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Statistical Multipath Signal Detection and Transmission Over CDMA Mobile Ad-hoc Network

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***Abstract* — In any communication network, Quality of Service (QoS) plays a major role as it is a measure of the performance of a system reflecting its transmission quality and service availability. Hence achieving QoS in networks such as Ad-hoc Network is a major challenge because the signal takes different paths to reach the receiver. While considering QoS, the major hurdles to overcome include: varying channel characteristics, bandwidth allocations, fault tolerance levels, Signal to Noise Ratio (SNR) and Bit Error Rate (BER). This paper is aimed to present the work carried out to find the strongest signal based on its BER and SNR, transmit the signal over ad-hoc network. Simulations results showed that the signal received is of negligible loss when the reconstruction algorithm was applied at the receiver side.**

***Keywords* – BER, SNR, CDMA, OFDM, QoS,**

I. INTRODUCTION

The world is increasingly adapting faster and advanced ways of communication for better quality and Code Division Multiple Access (CDMA) is one of these technologies in wireless world [1]. The ultimate objective of the today's communication Engineers is to provide communication services from any person to any person to any person in any place at any time without any delay in any form through any medium using one packetized unit with minimum cost using a personal telecommunication reference number [2]. The CDMA system proposed by Qualcomm for digital cellular phone applications has been adapted by the Telecommunication Industry Association (TR-45) committee as TIAEIA IS-95 standard for cellular and by the Alliance for Telecommunication Industry Solution Committee T1P1 and TIA-TR46 joint standard JSTD-008 for PCS [3]. CDMA is based on spread spectrum techniques in which each user occupies the entire available bandwidth [4] Since the Spread spectrum technologies permit interference averaging and tolerate co-located simultaneous transmissions, they are suitable for CDMA ad hoc networks. CDMA has been the access technology of choice in cellular systems, including 3G systems due to its superior characteristics [5]. In such systems, it was proved that the CDMA has six times the capacity of TDMA- or FDMA-based solutions. In conventional CDMA receivers, the detection of multipath components and RAKE finger management is normally based on the energy of the received signal per path. As a result, such schemes essentially overlook the interference component contaminating the total received power. Hence, they exhibit poor multipath detection capability especially at low signal-to interference-plus-noise ratio (SINR). Mohamed Abou-Khousa et al [6] investigated the impact of imperfect multipath detection on the performance of CDMA systems employing space-time spreading**.** It was shown that the errors produced by the conventional scheme in detecting the potential multipath components had severe impact on the performance of the receiver. To boost the performance, the authors introduced an improved multipath detection scheme based on estimating the interference power in the resolved paths. To improve the quality of the received signal, Mohamed Abou-Khousa et al [7] proposed a new multipath detection scheme that takes into consideration, the interference level in each resolved path individually.

II. CDMA TRANSMISSION OVER MOBILE AD-HOC NETWORK (MANET)

An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of existing network infra-structure or centralized administration. Due to the limited transmission range of wireless network interfaces, multiple network hops may be needed for one node to exchange data with another across the network. In such a network, each mobile node operate not only as a host but also as a router, forwarding packets for other mobile nodes in the network, that may not be within the direct reach wireless transmission range of each other. Each node participates in an ad hoc routing protocol that allows it to discover multi hop paths through the network to any other node. The idea of an ad hoc network is sometimes also called an infrastructure-less networking, since the mobile nodes in the network dynamically establish routing among themselves to form their own network on the fly [8].

In an MANET, the network topology changes rapidly and unpredictably, there by leading to dynamic topology [9]. One of the fundamental challenges in MANETs research is how to increase the overall network throughput while maintaining low energy consumption for packet processing and communications [10]. The CDMA transmission method has been a popular choice for the Ad-hoc network protocol standards such as IEEE 802.11 standard [11].

The paper is organized as follows. Section II explains CDMA transmission over MANET. Section III deals with multipath detection scheme. Section IV deals with Multipath signal detection in Ad-hoc Network. Section V deals with results and discussions. The paper is concluded in section VI.

III. MULTIPATH DETECTION SCHEME

The various multipath detection schemes in CDMA have been explained in this section.

A. Energy –Based Multipath Detection Scheme (EMDS)

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In this scheme, the correlation energy is averaged over N_A independent search blocks at each delay offset and the result is compared with the threshold.

If the average energy at a certain delay offset exceeds the threshold, the path with that delay offset is acquired. This process is repeated for all delay offsets in the search window. By employing a Delay Locked Loop (DLL), the selected delay offsets are fine aligned through the tracking process. The tracking loop will detect a wrong delay, which does not contain the desired user's signal and which passes the threshold test, declares a false alarm state after a relatively long period of processing time. In this scheme, it is very important to reduce the probability of false alarm. The correlation energy at the k^{th} delay offset is given by

$$Y(k) = \frac{1}{N_A}\sum_{n=1}^{N_A} |h_k(n)|^2 = \hat{P}(k) + \hat{\sigma}_I^{\,2}(k) \qquad (1)$$

Where $\hat{\sigma}_I^{\,2}(k)$ and $\hat{P}(k)$ respectively estimates of the interference power $\sigma_I^2(k)$ and the user power $p(k) = E_{b1}\phi_1(k)$ obtained from N_A independent search results [12].

B. Improved Multipath Detection Scheme (IMDS)

A better detection scheme should consider the received interference power at the searched delay offsets. For this purpose, the interference power should be estimated at each delay offset in the search window. To obtain an estimate of the interference power, the N_A search results can be used to estimate the interference variance using the equ. (2).

$$\sigma_I^{\,2}(k) = \frac{1}{N_A}\sum_{n=1}^{N_A} |h_k(n) - \sqrt{P(k)}\alpha_{1k}(n)|^2 \qquad (2)$$

With the assumption that the channel fading coefficients are known at the receiver, this estimator can be shown to be Minimum Variance Unbiased (MVU) estimator. Using the estimates computed from Equ. (2), the new detection metric is

$$Z(k) = Y(k) - \hat{\sigma}_I^{\,2}(k) \qquad (3)$$

Consequently, under the IMDS, the paths with maximum Z will be acquired. We observe that the proposed metric depends on the desired signal power as opposed to the conventional metric which uses the signal and interference power in the detection process.

The probability of detection can be found following the same steps used to find the probability of false alarm. The conditional probability of detecting the k^{th} multipath component where k^{th} dc is given by

$$P_D(k \mid \tilde{P}(k)) = Q\left(\frac{\sqrt{N_A}\left[\hat{\mathbf{o}} - \tilde{p}(k)\right]}{\sigma_I^2(k)}\right) \qquad (4)$$

Averaging over the envelope of the received signal results in the probability of detecting that component which is given by

$$P_D(k) = \int_0^{\infty} Q\left(\frac{\sqrt{N_A}\left[\hat{\mathbf{o}} - \tilde{p}(k)\right]}{\sigma_I^2(k)}\right) f(\tilde{p}(k))d\,\tilde{p}(k) \qquad (5)$$

From the equation, it is clear that the probability of detection is a function of the per path received SINR [13].

IV. Multipath Signal Detection in Ad-hoc Network

We have proposed a model to detect the strongest signal when it is passed through five channels having different SNRs. At the receiver, the signal having minimum BER was chosen to transmit the signal over Ad-hoc network. Figure 1 shows the proposed model to detect the signal having highest SINR and lowest BER.

The dynamic Adhoc network for 50-100 nodes was created and the shortest path between source node to destination node was calculated. The video signal having the least BER was selected for transmission via Adhoc network over the shortest path calculated. During transmission, when the nodes in the shortest path were error free, the received signal was almost same as the transmitted signal.

The same signal was sent over shortest path by inserting block hole (nodes which blocks the data) in between source node and destination node. The signal takes the alternate path whenever it finds the block hole on the path. The alternate path was selected based on the strength of the nodes on the alternate paths [14].

The signal is transmitted over five different paths (channels) to reach the receiver. The BPSK modulation was used to transmit the signal. BER for the signal passing through each channel was calculated and the signal having highest SNR was chosen to transmit the data thorugh Ad-hoc network. The simulation results are shown in fig 2, 3 and 4.. The dynamic Ad-hoc network having random nodes was simulated and the shortest path between the transmitter and the receiver node was calculated using Dijkstra's Algorithm and the same path was used to transmit the data. The simulation was done for transmitting the video signal.

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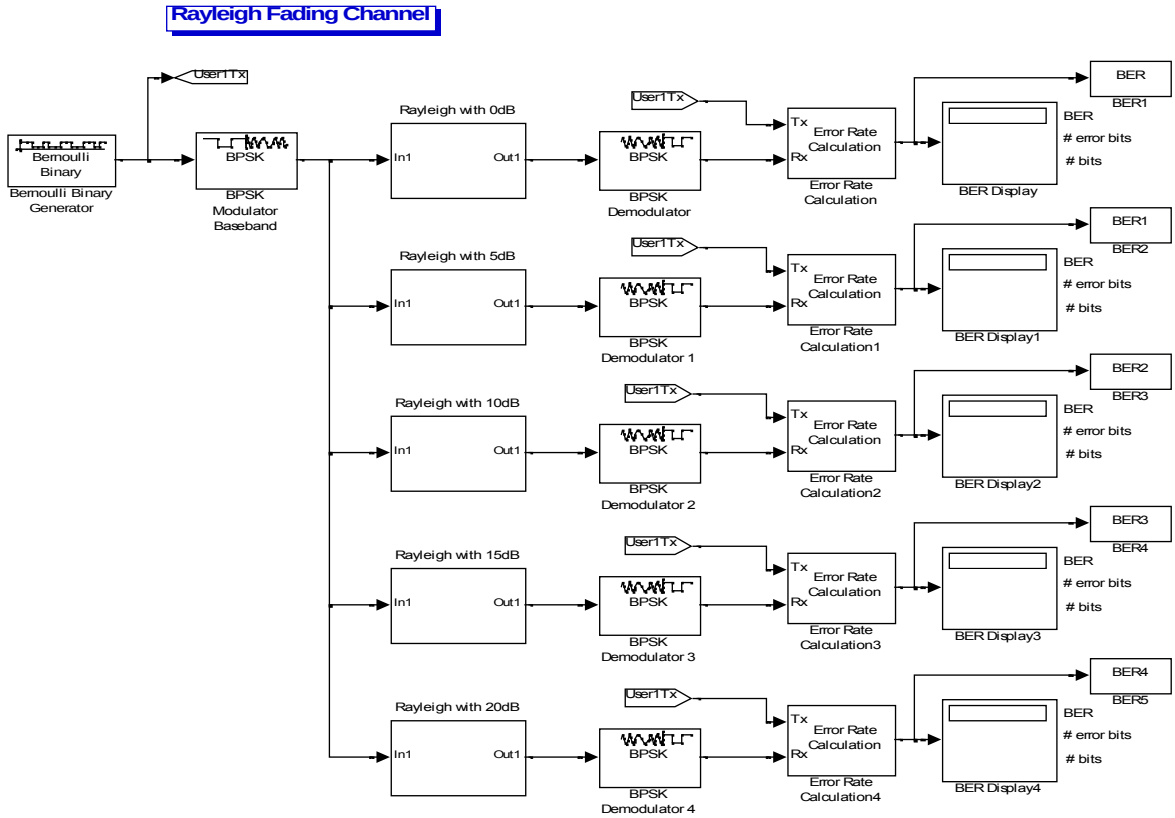

Fig.1. Verification of the proposed model using Simulink

V. Results And Discussions

Fig.5 shows the transmitted video signal over Ad-hoc network. Fig. 9 shows the received video signal, with noticeable loss, when the reconstruction algorithm was not used at the receiver. Fig. 10 shows the received signal with minimum loss when the reconstruction algorithm was applied to recover the signal with negligible loss.

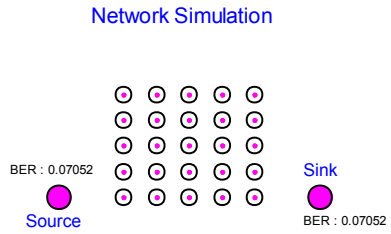

Fig.2. Network of 50 nodes

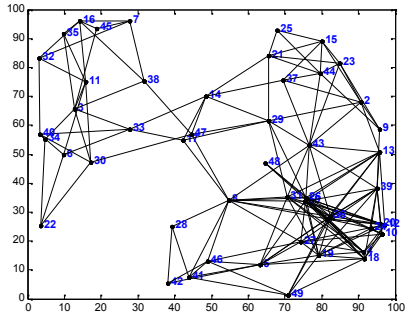

Fig.3. Network created for signal transmission

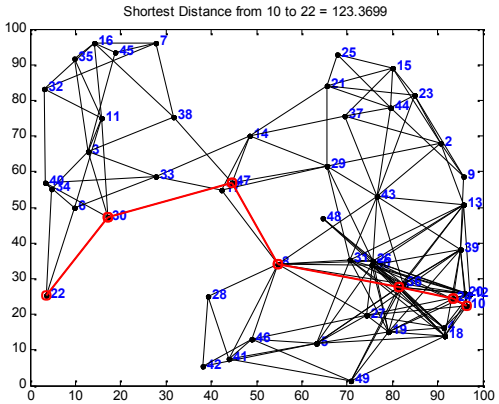

Fig.4. Shortest path between the source and the destination node

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Fig. 5. Transmitted video signal

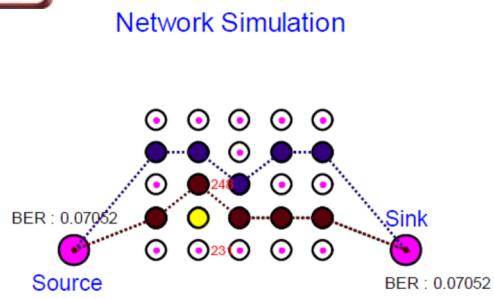

Fig.7. Input signal with the highest receiving power

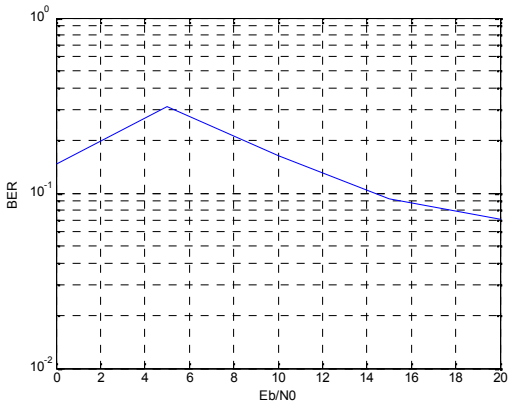

Fig 8. Transmission of data over shortest path

Fig.9. Reconstructed signal with noticeable loss

Fig.10. Reconstructed signal with minimum loss

VI. Conclusion

In this paper, the simulation of multipath signal detection and its transmission in Ad-hoc network has been presented. In a wireless communication scenario, the transmitted signal takes different paths to reach the receiver. The signal is deteriorated due to multipath fading and hence the selection of the signal having highest SNR need to be transmitted in order to get the exact replica of the transmitted signal at the receiver. The multiple paths were simulated and the transmitted signal having highest SNR and minimum BER was transmitted over the Ad-hoc network. The results showed that the transmitted video signal which takes the shortest path whenever it detects block holes on the path was reconstructed with minimum error by applying the reconstruction algorithm at the receiver.

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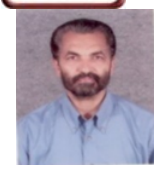

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