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Signal Interferences in Wireless Communication - An Overview

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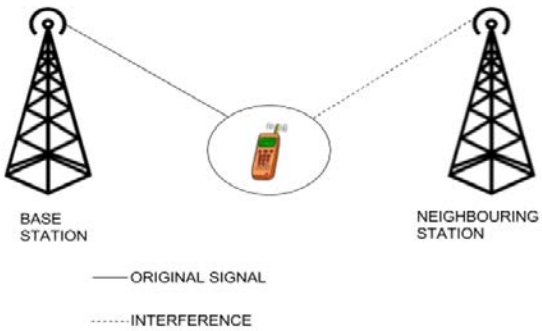
Abstract: With advancement in the field of communication, obtaining optimal solutions to minimize interference still remains a challenge because of the random nature of interference. Increased co-channel and adjacent channel interference results in dropped calls, slow data throughput, signal latency. Interference also affects non-cellular networks such as public safety systems, air-traffic radar and others, risking lives. In order to tackle these problems, more and more intelligent evolutionary algorithms are being explored. However, rapid growth in this domain makes researchers unaware of the progresses made over time. In this paper, a few types of interference namely co-channel interference, adjacent channel interference, inter symbol interference, inter user interference, inter cell interference and electromagnetic interference have been discussed. In general interference can be minimized to a large extent by transmitting signals at different frequencies, at different intervals of time. Furthermore, the optimal existing algorithms to mitigate interference such as Zero forcing equalizer, Transmit power and window control, Dispersion Interleaving, Channel Allocation and usage of Chemical compounds to mitigate interference have also been discussed.

Keywords: Communication, Interference, Interference Types, Evolutionary Algorithms, Zero Forcing Equalizer, Transmit Power and Window Control, Dispersion Interleaving, Channel Allocation.

INTRODUCTION

Interference is a phenomenon which modifies, or disrupts a signal as it travels from the source to the destination via a channel. Interference also means addition of unwanted signals to the desired signal. This disturbance may impede, debase or limit the effectiveness of the channel. Interference can occur in any communication system and is unpredictable because of its randomness/uncertainty.



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The above figure illustrates the concept of interference in communication sytems.

Telecommunication is the lifeblood of today's society. The technologies used for communication have undergone a sea change over the past 50 years but the problem of interference still prevails, despite various technologies to mitigate interference. Finding an optimal solution is an arduous process because of the complex nature of the problem. Therefore, a perspicacious approach is needed to understand the existing problems and provide feasible solutions. Owing to the difficulty to track the rapid developments in this domain, many researchers have limited awareness of the latest techniques and algorithms. Therefore, they tend to focus on the existing popular algorithms rather than exploring the apt ones, based on the requirements. To address this issue, this review paper discusses about the types of interference and the various techniques and algorithms to alleviate the problem of interference [1].

When several cells use the same frequency, interference occurs between these cells and it is known as co-channel interference. Interference that is caused by signals which are adjacent in frequency to the required signal is called adjacent channel interference. Inter symbol Interference occurs when one symbol interferes with subsequent symbols. Inter-user interference occurs when multiple body sensor networks are transmitting concurrently in close immediacy to each other. Electromagnetic interference occurs due to electromagnetic annoyance produced by another electromagnetic device at radio frequency spectrum [2]-[3].

The zero forcing equalizer technique reduces Inter Symbol Interference by determining inverse of the channel's impulse response. Window control and Transmit power technique decreases Inter-user interference by estimating the propagating conditions followed by packet-based data transmission. Channel Allocation algorithm is used to reduce co-channel interference by optimizing the allocations to channels. Dispersion interleaving makes use of residual fiber dispersion to reduce adjacent channel interference. Chemical compounds that have microwave absorbing properties are used to mitigate Electromagnetic Interference [4]-[8].

This paper has been subdivided as: Section 2 of the paper explains in detail about various types of interference namely, adjacent channel interference, inter symbol interference, inter user interference, inter cell interference, co-channel interference and electromagnetic interference. Section 3 of the paper discusses about the existing techniques and algorithms to mitigate interference in communication systems. The paper is concluded in Section 4 [9].

TYPES OF INTERFERENCE

Adjacent Channel Interference

In cellular systems, interference arising from adjacent channel frequencies leads to a very high noise floor and a bit error rate (BER) that is extremely difficult to reduce. Let us take the case of a bandpass modulated signal with centre frequency, fc in the receiver segment of the channel. The channels located at centre frequencies fc - fa and fc + fa, where fa is any arbitrary frequency, are the neighboring channels. The interference from these channels may leak into the exposure path of the desired channel causing an interference known as adjacent channel interference. [2] This interference has a non-uniform power spectral density imposing a noise floor on the system that depends on two factors: (a) the amount of spectral overlap that occurs between the adjacent channels and the desired channel (b) the ratio of power in the adjacent channel and power in the desired channel and is spread across all frequencies. This consequences in a bit error rate (BER) that is irreducible, i.e., the BER value remains the equal and this error rate is independent of the SNR per bit [10].

The influence of this type of interference on FM communication system has been examined in [11]. Also, the relationship between the parameters such as Signal to Distortion Ratio, Signal to Interference Ratio and Filter Bandwidth has been derived. The paper [12] gives expressions for signal to adjacent channel interference, signal to co-channel interference and signal to total interference in cellular communication systems. The occurrence of adjacent channel interference reduces the effective SINR (Signal to Interference and Noise Ratio) and as a result the number of errors in the reception segment is increased.

Co-Channel Interference

The key concept in cellular systems is that to reuse frequency and was developed to provide services to a very large number of subscribers while utilizing a limited spectrum. The frequency reuse patterns are used in such a way that the system capacity is maximized without much degradation in performance due to resulting interference. A badly designed reuse pattern can result in a serious increase in co-channel. [2] A thorough understanding of the performance of a system in the presence of co-channel interference

(CCI) is essential for successfully designing many applications such as in cellular networks and body area networks (BANs). [15] These performance factors include analyzing the special types of fading for the signal-of-interest (SoI) and the interfering links [16], the occurrence or absence of background noise (BN), and number of independent or correlated interferers [17].

The most ubiquitous effect are the fading distinctiveness of the SoI and the CCI links. As these are not always alike, to represent the fading observed in both,it is important to use flexible model. One of the most flexible model among the many fading models proposed is the κ-μ fading model [18]. The most an important performance metric is outage probability (OP) , that can be used to characterize the signal to interference ratio in systems with CCI. For widespread fading models, [17], [19] and [20] afford OP analyses when the SOI and the interfering links undergo η-μ/η-μ, η-μ/κ-μ and κ-μ/η-μ fading. These analyses either provide approximate expressions, or consider that μ takes positive integer values for the SoI or the interfering link. Furthermore, the authors in [19] provide an OP analysis over κ-μ/κ-μ fading channels is made to order to study interference-limited scenarios. [21] An in-depth analysis of OP is provided in [15].

Intersymbol Interference

In communication systems, high levels of inter symbol interference can lead to high bit error rates occurring in the recovery of the sequence transmitted. In addition to propagation induced factors such as multipath propagation, inter symbol interference is also caused by limited bandwidth channels. This system would be an Infinite Impulse Response (IIR) filter resulting in the spreading of digital signal pulses causing the adjacent pulses to overlap and in turn interfere. This type of interference is a challenge for developing digital communication channel with high transmission rates. [22] [23] [24].

Inter-User Interfernce

The inter-user interference (IUI) in wireless communication systems represents the interference power from one transmitter to the other [2]. In paper [3], a simple inter user interference suppression scheme is proposed where the base station knows the full state information of the uplink, the downlink, and the interference channels. To investigate the effectiveness of the proposed scheme, four cases are considered. First, when the uplink, the downlink, and the interference channels are Gaussian, it is concluded that the power ratio between the uplink and the interference channels decides the sum achievable rate if the base station power is not limited.

When considering the power constraint under energy efficient criterion, the energy efficient of proposed inter-user interference control design is near to the performance of the FD mode when the interference is painstaking as the additive Gaussian noise at the receiver. Second, when the downlink and the interference channels are Rayleigh and the uplink channel is Gaussian, the close form idiom of the sum achievable rate and energy efficient is derived. Third, the performance of the proposed scheme through Monte Carlo simulations when the downlink the uplink and the interference channels are Rayleigh or Rician fading is estimated. For Rayleigh fading with same channel power, the sum achievable rate approximates to the ideal FD mode especially when the SNR becomes larger. The energy efficient of the Rayleigh channels performs better than the HD mode, but worsen than the method considering the interference as additive Gaussian noise at the receiver. For Rician fading with same channel power, the sum achievable rate keeps constant when the Rician factor K is in between 0 dB and 80 db. [25] [26].

Electromagnetic Interference

Electromagnetic interference (EMI) is a disturbance generated by an external source that potentially affects any electrical circuit by processes such as electromagnetic induction, electrostatic coupling or conduction. Performance of the circuit is degraded due to this disturbance or functioning may even stop fully. In the case of a data path, total loss of the data transmitted or the effects may be an increase in error rate. Electrical components can cause interference to Wireless devices and vice-versa, and as newer devices are becoming widely used, this problem may increase drastically. However, To mitigate a lot of problems caused by interference, installation of lower power microcells and electrical design techniques [27] improved shielding.

REVIEW OF TECHNIQUES AND ALGORITHMS TO REDUCE INTERFERENCE

This section of the paper has been further categorized into independent reviews of various existing techniques and algorithms. Most of the algorithms discussed below address only a particular type of interference owing to the fact that causes for all types of interference are not the same.

Zero Forcing Equalizer

The zero forcing equalizer falls under the category of linear equalizers and this technique is used to reduce Inter symbol interference(ISI). In channels whose characteristics are not known equalizer is found to be a best alternative for filters, to compensate Inter symbol Interference caused by Rayleigh fading. This technique uses the Rayleigh fading model and the channel response is found to be a Rayleigh distributed random variable. This method uses a LTI filter with transfer function T(Y) which acts as the linear equalizer circuit. The transfer function T(Y) is chosen such that it is the inverse of impulse response of the channel, so that the output of the equalizer is the original signal. This technique is known as Zero Forcing Equalizer as the Intersymbol interference component at the output response of the equalizer is forced to be zero. The study also shows eye diagrams of the input and output signals of the equalizer and it can be seen that Intersymbol Interference has been eliminated. [4]

Dispersion Interleaving

Dispersion interleaving technique has been proposed and demonstrated to mitigate adjacent channel interference in return-to-zero wavelength-division-multiplexing systems which employ interleaves'. Existing techniques like polarization interleaving combined with sharp filters have disadvantages. This technique uses residual fiber dispersion to reduce interference in neighbouring channels. Mach–Zehnder interferometer (MZI) leads to leakage of power from adjacent channels as it suppresses the frequency separation. The compensation link is incomplete in case of dispersion-interleaved WDM system. The dispersion-compensating fiber (DCF) is removed from the first or the last span of the link, its effect is compensated by adding two DCFs which pre-compensate or post compensate the dispersion of the link. Hence, the desired signal is received with dispersion fully compensated while the interference signal is overcompensated or undercompensated and is eliminated. Simulation results prove the efficacy of this technique. [7].

Transmit Power and Window Control

To mitigate Inter-user interference Transmit Power and Window Control technique (TPWC) has been proposed in CDMA cellular packet systems. Conventional Transmit power control technique has the following disadvantages: it causes adverse inter-user interference and has a detrimental effect on the system capacity, Transmit Power and Window Control technique (TPWC) overcomes these disadvantages. This technique involves flexible scheduling in packet based data transmission. This technique allows packet based data transmission within transmit windows only, during the transmit window the power required to transmit the data packet will be lesser than a threshold power. Hence as a result the average transmitted power decreases, inter-user interference also decreases but at the expense of increased transmission delay. Simulation results are used to determine the reduction in transmit power. Following technique has been discussed for downlink systems however its scope can also be extended to uplink systems. [5].

Channel Allocation Algorithm

Cognitive radio (CR) networks suffer from Co-channel interference due to interference from adjacent cells. Channel Allocation Algorithm is used to mitigate Co-channel interference in CR networks. The basic assumption is that in a multi-cell CR network in a cluster no two cells can select the same channel at same time. A cell is divided into orthogonal narrowband subcarriers. In a cluster two factors are considered while allocating resources to cells: (i) required data rate of the cell (ii) degree of interference. In this algorithm, first the channels which are available at a particular cell are allocated to that cell to meet the capacity, then the cell with greatest value of required data rate is preferred and less interfering channel is allocated to this cell. Therefore, using this algorithm one channel is allocated to each cell and subcarriers are allocated to secondary CR users. Remaining unused channels can be used for allocating to another cluster thereby reducing channel reallocation and making it advantageous. Simulation results prove the efficiency of the algorithm. [6]

Electromagnetic Shielding Using Chemical Compounds

Electromagnetic shielding is done in order to confine electromagnetic energy or prevent its propagation. EMI shielding is based on the principle of reflection of radiation by the shield material. Metals are used for EMI shielding due to presence of free electrons, these free electrons interact with the electromagnetic field. The metal is coated on the surface of device by electroplating, electro less plating.

Another mechanism for EMI shielding is absorption. Chemical compounds like Barium ferrite decorated reduced graphene oxide nanocomposite, Carbon black, silicone rubber blends have very good microwave absorbing properties, light weight and hence find applications as absorbing materials to reduce Electromagnetic interference. These materials contain electric and magnetic dipoles which interact with the Electromagnetic field. A layer of the chemical compound is coated on the device. The researches however do not specify which type of material has to be used in different frequency ranges. [8] [12] [14]

CONCLUSION

The analysis of interference in communication systems and the algorithms to mitigate them have received a lot of attention from researchers in the recent years and still this domain is yet to be fully explored. There are several papers that bring about an application specific explanation to this problem. This paper presents a deep insight of the different types of interference and methodologies to reduce it. The focus of this paper is not to highlight the applications of these algorithms but to provide some stimulus for understanding their scope and objectives. The preliminary understanding of these techniques would be useful for researchers working in this domain. Depending upon the nature of the problem and its associated complexity, the apt algorithm can be chosen with the guidance provided in this paper. [1]

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