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Fuzzy Based Improvement in Handoff Decisions in GSM Networks

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Abstract
In this paper we had reviewed two conventional algorithms for handoff decision process and proposed algorithm based on fuzzy logic keeping in mind the essential criteria's for quality of signal and thus the channel capacity and lastly after improving the SNR ratio thus providing better quality of service we had shown improvement over the decision to made under the case of GSM-R regarding handoff. Thus, the probability of unnecessary handoff is eliminated and the graphical analysis shows the improvement over both aspects- i.e. noise or interference in the communication channel and thus the decision of handoff, the graphical analysis using a simulator helps to show the actual problem behind.

Keywords
Handoff Decision, Fuzzy Logic, High Speed, GSM-R, QOS- Quality of Service

I. Introduction

For making trains the first choice for 21st century travel, for increasing rail travel to minimize environmental footprint, for enhancing the perceived value of rail travel and provide more than just transport, for replacing the present day expensive to maintain and not so interoperable system, one integrated and standard solution was needed and here comes the answer to all such needs- GSM-R

From dynamic group communication to advanced dispatcher solutions, functional and location dependent addressing – all functionalities can be used with GSM-R.

A. Basic Introduction to GSM

GSM (The Global System for Mobile Communications)

The GSM system was specified by a team of experts who regularly met as part of a body known as the European Telecommunications Standards Institute (ETSI). GSM at the moment is now truly becoming a global system for mobile communications, spanning Europe, Asia, Africa and much of South America, to name but a few.

GSM after launch evolved into GSM900, DCS1800 (also known as PCN) and CS1900 (in the USA). PCN started in the UK with Mercury one-to-one and Hutchinson (Orange) offering the first two networks to use DCS1800. It has since spread to other areas worldwide.

B. GSM-R History

1995: UIC selects GSM as the most suitable platform for railways and specification work is started

1997: 32 railway sign MOU supporting GSM-R

2000:GSM-R specifications released; first end to end system in the world integrated in swedon, by nokia Siemens network; interoperability between Nortel and nokia Siemens networks successfully performed;

Today: Nokia Siemens networks: 24 contracts in 17 countries including India (NR- nothern railways, ECR- east central railway, NCR- north central railway and NFR- north frontier railway). Today- GSM-R ensure safe and reliable operations but present day challenges are totally different and complex from the previous ones

- Aging communication systems
- Difficult terrain and tunnels
- Tight time schedule

Add to the complexities and thus providing effective handoff decision algo and meet in standards for maintaining the QOS becomes difficult.

C. GSM Cell

The most visible part of the GSM cell is the base station and its antenna tower. It's common for several cells to be sectored around a common antenna tower. The tower will have several directional antennas, each covering a particular area. This co-location of several antennas is sometimes called a cell-site, or just a base station, or a base transceiver station (BTS). All BTSs produce a broadcast channel (BCH) which is on all the time, and can be viewed as a lighthouse beacon. The BCH signal is received by all mobiles in the cell, whether they are on call or not, in order to:

- allow mobiles to find the GSM network
- allow the network to identify which BTS is closest to a given mobile
- allow coded information like the network identity (e.g. vodaphone) to be known
- allow paging of messages to any mobiles needing to accept a phone call, and a variety of other information

The frequency channel used by the BCH is different in each cell. Channels can only be re-used by distant cells, where the risk of interference is low. Mobiles on a call use traffic Channel (TCH), which is a two way channel (known as an uplink and a downlink) used to exchange speech data between the mobile and base station. GSM separates the uplink and the downlink into separate frequency bands. It's interesting to note that while the TCH uses a frequency channel in both the uplink and the downlink, the BCH occupies a channel in the downlink band only. The corresponding channel in the uplink is effectively left clear. This can be used by the mobile for unscheduled or random access channels (RACH). When the mobile wants to grab the attention of a base station (perhaps to make a call), it can ask for attention by using this clear frequency channel to send a RACH.

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D. Handoff

When a mobile moves into a different cell while a conversation is in progress, the MSC automatically transfers the call to a new channel belonging to the new base station.

- Handoff operation – identifying a new base station
- – re-allocating the voice and control channels with the new base station.
- Handoff Threshold – Minimum usable signal for acceptable voice quality (-90dBm to -100dBm)
- – Handoff margin $\Delta = P_{r,handoff} - P_{r,minimum\ usable}$ cannot be too large or too small.
- – If delta, Δ is too large, unnecessary handoffs burden the MSC
- – If delta, Δ is too small, there may be insufficient time to complete handoff before a call is lost

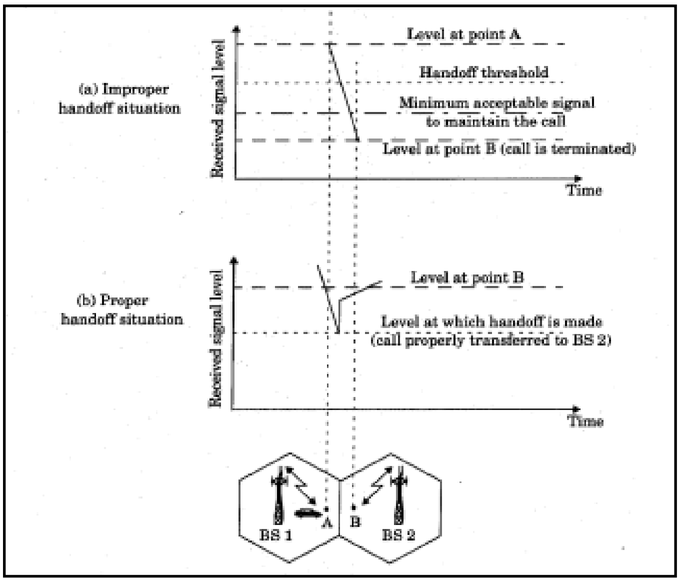

Fig.1: Handoff Situation

- Handoff must ensure that the drop in the measured signal is not due to momentary fading and that the mobile is actually moving away from the serving base station.
- Running average measurement of signal strength should be optimized so that unnecessary handoffs are avoided.
- – Depends on the speed at which the vehicle is moving.
- – Steep short term average -> the hand off should be made quickly
- – The speed can be estimated from the statistics of the received short-term fading signal at the base station
- Dwell time: the time over which a call may be maintained within a cell without handoff.
- Dwell time depends on – propagation, interference, distance, speed

E. Handoff Measurement

In first generation analog cellular systems, signal strength measurements are made by the base station and supervised by the MSC.

- – In second generation systems (TDMA), handoff decisions are mobile assisted, called mobile assisted handoff (MAHO)
- Intersystem handoff: If a mobile moves from one cellular system to a different cellular system controlled by a different MSC.
- Handoff requests is much important than handling a new call. Practical Handoff Consideration
- Different type of users – High speed users need frequent handoff during a call.
- – Low speed users may never need a handoff during a call.
- Microcells to provide capacity, the MSC can become burdened if high speed users are constantly being passed between very small cells.
- Minimize handoff intervention – handle the simultaneous traffic of high speed and low speed users.
- Large and small cells can be located at a single location (umbrella cell)
- – Different antenna height, – Different power level
- Cell dragging problem: pedestrian users provide a very strong signal to the base station
- – The user may travel deep within a neighboring cell

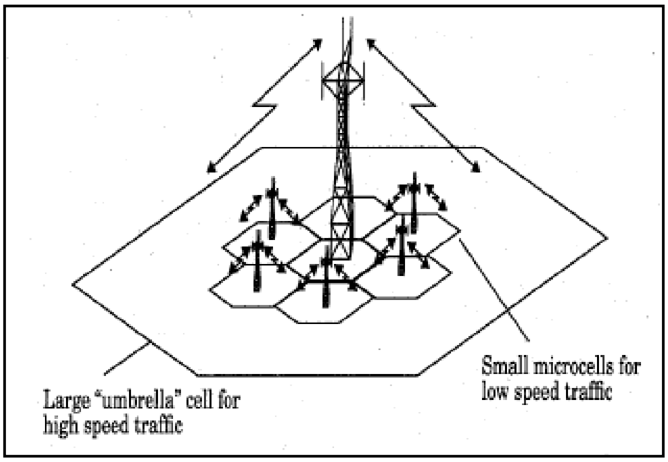

Fig. 2: GSM Cell

- Handoff for first generation analog cellular systems
- – 10 secs handoff time, – delta is in the order of 6 dB to 12 dB
- Handoff for second generation cellular systems, e.g., GSM
- – 1 to 2 seconds handoff time, – mobile assists handoff
- – delta is in the order of 0 dB to 6 dB, – Handoff decisions based on signal strength, co-channel interference, and adjacent channel interference.
- IS-95 CDMA spread spectrum cellular system
- – Mobiles share the channel in every cell.
- – No physical change of channel during handoff
- – MSC decides the base station with the best receiving signal as the service Station

F. Phases of Handoff

Handoff algorithms are designed to work in main three phases:

1. Handoff Initiation phase
2. Handoff Decision phase
3. Handoff authentication and re-association phase

1. Handoff Initiation

Handoff initiation is the procedure that tells that when to start the handoff mechanism. The main parameter based on which initiation begins is Received Signal strength Indicator.

Received Signal Strength Indicator roughly corresponds to how strong the signal and noise is in radio's receiver signal strength measured in dBm of both the mobile unit and the base station within a wireless environment. It is used to initiate a handoff. As MS starts moving away from the BS, RSSI value starts decreasing

and gets stronger as it gets closer to the other base stations in range. So before signal fades out completely, handoff must be performed. So when to initiate handoff can be done in following four ways:-
1. Choosing strong RSSI
2. RSSI with threshold,
3. RSSI with hysteresis, and
4. RSSI with hysteresis and threshold.

2. Handoff Decision phase
During this phase, decision about the optimal access point is taken on the bases of parameters like RSSI, bandwidth, Signal-to-noise ratio, data rate ratio, etc.

3. Handoff authentication and re-association phase
The re-authentication process involves re-authentication and re-association to the selected optimal AP. The reauthentication phase is used by the MS to establish its identity with the new AP with which it is going to establish link during handover. IEEE 802.11 supports several authentication schemes such as:-
1. Open System authentication,
2. Shared Key authentication,
3. WPA/WPA2 authentication and
4. 802.1X Port-based Network Access Control.

G. Handoff Types

1. Hard handoff and Soft handoff
Hard handoff term is used when the communication channel is released first and the new channel is acquired later from the neighboring cell. Thus, there is a service interruption when the handoff occurs reducing the quality of service. Hard handoff is used by the systems which use time division multiple access (TDMA) and frequency division multiple access (FDMA) such as GSM and General Packet Radio Service (GPRS). In contrast to hard handoff, a soft handoff can establish multiple connections with neighboring cells. Soft handoff is used by the code division multiple access (CDMA) systems where the cells use same frequency band using different code words. Each MS maintains an active set where BSs are added when the RSS exceeds a given threshold and removed when RSS drops below another threshold value for a given amount of time specified by a timer. When a presence or absence of a BS to the active set is encountered soft handoff occurs. The sample systems using soft handoff are Interim Standard 95 (IS-95) and Wideband CDMA (WCDMA)

2. Horizontal vs. Vertical Handoff
Handoff between homogenous networks where one type of network is considered is called horizontal handoff. On the other hand, handoff between different types of networks is also possible. A handoff in such a heterogeneous environment is named vertical handoff. The study in this paper is based on horizontal handoff.

H. Handoff Architecture
In GSM Handoff architecture a mobile station (MS) communicate with a base station subsystem (BSS) through the radio interface. The BSS is connected to the network switching subsystem (NSS) using the A interface.

I. GSM-R Need
Since the next generation wireless systems are expected to be of heterogeneous topology, traditional handoff (horizontal handoff/handover) mechanisms are not sufficient to meet the requirements of these types of networks. More intelligent vertical handoff algorithms which consider user profiles, application requirements, and network conditions must be employed in order to provide enhanced performance results for both user and network.

II. Conventional Algorithm
Many of the existing handoff algorithms has probability of unnecessary handoff when it is not required, this is due to the signal strength reduces due to some environment reasons that created excessive load occur on the MSC and BS. This is the disadvantage. It reduces efficiency of the system. Unnecessary handoff as in ping-pong effect increases the signaling overhead on the network and lead to unwanted delays and interruption in call.
In this section, we review two conventional handoff decision algorithms. Both of conventional algorithms are based on only the RSS (Received Signal Strength) and are using the average window to diminish "Ping-Pong" effects caused by the fluctuant RSS, which is illustrated in Figure

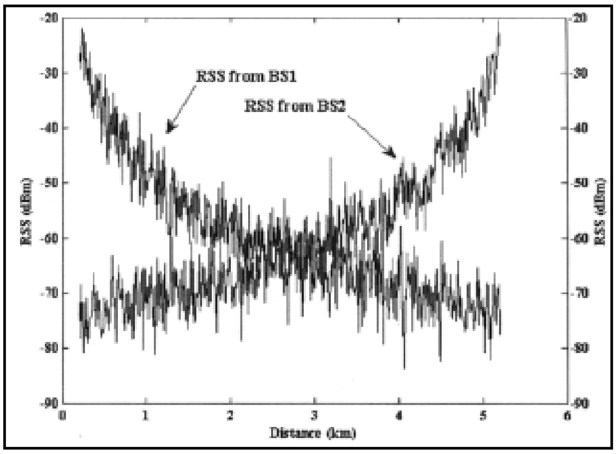

Fig. 3: RSS from 2 Base Stations

Difference between two conventional algorithms is using the hysteresis margin of the RSS to make the final handoff decision. Using the hysteresis margin allows a MT to make handoff decision only if the RSS received from the target BS (Base Station) is sufficiently stronger than the current one by the specified hysteresis margin.

A. Conventional Algorithm 1
In the existing conventional algorithm that uses only the Received signal strength received from the current Base Station and the target Base Station are Si (n) and Sj(n) respectively, where n means the sampling index. The handoff decision occurs if the following in equation:

$$Yj\ (n) > Yi\ (n) \qquad (1)$$

Is satisfied, where both Yi (n) and Yj (n) are the average RSS values. And, Y (n) is subject to the following equation:

$$n\ Y(n)= 1/N\Sigma s(k), \qquad (2)$$

K=n-N+1

Where N is the average window size and k is the sampling index. In this paper, we chose N=4.

B. Coventional Algorithm 2
This algorithm is mostly similar to the conventional algorithm I, and only difference is that the handoff decision occurs if the

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following in equation:

Yj(n)>Yi(n)+H (3)

is satisfied, where both Yi(n) and Yj(n) are the average RSS values, H is the hysteresis margin of the RSS, and Y(n) can be got from the equation(2). In our simulation, we chose N=4 and H=2dBm.

C. Proposed Work

In this study, a fuzzy logic-based handoff decision algorithm is introduced for GSM-R network. The parameters; data rate, received signal strength indicator (RSSI), and mobile speed are considered as inputs of the proposed fuzzy-based system in order to decide handoff initialization process and select the best candidate access point around a smart mobile terminal. Also, in contrast to the traditional fuzzy-based algorithms, the method proposed takes advantage of improved channel capacity. The results show that the performance is significantly enhanced by the method proposed.

The proposed algo is modeled and simulated using fuzzy logic via a MATLAB Software for performance evaluation. The contributions of this study can be summarized as follows:

_ Considering the fact that most of the wireless communication systems are interference limited, in contrast to the most of the fuzzy-based algorithms, the decision mechanism in the method proposed takes into account interference rates from different base stations as input to its fuzzy logic system in order to make a more reliable handoff.

_ A new adaptive multi-criteria handoff decision system, which has the ability to adapt its structure according to the application requirements and network conditions, is proposed.

As stated earlier, according to the inputs of available BSs the fuzzy inference system produces an output value between one and zero which describes the candidacy level of related BS. Any handoff initialization process is decided upon this value. One of the most crucial parts of this study is the new adaptive fuzzy inference system which is developed in order to make handoff decision. A fuzzy logic system consists of three main parts: Fuzzifier, Inference Engine, and Defuzzifier. Fuzzifier converts a crisp input into a fuzzy variable where physical quantities are represented by linguistic variables with appropriate membership functions. These linguistic variables are then used in rule base of Fuzzy Inference Engine. Since there are three input variables each has three levels (i.e., low, medium, and high), there are 27 rules used for producing a new set of fuzzy linguistic variables. Some of the fuzzy rules in the rule base are tabulated in Table 1. For instance, Rule 1 corresponds to the IF–THEN structure. Defuzzifier is responsible for converting this fuzzy engine output into a number. The output of the fuzzy system, decides whether to initiate the handoff process or not.

D. Proposed Algorithm 1

The handoff factors got from the current BS and the target BS firstly were averaged by the average window, whose size N, was set to 4 for our simulation. Given that HO_Factor_BSi(n) and HO_Factor_BSj(n) are described as the handoff factor of the Current BS and the target BS, respectively. Then, if

HO_ Factori(n) > HO _ Factorj(n) (5)

is satisfied, the handoff decision occurs. And, HO_Factor(n) is got from the following equation:

n HO_Factor(n)=-1/NΣHO_Factor_BS(k) (6)

K=n-N+1, where k is the sampling index.

E. Proposed Algorithm 2

This algorithm is the enhanced version of the proposed algorithm (only the hysteresis margin of the handoff factor, H, was added). So, if

HO_Factori(n)>HO_Factorj(n)+H (7)

is satisfied, the handoff decision occurs, where H is the hysteresis margin of the handoff factor. Here, H was chosen by 0.02 which was equivalent to the H (2dBm) mentioned in section 2.2. And, HO_Factor (n) is got from the equation (6).

F. Fuzzification

In the first step of the handoff initiation module is to calculate the context parameter like distance between BS and train, RSS, velocity of MT and feed into a fuzzifier. The fuzzifier transforms real-time measurements into fuzzy sets. Fuzzy sets contain elements that have a varying degree of membership in a set. For example, if signal strength is considered in crisp set, it can only be weak or strong. However, in a fuzzy set the signal can be considered as quite weak, medium or strong. The membership values are obtained by mapping the values obtained for particular parameter into a membership function.

G. Fuzzy Inference

The second step of handoff initiation involves feeding the fuzzy sets into an inference engine, where a set of fuzzy IF-THEN rules is applied to obtain fuzzy decision sets there were 3x3x4 "IF-THEN" rules in FIS to mapping the fuzzy inputs. To simply understand, we used the set {No_Handoff, Wait, Be_Careful, Handoff} to represent the fuzzy set of Decision which included {very low, low, medium, high}.

H. De-Fuzzification

Fuzzy rules can be defined as a set of possible scenarios which decides whether handover is necessary or not. Finally, the output fuzzy decision sets are aggregated into a single fuzzy set and passed to the defuzzifier to be converted into a precise quantity during the last stage of the handover decision. The centroid of area method was selected to defuzzify for changing the fuzzy value into the crisp value (i.e. the handoff factor without averaging) [2].

III. Simulation

Two proposed fuzzy logic based handoff decision algorithms were evaluated in the one of many deployments in Passenger Special Line in China-Two BSs are set in straight line along the trajectory of high speed railway And, given that the handoff execution was successful when the handoff decision occurred.

A. Simulation Model and Its Parameters

In our simulation, Hata model from [3] was used as large scale propagation model. Besides large scale path loss, there is shadow fading, which affects the quality of the RSS and is subject to a zero mean white Gaussian distribution. So, the RSS received by a MT can be computed by the following equation [7]:

Pr(d)[dBm]=Pt[dBm]-PL(d)[DB] (8)

where Pr(d) is the RSS received by a MT at distance d. P is the power transmitted from the current BS; PL(d) is the path loss at distance d. And, PL(d) can be got from the following equation [8]:

_ PL(d)[dB]=PL(d0)+10nlog(d/d0)+X (9)

_ Where PL(d) is the path loss at distance d. PL(d0) is the path loss at reference distance which is evaluated by Hata Model (using the open rural formula in our simulation due to the assumption that moving terminals were running in the open rural area along the railway); n is the path loss exponent. X is the shadow fading.

B. Simulation and Results

Under the specified scenario in our simulation, the probability of unnecessary handoff was calculated by the statistics method, which accumulated the number of unnecessary handoff at the beginning and computed the probability of unnecessary handoff at the dynamic slot (depending on the product of velocity and time) between two Base Stations at last. We simulated two conventional and two proposed algorithms in the specified scenario. Proposed algorithm will have the best performance because of getting the lowest probability of unnecessary handoff.
In our simulation, Hata model from [3] was used as large scale propagation model. Besides large scale path loss, there is shadow fading, which affects the quality of the RSS and is subject to a zero mean white Gaussian distribution.

1. Graphical response of conventional handoff decision algorithm.

Conventional Graphs are made only by considering Received Signal Strength for the current BS and target BS. And with the help of formula using the average RSS of current and target BS, sampling index , Average window size and hysteresis margin of RSS we obtain the two graph. One graph shows the errored handoff and other shows handoff factor varying with distance.
As shown in the figure 3.1, the probability of errored handoff is maximum at a distance between 6 to7 km as shown in the graph below. This probability is 8.5. which is maximum as the distance increases means conventional algorithm is not suitable for deciding that handoff should be initiated or not that create a problem in our conversation.

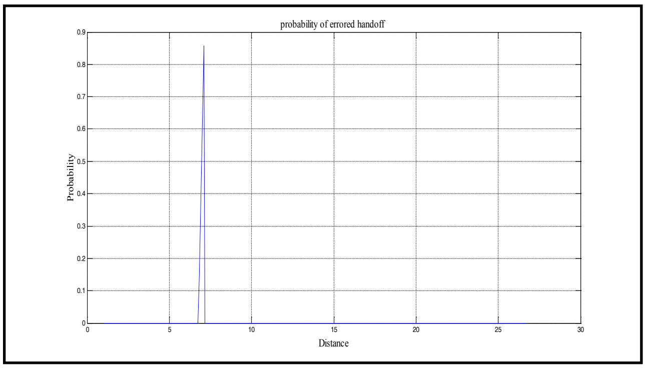

Fig.3.1

Conventional handoff also affects the handoff factor with distance as shown in the figure 3.2. At the distance of 2km. the value of handoff factor is maximum i.e. -4. The value of handoff factor is negative for all distance. Upto 5 km. distance the value of handoff factor decreases rapidly and after the distance of 5 km. its value decreases smoothly as shown in graph. At a distance of 26 km. the value of handoff factor is -92 as shown below

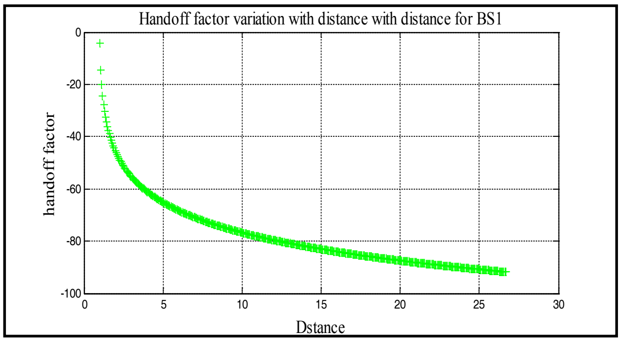

Fig.3.2

2. Graphical response of proposed 1 handoff decision algorithm

Due to the problems in the conventional algorithm we propose new algorithm which is better than that of previous algorithm. The probability of errored handoff is less in proposed -I handoff decision algorithm than conventional handoff decision algorithm. In this case maximum probability of errored handoff is 7.5 and the distance of 5.5 to 6 km as shown in the figure. 2. This probability of unnecessary handoff in proposed-I algorithm is less than the probability of unnecessary handoff as in Conventional algorithm.

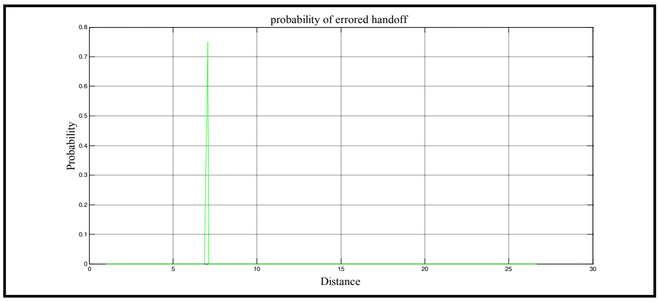

Fig.3.3

Proposed-I algorithm is better than conventional to use. Proposed 1 algorithm for handoff decision also affects the received power with distance. At a distance of 1km. received power is maximum i.e. -1. And upto 2km. distance received power decreases rapidly to -10 km. After 5km. received power for BS1 reduces and after 15km. Decrement is very small as shown in figure 3.4.

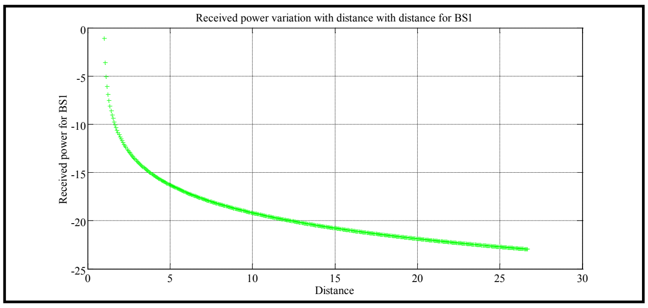

Fig.3.4

3. Graphical response of proposed 2 handoff decision algorithm

In this we implement the fuzzy assisted handoff with various ranges of values for all input parameters. This algorithm is best for deciding handoff among all handoff decision algorithms. In proposed-II algorithm the probability of errored handoff i.e. unnecessary handoff is smallest as with conventional and

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proposed-1 handoff decision algorithm. It is clear from the figure 3.5 that the probability of errored handoff is negligible in this type of algorithm. Received power also decreases with as the distance increases as shown in figure 6 below, but this decrement is less in this case than the conventional and proposed I algorithm. At 0 distance received power is also 0. After that as distance increases, received power decreases. In between 0 to50 km., the decrement of received power is very rapid. At 50km distance, the received is -60. After that decrement occurs Smoothly as at the distance of 100km the received power is -70. And at 200km distance received power is -80.

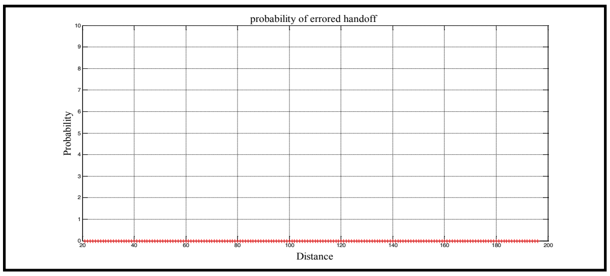

Fig. 3.5

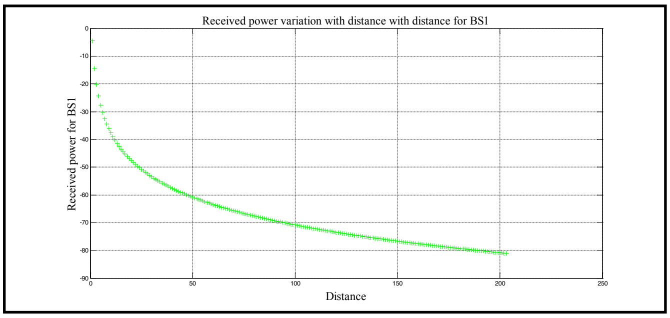

Fig. 3.6

4. Graphical response of comparision among Conventional, Proposed-1, Proposed 2 handoff decision algorithm

As shown in the following figure 3.7, Comparison between all three algorithms which shows the probability of errored handoff is maximum in conventional algorithm so this is not suitable for handoff decision. And proposed-1 handoff decision algorithm has also the probability of errored handoff but less than in conventional algorithm. But the probability of errored or unnecessary handoff is minimum in case of proposed-2 algorithm of handoff decision. So proposed-2 algorithm is best suited for deciding handoff decisions e.g. when to handoff? So comparison of these entire three handoff algorithm proposed -2 algorithms is best among these as shown in the figure 3.7

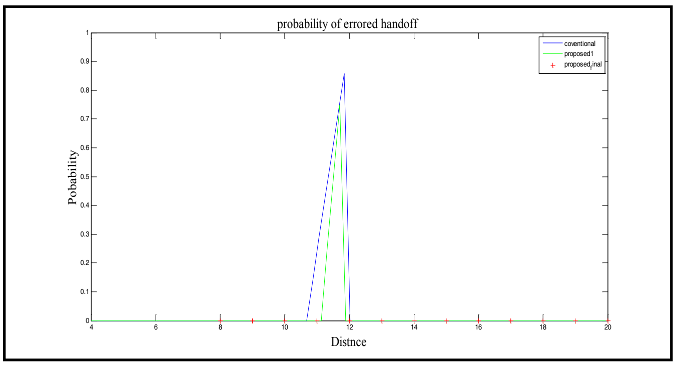

Fig. 3.7

Received power varies with distance for Base Station1 (BS1). Means as distance increases, the received power decreases like as in proposed-1 algorithm. But In case of proposed-II handoff decision algorithm it decrement is less as shown in figure 8 which shows that either the distance is increases very fastly there is no problem of handoff decision.

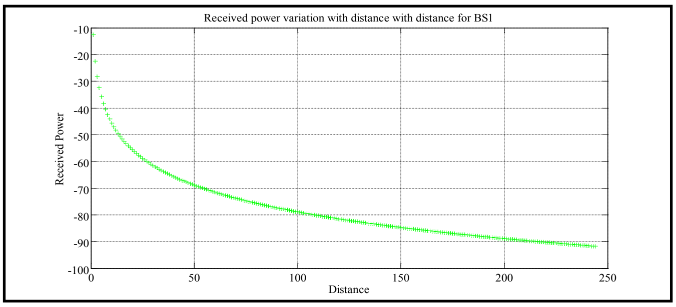

Fig. 3.8

5. Graphical response of all three Space Diversity Techniques

Fig. 3.9

A communication system is composed of few set of things including sender receiver and the channel for processing on the major hand. The channel can be infected by noise any time during processing and in the real life scenario, mostly signal is infected and moreover the channel capacity creates problem. Here, a plot of all 3 space diversity techniques is shown in a conventional environment; figure 3.9.

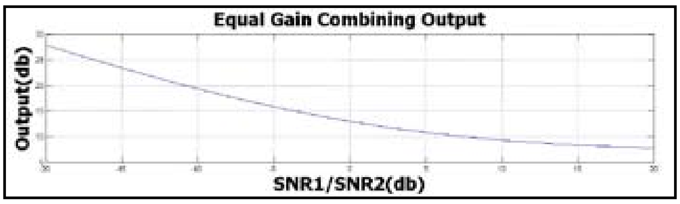

Fig. 3.10

DIVERSITY COMBINING: is the technique applied to combine the multiple received signals of a diversity reception device into a single improved signal.
EQUAL GAIN COMBINING OUTPUT: In this all the received signals are summed coherently. Figure 3.10.

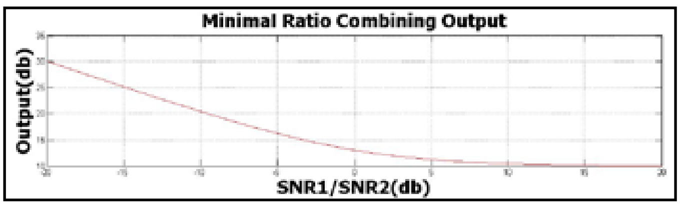

Fig. 3.11

MINIMAL RATIO COMBINING: it is often used in large in large phased array systems: the received signals are weighted with respect to their SNR and then summed. The resulting SNR yields summation of SNR K from k=1 to n, where SNR k is SNR of the received signal k. figure 3.11

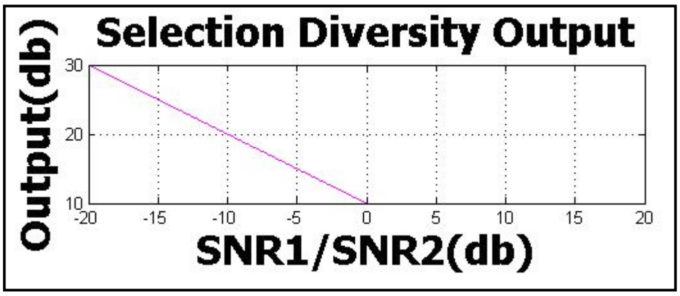

Fig. 3.12

SELECTION COMBINING: of the N received signals is selected. When the N signals are independent and Rayleigh distributed , the expected diversity gain has been shown to be summation of 1/k from k=1 to N, Expressed as a power ratio. Therefore, any additional gain diminishes rapidly with the increasing no. of channels. This is a more efficient technique than selection combining.
Sometimes more than one combining technique is used – for example, lucky imaging uses selection combining to choose (typically) the best 10% images, followed by equal gain combining of the selected images. Figure 3.12

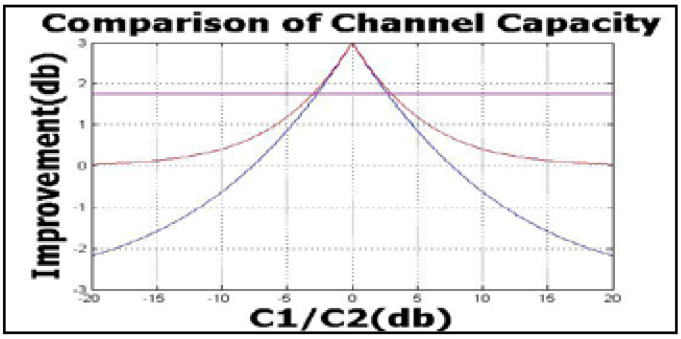

Fig. 3.13

A plot(figure 3.13) showing improvement over all three techniques is shown over conventional.

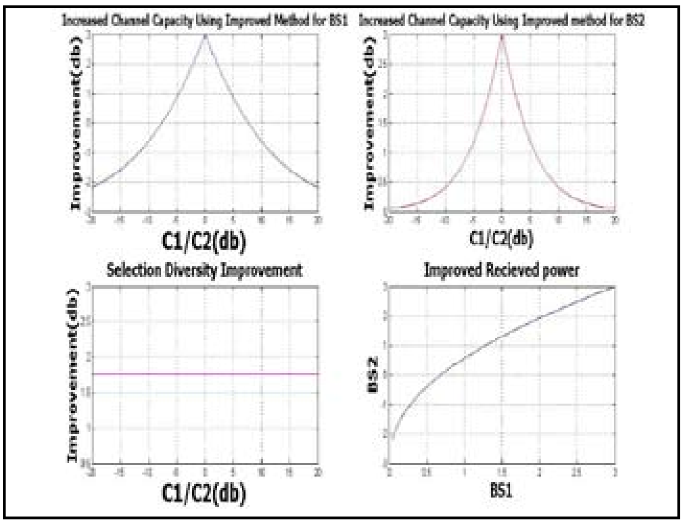

Fig. 3.14

IV. Conclusion and future work

We have to:

- Make passengers passionate about travelling in train
- I.e the real problem was to make TRAINS the first choice for 21st century travel.
- To increase the rail travel to minimize the environmental footprint.
- Enhanced the percieved value of rail travel and to provide more than 'JUST TRANSPORT'.AND LAST, ALL TRAVELS UNDER 1000KM SHOULD IN THE FUTURE BE DONE WITH RAILWAYS

SCOPE

- Dynamic Group Communication
- SMS to Functional Members
- Advanced Dispatcher Solutions
- Functional and Location Dependent Addressing
- Voice Group Call Services
- Voice Broadcast Services
- Enhanced Multi-Level Precedence and Pre-Emption

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