International Journal of Technology Research and Management
ISSN (Online): 2348-9006
Vol 4 Issue 7 July 2017

A Survey on Multi User Detection in Wireless Networks

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Abstract: *With increasing number of users using cellular networks, challenges pertaining to the same have gained great significance. Cellular traffic has resulted in degraded BER performance for multipath channels. The main challenge is detecting the signals of weaker users in the presence of stronger users. Several techniques have been proposed to detect the signals with weaker strength in the presence of stronger signals often termed as multi-user detection (MUD). This paper puts forth previous techniques used for multi user detection.*

Keywords: *Wireless Networks, Multi User Detection (MUD), User Equipment (UE), Bit Error Rate (BER).*

1. INTRODUCTION

The advent of high speed global communication ranks as one of the important developments of human civilization from the second half of twentieth century to till date. This was only feasible with the introduction of digital communication systems. Today there is a need for high speed and efficient data transmission over the communication channels. It is a challenging task for the engineers and scientists to provide a reliable communication service by utilizing the available resources effectively in-spite many factors that distort the signal. The main objective of the digital communication system is to transmit symbols with minimum errors. The high speed digital communication requires large bandwidth, which is not possible due to limited resources available. Digital communication systems are designed to transmit high speed data over communication channels. The channel is the medium through which information propagates from the transmitter to the receiver. At the receiver the signal is first demodulated to recover the baseband transmitted signal. This demodulated signal is processed by the receiver filter, also called receiver demodulating filter, which should be ideally matched to the transmitter filter and channel. Typically, an Analog to digital converter (A/D) converts the analog signal to digital signal or in the form of data stream, then source encoding is used to compress the digital data up to an extent such that it can be received without any loss. Then, the information symbol is obtained from source encoder which is passed through a channel encoder which adds the redundant bits to the data sequence for reliable communication or to make the data transmission robust to disturbances which are present in the transmission channel.

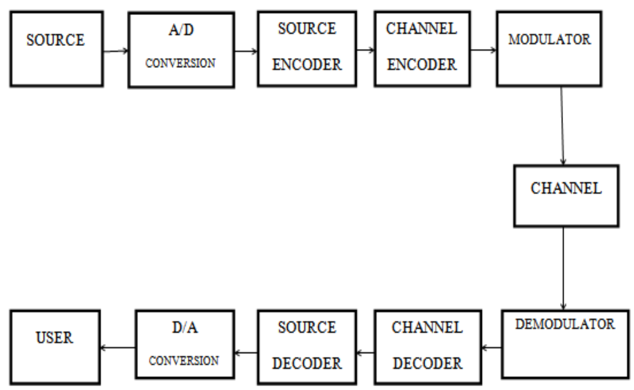

Fig. 1: Block Diagram of Digital Communication System

In the present world, the requirement of high data rate is increasing very rapidly. The data transmission or exchange of information can be made by two modes i.e. wired and wireless medium and these services also require a reliable transmission of data in the harsh environment. As we know that, in real time system the transmission of data experiences much attenuation due to noise, multipath propagation, interference, nonlinearity etc. and also transmission system has power limitation and cost factor. So, multicarrier modulation technique gained lot of popularity due to its robustness in dealing with impairments. The problem becomes even more severe since the number of users utilizing cellular and allied services is growing by leaps and bounds.

2. MULTIPATH PROPAGATION

The Cellular systems now days have several users within a cell site with high mobility. Therefore for limited power systems suffer from the near-far effect in which it becomes exceedingly difficult to detect users with low signal strength in the presence of users with high signal strength.

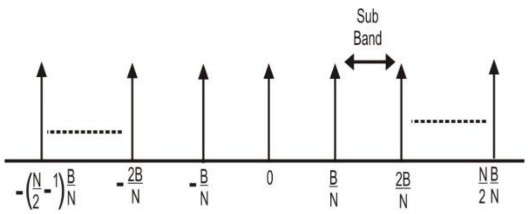

Fig. 2: Multi-user scheme in Wireless Networks

The process of detecting signals from a particular user in the presence of multiple users is termed as Multi-User Detection or MUD. We consider $f_i = i\frac{B}{N}$, where f_i is centre frequency of i^{th} subcarrier and i ranging from

$$-\left(\frac{N}{2}-1\right) \leq i \leq \frac{N}{2}$$

Let data streamX_i is transmitted on i^{th} subcarrier then modulated signal is given by

$$s_i(t) = X_i e^{j2\pi f_i t} = X_i e^{j2\pi i\frac{B}{N}t}$$

There areN subcarriers, hence there will beN data streams indexed by X_i (i^{th} data stream), then multi-carrier composite transmitted signal will be.

$$s(t) = \sum_i s_i(t) = \sum_i X_i e^{j2\pi i\frac{B}{N}t}$$

3. MULTICARRIER DATA DETECTION SCHEME

$$y(t) = s(t) = \sum_i X_i e^{j2\pi i\frac{B}{N}t}$$

here,$y(t)$ is received signal in absence of noise. Now, the different sub carriers are demodulated at lth sub-carrier i.e. $y(t)\left(e^{j2\pi f_l t}\right)^*$, this is actually matched filtering kind of operation/correlation.

We have,

$$= \frac{B}{N}\int_0^{N/B} y(t)(e^{j2\pi f_l t})^* \, dt \qquad (1)$$

Fundamental frequency,$f_o = \frac{B}{N}$, and the time period of integration is given by

$$\frac{1}{f_o} = \frac{1}{B/N} = \frac{N}{B}$$

Now, on putting $y(t)$ in eq.1

$$= \frac{B}{N}\int_0^{N/B} \sum_i X_i e^{j2\pi i\frac{B}{N}t} e^{-j2\pi l\frac{B}{N}t} \, dt$$

$$= \frac{B}{N}\int_0^{N/B} X_l + \sum_{i\neq l} X i e^{j2\pi(i-l)\frac{B}{N}t} \, dt$$

$$= \frac{B}{N} X_l \frac{N}{B} + \frac{B}{N}\sum_{i\neq l} X_i \int_0^{N/B} \sum_{i\neq l} e^{j2\pi(i-l)\frac{B}{N}t} \, dt \qquad (2)$$

Second term of above expression will become 0 from the concept of orthogonality.

$$= X_l + 0 = X_l$$

WhereX_l = information symbol transmitted on l^{th} sub-carrier, hence X_l can be recovered by coherently demodulating withe$^{j2\pi l\frac{B}{N}t}$.

To recover symbols corresponding to N subcarriers, coherently demodulate with N subcarriers corresponding to $l = -\left(\frac{N}{2}-1\right) \ldots \ldots \ldots \left(\frac{N}{2}\right)$.

This scheme is often termed as multi-user transmission and reception in wireless networks.

The window of time associated with detection of this multi carrier signal is $\frac{N}{B}$.

N symbols in time period$\frac{N}{B}$, therefore

$$\text{Symbol rate} = \frac{N}{N/B} = B \qquad (3)$$

Thus symbol rate in single carrier v/s multicarrier is unchanged. Advantages of multi carrier modulation over single carrier modulation.

For example, consider a bandwidth B = 1024 kHz for SC system,

$B \gg B_c$ (200 kHz~300 kHz)

Where B_c = coherence bandwidth,

Hence, each sub-carrier experiences frequency flat fading or there is no ISI.

Implementing bank of N modulators and N demodulators on hardware chip is challenging. So the digital implementation technique of the above was proposed. [18].

We have composite signal as:

$$s(t) = \sum_i X_i e^{j2\pi i \frac{B}{N} t}$$

Considering the u^{th} sample,

$t = uT_s = \frac{u}{B}$, then the sampled signal $s(uT_s)$ is given as

$$s(uT_s) = x(u) = \sum_i X_i e^{j2\pi i \frac{B u}{N B}} \quad (4)$$

$$x(u) = \sum_i X_i e^{j2\pi i \frac{u}{N}}$$

$x(u)$ are samples of MCM signal and eq.2 is IDFT of information symbols $X_0, X_1, \ldots \ldots X_{N-1}$.

The above scheme is the mathematical formulation for a multi user detection scheme.

4. PREVIOUS WORK

Several researchers have carried out their work in the field of multi user detection pertaining to wireless networks, some of the most noteworthy are mentioned below:

In the paper Compressive Sensing Multi-User Detection for Multicarrier Systems in sporadic Machine Type Communication by Fabian Monsees et.al [1] a paradigm for massive machine type communication has been proposed for multi-user detection. In this technique, compressed technique has been proposed to avoid the excessive overhead compared to conventional signal strength based sensing.

In the paper 'Efficient Computation of the Feedback Filter for the Hybrid Decision Feedback Equalizer in Highly Dispersive Channels' by Maurizio Magarini et.al, IEEE 2012, [2] the authors present a hybrid decision feedback equalizer (DFE) for a time-frequency conjugate analysis. It addresses the issue of trade-off between performance and computational complexity in single carrier transmission over severely frequency-selective channels. The tap weights are often decided by the training pulse initially but later after passage through the channel, makes use of the feedback error propagation.

In the paper 'Design techniques for decision feedback equalization of multi-giga-bit-per-second serial data links: a state-of-the-art review' by Fie Yuan et.al, IET 2012 [3], the authors derived a simplified maximum likelihood (ML) decoder for multiuser detection that operates without side information. These decoders recover received composite signal in additive white Gaussian noise (AWGN), fading, and the presence of nonlinear amplifiers. They proposed systems neither lose throughput due to side information nor degrade bit error rate (BER) due to errors inside information.

5. CONCLUSION

It can be concluded that the detection of single weak user in the presence of multiple users in wireless networks is a challenging job. While stronger signals from nearby users easily override the weaker signals, the degrading effects of a multi-path communication add to the adversities. It can be concluded from the previous analysis that multi user detection can be successfully carried out using successive cancelling of strong signals descending from the strongest to the weakest.

ACKNOWLEDGMENTS

I am grateful and would remain highly indebted to Prof. Amit Vajpayee for his patient hearings and continuous support. I would also like to express my gratitude to all faculty members of LNCT, Indore for their relentless patronage. Without any one of them, this research work would not have seen the light of the day.

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