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A Comparative Analysis of Cell Planning for Path Loss Reduction

Nagendra Sah

Abstract— **In this paper, an optimized cell planning for path loss reduction has been proposed. A 10 by 10 Km square block is considered as Traffic Required Area (TRA) which consists of number of base stations (BSs) and mobile stations (MSs). The optimization algorithm: Tabu search, is used to optimize the position of base stations in such a way that the path loss (or reciprocal signal strength) between the BS and MS is minimum (or maximum). In order to accommodate large number of users, algorithm adds new BSs and also drops existing BSs. Then, the propagation path loss from a base station to a receiver point was calculated according to Okumura-Hata and Walfisch-Ikegami model. These are empirical models based on the measurement data. In order to improve the efficiency of the Tabu search, intensification through dynamic Tabu list and Tabu time have been used. Results obtained showed that proposed algorithm is highly effective. There is a capacity improvement by 14% at 900 MHz and 15% at 1800 MHz and the corresponding reduction in outdoor propagation path loss varies from 1 to 15 dB.**

Index Terms—**Cell Planning, Cellular Concepts, Pathloss, Propagation Models, Tabu Search Algorithjms**

I. INTRODUCTION

The Cellular wireless communication networks provide voice and data communication throughout a wide geographic area. Every cellular network requires cell planning to ensure coverage and avoid interference. Cell planning process consists of many different tasks. Each task is critical to produce an efficient working network.

The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. It offered very high capacity in a limited spectrum allocation without any major technological changes. The cellular concept is a system-level idea which calls for replacing a single, high power transmitter (large cell) with many low power transmitters (small cells), each providing coverage to only a small portion of the service area.

As the service demand increases (i.e., as more channels are needed within a particular market), the number of base stations may be increased (along with a corresponding decrease in transmitter power to avoid added interference), thereby providing additional radio capacity with no additional increase in radio spectrum [1]. This fundamental principle is the foundation for all modern wireless communication systems, since it enables a fixed number of channels to serve an arbitrarily large number of subscribers by reusing the channels throughout the coverage region.

Service areas are covered by BSs, i.e., the area from which incoming calls reach that base station, is called a cell [2]. One often pictures a cell as a hexagonal region with the base station in the middle. One then pictures a city or region as being broken up into a hexagonal lattice of cells. In reality, the base-stations are placed somewhat irregularly, depending on the location of places such as building tops or hill tops that have good communication coverage and that can be leased or bought. Similarly, mobile users connected to a base-station are chosen by good communication paths rather than geographic distance.

Recently, there has been a tremendous increase in traffic demand for communication services in cellular mobile communication systems. However, the frequency spectrum allocated to the systems is limited. Hence, how to use frequency channels in the most economical way whether the systems are based on the frequency division multiple access or the time division multiple access becomes very important. [3]

In reality, hexagons are extremely simplified models of radio coverage patterns because radio propagation is highly dependent on terrain and other factors. The problems of path loss, shadowing and multi-path fading all affect the coverage of an area [1]. Further, most cellular radio systems operate in urban area where there is no direct line-of-sight path between the transmitter and the receiver, and where the presence of high-rise buildings causes severe diffraction loss. Due to multiple reflection from various objects, the electromagnetic waves travel along different path of varying length.

Propagation models 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 T-R separation distance are useful in estimating the radio coverage area of a transmitter and are called large scale propagation models. On the other hand, propagation models that characterize the rapid fluctuations of the received signal strength over very short travel distance or short time duration are called small scale or fading models.

The paper is organized as follows. In Section II, we present the statements of problems. Section III presents a Tabu solution to the problem. In Section IV various results have been shown. Finally, we conclude the paper in Section V.

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F. A. Prof.Nagendra Sah is with PEC University of Technology, Sector-12, Chandigarh, PIN-160012, India.Phone No. +911722749601, Mobile No. =919872560513, Email: nagsah@yahoo.com

II. Statement Of Problems

Each hexagonal cell is considered as TRA. The radio base stations (RBSs) in a network cover different areas. The area covered by each of BS is in square kilometers and varies through the geographical areas. More RBSs/Km^2 mean that the coverage area of one RBS can be smaller without bringing coverage problems to the subscribers. The users will continue to access the services with the desired quality.

The sectors of the base station do not cover the same area. Therefore the sectors have to be treated individually with respect to a capacity expansion. This is due to the fact that traffic cannot be moved between the sectors when others have spare capacity. Multiple carriers on a unique sector cover the same area. Thus, our analysis is on the cell level. We analyze six complete hexagonal cells and three half cells.

Let us assume that each TRA has ψ_q number of subscribers where q = {1, 2,…,w}. Also, for each half cell under consideration (half TDA) number of subscribers are greater than or equal to$\lceil \psi_q \rceil$. ⌈x⌉. represents lowest integer larger than or equal to x.

To keep the problem within limits, we assume that all the base-stations transmit and receive on the same frequency channel initially. Thus, adjacent cells are co-channel cells. It will allow us to better demonstrate the proposed schemes under adverse conditions. The traffic module is based on the simple assumption of equal demand from every MS.

The number of the BSs is constant and equal to N. The N base stations can be recognized as $BS_1, BS_2, \dots BS_N$ are placed at points $(x_1, y_1), (x_2, y_2), \dots, (x_N, y_N)$ respectively. $\overline{\overline{BS}}_N$ represents selected base.

$$BS_N = \begin{cases} \overline{\overline{BS}}_N = 1 \text{ if BS is selected} \\ 0, \quad \text{if not selected} \end{cases}$$

Similarly mobile stations are located at points $(p_1, q_1), (p_2, q_2), \dots, (p_m, q_m)$ to access the network. Each mobile station is assigned to the BS depending upon the available cost, capacity and its distance from the BS. The allotment of BS assures the best signal and communication quality.

Let θ_s be the strength of signal from each BS to the location of the mobile (p_m, q_m). The mobile is assigned to the $\overline{\overline{BS}}_N$ with the largest value of this signal strength. The strength of signal must exceed a given threshold T_{rs} that depends upon sensitivity of the receiver. [2]

$$\overline{\overline{BS}}_N(\theta_s) \geq T_{rs}$$

In the free space, the received power at a distance d from the transmitter is given by, [3]

$$\theta_s = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 r^2}$$

where Pt is the transmitted power. G_t and G_r are the transmitter and receiver antenna gains, respectively. λ is the wavelength. Thus the shape of a cell can be described as a circle, the radius r of which is given by, [3]

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{\theta_s G_t G_r}{T_{rs}}}$$

When the above condition is satisfied, the mobile lies within the cell associated with $\overline{\overline{BS}}_N$. Outside this area, the base-station can act only as co-channel interferer. Once a mobile is assigned to a BS, a communication link can be established unless the co-channel interference at the location of the mobile is too high.

The total traffic demand in the TRA must be satisfied for a fully functional network. In the specified region minimum portion of traffic has to be covered by a wireless carrier. At least μ portion of total traffic required has to be covered by a selected base station in the region. For μ = 0.5 $(0 \leq \mu \leq 1)$ we,

$$\sum_{r=0}^{N}\sum_{l=0}^{q-1} \psi_l \overline{\overline{BS}}_{lr} \geq 0.5 \sum_{l=0}^{q-1} \psi_l$$

Capacity per base station δ_N and cost per base station BS_c depend upon type of multiple access technology used, number of T-R carriers configured per BS, and no of available channels. We have to enhance the capacity to accommodate maximum no of mobile stations. This can be given by, [1]

$$\sum_{l=0}^{q-1} \overline{\overline{BS}}_l \psi_l \leq \overline{\overline{BS}}_p \delta_p$$

for p = 1, 2, …, N. The above capacity improvement problem can be formulated as linear integer problem. Considering the system path losses as a principle for radio resource management can lead to overall interference reduction and performance and/or capacity improvement. Path loss measurements in cellular systems are typically obtained at the mobile terminal by measuring the received power from a downlink channel whose transmit power is known and then reported to the network [4]. Empirical models can be used to estimate the path loss. We use to important empirical models: Okumura-Hata and Walfisch-Ikegami (or cost 231model) to calculate path loss associated with each mobile station. [5]

III. Tabu Solution To Problem

The idea of TS is to derive and exploit a collection of principles of intelligent problem solving. It can be said that TS is based on selected concepts that unite the fields of intelligence and optimization. This algorithm is a meta-heuristic (means to learn by discovering things themselves and learning from their own experience rather than by telling them things) method recently developed by Fred Glover that guides local heuristic search procedure to explore the solution space beyond local optimality. The local procedure is a search that uses an operation called moves to define the neighborhood of any given solution. One of the main components of TS is its use of adaptive memory, which creates a more flexible search behavior. Therefore memory based strategies are most important part of TS approach. [8]

A. Greedy approach to TS

Initial allocation list consist of distance associated with each MS with its nearest BS. All active BSs are present in greedy active list and inactive BSs are present in greedy candidate list.

1) System checks the distance of each mobile with all active BSs in greedy active list. MSs having minimum distance are assigned to nearest BS.
2) At the same time, capacity of each BS is also checked. When both the conditions are satisfied, final allocation of MS is done.
3) After the initial cell planning process, path loss is calculated using Okumura-Hata and Walfisch-Ikegami model for greedy approach. To calculate path loss, we have to select BS and its associated MSs from TRA.

B. TS approach:

Tabu allocation list consist of distance associated with each MS with its nearest BS after application of optimization algorithm. All active BSs are present in tabu active list and inactive BSs are present in tabu candidate list.

1) Again, system initially calculates the current solution in greedy active list and find out the BS which is not able to utilize its capacity properly to accommodate maximum no. of MSs.
2) This BS is selected to be dropped from greedy active list to tabu candidate list.
3) Then the system starts looking for other suitable BSs from greedy candidate list that can accommodate dropped BS's mobile (as mentioned in ii) and other new requesting MSs in TRA. Finally, BS from greedy candidate list is added to tabu active list.
4) These MSs are assigned to selected base station to make the network fully functional.
5) Select the same model, MS and its associated BS to calculate the loss. Compare both the loss in order to make comparisons. Repeat the entire process for another comparison.

IV. Results And Discussion

The system has been dimensioned at 10x10 Km TRA at 900 MHz, and 1800 MHz. The analysis on path loss reduction based on cell planning for above mentioned frequencies has been done. This analysis is also carried for different MSs and BSs height.

TS algorithm makes an efficient use of the search history and avoids cycling of the optimization process. Different strategies use path loss information to distribute BSs in a 10x10 TRA. Thus, a synthesis cell planning network process is possible. The algorithm described was implemented in visual basic 6.0 at different frequencies, BS and MS heights.

A. Line And Bar Diagram For Different Base Station (Bs) And Mobile Station (Ms) For Hata Model

In this section line diagrams are analyzed for Okumura-Hata model at 900 MHz and 1800 MHz. Corresponding change in distance between BS and MS is shown by bar diagram. At 900 MHz and 1800 MHz load offered per MS is 70E load offered is 70E. Line diagrams are plotted between Mobile Station number and obtained Path Loss and bar diagrams are plotted between Mobile Station number and distance from BS.

1) Line Diagram and Bar Diagram at 900MHz for Different BS and MS height at BS Number Three

Line diagram for seven users at 900MHz has been shown below. Bar diagram shows distance between BS and MS before and after application of Tabu Search Algorithm. These seven MSs are associated to BS number 3 which is dropped and attached to BS no. 10 at .MHz. The reduction in path loss and distance from BS shows the system performance.

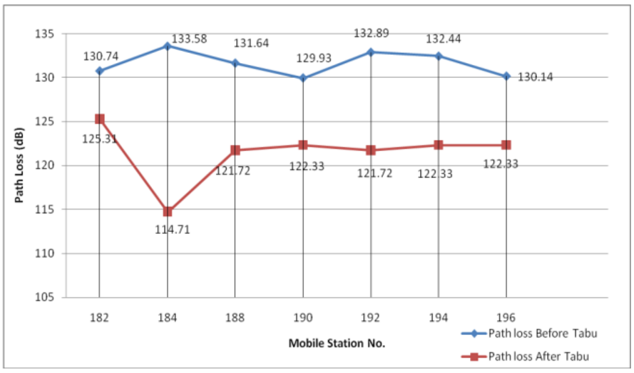

Fig. 4.1 line Diagram for BS height 30M and MS height 3M at 900MHz for 7 users

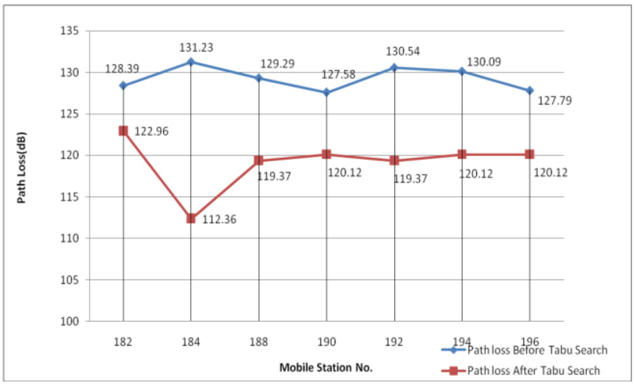

Fig. 4.2 line Diagram for BS height 30M and MS height 5M at 900MHz for 7 users

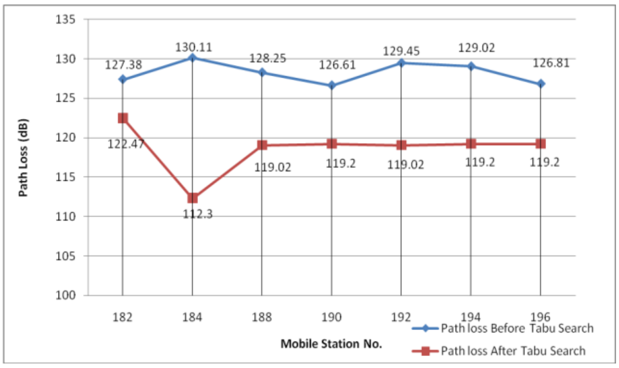

Fig. 4.3 line Diagram for BS height 50M and MS height 3M at 900MHz for 7 users

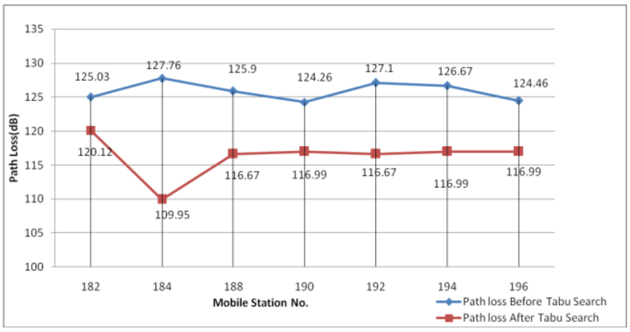

Fig. 4.4 line Diagram for BS height 50M and MS height 5M at 900MHz for 7 users

1) 4.1.2Line Diagram and Bar Diagram at 1800MHz for Different BS and MS height at BS Number Three:

Line diagram for seven users at 1800MHz has been shown below. Bar diagram shows distance between BS and MS before and after application of Tabu Search Algorithm. These seven MSs are associated to BS number 3 which is dropped and attached to BS no. 10 at .MHz. The reduction in path loss and distance from BS shows the system performance.

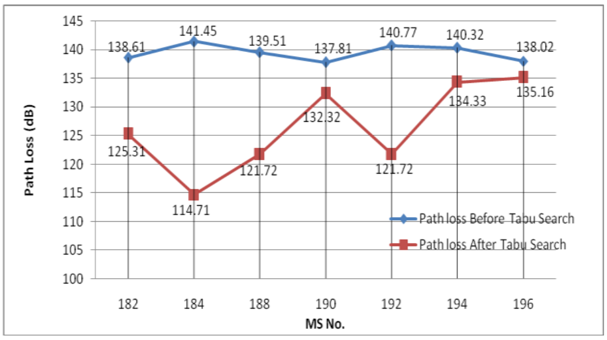

Fig. 4.5 line Diagram for BS height 30M and MS height 3M at 1800MHz for 7 users

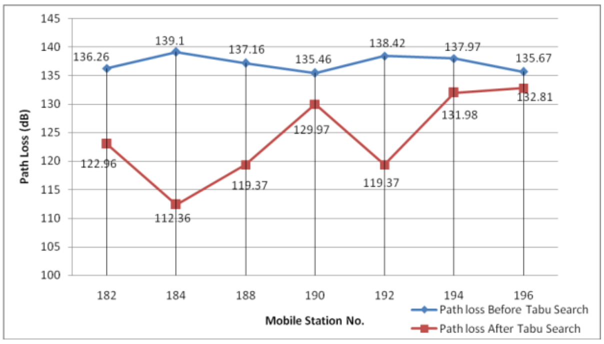

Fig. 4.6 Line Diagram for BS height 30M and MS height 5M at 1800MHz for 7users

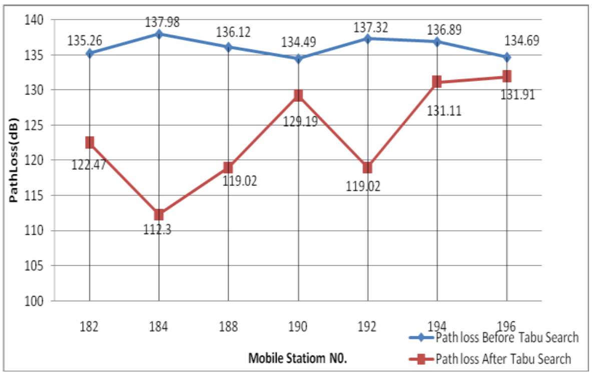

Fig. 4.7 Line Diagram for BS height 50M and MS height 3M at 1800MHz for 7 users

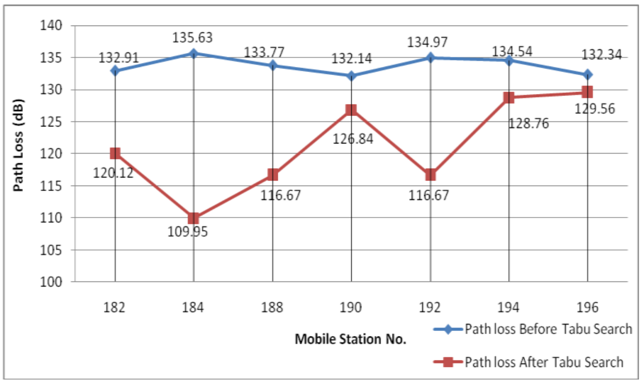

Fig. 4.8 Line Diagram for BS height 50M and MS height 5M at 1800MHz for 7 users

2) 4.1.3 Line Diagram and Bar Diagram for different height of BS and MS and different BS Number at different frequency:

Line diagram for seven users at 900MHz has been shown below. Bar diagram shows distance between BS and MS before and after application of Tabu Search Algorithm. These seven MSs are associated to BS number 7 which is dropped and attached to BS no. 12 at MHz. The reduction in path loss and distance from BS shows the system performance.

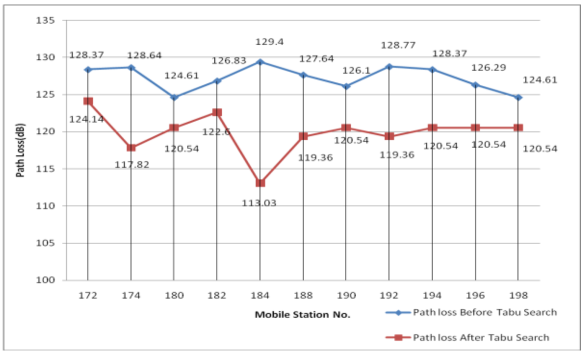

Fig. 4.9 Line Diagram for BS height 100M and MS height 1M at 900MHz for 11 users

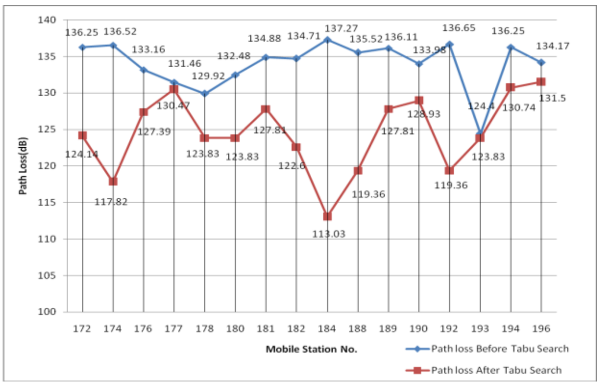

Fig. 4.10 Line Diagram for BS height 100M and MS height 1M at 900MHz for 17 users

B. Line And Bar Diagram For Different Base Station(Bs) And Mobile Station(Ms) For Costa 231 Model:

In this section line diagrams are analyzed for Walfisch-Ikegami model at 900 MHz and 1800 MHz. At 900 MHz and 1800MHz load offered per MS is 70E. In this model, roof height of 30m **a**nd width of street 15m is used. Incident angle relative to street varies from 55 to 90 degrees. The Walfisch-Ikegami model here presents a path loss that considers diffraction and reflection of urban building groups. The multi-scatter loss increase losses significantly when Mobile station height is changed. The reduction in path loss justifies the system performance.

1) Line Diagram at 900MHz for Fixed BS(30M) and Different MS height (1M,3M,5M,10M)at BS Number Three:

Average path losses at increasing MS height for twelve users at 900 MHz have been shown below. Although BS height is kept constant at 30m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 55 degree in this case. These twelve MSs are 26,28,30,32,34,36,38,40,42,44,46,50. The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance

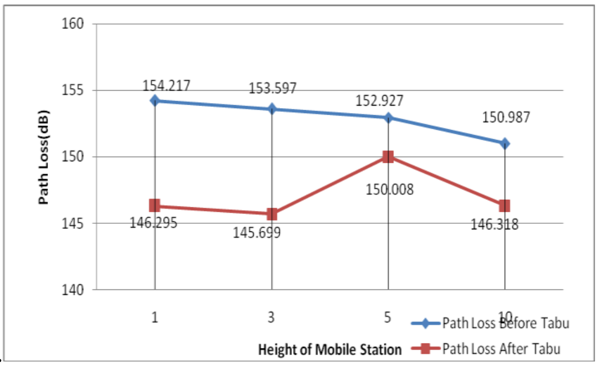

Fig4.11 Line Diagram at 900MHz showing avg. path loss for 12 users at BS Height 30M

2) Line Diagram at 900MHz for Fixed BS(50M) and Different MS height (1M,3M,5M,10M)at BS Number Six:

Average path losses at increasing MS height for twelve users at 900 MHz have been shown below. Although BS height is kept constant at 50m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 70 degree in this case. These twelve MSs are 12,14,16,18,20,22,24,26,28,30,32,34. The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance.

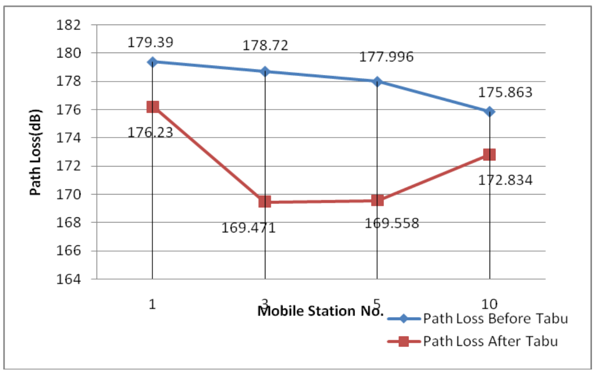

Fig.4.12 Line Diagram at 900MHz showing avg. path loss for 12 users at BS Height 50M

3) Line Diagram at 900MHz for Fixed BS(100M) and Different MS height (1M,3M,5M,10M)at BS Number Seven

Average path losses at increasing MS height for twelve users at 900 MHz have been shown below. Although BS height is kept constant at 100m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 90 degree in this case. These twelve MSs are 224,226,228,230,232,234,236,238,240,242,244,246. The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance.

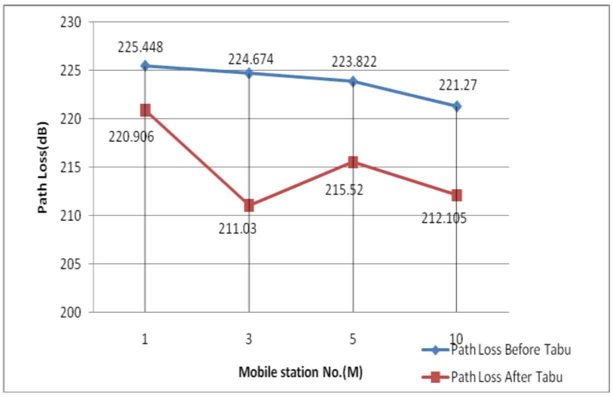

Fig. 4.13 Line Diagram at 900MHz showing avg. path loss for 12 users at BS Height 100M

4) Line Diagram at 1800MHz for Fixed BS(30M) and Different MS height (1M,3M,5M,10M)at BS Number Three:

Average path losses at increasing MS height for twelve users at 1800 MHz have been shown below. Although BS height is kept constant at 30m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 55 degree in this case. These twelve MSs are 26,28,30,32,34,36,38,40,42,44,46,50.The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance.

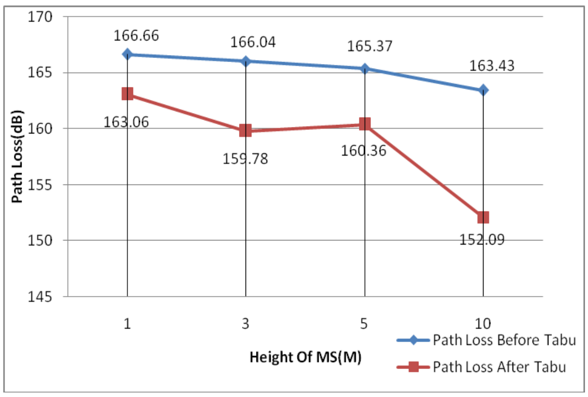

Fig.4.14 Line Diagram at 1800MHz showing avg. path loss for 12 users at BS Height 30M

5) 4.2.5 Line Diagram at 1800MHz for Fixed BS(50M) and Different MS height (1M,3M,5M,10M)at BS Number Six:

Average path losses at increasing MS height for twelve users at 1800 MHz have been shown below. Although BS height is kept constant at 50m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 70 degree in this case. These twelve MSs are 14,16,18,20,22,24,26,28,30,32,34,36.The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance.

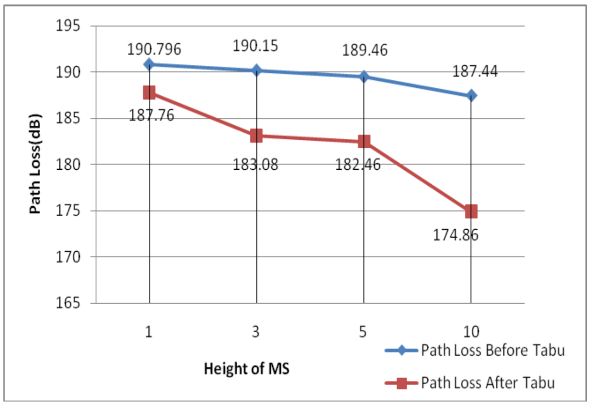

Fig.4.15 Line Diagram at 1800MHz showing avg. path loss for 12 users at BS Height 50M

6) 4.2.6 Line Diagram at 1800MHz for Fixed BS(100M) and Different MS height (1M,3M,5M,10M)at BS Number Seven:

Average path losses at increasing MS height for twelve users at 1800 MHz have been shown below. Although BS height is kept constant at 100m. Path loss model Walfisch-Ikegami is used. Incident angle relative to street is 90 degree in this case. These twelve MSs are 224,226,228,230,232,234,236,238,240,242,244,246.The graph shows that with increase in MS height average path loss decrease significantly. The reduction in path loss justifies the system performance.

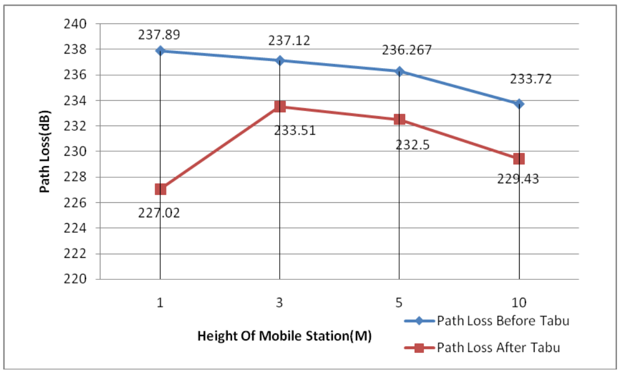

Fig.4.16 Line Diagram at 900MHz showing avg. path loss for 12 users at BS Height 100M

V. CONCLUSION

The system has been designed for 900 MHz, and 1800 MHz. A comparative Line diagram analysis of multiple users (MSs) at above mentioned frequencies has been done.

1) From the results at 200 MHz and 500 MHz, it has been seen that if required capacity is lower than or equal to system capacity than path loss remains constant.
2) At 900 MHz with higher capacity requirement, the system reduces the losses significantly by adding and dropping BSs in the TRA. Total number of MSs (70E load offered) accommodated increases from 201 to 234.
3) Results have shown that by making the use of path loss information depending upon the technology (GSM, CDMA or WLL) used, extensive loss reductions can be achieved.
4) At 1800 MHz total number of MSs (91E load offered) accommodated increases from 210 to 247. Thus, there is a capacity improvement by 15% and the corresponding reduction in outdoor path loss varies from 1 to 15 dB.

From the above points, it is found that there exists a trade-off between the number of MSs and load offered per MS in order to achieve higher system capacity. It also reveals that, to get more precise network accurate data on the specific area to be planned is needed on the traffic demand and on propagation characteristics.

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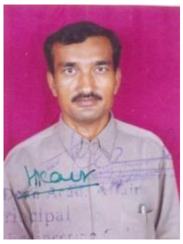

Prof. Nagendra Sah was born in Jaynagar, India, on 05-01-1960. He is Sr. Lecturer in PEC University of Technolgy (Formerly PEC-Deemed University), Chandigarh, India. He has done his B.Tech degree in Electronics and Communication Engg. from Regional Engineering College (Now National Institute of Technolgoy) Warangal, Andhra Pradesh, India in 1986 and Master of Engg. Degree in Electronics Engg. From Panjab University, Chandigarh, India in 2005. He has teaching experience of about 18 years. Presntly, he is working as Sr. Lecturer. He has published about 22 papers in national and international conferences. His research is focused on the radio-system design, the investigation and modeling of mobile radio propagation and the development of simulation methodsfor a mobile radio channel.

Membership in Professional Societies: Member of IACSIT, SINGAPORE.
IACSITMemberNumber 80331337