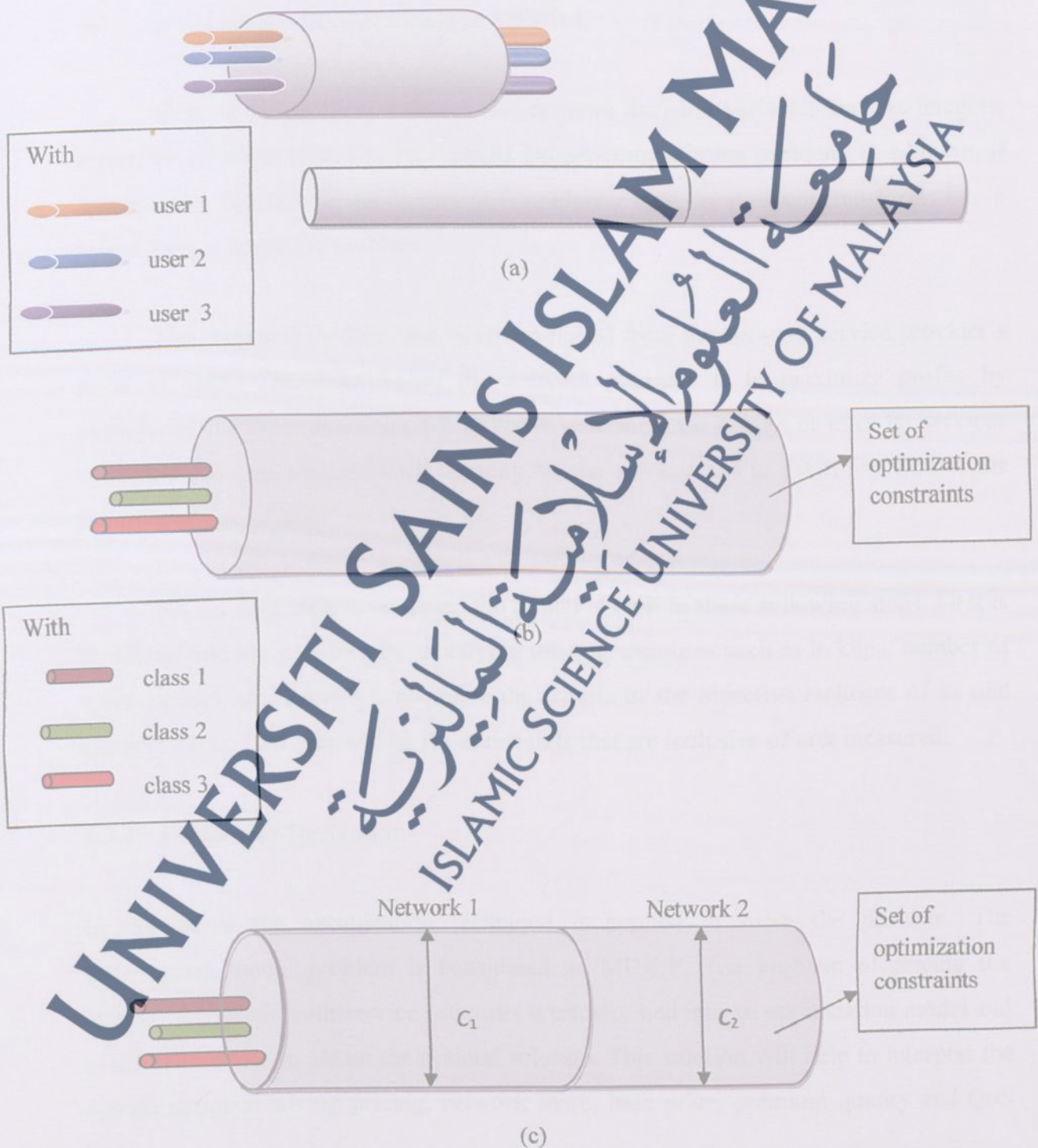


Figure 9 depicts the diagrams of our pricing scheme in multiple class QoS network. It shows the scheme in single bottleneck link (Figure 9(a) and 9(b)) and in multiple Bottleneck link (Figure 9(c)).

**FIGURE 9:** (a) Pricing Scheme Diagram in Multiple class QoS Network, (b) in Single Bottleneck Link QoS Networks, (c) in Multiple Bottleneck Link QoS Networks



### 3.3. Model Formulation

Formulating the parameters and decision variables into complete models for optimization of the MINLP problem is generated. The MINLP model consists of four parts.

- i. Parameters (constants).
- ii. Decision variables.
- iii. Objective function to be a nonlinear function
- iv. Set of constraints that should be satisfied.

Thus, if the problem involves one or more decision variables such as integers, hence, the problem is said to be a mixed integer-programming problem. In addition, if the objective function or the constraint is nonlinear then the problem transforms into a mixed integer nonlinear problem.

The proposed models have been developed from the network service provider's point of view. The objective of the network provider is to maximize profits by considering the three decisions, which are to determine the charge or rates for services offered, to allocate total network capacity for the services and to determine QoS levels for each service offered.

So, the approach to construct the model is built in these following steps. First is by identifying the variables by specifying the unit measures such as in kbps, number of users, dollars, etc. Second is to define the criteria or the objective inclusive of its unit measurements. Last part will be the constraints that are inclusive of unit measured.

#### 3.3.1 Parameter Derivation

In this thesis the optimization technique is applied in solve the problem. The optimization model problem is considered as MINLP. The problem of pricing the internet services in multiservice networks is transformed into an optimization model and is solved in order to obtain the optimal solution. This solution will help to interpret the current issues involving pricing, network share, base price, premium quality and QoS level.

It is assumed that there is only one single network from the source to the destination; hence the service-pricing scheme is the main focus of the research since the routing schemes are already set up by the ISPs. There are two parts to the utility function, namely the base price, which does not depend on consumption of resources and other part is cost which depends on the consumption of resources. The utility function has characteristics such as marginal profit, which is a function of decreasing and increasing bandwidth. The objective of ISPs is to obtain maximum revenue subject to constraints based on the systems available resources. Table 2 below explains the various conditions for base price ( $\alpha$ ) and quality premium ( $\beta$ ) in internet pricing models. ISPs can adopt the model formulation scheme by simply choosing to set up the base-price and quality premium for each model formulation in the internet pricing scheme proposed.

TABLE 2: Target of ISPs in Adopting the Pricing Scheme Proposed by Byun and Chatterjee (2004)

Target	$\beta$ fixed (constant)	$\beta$ varies
$\alpha$ fixed (constant)	Recover cost and user can select service	Recover cost and can promote certain services
$\alpha$ varies	Market competition and user can select services	Market competition can promote certain services

Two kinds of models for solving the internet-pricing were proposed. First is by considering the problem of internet pricing in multiservice networks and second is focussing on the problem of internet pricing on multiple class QoS networks.

The first stage of proposed model formulation in multiservice network is by improving Sain & Herpers (2003) model formulations and Byun & Chatterjee (2004) model formulation. The improved models are applied in single and multiple bottleneck links. The parameters have been predetermined as the constant values for each service.

The next stage will be models to be generated in multiple class QoS networks. The new improved model in internet pricing is described by improving the formulation of models by Yang (2004) and Byun & Chatterjee (2004) in single and multiple

bottleneck link networks. The parameters are predetermined as the constant values for each class.

### 3.3.2 Decision Variables

The decision variables describe the quantity to be determined to solve the problem of internet pricing model. Certain symbols are chosen and put into tables. These variables can be integer value or real value. The case of MINLP will yield the real valued, integer valued and binary integer valued decision variables. The value of final bandwidth obtained of a user, minimum bandwidth for class  $j$  will be real valued decision variables, number of users subscribing the service will be integer valued decision variables and admission of user  $i$  in class  $j$  will be shown by binary integer valued decision variables.

### 3.4 Modeling Process

Three stages performed in processing the model of internet pricing scheme (Chen et al., 2010) are as follows.

1. Model construction
2. Model solution
3. Model result validation and interpretation

For Stage 1, identification and definition of parameters, decision variables, constraints and objective function are needed. Assigning the proper symbols to parameters, decision variables are necessary to transform the internet pricing problem into mathematical formulation. Objective function should be stated clearly in a way to maximize the profit for ISPs. Constraints always connect with availability of resources, requirements and rules in performing the model. The functions of objective are in the form of nonlinear while the some constraints are in the form of linear and nonlinear.

For Stage 2, translate all descriptions in Stage 1 into mathematical formulations using the parameters, decision variables and objective function symbols. Function of the variables which represents the objective will be maximized and other functions together

with parameters and decision variables will form the constraints. The constraints can be inequality or equality constraints. These constraints usually show the limitation of resources in the networks, such as the bandwidth availability or certain requirements that should be satisfied in solving the mathematical formulation such as the nonnegativity constraints that inform to have nonnegative values of the decision variables. Solving the models manually is quite difficult since the problem is NP-hard. The software application LINGO 11.0 is used to help with iterations. Creating the formulation based on the LINGO format will reveal the solutions for maximizing the objective function and values of decision variables.

For Stage 3, the non MINLP factors in pricing scheme such as discrete but not integer variable, nonlinear constraints are examined to check whether those factors can be transformed into mathematical expressions and satisfy the MINLP assumptions. The MINLP assumptions (Chen et al., 2010) are as follows.

1. Divisibility, that each variable must be real value.
2. Integrality, that each integer variables should in form of integer value  $\{0, 1, 2, \dots\}$  or binary values  $\{0 \text{ or } 1\}$ .
3. Constant, that each parameter is constant or fixed.
4. Linearity, that the total contribution of function value for variable unit is constant.
5. Separability, that each function are expressed in forms of sums of some functions.
6. Single objective function, that the objective function of internet pricing scheme to be maximize is in single objective function form.
7. Simultaneously, that refers to any feasible solution of the models does not violate the constraints in MINLP.

So, the all assumptions should not be violated in forming the MINLP. If some assumptions are violated, the transformation into MINLP is needed.

### 3.5. Summary

Chapter III focuses on the methodology concept regarding the optimization of internet pricing schemes under multiple class QoS networks. The decision to choose parameters and decision variables is important in order to generate optimization models. The models created can pose as preferences for Telcos to decide and adopt accordingly.

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