A Linear Response Surface Analysis Approach to Evaluate QoS Factors in Wireless Networks

(Work in progress report)

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Abstract - With the growth of wireless networks and the increase in personal internet use for diverse applications, the importance of the quality of service (QoS) delivered to clients has become of great importance. In order to evaluate QoS the study proposes a linear response surface analysis (LRSA) approach. A 802.11n prototype wireless network will be constructed to capture QoS data. The objective is then to use this data to construct a LRSA model in order to evaluate the QoS factors and make recommendations on the performance of wireless networks.

Index Terms—QoS, Linear response surface analysis, Wireless Networks

I. INTRODUCTION

IN THE LAST few years wireless technologies have become more popular with businesses discarding wired networks due to their limitations. This has increased the need for providing the same quality of service (QoS) over an unguided media as over guided media. It has therefore become important to evaluate the QoS of a wireless network in order to improve it. There are a number of mathematical methods available that can aid network administrators in evaluating the quality of service of their networks.

Stepwise models such as linear regression and linear programming could be used to evaluate the quality of service. These techniques analyze the relationship between certain variables and can be used to predict possible values for certain QoS factors based on the values of other variables [1]. However, the techniques may have some limitations in explaining interdependencies between variables and to determine the exact variables to include in a model. The techniques may therefore result in unrealistic solutions in some instances. In order to overcome such limitations, a LRSA approach is proposed for the evaluation of the QoS of a wireless network.

This paper is a work in progress report. The research has only recently started and this report will present a brief outline of QoS and LRSA as well as the planned future work.

II. QUALITY OF SERVICE

Quality of service can be defined as a collection of techniques and technologies applied in a network in order to

ensure predictable delivery results for the network [2]. QoS can be characterized as prioritized or parameterized. This study focuses on parameterized QoS as it has a quantitative nature which is well suited to mathematical analysis.

Parameterized QoS can be measured with many different metrics, each shedding light on different aspects of the wireless network monitored. The prominent metrics are jitter, delay, packet loss and throughput [3]. These metrics share some underlying factors, but also influence each other.

Jitter, or also known as packet delay variation, is the variation of the delay between consecutive packets. These delays occur within a packet switched network due to the fact that some packets may follow a shorter or better route than other. Jitter can be calculated with the following formula:

$$\begin{aligned} \text{Jitter} &= Variance (|\{TX(i) - RX(i)\} - \{TX(i-1) \\ &- RX(i-1)\}|), \end{aligned}$$

where TX is the timestamp when the packet was transmitted at the sender and RX is the timestamp when the packet was received at the receiver and i is the packet order.

The delay of a packet in a network is the time elapsed from the packet leaving the source to arriving at the destination [4]. However, this study focuses on the sending of an entire file and therefore the delay is measured as the time it takes to send a file across the network. The delay portrait in the study is therefore the sum of all the packet delays including the queuing delay at the source.

Packet loss is the occurrence of one or more packets of data which is send over a computer network failing to reach their destination. It is known to be one of the main error types of digital communication [5]. Packet loss occur due to various reasons including jitter and signal loss.

Throughput is generally defined as the average rate at which data is successfully delivered over a communications channel [6]. This rate is usually measured in mb/s or kb/s. Throughput can be calculated with the formula:

$$Throughput = DS/ST,$$

where *DS* is the size of the correct data received across the network and *ST* is the time it took to send the data.

III. LINEAR RESPONSE SURFACE ANALYSIS

As stated earlier a linear regression model may not always be sufficient to evaluate variables within certain specific situations. In order to overcome these limitations the study will use a linear response surface analysis technique to evaluate the QoS in a wireless network. This technique can briefly be explained as follows.

Firstly, the area of experience, that is, the space enveloped by the available data points, is considered. The area of experience is referred to as the convex hull of the data. A linear programming model is then applied in order to maximize or minimize the dependent (QoS) variables. These results are then plotted on a graph to facilitate the evaluation of variables [1].

Suppose the following data points, representing measurements on regressors, are available

 $V_i = (X_{i1}, X_{i2}, \dots, X_{in})$ for $i = 1, 2, \dots, n$

The convex hull could now be represented by the following set:

$$C = \left\{ \begin{aligned} Z &| Z \in E^k \text{ and} \\ Z &= \sum_{i=1}^n \lambda_i V_i \text{ with } \lambda_i \ge 0 \text{ and } \sum_{i=1}^n \lambda_i = 1 \end{aligned} \right\}$$

where $E^k \equiv k$ dimensional Euclidean space.

If one assumes that an estimated model in a specific instance is available we will denote the estimated function as $\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \dots + \hat{\beta}_k X_k$ where the $\hat{\beta}_k$ are obtained by some regression method like least squares

Suppose now that the influence of a specific variable X_p on a dependent variable \hat{Y} needs to be determined where X_p is not under the control of the researcher. If the range of X_p is determined with a maximum value of k'' and a minimum value k' let $X_p = q$ where $q \in (k', k'')$. It is now possible to find maximum and minimum values for \hat{Y} as well as for the remainder of the decision variables by solving the following linear program.

Maximize
$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \dots + \hat{\beta}_k X_k$$

subject to

$$\sum_{i=1}^{n} \lambda_i X_{ij} = X_j \text{ for } j = 1, 2, \dots, k$$
$$\sum_{i=1}^{n} \lambda_i = 1, \ \lambda_i \ge 0 \text{ for } i = 1, 2, \dots, n$$
$$X_n = q$$

The solution of this linear programming model will provide the user with maximum/minimum values of \hat{Y} as well as the levels of the decision variables $X_1, X_2, ..., X_k$ where this optimum is reached. These results will enable us to determine the influence of QoS factors and make recommendations on the performance of wireless networks.

IV. PLANNED APPLICATION

In the application of LRSA to the QoS data, *throughput* may, for example, be treated as a dependent variable (\hat{Y}) which is dependent on the number of simultaneous communications in the network (X_1) , the distance between the nodes in the network (X_2) , data size (X_3) , and the number of hops between sender and receiver (X_4) . It would then be possible to estimate a linear regression model of the form:

$\begin{aligned} Throughput &= \hat{\beta}_0 + \hat{\beta}_1 Communications \\ &+ \hat{\beta}_2 Node \ Distance + \hat{\beta}_3 Data \ Size \\ &+ \hat{\beta}_4 Hop \ Count \end{aligned}$

Maximizing this model for specific values of selected variables and subject to the constraints explained earlier, it would be possible to derive information or recommendations such as:

"The current throughput of the network is 2mb/s, this could be improved to 3.5mb/s and in order to achieve this improved level of throughput the number of communications in the network need to be less as well as the number of hops between sender and receiver." This type of information would be much more useful than the traditional predicted values obtained from an ordinary regression model.

V. PLANNED RESEARCH

This section briefly describes the planned research to be done.

• Construct a prototype wireless network to capture QoS data.

• Use the LRSA technique to develop a model to analyze the data.

• Analyze the captured data with the developed model.

• Make recommendations on QoS performance within wireless networks.

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