Iterative joint receiver with parallel RAKE structure for multipath coded CDMA

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Abstract:
Joint detection and PCC/SCC or LDPC codes are two very promising techniques to increase the capacity of future wide-band CDMA systems.
In this paper, we study an iterative joint receiver for PCC CDMA systems in uplink operating in multipath fading, utilizing the high reliability and low complexity characteristics of iterative schemes.

I **Introduction**:

Parallel and serial concatenated codes, LDPC codes are considered the most important invention in the coding research in the recent years. As these codes can achieve near-Shannon-limit error correction performance with significant low complexity, they are becoming the default coding technique for future generation cellular, Wireless, Wireline systems and standards.
In this paper, a low-complexity iterative joint receiver is described for turbo-coded asynchronous CDMA systems in uplink over multipath fading channels. Asynchronous CDMA system considers the practical frequency selective multipath channel for each user.
The soft joint detector uses the conventional RAKE receiver statistics (i.e., the outputs of the maximum ratio combiners for all the users), and it achieves significant performance gains by performing interference cancellation/suppression at a moderate computational complexity.

II **Transmitter Section**:

We consider a K-user turbo-coded CDMA system signaling through multipath fading channels, where each user employs BPSK spread-spectrum modulation. The block diagram of the system is illustrated in Fig 1. The binary information bit stream $\{d_k(i')\} \in \{0, 1\}$ with i'=1 to L for user k = [1,K] is encoded by a rate k_0/n_0 turbo encoder. The output of the turbo encoder is the code bit stream $\{b_k(i)\} \in \{-1, +1\}$ with i=1 to M. For each user, a different code bit interleaver is used to reduce the influence of the error bursts at the input of each channel decoder. The interleaved bit of User k is denoted by b^{π}_k (i), where the superscript π indicates an interleaved quantity. Using BPSK, each interleaved code bit is modulated by a signature waveform of duration T, denoted by $s_{k,i}(t)$. That is, b^{π}_k (i) = 1 is mapped to $s_{k,i}(t)$ and b^{π}_k (i)= −1 is mapped to $-s_{k,i}(t)$. The spread spectrum signal is then transmitted through a multipath fading channel.

III **Multipath Channel**:

We assume a time-variant, asynchronous multipath channel. The k-th user's signal x_k (t) is transmitted through the multipath channel with impulse response

$$h_k(t) = \sum_{l=1}^{L_k} g'_{kl}(t)\delta(t - \tau_{kl})$$

where L_k is the number of paths in the k-th user's channel, $g'_{kl}(t)$ are complex fading processes, and τ_{kl} is the delay of the l-th path of the k-th user's signal. The received faded signal due to the *k*-th user is

$$q_k(t) = A_k \sum_{i=1}^{M} b^{\pi}_k(i) \sum_{l=1}^{L_k} g_{kl}(i)\, s_{k,i}(t - \tau_{kl})$$

where * denotes convolution. The received signal is then

$$r(t) = \sum_{k=1}^{K} q_k(t) + \sigma n(t)$$

where σn(t) is zero-mean, complex, white Gaussian noise of power spectral density σ^2.

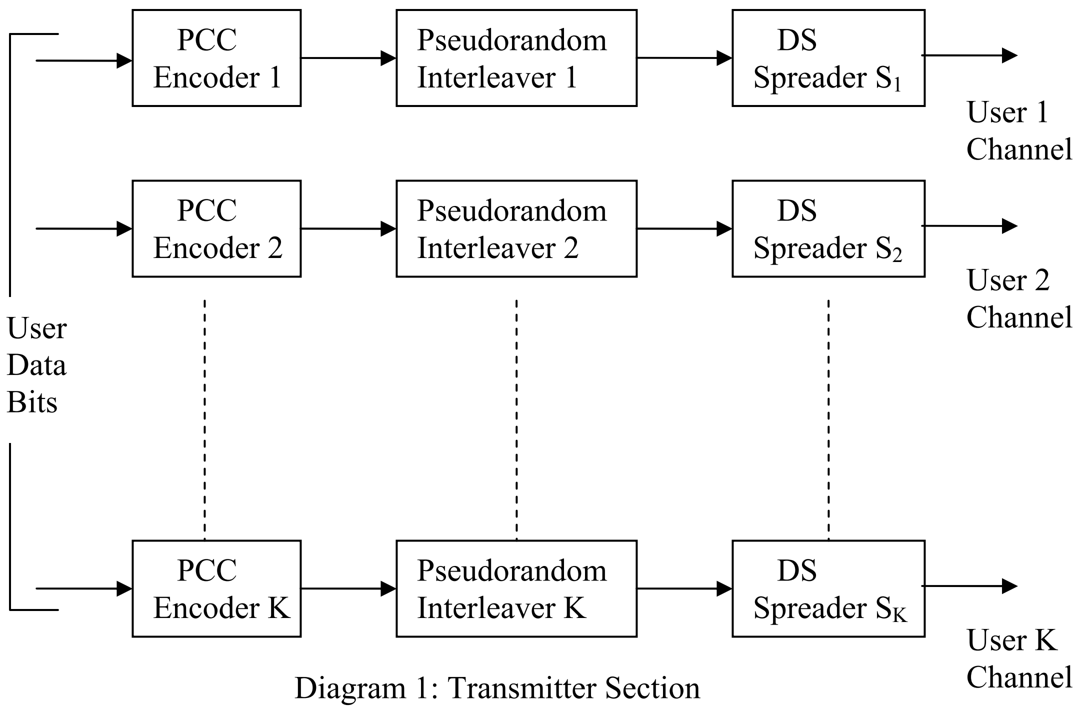

Diagram 1: Transmitter Section

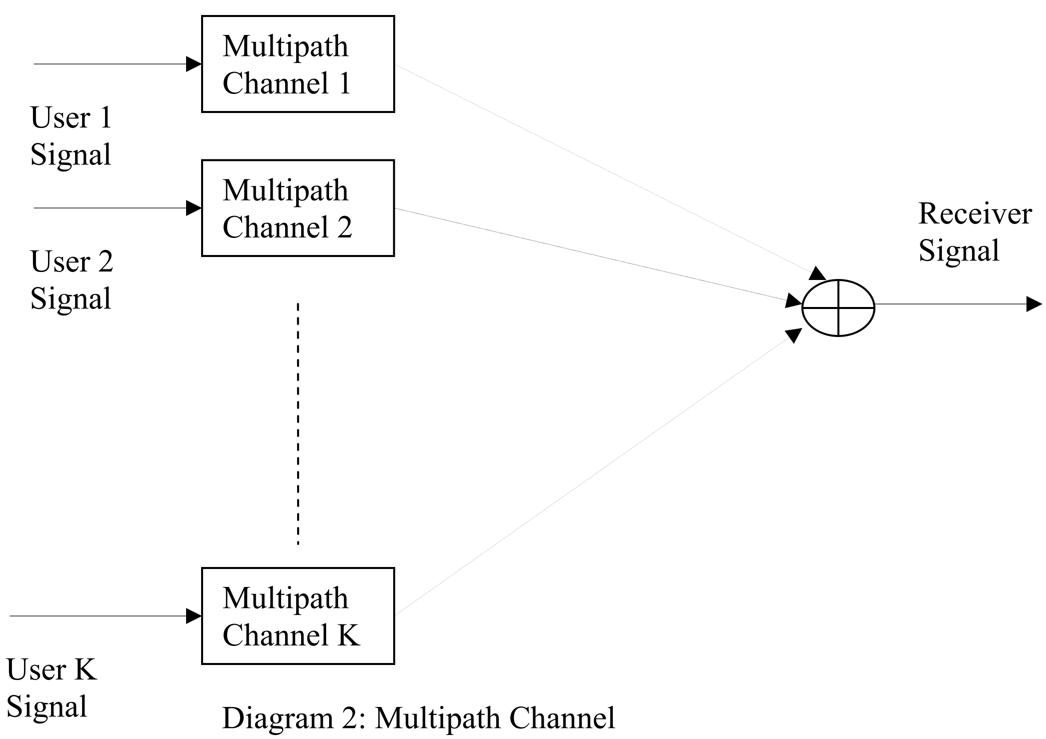

Diagram 2: Multipath Channel

IV **Iterative Receiver**:
It consists of two stages: a soft input soft output joint detector followed by K parallel single-user turbo decoders.
The SISO joint detector delivers extrinsic information, which can be expressed as:

$$\lambda_M[b_k^\pi(i)] = \log \frac{p\left[b_k^\pi(i) = +1 \,\middle|\, \{\lambda_C^p[b_k^\pi(i)]\}_{i=1}^M,\, r(t)\right]}{p\left[b_k^\pi(i) = -1 \,\middle|\, \{\lambda_C^p[b_k^\pi(i)]\}_{i=1}^M,\, r(t)\right]} - \underbrace{\log \frac{P[b_k^\pi(i) = +1]}{P[b_k^\pi(i) = -1]}}_{\lambda_C^p[b_k^\pi(i)]}.$$

Based on the priori information $\{\lambda_M[b^\pi_k(i)]\}$ and the structure of the turbo code, the k-th user's turbo decoder computes the extrinsic information of each code bit using

$$\lambda_C[b_k(i)] \triangleq \log \frac{P\left[b_k(i) = +1 \middle| \{\lambda_M[b_k(i)]\}_{i=1}^M;\, C\right]}{P\left[b_k(i) = -1 \middle| \{\lambda_M[b_k(i)]\}_{i=1}^M;\, C\right]} - \lambda_M[b_k(i)],$$

$$k = 1, \ldots, K, \; i = 1, \ldots, M.$$

Parallel RAKE structure:
It consists of parallel RAKE combiners, one for each of the K users.

Interference Cancellation Stage:
This stage cancels multiuser interference using two inputs
1. RAKE output.
2. Code bits of all users.
Based on the a priori LLR of the code bits of all users, $\lambda_C^p[b^\pi_k(i)]$, for $1 \le k \le K$ and $1 \le i \le M$ provided by the turbo decoder from the previous iteration, the soft estimates of the user code bits are formed. The soft estimates of all user's $(i-1)^{th}$, i^{th} and $(i+1)^{th}$ code bits, except that a zero taking the place of user k' s i^{th} code bit is considered. At symbol time i, for each user k, MAI from all other users is cancelled on the RAKE output.

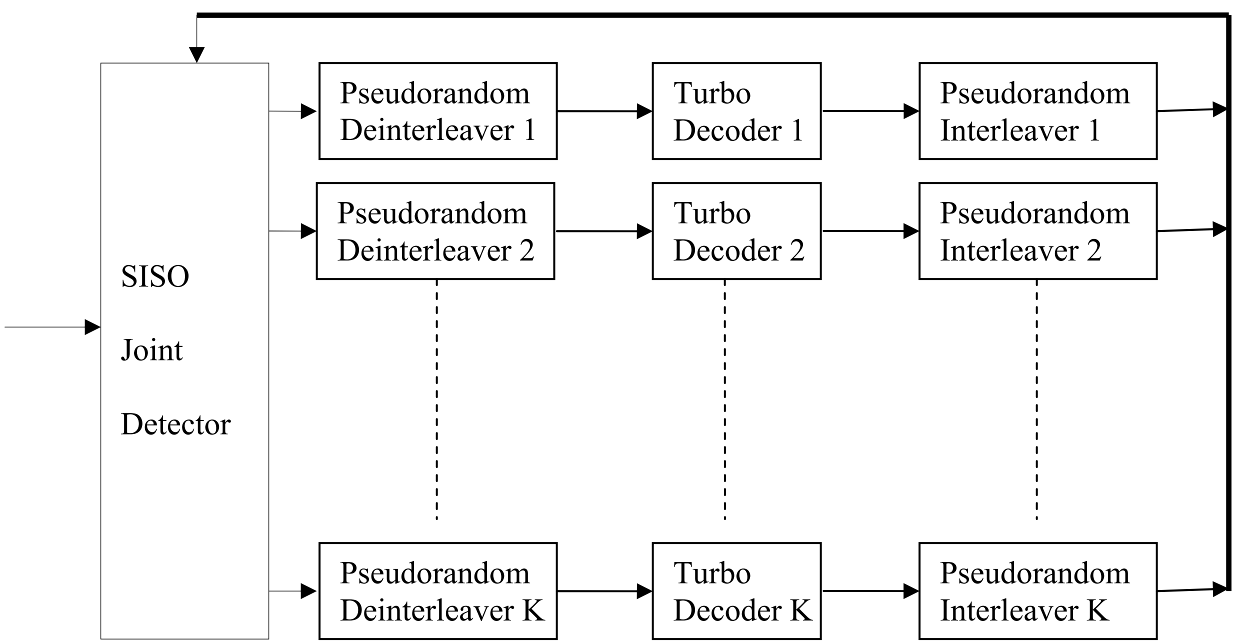

Diagram 3: Iterative Joint Receiver

SISO Joint Detector:
The soft input soft output joint detector is constituted by 3 cascaded blocks
1. Parallel RAKE structure.
2. Interference Cancellation Stage.
3. Linear MMSE.

Linear MMSE:
Convergence of the joint detector is expedited by one more level residual MAI cancellation by applying an instantaneous linear MMSE block to the ICS output.

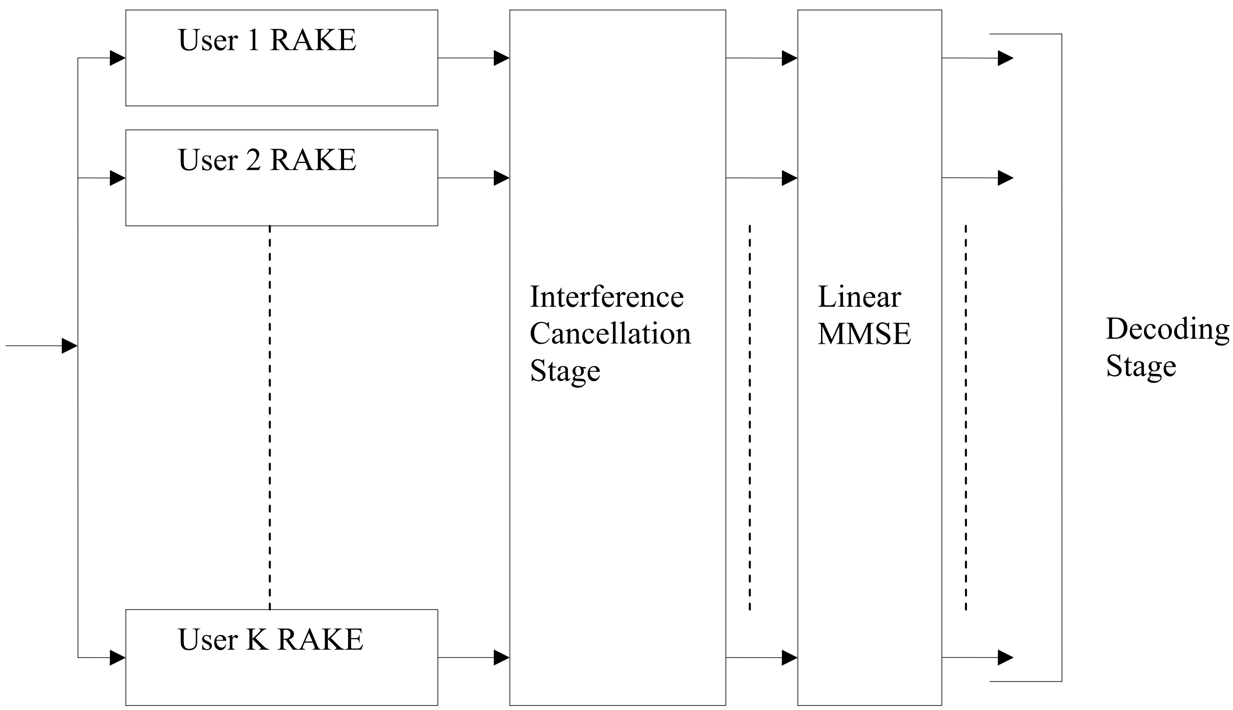

Diagram 4: SISO Joint Detector

V **Simulation Results**:

For simulation analysis of the system, the following cases were considered

1. BER V/s No:of iterations for 2, 3, 4 users.
2. BER V/s Frame size for 2, 3, 4 users.
3. BER in the presence of strong weak user environment for 2, 3 users.

VI **References**:

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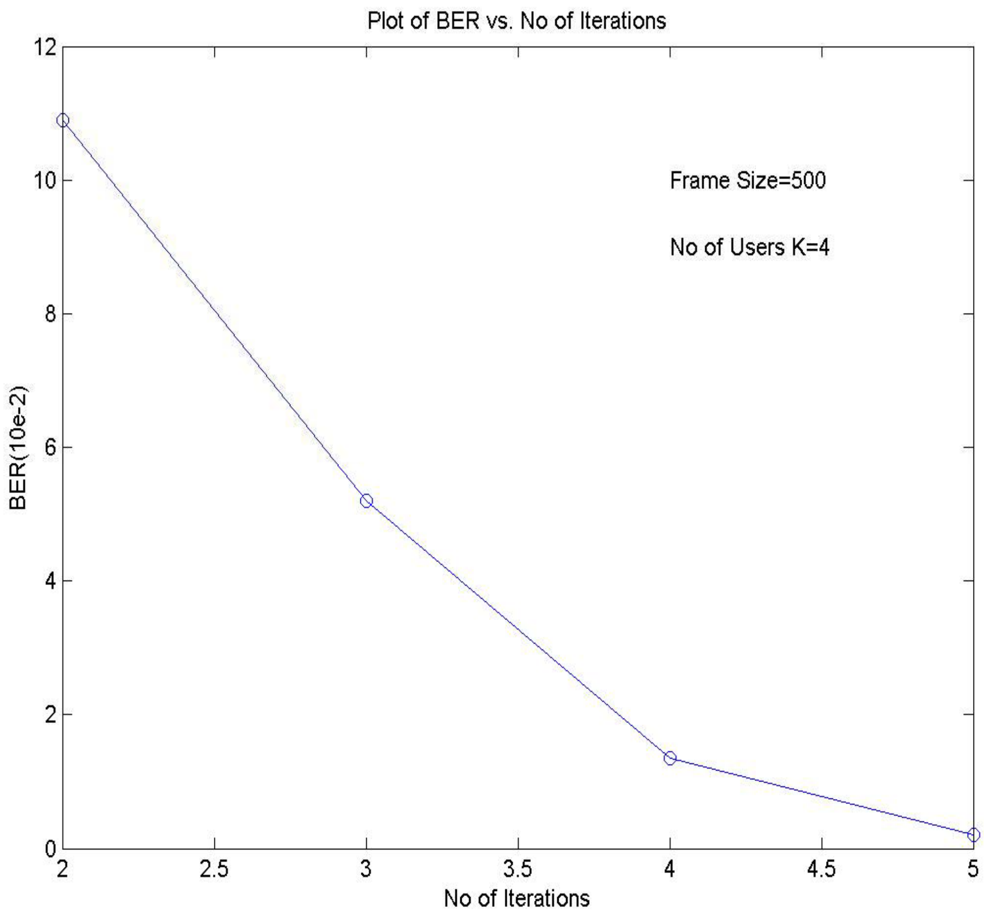
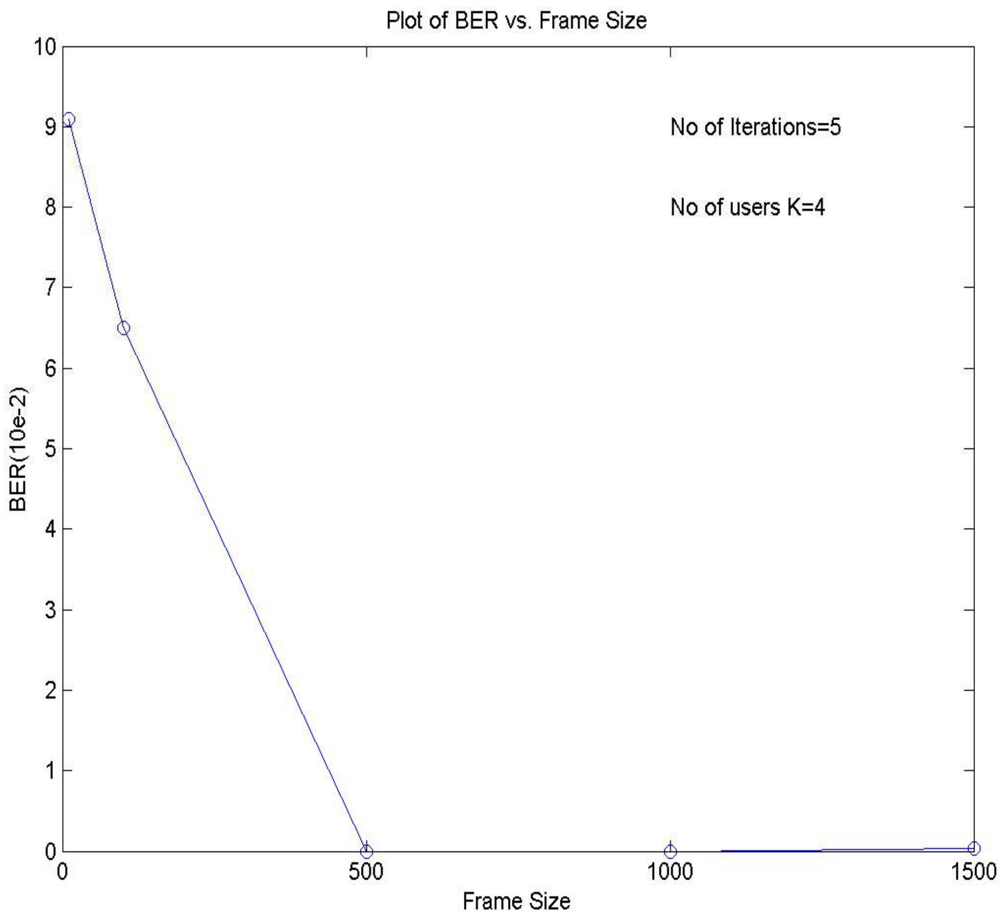
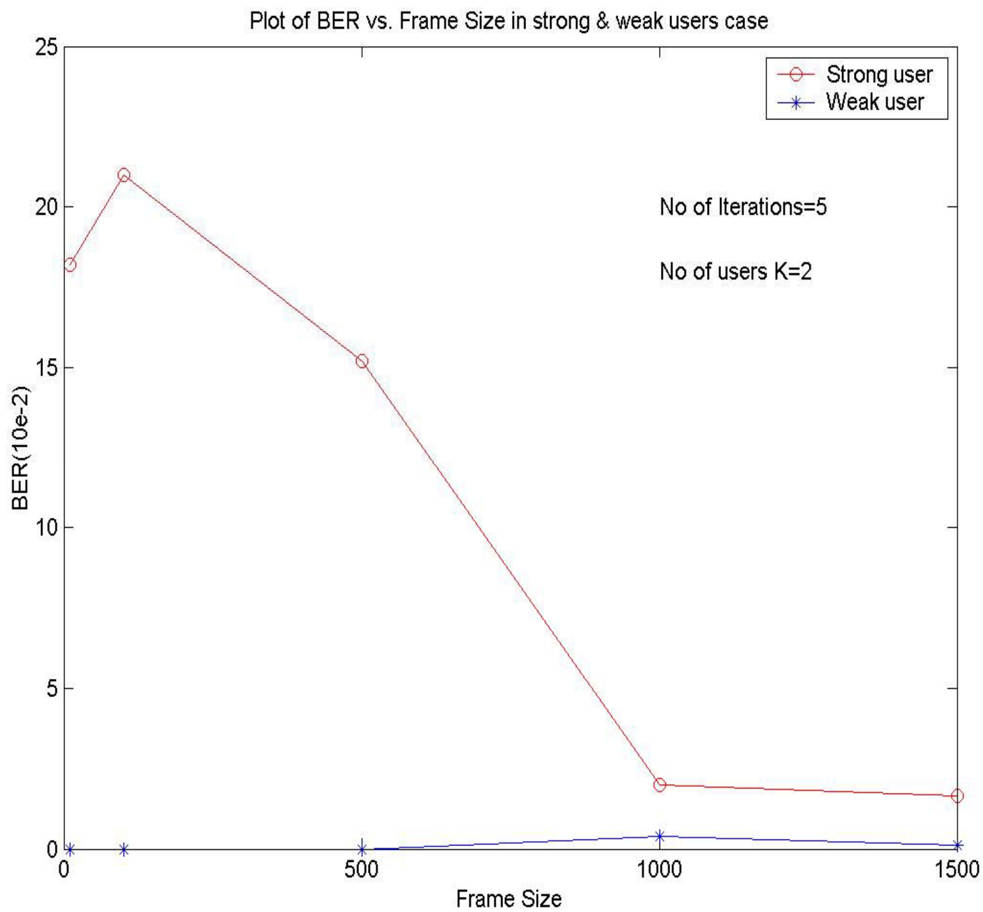


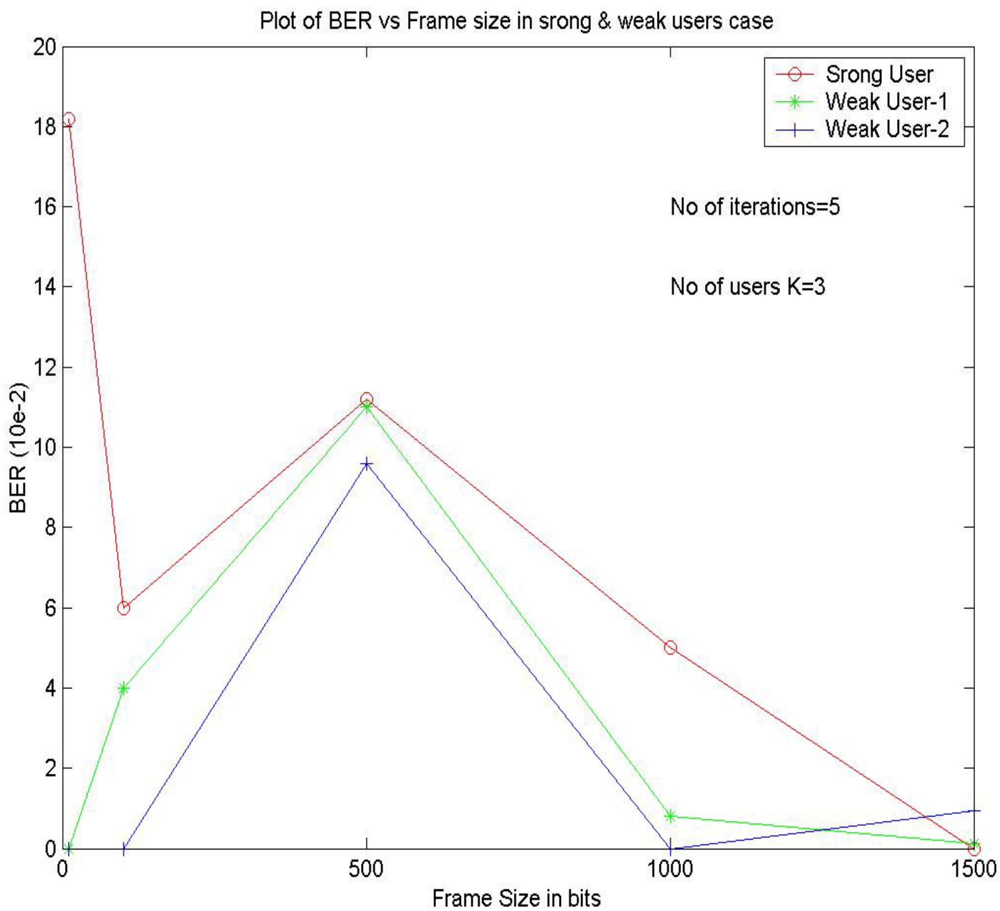
Plot of BER v/s No of Iterations, for K=4



Plot of BER v/s Frame Size, for K= 4



Plot of BER v/s Frame Size in Strong and Weak users case, K=2



Plot of BER v/s Frame Size in Strong and Weak users case, K=3