PERFORMANCE ANALYSIS OF BROADBAND WIRELESS AD-HOC NETWORK

A Project Report

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PROJECT CERTIFICATE

This is to certify that the project report titled **PERFORMANCE ANALYSIS OF BROADBAND WIRELESS AD-HOC NETWORK**, submitted by **Shailendra Panwar (EE12M013)**, to the Indian Institute of Technology, Madras, in partial fulfilment of the requirements for the award of the degree of **Master of Technology**, is a bonafide record of the work carried out by him in the Department of Electrical Engineering, IIT Madras. The contents of this report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

A wireless ad hoc network is a collection of autonomous nodes which communicate with each other by forming a multi-hop radio network and maintaining connectivity in a decentralised manner. In this project we are considering the optimum frequency assignment for tactical communication system (TCS) network comprising of a number of communication nodes connected in partial meshed topology over the requisite operational area termed as tactical battlefield area (TBA). TCS network comprises of static and frequency hopping communication links. Spectrum Management Tool, ICS Telecom is utilised for frequency assignment to all the communication links in the TCS network in order to minimise the Carrier to Interference (C/I) ratio for each Link. The simulations are carried out for TCS network configured with 0% (ideal), 10%, 20% and 50% link or node failures case to simulate partial network failure. The thesis also includes the interference analysis of the network under frequency and power constraint.Results of frequency allocation and C/(N+I) value are validated for static frequency links.

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ABBREVIATIONS

AN	Acces Node
ANA	Acces Node Type A
ANB	Acces Node Type B
ANC	Acces Node Type C
BER	Bit Error Rate
C/I	Carrier to Interference Ratio
C/(N+I)	Carrier to Noise Plus Interference Ratio
FHRR	Frequency Hopping Radio Relay
FZ	Fresnel Zone
HCLOS	High Capacity Line of Sight
HCR	High Capacity Radio
HCRR	High Capacity Radio Relay
HQ	Head Quarter
Mbps	Million Bits Per Second
RX	Receiver
SER	Symbol Error Rate
SINR	Signal to Interference plus Noise Ratio
SMT	Spectrum Management Tool
TBA	Tactical Battlefield Area
TCS	Tactical Communication System
TX	Transmitter
TN	Trunk Node
ULN	Unit Level Node

CHAPTER 1

INTRODUCTION

1.1 TCS Network for Military Application

The TCS network under consideration is set up to provide integrated voice, data and video communication services to army corps in battle field area. The communication nodes in TCS network are of different capacities and capabilities scattered over an area of 100x100 km. Each node has requisite numbers of Tx/Rx sets depending on its connectivity with other nodes in the network and bidirectional links are established between the linked nodes. High capacity backbone network is formed using trunk nodes placed at a distance of approximately 25 kms and users nodes of different capacities are connected to trunk nodes. To enable reliable communication in the event of jamming from adversary, user nodes are linked with frequency hopping links. Interference between different nodes is measured by the carrier- to-interference ratio (C/I), at the receiving end of a connection. ICS telecom, a spectrum management tool is used for frequency allocation to links connecting different nodes. ICS telecom facilitate the frequency assignment to all the links in the TCS network to achieve a high value of Carrier to interference ratio (C/I) for each link.

1.2 Objective

- Frequency assignment to static and frequency hopping links using ICS telecom, to ensure minimum interference observed by each link.
- To analyse the effect of partial link or partial node failure on existing interference for each link.
- To analyse the effect of bandwidth and power constraint on interference of the network.
- To develop an algorithm for static frequency assignment and comparison of frequency allocation and C/(N+I) for each link with ICS telecom.

- Comparison of SINR profile for a static link with SNR profile and explore the possibility of using multi chain receiver to improve SER of the test link.

1.3 Organisation of Thesis

A brief introduction of ICS telecom is provided in Chapter 2. It highlights the requirement of ICS telecom. The details of TCS architecture are also enumerated in this chapter. Various parameters, which need to be set in ICS telecom to emulate the network are provided in this chapter.

Chapter 3 discuss the simulation results obtained with ICS telecom. It also describes, the partial network failure cases in terms of link or node failure.

A brief description of interference analysis of HCRR links and FHRR links with frequency and power constraint is provided in chapter 4.

Chapter 5 provides the details of algorithm developed for validating the ICS telecom results. The comparison of results obtained using both methods is placed in this chapter. The chapter also provide SINR profile of HCRR links for single and multi chain receivers.

Chapter 6 includes the conclusion of thesis.

CHAPTER 2

INTRODUCTION TO ICS TELECOM AND TCS NETWORK CONFIGURATION

2.1 Need for ICS Telecom Spectrum Management Tool

The project entails at optimising the frequency bandwidth allocation to all the links of TCS network to ensure minimum interference for each link. Below mentioned features of ICS telecom has ensured optimum frequency allocation to the network:

- SMT can cater for path loss along line of sight due to the underlying vegetation, diffraction geometry, obstacles such as building etc in a given topographic map. Different propagation models such as Okumura-Hata, 3GPP and different ITU Models can be selected.
- The tool supports specific Ultra High Capacity radio (HCR) Set.
- SMT is able to handle multiple directional antennas on a single base station with microwave point to point communication link. Antennas can be selected suitably for the required frequency band of operation with specific antenna gain.
- ICS telecom has an ability to analyze the NLOS conditions, channel environment, and waveform parameters.
- It has ability to customise the Tx and Rx parameters such as transmitted power, antenna gain, threshold, noise factor, modulation scheme, code rate etc.
- It is capable of simulating static frequency assignment as well as frequency assignment in frequency hopping mode.
- The interference experienced by each link is specified in term of C/I value which in turn can be mapped to calculate the SER value for each link for the given network.

2.2 Architecture of Network

TCS Architecture consists of a backbone network formed by trunk nodes which can interact among themselves. The subscriber stations (access nodes) may connect to one or more trunk nodes. The trunk nodes communicate over a maximum distance of 30 km and use microwave point to point communication link between every such pair. The link capacity of high capacity radio link (HCRR) for communication between trunk nodes is 34 Mbps. The access node communicates with trunk node using frequency hopping radio relay (FHRR) link of 8/4 Mbps capacity. The access nodes communicate with each other through at least one trunk node PDR (2012).

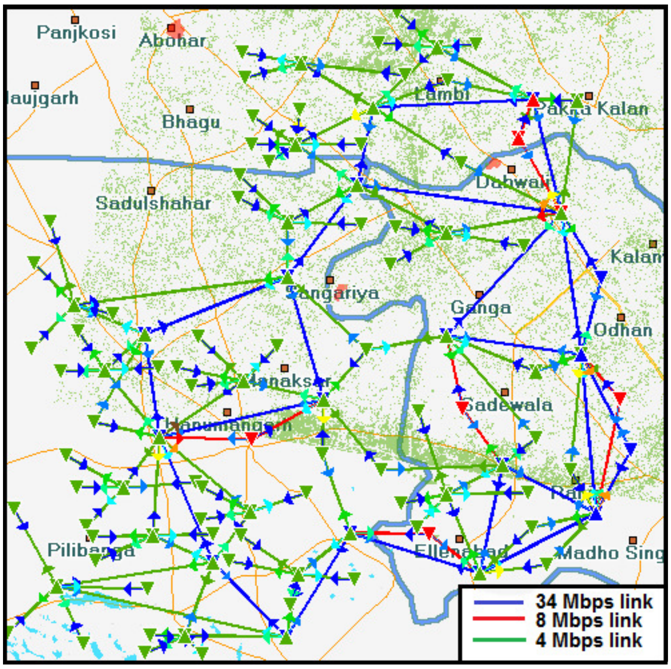

Figure 2.1: TCS Network Node Deployment

2.2.1 Types of Node

Trunk Node

The network backbone is formed using a number of trunk nodes inter-connected in a flat partial-mesh network with high capacity line of sight (HCLOS) links operating at 34 Mbps. A total of 16 in number trunk nodes are deployed in this network TCS (2011).

Access Node

Access nodes provide user level connectivity. There are three types of access nodes:

- Type A access nodes are deployed at corps headquarter (HQ) level. There are three ANA nodes, which are connected to nearest trunk nodes at 34 Mbps, 8 Mbps and 4 Mbps capacity link respectively.
- Type B access nodes are deployed at division HQ level. There are 12 in number type B access nodes deployed in present architecture. They are connected to the nearest trunk node at 8/4 Mbps capacity link.
- Type C access nodes are deployed at brigade HQ level. There are 18 in number type C access nodes deployed in present architecture. They are connected to the nearest trunk nodes at 8/4 Mbps capacity links.

Unit Level Node

Unit level nodes are deployed at Battalion/Regiment HQ level. The ULNs are connected to the access nodes at 4 Mbps capacity links. A total of 106 ULNs are deployed.

2.3 Emulation of Network using ICS telecom

The position of trunk nodes, access nodes and unit level nodes in tactical battlefield area (TBA) is available in X-Y co-ordinates system. However there is no provision of positioning the station in the map in terms of X-Y co-ordinates as the tools take the co-ordinate values in lat-long format. Thus co-ordinates from the NED file are converted to lat-long values using the on-line converter called NDSF Utility. A total of 140 links connecting TNs, ANs and ULNs are created. Fig. 2.1 shows the TCS network nodes configuration with deployment of TNs, ANs and ULNs in TBA.

- 24 links with 34 Mbps capacity (11 MHz)
- 10 links with 8 Mbps capacity and (7 MHz)
- 106 links with 4 Mbps (7 MHz)

2.4 Assignment of Parameters

2.4.1 Propagation Model

Various propagation models are available in ICS telecom to cater for underlying vegetation and terrain conditions. These models cover the effect of diffusion, diffraction, refraction and reflection. The standard propagation models available in ICS telecom are shown in fig. 2.2.

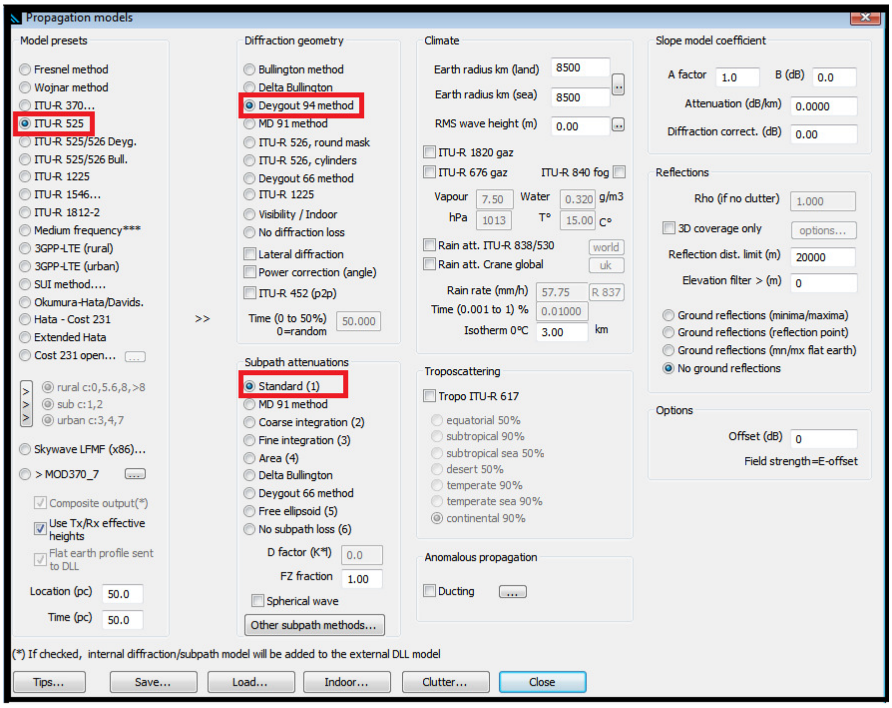

Figure 2.2: Propagation Models

ITU-R-P 525 propagation model is selected for simulation purpose. It is a geometrical (or deterministic) model which provides an estimation directly derived from the path profile ATDI (2004). Apart from the free space attenuation term L_{fsd}, the two major terms L_d and L_{sp} stand for geometrical attenuation terms. L_d is a diffraction correction term can be selected in the diffraction geometry box of the propagation models dialog box. Geometrical model take the Earth curvature into account (i.e. the require altimetric correction due to the rotundity of the Earth). The propagation loss is given by:

$$L_{prop} = L_{fsd} + L_d + L_{sp} + L_{gas} + L_{rain} + L_{clut} + L_{model}$$

where,

L_{prop}=Propagation Loss

L_{fsd}=free space distance loss,

L_d=diffraction loss,

L_{sp}=sub path loss,

L_{gas}=attenuation caused by atmospheric gas,

L_{rain}=attenuation caused by hydrometeor scatter,

L_{clut}=clutter attenuation,

L_{model}=specific unclassified attenuation deriving from model selection in the model dialog box

2.4.2 Free Space attenuation

The free space attenuation term is always given by:

$$L_{fsd} = 20 * log(d)$$

It only depends on distance (d) between Tx and Rx

2.4.3 Diffraction Loss

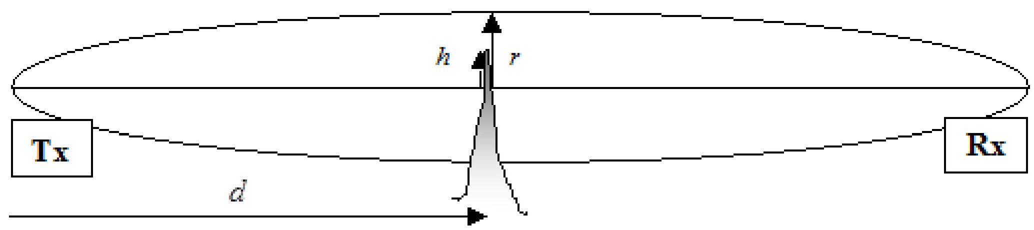

Figure 2.3: Diffraction Loss in case of Single Obstacle

Deygout 1994 Method is chosen to cater for the uneven terrain model Deygout (1994). In this method the search for the edges is sequential: if the primary obstacle exists, one searches for two secondary obstacles (one between Tx and the obstacle and the other between the obstacle and Rx). Then, this search is performed again on each side of the secondary obstacles possibly looking for ternary obstacles. This process is reiterated recursively until no new obstacle is found. Then, the global diffraction loss is

$$L_d = \sum_i L_d(V_i)$$

Where L_d is Diffraction loss and $V_i = \sqrt{\frac{2h}{r}}$ is the clearance ratio for the obstacle. In ICS Telecom, this method is implemented in a slightly different way. Once the primary obstacle has been found, the other obstacles are determined from the convex envelope of the profile. The corresponding V_i is then evaluated between the $i-1$ obstacle and the $i+1$ obstacle (all the obstacles being ascending sorted w.r.t to their distance to Tx). The global attenuation term is the same as above.

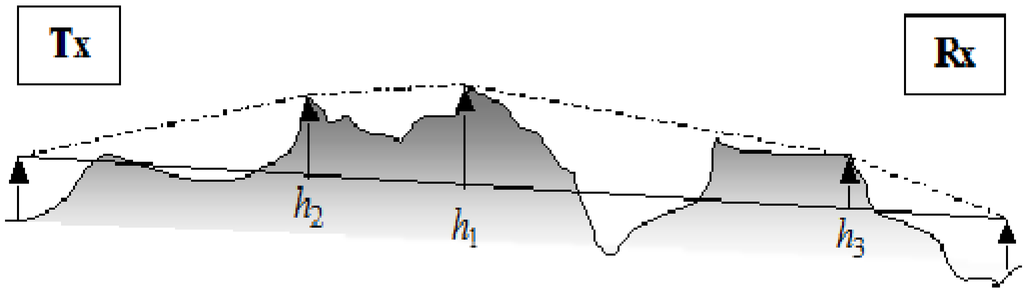

Figure 2.4: Diffraction Loss in case of Multiple Obstacles

2.4.4 Standard Sub Path Attenuation

This attenuation is based on L_{gr} value, but with a correction coefficient:

$$L_{sp} = FZ * \rho * L_{gr},$$

where, $L_{gr} = 20log(75000d) - 20log(\pi * h_1 * h_2 * f)$

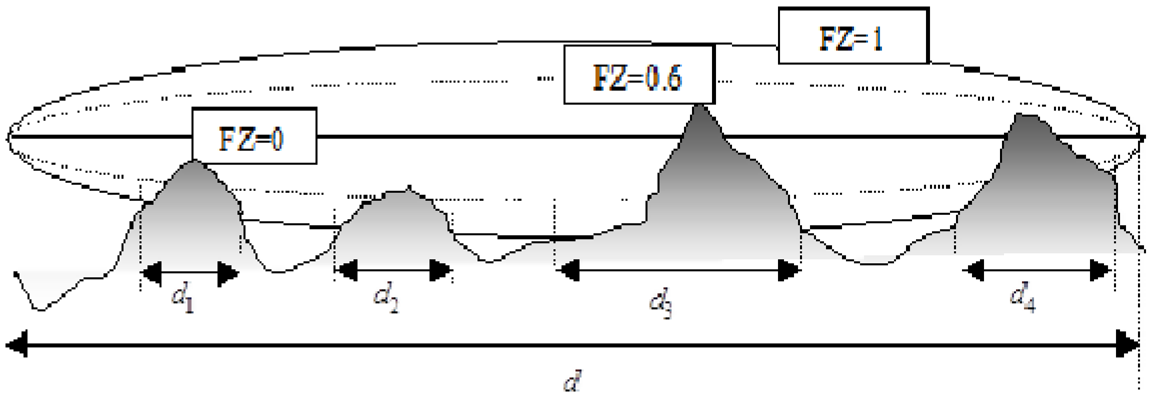

Figure 2.5: Fresnel Zones in case of Multiple Obstacles

where d is the distance to Tx (in km), h_1 and h_2 are respectively the Tx and Rx antenna height (in m) and f the frequency (in MHz). This correction term is directly derived from surface reflection modeling (for low incident angles). This correction (called L_{gr} for ground reflection attenuation) works, but only in specific conditions (limited bandwidth, antenna heights). Where ρ is the proportion of the total path that is located above the first Fresnel virtual ellipsoid, refer fig. 2.5 ($\rho = \frac{d_1+d_2+d_3+d_4}{d}$) and FZ (for fresnel Zone) is a coefficient of reduction of this virtual ellipsoid: $FZ = 1$ means that the whole ellipsoid is considered, $FZ = 0$ means that the virtual ellipsoid reduces to the straight line of sight segment (refer fig. 2.5).

2.4.5 Base Station (Tx/Rx) Configuration

- Transmitted power (in dBm) of radio sets connected via 34 Mbps HCRR link is set at 26 dBm. However the transmitted power for radio sets connected via 8 Mbps and 4 Mbps frequency hopping radio relay (FHRR) link is fixed at 25 dBm and 26 dBm respectively.

- Modulation type for 34 Mbps (HCRR), 8 Mbps (FHRR) and 4 Mbps (FHRR) radio set is set as 32 QAM (4/5), 64 QAM (4/5) and 16 QAM (2/3) respectively.

- The Threshold BER ($10^{-6}/10^{-3}$) represents the reference required received power to get a BER (bit error rate) below $10^{-6}/10^{-3}$ bit/s. The difference between the power received and the threshold is called margin. Receiver threshold for 34 Mbps (HCRR), 8 Mbps (FHRR) and 4 Mbps (FHRR) radio set is set at -79 dBm, -77.7 dBm and -85.5 dBm respectively.

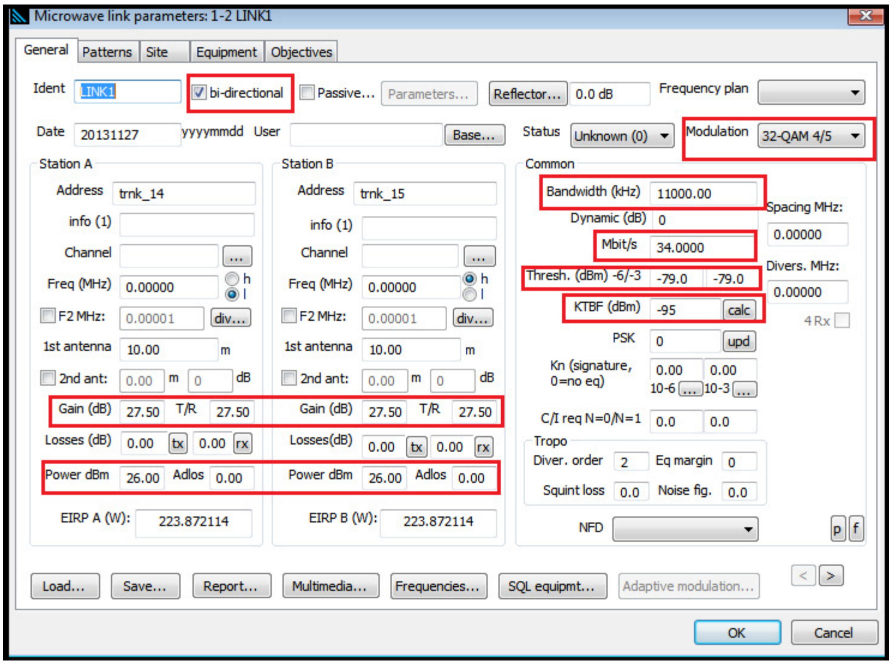

Figure 2.6: Window for Setting up TX/RX Parameter

- KTBF (dBm) value represents the thermal noise power of the receiving equipment. The KTBF can be computed, as it is the product of the Boltzmann constant (K), the noise temperature (T in Kelvin), the bandwidth (B) and the noise figure (F). The KTBF value is set at -95 dBm.
- Bandwidth is used for interference calculation. Bandwidth for HCRR and FHRR link is 11 MHz and 7 MHz respectively.
- Antennas are defined in pattern tab. An RPE 3D pattern gives the attenuation following the angle off the axis of the main radiation. Andrew corporation FP10-36 antenna has been chosen as its frequency range (3600-4200 MHz) of operation is closest to the required band. In addition the antenna height is chosen to be 10 mtrs and antenna gain for both Tx and Rx antennae is fixed to be 27.5 dB.

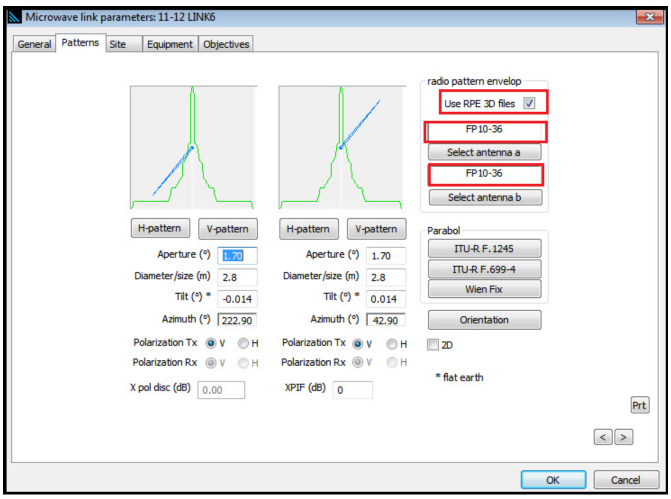

Figure 2.7: Antenna Parameter

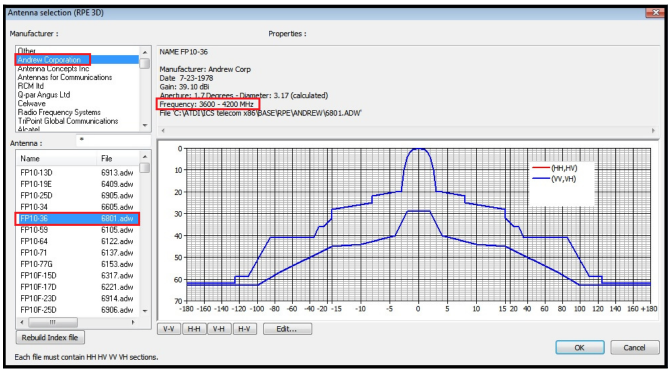

Figure 2.8: Directivity Pattern of Antenna

2.5 Frequency Assignment

The principle of the frequency assignment is first to calculate the coverage using a nominal frequency of the transmitters and then, to modify the frequencies in order to minimise the interferences.

2.5.1 Frequency Assignment for HCRR Links

Frequency assignment is done for 24 HCRR bidirectional links operating at link capacity of 34 Mbps. These links are simulated as microwave links in ICS telecom. The frequency assignment is done using C/I method i.e. the frequencies are assigned to each station in order to limit interference in terms of C/I.

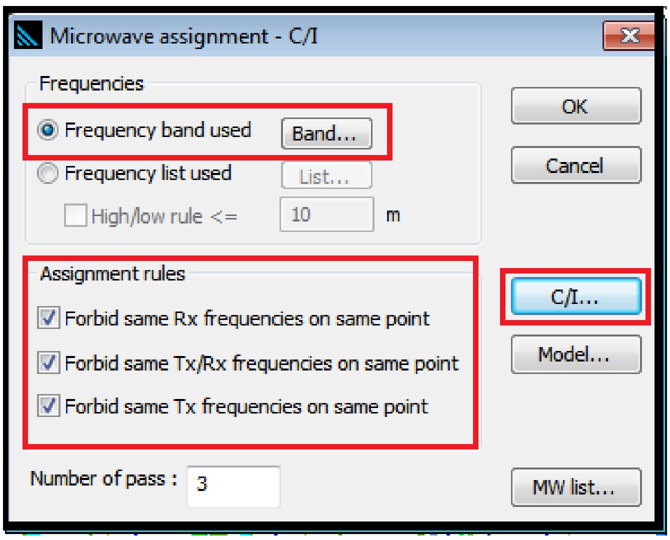

Figure 2.9: C/I Method of Frequency Assignment to HCRR Links

150 MHz frequency bandwidth is assigned to these 24 HCRR links. Since these links are frequency duplex, a frequency spacing of 75 MHz is set between Tx and Rx. The step size is kept 11 MHz as the occupied channel bandwidth for each link is 11 MHz.

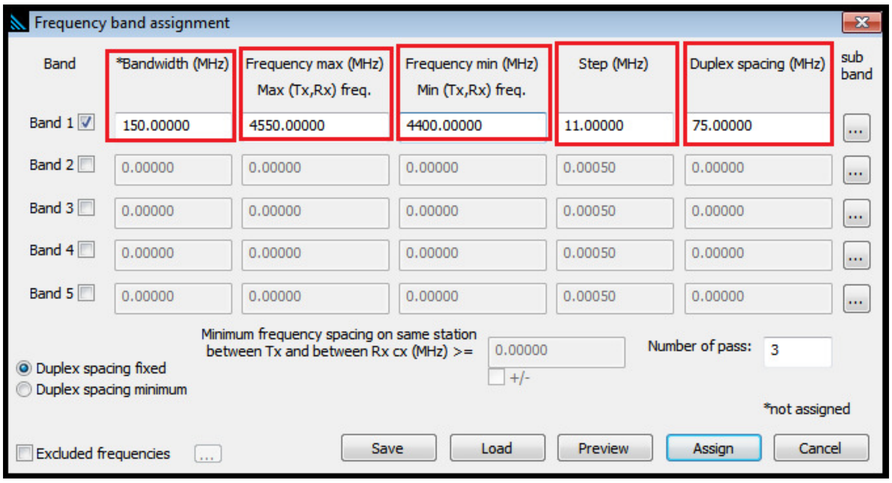

Figure 2.10: Frequency Assignment to HCRR Links

2.5.2 Frequency Assignment for FHRR Links

- There are a total of 116 bidirectional link which are operating in Frequency hopping mode. Out of these 116 links, 10 links are operating at 8 Mbps capacity and rests 106 are 4 Mbps capacity links. Frequency assignment is done to all these links in Tx/Rx mode in ICS telecom as Frequency hopping function is not available in Microwave link mode.

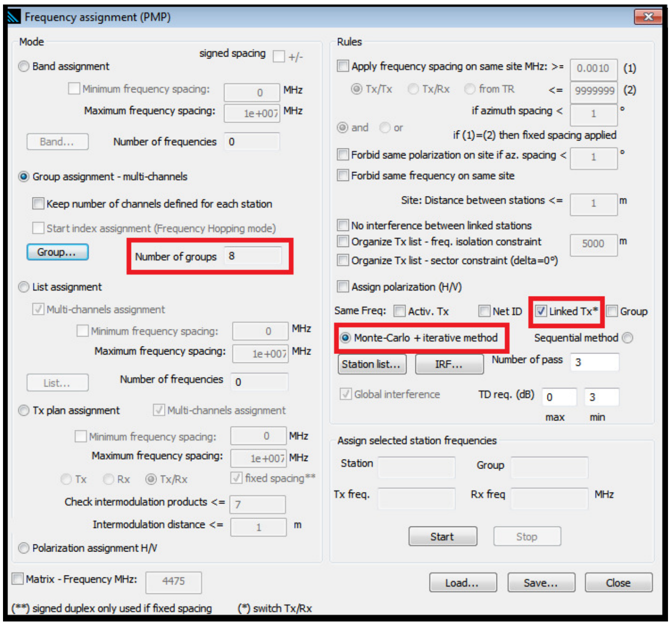

Figure 2.11: Frequency Assignment to FHRR Links

- 116 FHRR links are divided into 8 groups based on the spatial location of nodes in the network. The frequency band (450 MHz) is divided into 8 groups with each group having 8 different frequencies at regular interval of 56 MHz. 8 orthogonal hopping patterns are generated corresponding to each group. These orthogonal hopping patterns are assigned to each link in corresponding group in order to minimize interference. Monte Carlo method is used for frequency assignment.

2.6 Interference analysis

Interference analysis is done for all the links (HCRR and FHRR) by activating them simultaneously. Interference analysis is done in terms of calculating the C/(N+I) value for each link in the network. All the nodes are activated in Tx/Rx mode for interference calculation, although separate methods have been used for frequency assignment to HCRR and FHRR links. The required C/(N+I) value for each link is set to be 16 dB.

2.7 C/(N+I) to SER Conversion

Since the SER values are required to be fed to OMNET++ to calculate System throughput and throughput at node level, packet loss and packet delivery ratio, end-to-end delay, per-hop delay and jitter etc for TCS network. The C/(N+I) values obtained after interference analysis are mapped to respective SER values. The formula used for mapping is

$$SER = 2\left(1-\frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{3}{2(M-1)}}\sqrt{\frac{E_s}{N_o}}\right) - \left(1-\frac{2}{\sqrt{M}}+\frac{1}{M}\right) erfc^2\left(\sqrt{\frac{3}{2(M-1)}}\sqrt{\frac{E_s}{N_o}}\right)$$

Where M is the value of M-array QAM and $\sqrt{\frac{E_s}{N_o}}$ is the C/(N+I) value of a given link Proakis and Salehi (2008) and DSPLOG (2012).

CHAPTER 3

ICS TELECOM SIMULATION RESULTS

3.1 Ideal Case

Ideal case for interference analysis is considered with no node and no link failure in the TCS network i.e. all the nodes and links in the network are active. C/(N+I) value is obtained for each link by running the interference analysis simulation for the network without any node failure and link failure. The C/(N+I) values thus obtained after simulation are well above 16 dB for most of the links. The C/(N+I) and corresponding SER values for few links are shown in the table 3.1
As seen in table 3.1, the C/(N+I) value for Link connecting `trnk_12 and trnk_13` is found to be 16.6 dB which is close to the required C/(N+I) value. To analyse the cause of low C/(N+I) value, the path profile of the link connecting the two station is obtained. It is understood that the low C/(N+I) value is due to the terrain condition between the Tx and Rx stations as shown in the fig. 3.1. The C/(N+I) value can be improved by either increasing the Tx and Rx antenna height or by increasing the transmitted power.

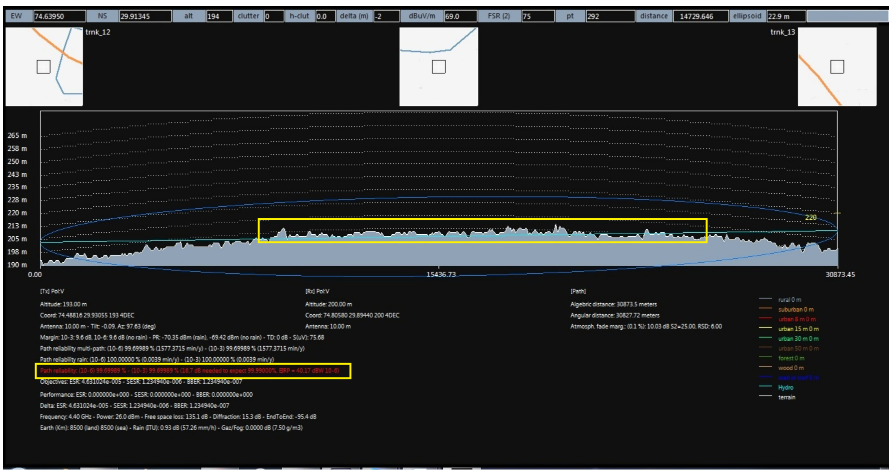

Figure 3.1: Path Profile for Link with Low C/(N+I) Value

S. No.	Tx Station	Rx Station	Rx Frequency	Interferer	Tx Frequency	C/(N+I) (dB)	SER
1	trnk_15 (2)	trnk_14 (1)	4475	trnk_12 (4)	4486	37.9	0
2	trnk_14 (1)	trnk_15 (2)	4400	trnk_14 (3)	4411	38.1	0
3	trnk_12 (4)	trnk_14 (3)	4486	trnk_15 (2)	4475	48.9	0
4	trnk_14 (3)	trnk_12 (4)	4411	trnk_14 (1)	4400	48.5	0
5	trnk_14 (3)	trnk_12 (4)	4411	trnk_12 (5)	4400	46.3	0
6	trnk_13 (6)	trnk_12 (5)	4475	trnk_15 (2)	4475	25.4	1.1405E-08
7	trnk_13 (6)	trnk_12 (5)	4475	trnk_12 (4)	4486	23.2	1.13709E-05
8	trnk_12 (5)	trnk_13 (6)	4400	trnk_14 (1)	4400	25.5	7.63191E-09
9	trnk_12 (5)	trnk_13 (6)	4400	trnk_13 (7)	4411	23.3	8.89055E-06
10	trnk_12 (5)	trnk_13 (6)	4400	trnk_13 (9)	4422	16.6	0.057512673
11	trnk_15 (8)	trnk_13 (7)	4486	trnk_15 (2)	4475	41.3	0
12	trnk_15 (8)	trnk_13 (7)	4486	trnk_13 (6)	4475	39.1	0
13	trnk_13 (7)	trnk_15 (8)	4411	trnk_14 (1)	4400	41.5	0
14	trnk_11 (10)	trnk_13 (9)	4497	trnk_15 (2)	4475	34.4	0
15	trnk_11 (10)	trnk_13 (9)	4497	trnk_13 (6)	4475	25.6	5.06071E-09
16	trnk_11 (10)	trnk_13 (9)	4497	Strk_Crp_Main_1 (42)	4519	33.9	0
17	trnk_13 (9)	trnk_11 (10)	4422	trnk_14 (1)	4400	34.5	0
18	trnk_13 (9)	trnk_11 (10)	4422	trnk_10 (13)	4400	34.4	0
19	trnk_13 (9)	trnk_11 (10)	4422	trnk_11 (39)	4411	32.2	0
20	trnk_13 (9)	trnk_11 (10)	4422	trnk_11 (277)	4444	25.6	5.06071E-09
21	trnk_10 (12)	trnk_13 (11)	4508	trnk_12 (4)	4486	32.1	0
22	trnk_13 (11)	trnk_10 (12)	4433	trnk_14 (3)	4411	32.1	0
23	trnk_11 (14)	trnk_10 (13)	4475	trnk_15 (2)	4475	37.5	0

Table 3.1: C/(N+I) Value for Links in the TCS Network

3.2 Link Failure Cases

10%, 20% and 50% links failure cases in network are simulated to observe the effect of link failures on the SER value of each link. These links are 34 Mbps HCRR links. This is achieved by deactivating the respective link i.e. the failed link in the network.

Three cases are considered for each percentage link failure.Case 1, Case 2 and case 3 identify link failure with minimum, average and maximum degree respectively. The degree of a link is decided by the numbers of links it is connected with i.e. a link with higher degree will be connected to more number of links. For comparing the result of each link failure case, we have considered the number of links whose SER is above 10^{-9}.

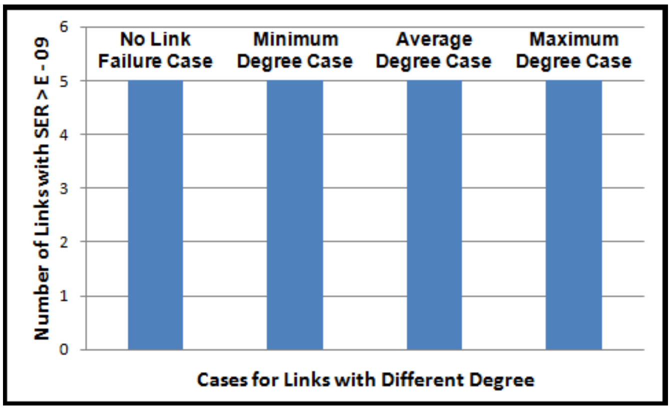

Figure 3.2: 10% Link Failure of Different Degree Links Comparison with Ideal Case

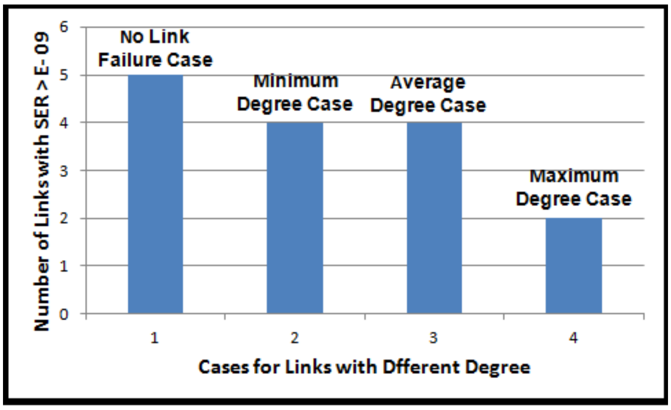

Figure 3.3: 20% Link Failure of Different Degree Links Comparison with Ideal Case

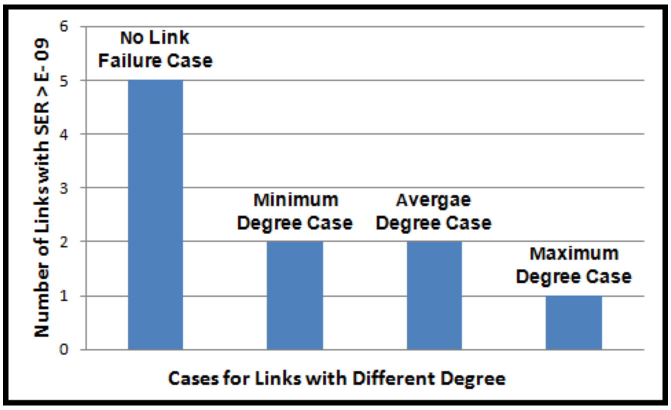

Figure 3.4: 50% Link Failure of Different Degree Links Comparison with Ideal Case

As observed in the graphs, the number of links with SER above 10^{-9} has reduced with increase in number of failed links. As the number of activated links has reduced, the interference has reduced proportionately. Also in case of failure of links with high degree, the number of links with BER value above 10^{-9} is less compare to lower degree Link.

3.3 Node Failure Cases

To observe the effect of partial network failure, the node failure cases are simulated. 10%, 20% and 50% trunk nodes with different degree are failed and their effects on SER of each link is observed. The degree of a node is decided by the number of nodes it is connected with.

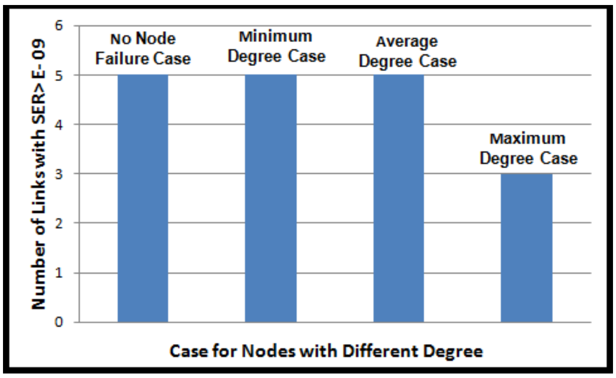

Figure 3.5: 10% Node Failure of Different Degree Nodes Comparison with Ideal Case

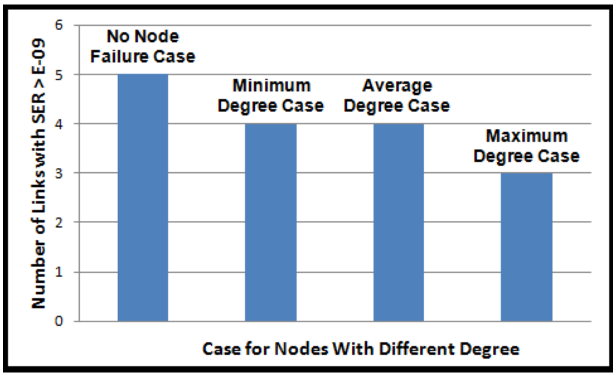

Figure 3.6: 20% Node Failure of Different Degree Nodes Comparison with Ideal Case

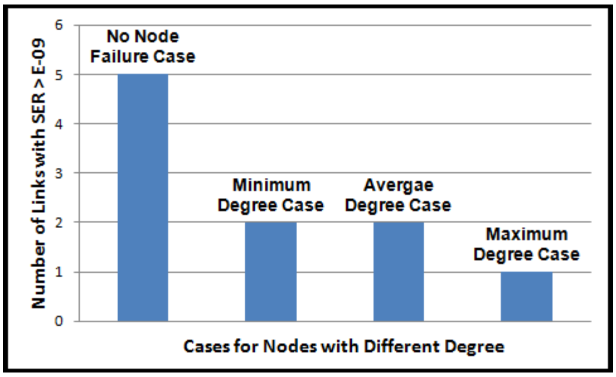

Figure 3.7: 50% Node Failure of Different Degree Nodes Comparison with Ideal Case

The number of links with SER above 10^{-9} is reduced with increase in number of failed nodes. Also in case of the failure of a node with higher degree, the number of nodes with SER above 10^{-9} is less than a lower degree node.

CHAPTER 4

INTERFERENCE ANALYSIS WITH BANDWIDTH AND POWER CONSTRAINT

4.1 Introduction

To understand the effect of reduction in frequency and power bandwidth on BER values of links, interference analysis is carried for TCS network using ICS telecom with different frequency Bandwidth allocation to HCRR and FHRR links and different power level assigned to all the transmitters.

4.2 Bandwidth Reduction for HCRR Links

For ideal case 150 MHz bandwidth is used while assigning frequency to 24 HCRR links. These links are frequency duplex bidirectional links with 11 MHz channel bandwidth. To observe the effect of band reduction on C/(N+I) values, the interference analysis for HCRR links is done for 150 MHz, 100 MHz, 75 MHz, 50 MHz and 25 MHz bandwidth. Fig 4.1 shows the change in number of links with SER>10^{-9} as available bandwidth for HCRR links is reduced.

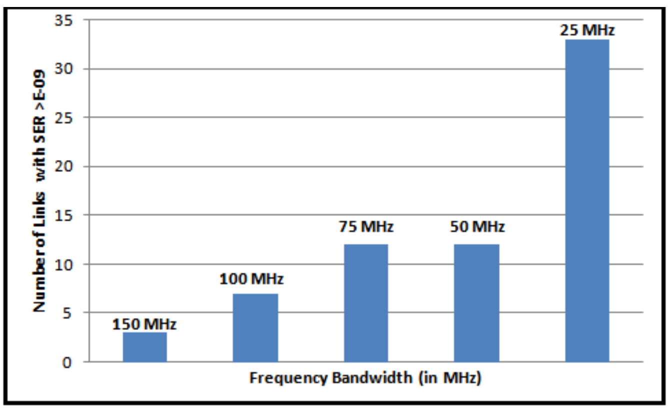

Figure 4.1: Effect of Bandwidth Constraint on Interference

The number of links with SER >10^{-9} has increased, as the available bandwidth is reduced in steps from 150 MHz to 25 MHz. C/(N+I) value for all the HCRR links is found well above the required C/(N+I) value for frequency band 150 MHz and 100 MHz. However the C/(N+)I value for some links has fallen below the required value, when the bandwidth is reduced to 75 MHz. The number of such links i.e. with C/I value less than 16 dB, has increased further with 50 MHz and 25 MHz bandwidth. It is observed that as the frequency bandwidth is reduced the number of links suffering with interference has increased.

4.3 Bandwidth Reduction for FHRR Links

To understand the effect of bandwidth reduction on C/(N+I) value of FHRR links, interference analysis is carried for TCS network. Three frequency bands i.e. 150 MHz, 50 MHz and 20 MHz are selected for interference analysis. No significant changes have been observed in C/(N+I) values for FHRR links with reduction in frequency bandwidth.

4.4 Interference Analysis with Reduction in Power

To understand the effect of change in transmitted power on interference of the network, Tx power is varied in steps from 6 dBm to 26 dBm. As shown in fig 4.2, the percentage of links with SER greater than 10^{-9} has increased with reduction in Tx power.

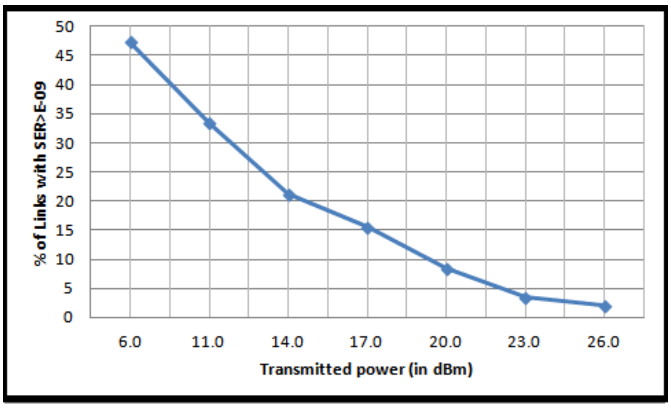

Figure 4.2: Effect of Power Reduction on Interference

CHAPTER 5

VALIDATION OF ICS TELECOM RESULTS

5.1 Introduction

HCRR links connecting the trunk nodes, form the high capacity backbone network for the TCS. Static frequency allocation for these 24 HCRR links is performed using ICS telecom in order to minimise the interference for each link. The interference is calculated in terms of C/(N+I) value of each link. This frequency assignment by ICS telecom is validated using an algorithm discussed subsequently. The algorithm is a modified version of graph colouring algorithm for frequency assignment Taehoon and Lee (June 1996). Fig 5.1 shows the architecture of backbone network comprising of trunk nodes connected via HCRR links.

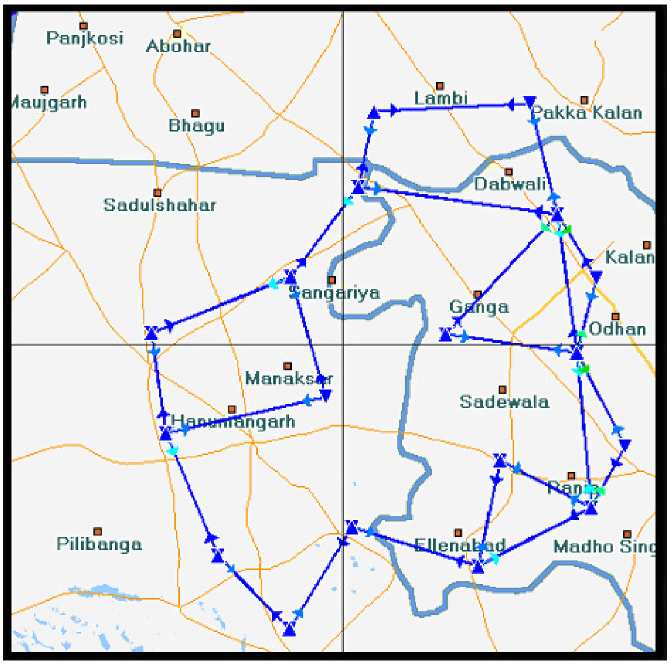

Figure 5.1: TCS Backbone Network

5.2 Algorithm for Static Frequency Assignment

5.2.1 Assumptions

Following assumptions are made while implementing the algorithm.

- HCRR links are Frequency division duplex(FDD), with up-link and down-link separated by a fixed frequency. To simplify the frequency allocation HCRR links are considered as unidirectional.
- Transmitter and receiver antennas gain is fixed at 27.5 dB each. Each transmitter is assumed to transmitting at 26 dBm.
- The receiver noise floor is set at -95 dBm. The required C/(N+I) value is fixed at 16 dB.
- Throughput of each link is 34 Mbps and the channel bandwidth for each link is 11 MHz.
- Transmitter and receiver are assumed to be in line of sight. Free space propagation path loss is considered with path loss exponent, n=2.
- Links operating at same spot frequency are considered to be interferring with each other.

5.2.2 Algorithm Outline

The algorithm is developed with two constraints:

- Tx/Rx located at same node cannot be assigned same frequency.
- C/(N+I) observed by each link should be greater than 16 dB.

Optimal frequency assignment is achieved by maximising the total throughput of the network. The total throughput of the network is given by:

$$\textit{Total throughput} = 34 \sum_{i=1}^{24} (1 - SER(i))$$

where SER(i)= symbol error rate of link i

Algorithm 1 Frequency Assignment for HCRR Links

Input: Tx power, n=path loss exponent, x-y coordinates of nodes, Required C/(N+I), F=(f_1, f_2, f_3,...)
Output: Frequency assignment for static links.

initialise the arrays for storing node's index and node's coordinates
for $r \leftarrow 1, 100$ **do**
    [node-index node-coordinates]=**function**(FREQUENCY ASSIGNMENT ▷ Frequency Assignment to links
    Calculate C/(N+I) for each link for each iteration r
    Calculate throughput of each link for each iteration r
    Calculate Throughput of network for each iteration r
end for
Find Maximum throughput and index r for Max Throughput
Find the frequency assignment for TCS network corresponding to maximum network throughput
function FREQUENCY ASSIGNMENT(x,y,Tx power,n,L,F,Threshold)
    Create distinct arrays i for frequency f_i, where i=1,2,3....
    for $k \leftarrow 1, 24$ **do**
        Select link l_k i.e. Tx/Rx pair, s.t. $l_k \in \mathbf{L}$
        $i = 0$
loop1:
        $i = i + 1$
        Select a frequency f_i, s.t.$f_i \in \mathbf{F}$
        if f_i is assigned to any other Tx/Rx co-located with the selected Tx/Rx **then**
            goto *loop1*
        else
            Calculate Interference observed by link l_k
            if *interference* > *threshold* **then**
                goto *loop1*
            else
                Store index and x-y coordinates of Tx/Rx of link l_k in i-array
            end If
        end If
    end for
return Index and coordinates of Tx/Rx belonging to different frequency group i.e. arrays
end function

5.3 Comparison of Algorithm Results with ICS Telecom

Table 5.2shows the frequency assigned to each link in the backbone network using ICS telecom and algorithm discussed above. The table also gives the C/(N+I) and corresponding SER value for each link for both the cases. Following maybe inferred from the data given in the table:

- The SER for most of the links is either zero or very small in case of both the frequency assignments. This is due to the high transmit power and antenna gain of the Tx/Rx pair of a link.
- Five spot frequencies have been used by both the algorithm. Although frequency assignment pattern by ICS telecom is different from algorithm pattern, however the number of links assigned with a particular spot frequency is same in both the cases, refer table 5.1.

Frequency Assignment to Links	**ICS Telecom**	**Algorithm**
No.of Links assigned f_1 (400 MHz)	8	8
No.of Links assigned f_2 (4411 MHz)	6	6
No.of Links assigned f_3 (4422 MHz)	5	5
No.of Links assigned f_4 (4433 MHz)	3	3
No.of Links assigned f_5 (4444 MHz)	2	2

Table 5.1: Comparison of Frequency Assignment

- The throughput of the network is **815.9713025 Mbps** and **815.9751308 Mbps** in case of ICS telecom and algorithm respectively. The network throughput obtained by algorithm is **3.83 Kbps** more than ICS telecom.

Link No.	Tx Station	Rx Station	ICS Telecom Assignment			Algorithm Assignment		
			Frequency Assigned	C/(N+I) in dB	SER	Frequency Assigned	C/(N+I) in dB	SER
1	trnk_14	trnk_15	f1	25.3118	1.61375E-08	f1	25.3118	1.6137E-08
2	trnk_14	trnk_12	f2	28.9304	0	f3	33.3919	0
3	trnk_12	trnk_13	f1	21.2847	0.00051042	f1	21.2847	0.00051042
4	trnk_13	trnk_15	f2	27.9235	0	f3	28.7082	0
5	trnk_13	trnk_11	f3	24.5276	2.65618E-07	f5	28.4271	0
6	trnk_13	trnk_10	f4	24.2805	5.82752E-07	f2	22.1091	0.00012042
7	trnk_10	trnk_11	f1	24.765	1.19719E-07	f1	24.765	1.1972E-07
8	trnk_12	trnk_9	f3	24.3757	4.32717E-07	f2	29.0113	0
9	trnk_9	trnk_6	f1	22.2349	9.43282E-05	f1	22.2349	9.4328E-05
10	trnk_9	trnk_5	f2	22.6838	3.72792E-05	f4	34.4478	0
11	trnk_5	trnk_2	f1	26.4336	1.1217E-10	f1	26.4336	1.1217E-10
12	trnk_2	trnk_6	f2	21.8674	0.000188976	f3	26.0263	7.8879E-10
13	trnk_2	trnk_0	f3	23.6214	3.88106E-06	f2	23.7145	3.0185E-06
14	trnk_0	trnk_1	f1	27.2115	0	f1	27.2115	0
15	trnk_1	trnk_3	f2	25.5171	7.12006E-09	f2	25.9369	1.1821E-09
16	trnk_3	trnk_4	f1	23.8402	2.13232E-06	f1	23.8402	2.1323E-06
17	trnk_4	trnk_7	f2	26.5701	0	f2	26.9121	0
18	trnk_4	trnk_8	f3	23.6317	3.77611E-06	f3	27.7064	0
19	trnk_7	trnk_8	f1	29.8699	0	f1	29.8699	0
20	trnk_11	trnk_8	f2	23.8951	1.82618E-06	f2	24.1059	9.8966E-07
21	trnk_13	strk_crp	f5	27.8763	0	f4	27.6657	0
22	trnk_11	strk_crp	f4	26.7676	0	f3	26.636	0
23	trnk_8	Asco_net	f4	30.9167	0	f5	39.5457	0
24	trnk_11	Asco_net	f5	35.4887	0	f4	34.0712	0

5.4 SINR Profile of a HCRR Link

Effect of interference on SER of the test link is observed by plotting SINR profile and comparing it with SNR profile. Link suffering with maximum interference is chosen from the TCS network.The C/(N+I) is varied over 0 to 26 dB. Comparison of SINR profile with SNR profile is shown in fig 5.2 for a single chain receiver.

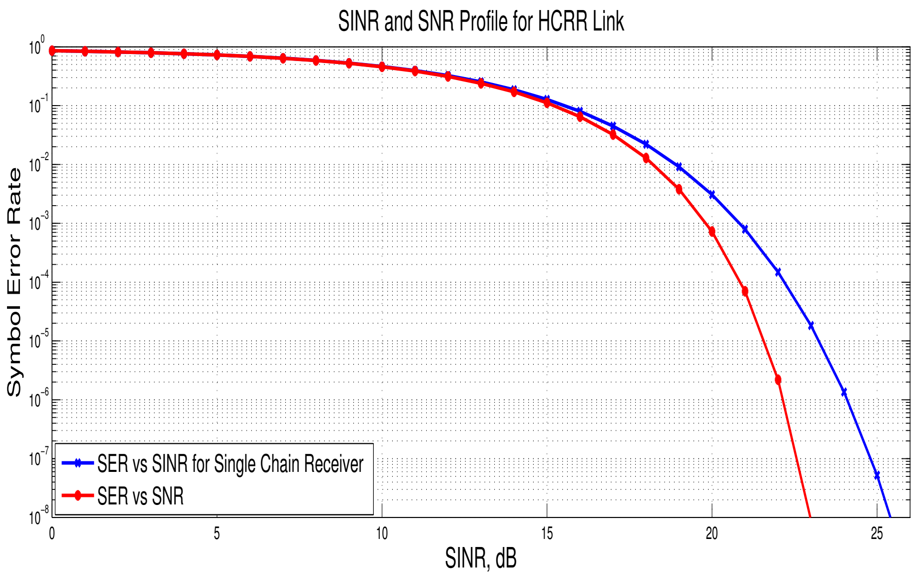

Figure 5.2: SINR and SNR Profile for Single Chain Receiver

The test link is subject to interference form other links operating with same spot frequency. The maximum interference among these interference levels is neglected in case of dual chain (D=1) receiver. Similarly two highest interfering signal are neglected in case of triple chain (D=2) receiver. SINR profile for receiver with D=1,D=2 and it's comparison with SNR profile is plotted in fig 5.3.

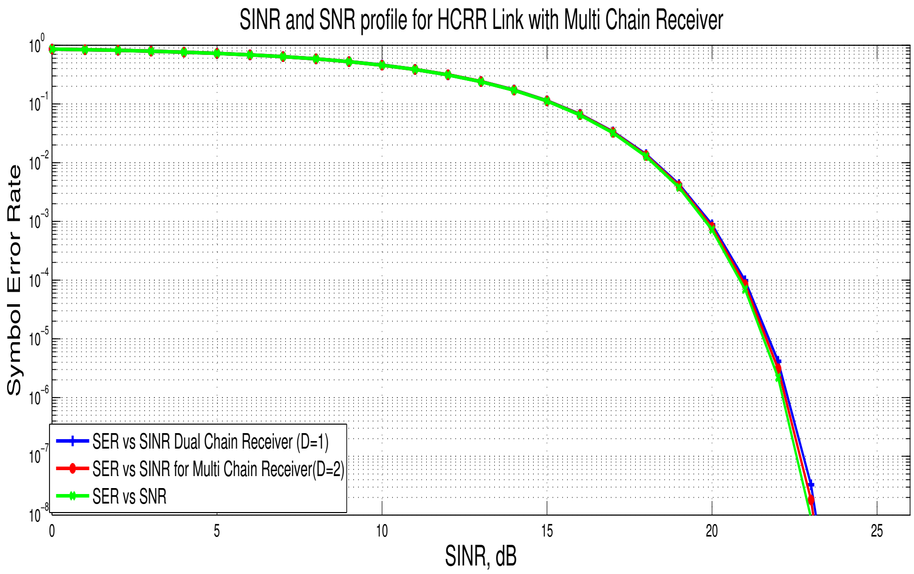

Figure 5.3: SINR Profile for Multi Chain Receiver

CHAPTER 6

CONCLUSION

The thesis has given an overview of frequency assignment for static and frequency hopping links of TCS network using ICS telecom. Frequency assignment is done to ensure minimum interference being observed by a link in the network. Terrain conditions and underlying vegetation of the battlefield area are considered while calculating the interference level for a link. The effect of partial network failure are simulated with failure of some links and nodes in the network. Frequency assignment and interference level results obtained via ICS telecom are validated using an algorithm.

The project was undertaken to optimise frequency assignment in terms of maximising C/(N+I) for each link and analyse the effect of partial network failure on interference level observed by each link.

The results obtained for static frequency assignment are found to be matching with the results of algorithm. The link suffering with higher interference has been found to be increasing with reduction in power. Also the interference level for HCRR links has reduce with reduction in available bandwidth, however of FHRR links, no significant changes are observed with reduction in bandwidth. SINR profile of HCRR link has been found to improve with use of multi chain receiver.

The results of the study ascertain the suitability of ICS telecom for frequency assignment to static frequency link, however frequency assignment to frequency hopping links needs to be verified. The study also suggest that use of multi chain receiver will improve the throughput of a link.

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