

# Application of CSP in Optimizing the Path Loss of Wireless Indoor Propagation Model

Nagendra Sah, Neelam Rup Prakash, Deepak Bagai

**Abstract** - Constraint satisfaction programming (CSP) is an emergent software technology for declarative description and effective solving of large particularly combinatorial problem especially in term of planning and scheduling. Constraint programming is the study of computational system based on constraints. The idea of constraint programming is to solve problem by stating constraints about the problem and consequently finding the solution satisfying all the constraints. In this paper the application of constraint satisfaction programming is used in predicting the path loss of various empirical propagation models using chronological backtrack algorithm, which is basic algorithm of CSP. After predicting the path loss at different set of parameter such as frequencies, floor attenuation factor (faf), path loss coefficient(n), penetration attenuation factor (paf), we find the optimum set of parameter (frequency (f), floor attenuation factor (faf), path loss coefficient(n), penetration attenuation factor (paf) at which path loss is minimum with the help of Branch and bound algorithm, which is used to optimized the constraint satisfaction problem.

**Index Terms** - CSP; Path Loss; Propagation Model; Wireless Communication.

## I. INTRODUCTION

In last few years, the constraint satisfaction programming (CSP) has attracted high attention among experts from many years because of its potential for solving problems. The constraint satisfaction programming approach has been widely used in many academics and research parlance to tackle wide range of search problem. It is defined by finite set of variables, a set of domain and constraints. Basically CSP composed of finite set of variable, each of which is associated with a set of domain, and set of constraints that restrict the value that variable can take. The constraints satisfaction problem deal with the assignment of values from its domain to the variable in such a way that no constraint is violated [1]. There are currently two branches of constraint programming, namely constraint satisfaction and constraint solving. Constraint satisfaction deals with the problem defined over finite domain and currently, probably more than 95% of all industrial constraint applications used finite domains, on other hand constraint solving algorithm are based on mathematical techniques. The CSP is worth studying in isolation because it has a unique feature that can be exploited to arrive at solution.

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The (CSP) constraint satisfaction programming offers its basic algorithm to solve and optimize the problem.

A constraint satisfaction algorithm can be viewed as an iterative procedure that repeatedly assigns domain value to the variables [2].

In this paper problem of finding the path loss of various Empirical wireless propagation models has been stated as a CSP (constraint satisfaction problem) and has been solved by chronological backtracking algorithm and after solving the problem the result was optimized using constraint satisfaction optimizing algorithm named as branch and bound algorithm which is the very basic algorithm used for optimization in CSP.

## II PROPAGATION MODELS

There is greater interest in characterizing the radio communication channel inside a building. The indoor propagation model differs from the outdoor propagation because of variation in fading rate and type of interference. For example floor attenuation factor and penetration attenuation factor are two main parameters of indoor propagation models. The ITU Model for indoor attenuation. This model is applicable for frequency range 900 MHz to 5.2 GHz. The ITU indoor path loss model is formally expressed as

$$L = 20 \log f + N \log d + P_f(n) - 28$$

Where , N is distance power loss coefficient,  $P_f(n)$  is the floor loss penetration factor.[8] propagation loss prediction model plays an important role in design of cellular mobile radio communication system. Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. These are also very important for performing interference studies as the deployment proceeds. Propagation loss modeling of cellular mobile system is important for site planning; the transmission loss and signal coverage can be predicted by set of propagation loss modeling equations [4].

Propagation models in wireless communication have traditionally focused on predicting the average received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in close proximity to a particular location. Propagation models that predict the mean signal strength for an arbitrary transmitter – receiver separation distance are useful in estimating the radio coverage area of transmitter and are called large scale propagation models, since they characterize signal strength over large T-R separation distance. On the other hand, propagation model that characterize the rapid fluctuation of the received signal strength over very short travel distances or short time duration are called small scale or fading models.



As mobile moves over very small distances, the instantaneous received signal strength may fluctuate rapidly giving rise to small scale fading. The reason for this is that received signal is sum of many contribution coming from different directions [5].

The propagation models are generally used to characterize the quality of mobile communication. It can be used as prediction tool for those telecommunication engineers who deal with the site planning for base station. These models can be broadly categorized into three types: empirical, deterministic and stochastic. Empirical models are based on observation and measurement alone. These are mainly used to predict path loss. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Stochastic model, on other hand model the environment and use much less processing power to generate prediction [4]. The concept of constraint satisfaction programming has been implemented on empirical wireless propagation models in order to predicting and optimizing the propagation loss [6].

### III METHODOLOGY OF CSP

The two algorithms of CSP, chronological backtracking and branch and bound which were used to solve and optimize the wireless empirical propagation models may be explained as below:- The basic operation of chronological backtrack algorithm in CSP context is to find the solution tuples. This algorithm took one variable at a time, and consider one value for it at a time, making sure that newly picked variable is compatible with the all the labels picked so far. Assigning a value to variable is called labeling. If labeling the current variable with the picked value violates certain constraints, then next value is assigned to the variable. If all the variables are labeled, then the problem is solved [3]. The flow diagram of the chronological backtracks algorithm may be shown as below:-

#### FLOW DIAGRAM OF CHRONOLOGICAL BACKTRACK ALGORITHM:-

The above flow diagram explain the working of backtrack algorithm. As its name indicate that it will backtrack until and unless all the variables are labeled, and in last when all the variables are labeled the problem get solved. In context with the wireless empirical propagation model, we have different types of variables, such as base station antenna height (hb), frequency (f), range of cell (d/r), the height of the mobile station antenna height (hm) etc. Each empirical propagation models has the particular range for its variables (f, hb, d/r, hm), for which a particular empirical propagation model is valid. These ranges of variables were treated as domain for these set of variables by stating the constraints that value of variables should not go beyond the specified domain i.e. it should not violate the constraints. After implementation of the backtrack algorithm we found the path loss of empirical propagation model at different set frequency(f), base station antenna height(hb), cell radius(d/r), and mobile antenna height(hm). Now after finding the path loss for different set of parameters (f,hb;d/r,hm), we have to find that particular set of parameter at which propagation loss is minimum. For this optimization CSP provide an optimization algorithm called branch and bound algorithm which may be explained as below:-

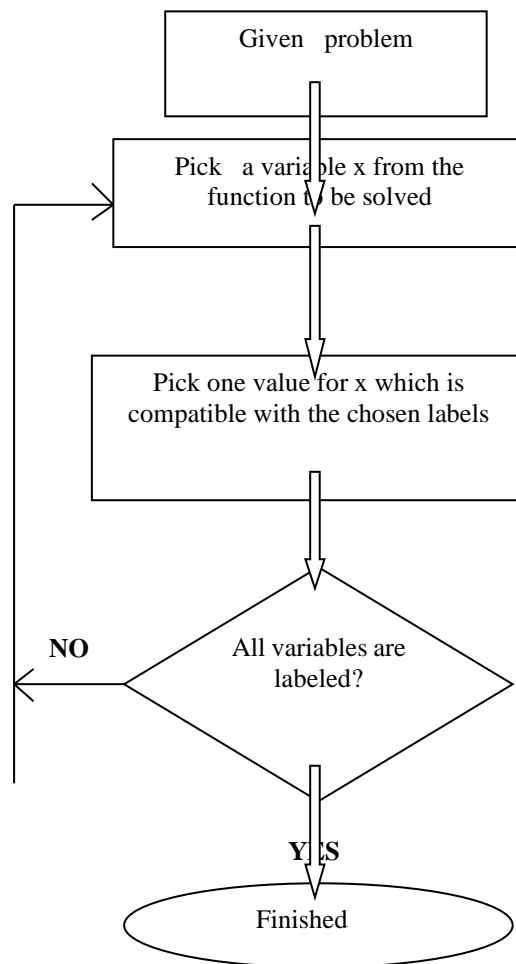


Figure (a)

**BRANCH AND BOUND ALGORITHM:-** Branch and bound is a general search algorithm for finding optimal solution, make use of knowledge on the f value. A constraint satisfaction optimization problem (CSOP) is defined as CSP, together with an optimization function f which maps every solution tuple to a numerical value. So constraint satisfaction optimization problem is written as: (Z, D, C, f) where (Z, D, C) represent CSP with a set of variables (Z), domain (D) and constraints(C) and f is the optimization function. To apply the branch and bound algorithm to CSOP one needs to have knowledge of heuristic function which maps every compound label to numerical value. A bound is nothing but a global variable which is defined according to the minimization or maximization problem, it depend upon the case that either you want minimum or maximum value of the function you are solving[3]. The branch and bound algorithm in empirical wireless propagation models was used to find that particular set of frequency(f), base station antenna height(hb), the range of cell(d\r), and mobile antenna height(hm) at which propagation loss is minimum. The propagation loss of different type of empirical model can be predicted by set of propagation loss modeling equations which are different for each empirical propagation model. The propagation loss modeling equation consist of different variables ,in branch add bound algorithm a heuristic function is needed to assign value to these variables.

After all the variables are labeled the calculated value of path loss is taken as the f value in branch and bound algorithm. This f value in branch and bound algorithm is compared with the estimated value of the global variable (bound), and if this computed f value is less than the value of the existing bound, it will become the new bound. This procedure will carry on until and unless a minimum value is found and reverse of this procedure is used if we have to find the maximum value.

#### IV ANALYSIS OF THE INDOOR PROPAGATION MODELS

The following wireless indoor propagation models were implemented with the constraint satisfaction programming:-

- ITU indoor propagation model
- Log distance path loss model
- Floor attenuation model

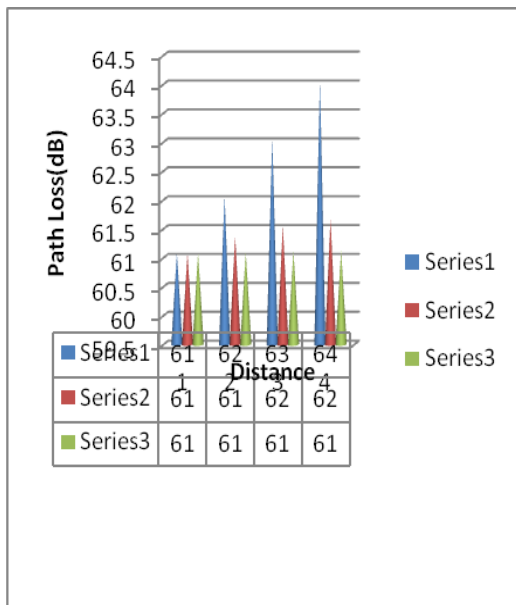
Let us analyze the empirical propagation model by taking example of ITU model. It is also known as ITU Model for indoor attenuation. This model is applicable for frequency range 900 MHz to 5.2 GHz. The ITU indoor path loss model is formally expressed as

$$L = 20 \log f + N \log d + P_f(n) - 28$$

Where

N is distance power loss coefficient

$P_f(n)$  is the floor loss penetration factor



For series 1:-

f(MHz)	d(m)	N	Pf
900	1	1	30-33

For series 2:-

f(MHz)	d(m)	N	Pf
900	1-4	1	30

For series 3:-

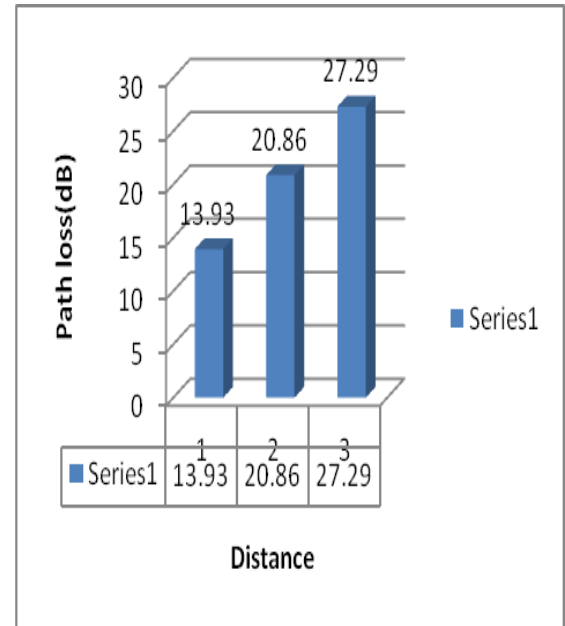
f(MHz)	d(m)	N	Pf
900-903	1	1	30

From the above graphical analysis it may be noted that the propagation loss increases with the floor attenuation factor ( $P_f(n)$ ), increases with frequency and distance.

#### RESULTS OF OTHER MODELS:-

- **Log distance path loss model:-**

1. Effect of path loss coefficient (n):-

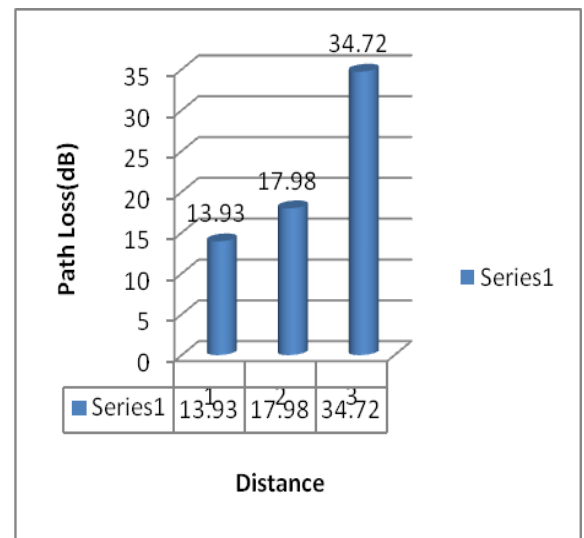


For series 1:-

f(MHz)	d(m)	n
900	2	1-4

As clear from above figure that the path loss increases with the path loss coefficient (n).

2. Effect of distance on path loss:-



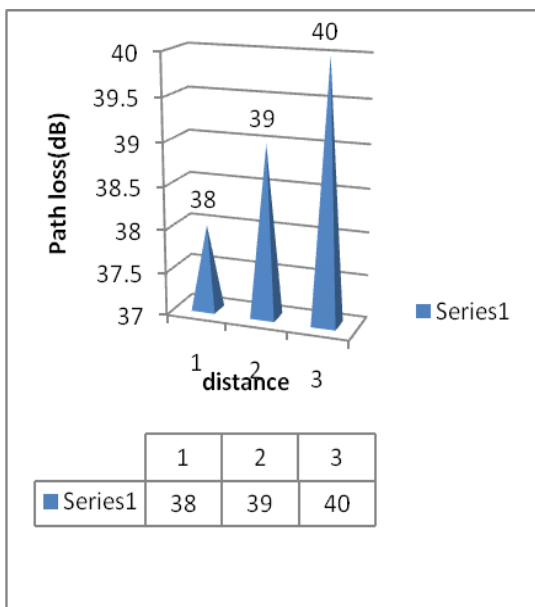
For series 1:-

f(MHz)	d(m)	n
900	2-4	1

It is very much clear from the above diagram that the path loss is increasing with the distance.

- **Floor attenuation model:-**

1. The effect of FAF(floor attenuation factor) and PAF(penetration attenuation factor) on path loss:-

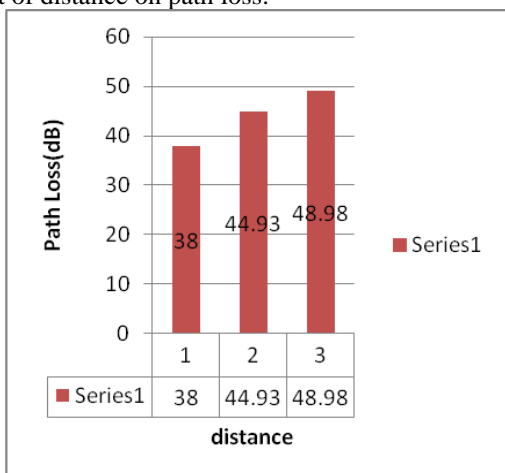


For series 1:-

f(MHz)	d(m)	FAF	PAF
900	1	1-3	1-3

From the above figure it is clear that the path loss increases with floor attenuation factor and penetration attenuation factor.

2. Effect of distance on path loss:-

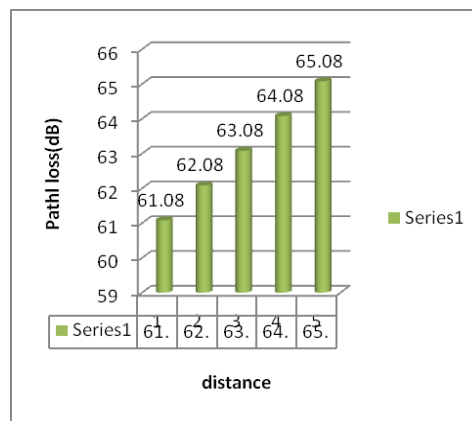


f(MHz)	d(m)	FAF	PAF
900	1-3	1	1

It is very much clear from the above diagram that the path loss is increasing with the distance.

• ITU MODEL

1. The effect of floor loss penetration factor:-

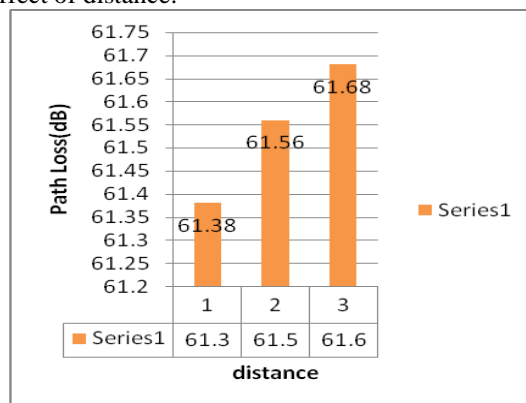


For series 1:-

f(MHz)	d(m)	N	Pf
900	1	1	30-33

It may be concluded that path loss increases with increase in floor loss penetration factor.

2. Effect of distance:-

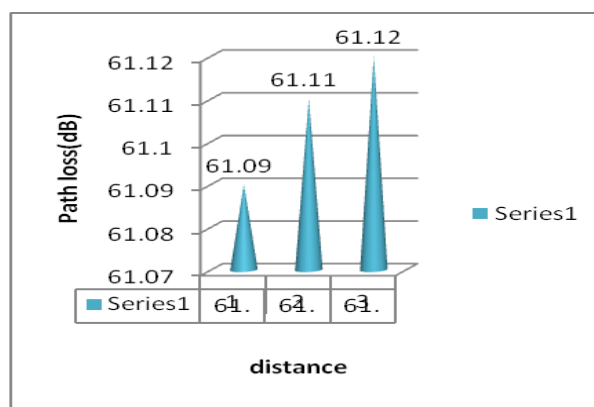


For series 1:-

f(MHz)	d(m)	N	Pf
900	1-4	1	30

It is very much clear from the above diagram that the path loss is increasing with the distance.

3. Effect of frequency:-



For series 1:-

f(MHz)	d(m)	N	Pf
900-903	1	1	30

Thus it may be seen that path loss is getting increased with the increase in frequency.

## V. EXPERIMENTAL RESULTS

The computed results of various empirical propagation models after implementation of concept of CSP provide a set of parameters of, (frequency (f), floor attenuation factor(faf), path loss coefficient(n), penetration attenuation factor(paf) at which path loss is minimum with the help of Branch and bound algorithm, which is used to optimized the constraint satisfaction problem.

## VI. CONCLUSION

From the work reported herein, it gives a brief survey of basic solving techniques behind constraint programming. In particular we concentrate on constraint satisfaction algorithm that are use to solve the constraint satisfaction problem. In this paper the various wireless empirical propagation models has been solved to find the propagation loss using the constraint satisfaction algorithm. We also overview the main technique of solving constraint optimization problem. For this we make use the constraint satisfaction optimization algorithm and optimization algorithm has been implemented on the different empirical propagation models in order to find the parameters(frequency (f), floor attenuation factor(faf), path loss coefficient(n), penetration attenuation factor(paf)) at which path loss is minimum.

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