CONSTRAINT SATISFACTION APPROACH TO IMPROVE CAPACITY FOR INDOOR MOBILE NETWORK

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Abstract: -

The investments in indoor mobile networks are highly related to the spectrum availability and its associated approval options. The goal of this paper is to figure the physical network setup criteria for both wide and local area network deployment conditions. To produce the efficient output from the network, it is required to define network under defined constraints. These all constraint depends on type of network, its topology and the type of communication performed in that network. Constraint programming is the study of system which is based on constraints. The solution of a constraint satisfaction problem is a set of variable value assignments, which capture all members of the set of constraints in the CSP. In this paper the appliance of constraint satisfaction programming is used in predicting the signal processing in indoor topological environment. The distinct set of parameters such as distance (d), density, energy is used to define the constraints. The Branch and bound algorithm is used to optimize the constraint satisfaction problem. In this work, channel capacity will be figured out and then reduction of BER is predicted. The presented work will be performed on Ray-Leigh indoor propagation model.

Keywords- *Indoor mobile network, CSP problem & algorithms, Fading, BER,.*

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I. INTRODUCTION

In the past two decades, wireless telecommunications have experienced an explosive growth. On the one hand, a wide variety of advanced wireless telecommunication technologies have greatly facilitated our daily lives and thus stimulated an increasing demand for smart mobile devices, such as laptops, smart phones, tablets etc. On the other hand, the popularity of these smart mobile devices has, in turn, inspired the rapid development of wireless telecommunications. However, the increasing demand for various smart mobile devices has led to an exponential growth of mobile which has set a formidable challenge to the wireless system capacity. Due to the fact that there is a capacity limit of conventional macro-cellular systems, the concept of heterogeneous networks has been proposed to smaller cells. The main idea of heterogeneous networks is to overlay the conventional single-tier macro-cellular networks with one or more tiers of low power and low cost devices, e.g. base stations or access points in Microcells, Pico cells, and Femto cells to increase local capacity at capacity-demanding areas. In cellular networks, the term Macro cells is used to describe the cellular networks with the largest range of cell sizes. Normally, the cell sizes of Macro cells range from 1 km to 20 km [2]. Macro cells are usually used to provide radio coverage for rural or suburban areas. For urban areas which are more capacity demanding than rural and suburban areas, the radio coverage is usually provided by Microcells. Microcells typically have the cell sizes ranging from 500 m to 2 km. Unlike Macro cells and Microcells which provide radio coverage for wide areas, Pico cells and Femto cells, by contrast, provide radio coverage for small areas. Pico cells are usually used to increase local capacity of networks for small areas with very dense mobile users, for instance, shopping malls and train stations. Pico cells extend radio coverage to indoor areas where outdoor signals from Macro cells or Microcells are not strong enough to provide the required quality of radio links after wall penetration. At last, indoor mobile networks are designed for providing radio coverage in home or small areas. By shrinking the service range and dense spatial reuse of the frequency spectrum, smaller cells (e.g. Femto cells, Pico cells, Microcells compared to Macro cells) can achieve significant improvement in radio link quality and system capacity. It is believed that indoor network architecture is one of the most promising low-cost approaches to increase the system capacity and improve the Quality of Service (QoS).

II. INDOOR MOBILE NETWORK

It is reported that about 2 to 3% of calls and 90% of data services occur indoors[3]. A good radio coverage is the basis to guarantee the required quality of services, thus it is extremely significant to investigate the radio propagation in indoor environments. In the initial stages of cellular networks, the indoor radio coverage was usually provided by the outdoor signals penetrating from Macro cells or Microcells. With the development of wireless cellular networks, nowadays, the indoor radio coverage is normally provided by the indoor base stations or access points, e.g. pico base stations (PBSs) and femto access points (FAPs). Thus, the indoor radio coverage should be reinvestigated from a new perspective. Due to the complexity of radio propagation environments and various propagation mechanisms, in reality, the instantaneous path loss is a combination of the mean path loss, the large scale fading and the small scale fading. Those which tackle the large scale fading and the small scale fading are called the large scale fading models and the small scale fading models, respectively. The architecture of indoor propagation model is as shown below.

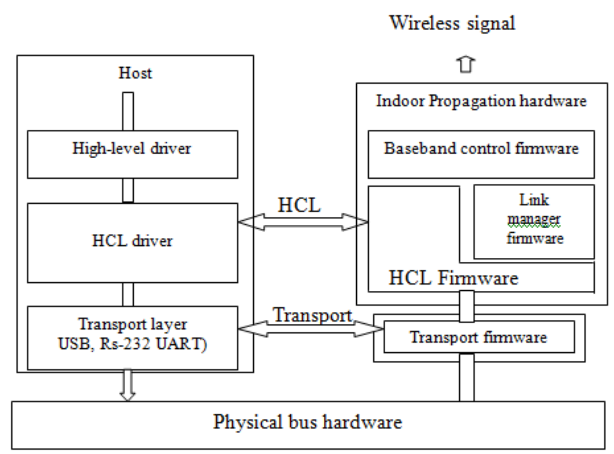

Figure 1: Indoor Propagation Architecture

The commonly used radio propagation modeling methods for indoor environments can be mainly categorized into the following four types :-

1. Empirical models:

Empirical models are usually extracted from channel measurements conducted at some typical places. They are extracted by fitting the measurement data with some simplified mathematical formulas or distribution functions. Thus, empirical models are normally very easy to implement and with very low computational load. However, since empirical models are extracted from measurements conducted only at some typical places, they retain some general channel characteristics without taking into account the specific propagation environments. For a specific propagation scenario, empirical models usually suffer from a low level of accuracy. The widely used empirical models for indoor environments include, for instance, the one-slope model, wall and for factor models, COST231 multi-wall model and linear attenuation model etc.

2. Stochastic models:

Stochastic models are usually used to model the random aspects of radio channels with random variables, e.g. fading characteristics of radio channels. Stochastic models require very little information of the propagation environments. For radio propagation channels, there exist two typical types of fading's: the large scale fading and the small scale fading. The large scale fading characterizes the signal strength variation over large distances [4]. On the contrary, the small scale fading characterizes the rapid fluctuations of the received signal strength over very short travel distances (usually a few wavelengths). The large scale fading and the small scale fading are usually modeled with stochastic models. For instance, the large scale fading, i.e. the shadow fading. The widely used small scale fading models include the Rayleigh fading model, the Rice fading model and the Nakagami-m fading model etc. The large scale fading models include the Log-normal fading model etc.

Rayleigh fading model

The Rayleigh fading model is widely used to model multipath fading when there is no LOS path. In NLOS scenarios, the received signal amplitude _ is distributed
according to the Rayleigh distribution

$$P_\alpha(\alpha) = \frac{2\alpha}{\Omega}\exp\left(-\frac{\alpha^2}{\Omega}\right), \qquad \alpha \geq 0$$

Where $\Omega = \overline{\alpha^2}$ is the average power of the fading.

3. Deterministic models:

Deterministic models simulate the real physical propagation phenomenon of radio waves. Deterministic models are based on the Maxwell's equations describing the behavior of electromagnetic field and take into account the specific propagation environments. Thus they usually possess a high level of accuracy. Since deterministic models take into account the specific propagation environments, they are also called site-specific models. The predicted results provided by the deterministic models are deterministic, i.e. the predicted results are always the same no matter how many times you rerun it if there is nothing changed in the simulated scenarios. Although deterministic models have the advantage of high accuracy, they have also the disadvantage of heavy computational load. Moreover, the high accuracy of deterministic models depends strongly on the accuracy of databases of the simulated scenarios. Ray-optical models and Finite-Difference Time-Domain (FDTD) models are the two widely used deterministic propagation models.

4. Semi-deterministic models:

Semi-deterministic models are the combinations of deterministic models and stochastic models or empirical models. Thus, semi-deterministic models benefit from both deterministic models and stochastic models or empirical models. For instance, semi-deterministic models usually require less computational time and lower computational load than deterministic models, but possess a higher level of accuracy than stochastic models or empirical models. The existing semi-deterministic models include for example, the Dominant model, the Motif model and the Geometry-based Stochastic Channel Models (GSCMs) etc.

III. CONSTRAINT SATISFACTION PROBLEM

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.CSP problem is known as NP-complete problem[2][3]. We can't find a polynomial time algorithm until we can prove P=NP, but we've developed some algorithm to accelerate the process to find the solution of CSP.

It is defined by finite set of variables, a set of domain and constraints [1]. All CSPs are characterized by the inclusion of a finite set of variables; a set of domain values for each variable; and a set of constraints that are only satisfied by assigning particular domain values to the problem's variables [2]. The CSP deals with the set of values from its domain to the variable in order that no constraint is violated. A CSP problem includes some variables, and valid values for those variables (we call it domain of the variables) and conflict tables. We must find a solution to assign values to all the variables and those values must satisfy the conflict tables [3]. There are currently two branches of constraint programming, namely constraint satisfaction and constraint solving. Constraint satisfaction deals with the problem defined over finite domain, on the other hand constraint solving algorithm are based on mathematical techniques. The constraint satisfaction programming (CSP) offers its basic algorithm like backtracking and branch and bound algorithm to solve and optimize the problem. Constraints satisfaction algorithm can be viewed as an iterative procedure that repeatedly assigns domain value to the variables.

CSP benefits:-

- Standard representation pattern
- Generic goal and successor functions
- Generic heuristics (no domain specific expertise).

Applications:-

- Scheduling the time of observations on the Hubble Space Telescope
- Airline schedules
- Cryptography
- Computer vision - image interpretation
- Scheduling your MS or PhD thesis exam

IV. DIFFERENT CSP ALGORITHMS:-

A. Backtracking:

This Backtracking is the basic algorithm to solve CSP. In every step, find a valid value to assign to current variable.

I. If a valid value is found, assign it to current variable and go to next step.

II. If there's no any valid value, back-track to the last variable to assign another value, expect another value of the last variable can lead to success of finding valid value for current variable.

III. A valid value for current variable is a value that is not conflict with any assigned variable.

For example, in the Chart 1, Variable C can't find valid value, and then we backtrack to Variable B to change the value, then check Variable C again. Backtracking is a Depth-First Search algorithm in search-space. Time complexity: O(bd), when b is the average tightness of constraints, which is the branching factor of the searching tree, and d is the number of variables, the depth of the searching tree.

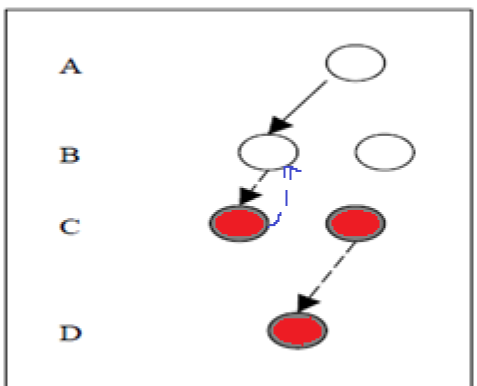

Chart 1: Different

B. Branch & Bound algorithm:

For the optimization CSP provides an optimization algorithm called branch and bound algorithm. Branch and bound strategy involves two mechanisms, a mechanism to generate branches when searching the solution space and a mechanism to generate a bound so that many branches can be terminated. The branch and bound algorithm uses a breadth-first search with pruning and a queue as an auxiliary data structure. Branch and bound algorithm starts with considering the root node and apply a lower-bounding and upper bounding technique to it. A bound is nothing but a global variable which is defined according to the minimization or maximization problem, it depends upon the case that either problem needs minimum or maximum value of the function [4]. Once the bound match, an optimal solution has been found and the algorithm is finished. If the bound does not match, then algorithm runs on the child nodes. The branch and bound algorithm in indoor wireless propagation models is used to find that particular set of frequency , the distance , density and energy at which the propagation loss is minimum. 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 [4]. A constraint satisfaction problem is defined as tuple (X, D, C, and f) where,

•x is a finite set of variables,

•d is a finite set of domains, one domain is assigned for each
Variable,

• C is the finite set of constraints that restrict certain value
assignments [8].

Domains of variables are: frequency, distance, density and energy.

V. BIT ERROR RATE (BER)

The Bit error rate and bit error probability The Bit Error Rate (BER) is a key parameter for measuring the quality of radio links. It is defined as the ratio of the number of error bits to the total number of transferred bits

$$BER = \frac{N_{error}}{N_{total}}$$

where Nerror and Ntotal are the number of error bits and the number of transferred bits, respectively. The BER provides an end-to-end measure of radio links. Unlike other parameters stated above which reflects radio link quality indirectly, the BER measures the link quality directly, i.e. the SNR, the average fade duration etc reflect the radio link quality through their impacts on the BER. Hence, the BER is the fundamental parameter for radio link quality and it has been widely used. Another relevant parameter is the Bit Error Probability (BEP). The BER can be considered as the estimate of the BEP. The larger the total number of the transferred bits is, the more accurate the estimate becomes.

VI. FADING CONCEPT

In wireless communications, fading is deviation of the attenuation affecting a signal over certain propagation media. The fading may vary with time, geographical position or radio frequency, and is often modeled as a random process. A fading channel is a communication channel comprising fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices.

Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communications channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables.

Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals.[1][2]

Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. If there is a dominant line of sight, Rician fading may be more applicable

Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver. The central limit theorem holds that, if there is sufficiently much scatter, the channel impulse response will be well-modelled as a Gaussian process irrespective of the distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be distributed. Calling this random variable R, it will have a probability density function:[1]

$$p_R(r) = \frac{2r}{\Omega} e^{-r^2/\Omega}, \ r \geq 0$$

Where $\Omega = E(R^2)$.

Often, the gain and phase elements of a channel's distortion are conveniently represented as a complex number. In this case, Rayleigh fading is exhibited by the assumption that the real and imaginary parts of the response are modelled by independent and identically distributed zero-mean Gaussian processes so that the amplitude of the response is the sum of two such processes.

VII. CONCLUSION

In this paper, a brief survey of basic solving techniques behind constraint programming has been studied. An overview of the main technique of solving constraint optimization problem i.e. branch and bound algorithm has been used. There are various wireless indoor propagation models used for channel communication using the constraint satisfaction algorithm. Besides, many radio propagation simulators provide only the mean power prediction, but it has been shown that fading has also an important impact on the system performance. Hence, the fading information was extracted based on the Ray-Leigh model and then an accurate prediction of the BER was achieved. The prediction of the BER has been tackled for three parameters: distance, density, energy. As is known, the BER depends not only on the mean power, but also on the fading severity, even also on the correlations among diversity branches for diversity systems.

VIII. REFERENCES

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