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The LNM Institute of Information Technology

MULTI USER DETECTION SYSTEM WITH SUCCESSIVE INTERFERENCE CANCELLATION RECEIVER

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OUTLINES OF PRESENTATION :

- CDMA
- DS – SS CDMA System
- Single & Multi user CDMA
- Near-Far Effect in CDMA
- Multiuser Detection
- Multiuser Techniques
- Successive Interference Cancellation
- Conclusion
- Future Work

WHAT IS CDMA ??

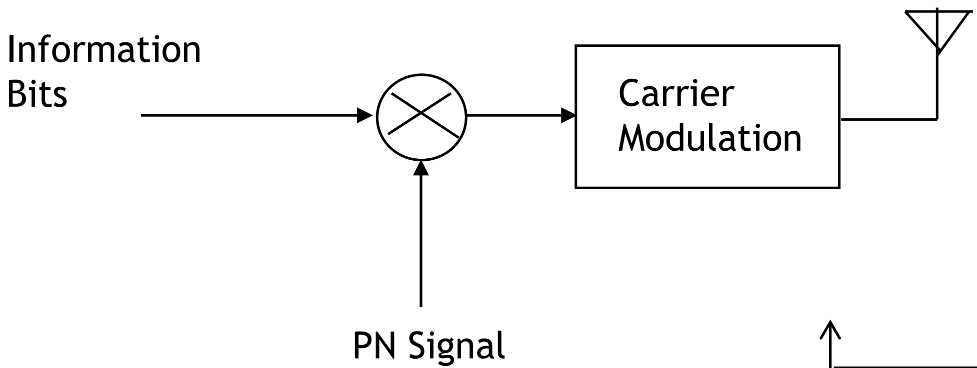
- CDMA stands for Code Division Multiple Access.
- Digital cellular technology that uses spread-spectrum technique.
- Several users share the share the same physical medium i.e. same frequency band at same time.
- Uses codes to identify subscribers. Every User is assigned with a Unique Code.

DS – SS CDMA :

- Efficient means of sharing a given RF spectrum among different users .
- User data is spread by multiplying with a specific PN Sequence before transmission.
- Receiver distinguishes different users based on different PN codes assigned to them.
- All CDMA users simultaneously can occupy the entire spectrum
  - Hence system is Interference limited

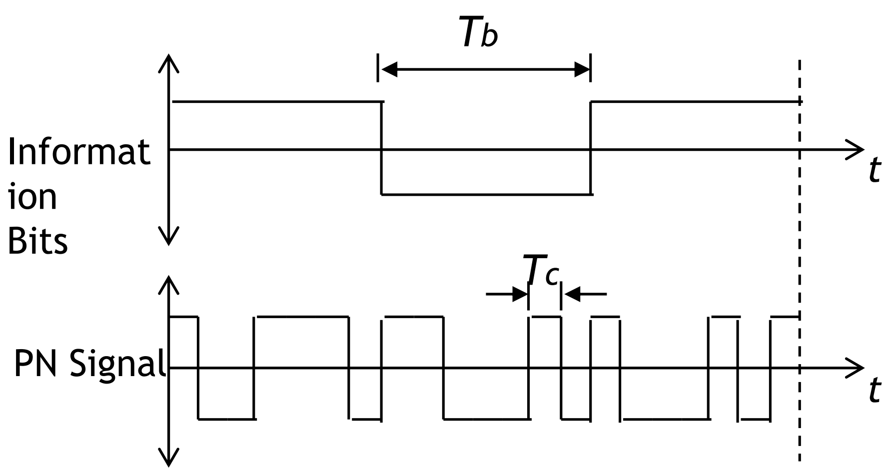
DIRECT SEQUENCE SPREAD SPECTRUM :

- DS-SS signal is obtained by multiplying the information bits with a wideband PN signal

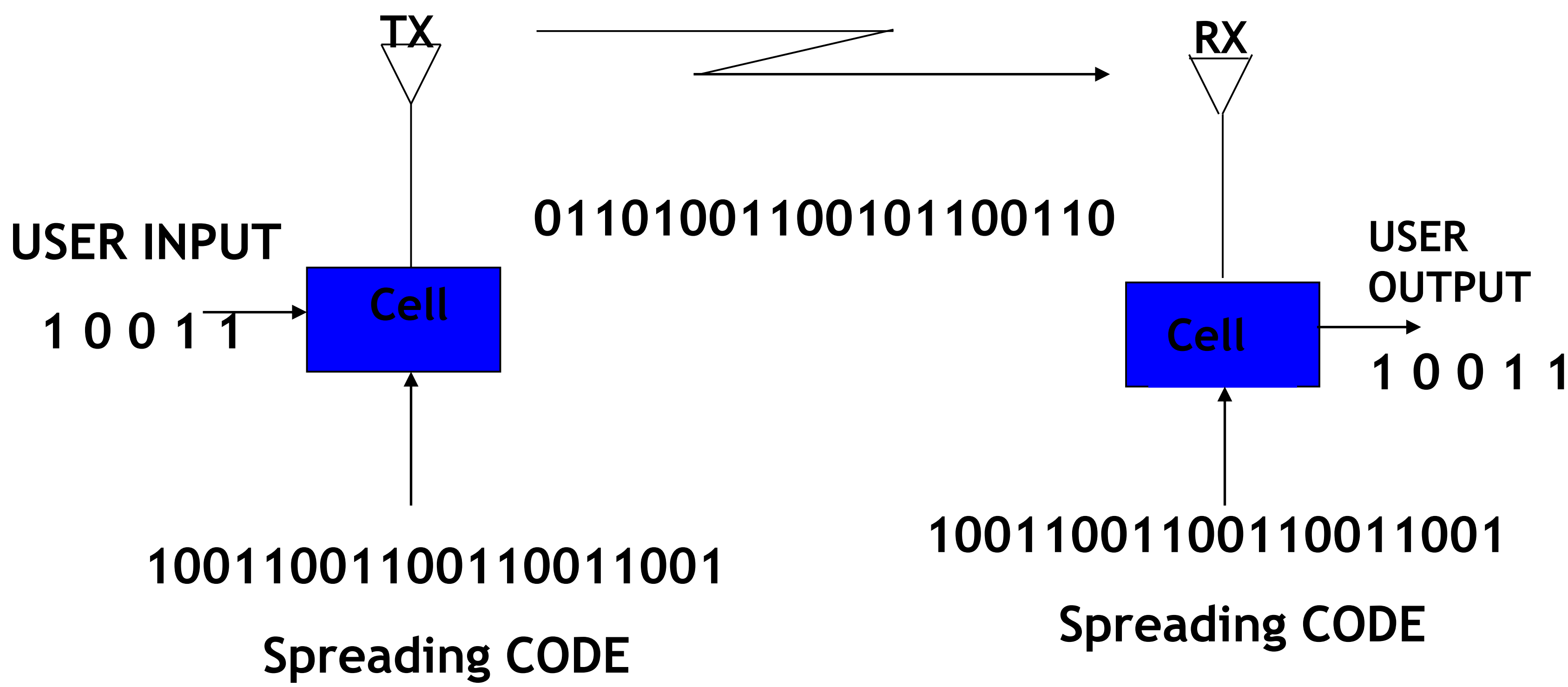


$$T_b = N\,T_c$$

N : Processing Gain



ORTHOGONAL SPREADING :

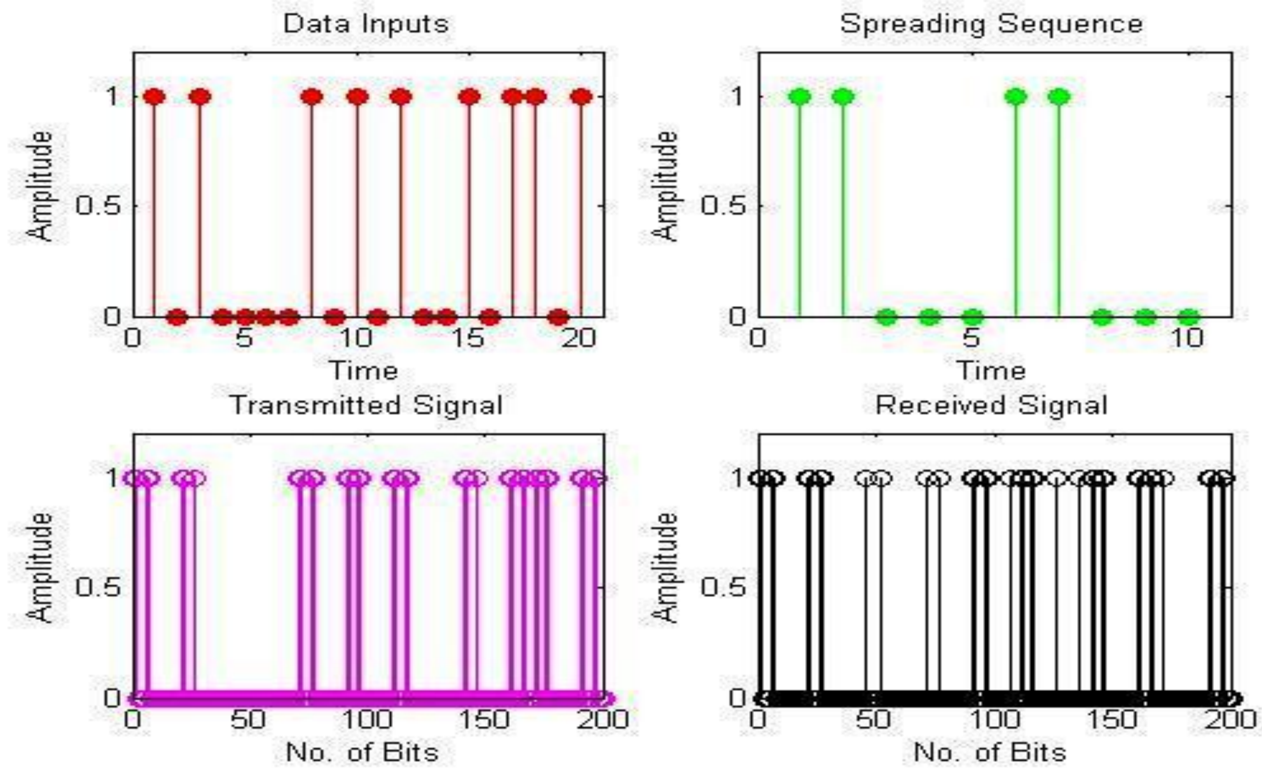


User Input	1	0	0	1	1
Spreading Sequence	1001	1001	1001	1001	1001
TX Data	0110	1001	1001	0110	0110

A SIMPLE CDMA SYSTEM :

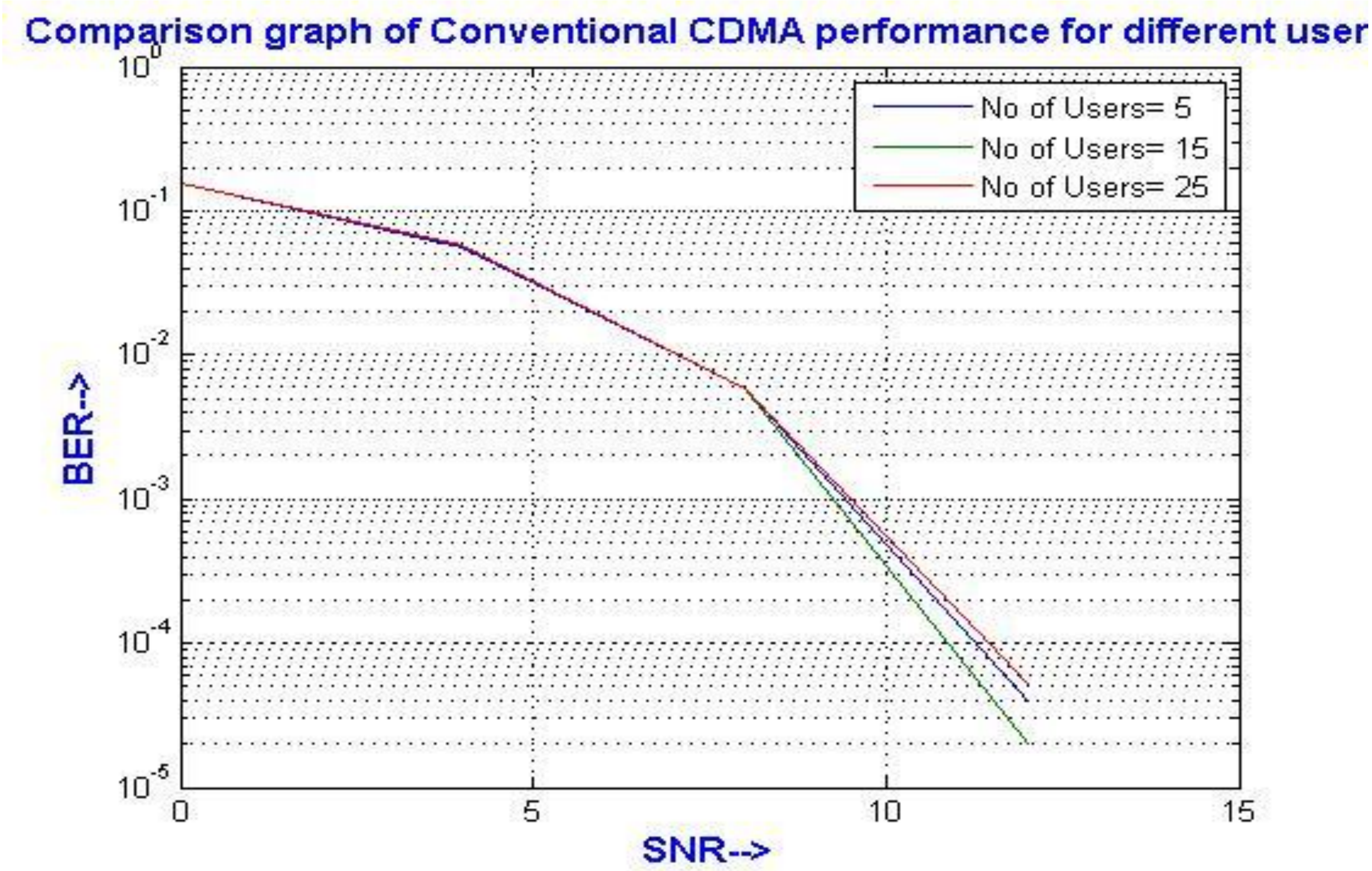
SNR = 10

ERROR BITS = 12



CDMA SYSTEM FOR MULTI USERS :

BER V/s SNR Curve For 5, 15 and 25 users



- A conventional DS/CDMA system treats each user separately as a signal, with other users considered as noise or MAI (Multiple Access Interference)
- All users interfere with all other users and the interferences causes to performance degradation
- Capacity is ***interference-limited .***
- Near/far effect: users near the BS are received at higher powers than those far away
  - Those far away suffer a degradation in performance
  - Need tight power control to avoid .

NEAR FAR EFFECT : (1/2)

- Assume K users in the system.
- Let P_s be the average Rx power of each signal.
- Model interference from K-1 users as AWGN.
- SNR at the desired user is $$\frac{E_b}{I_0} = \frac{P_s T}{N_0 + (K-1) P_s T_c}$$
- Let one user is near to BS establishes a stronger Rx signal equal to aP_s, (a>1)
- SNR then becomes $$\frac{E_b}{I_0} = \frac{P_s T}{N_0 + aP_s T_c + (K-2) P_s T_c}$$
- When a is large, SNR degrades drastically.
- To maintain same SNR, K-2 has to be reduced,
- i.e. loss in capacity.

NEAR FAR EFFECT : (2/2)

- Factors causing near-far effect (unequal Rx Signal powers from different users) in cellular CDMA
  - Distance loss
  - Shadow loss
  - Multipath fading (Most detrimental. Dynamic range of fade power variations: about 60 dB)
- Two common approaches to combat near-far effect
  - Transmit Power Control
  - Near-far Resistant Multiuser Detectors

MULTIUSER DETECTION :

- Multiuser detection considers all users as signals for each other -> joint detection
  - Reduced interference leads to capacity increase.
  - Alleviates the near/far problem.
- MUD can be implemented in the BS or mobile, or both .
- In a cellular system, base station (BS) has knowledge of all the chip sequences.
- Size and weight requirement for BS is not stringent .
- Therefore MUD is currently being envisioned for the uplink (mobile to BS) .

MUD CONCEPTS AND TECHNIQUES : (1/5)

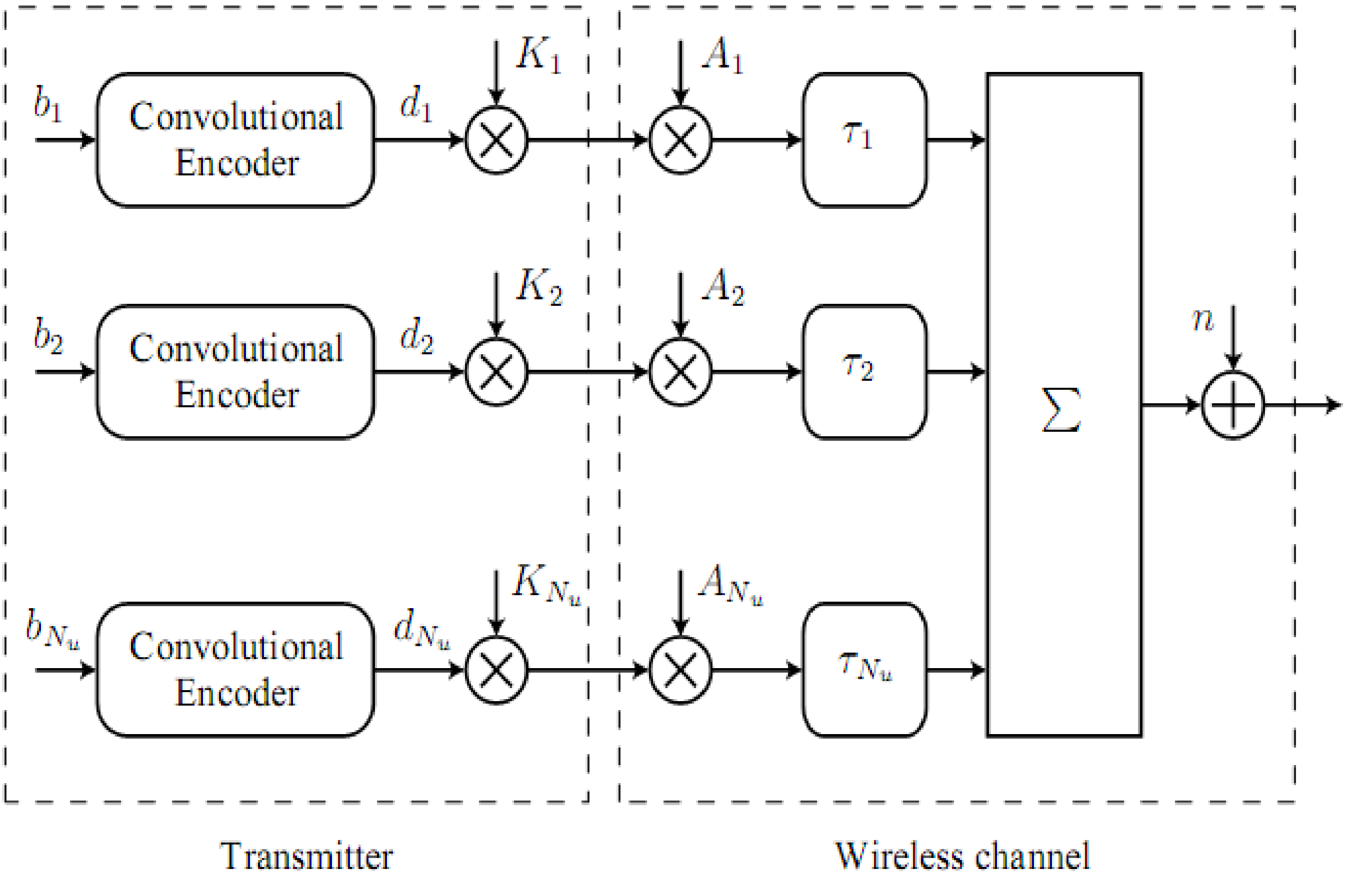
- The signal received at the BS is the superposition of signals from all users, multipath components for each user's signal, and Additive White Gaussian Noise (AWGN)

- Simplified system model (BPSK)
  - Baseband signal for the k^{th} user is:

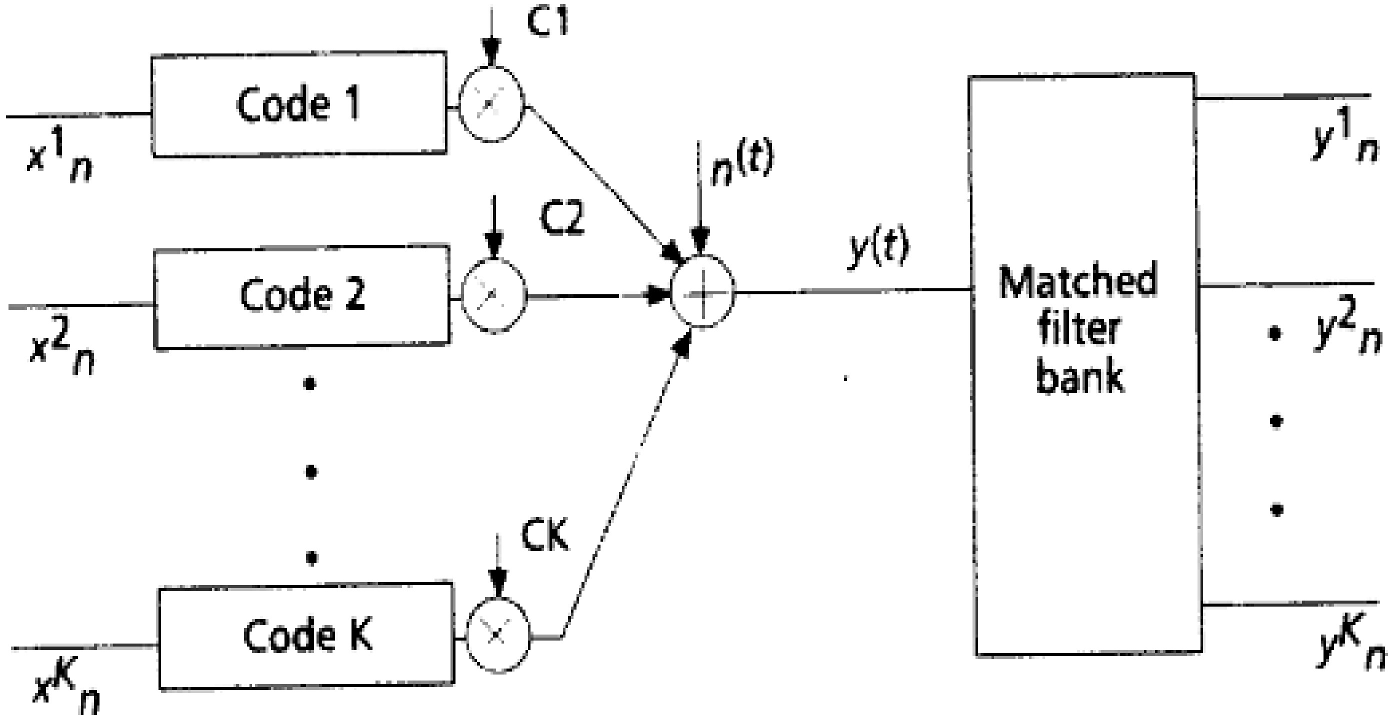
$$u_k(t) = \sum_{i=0}^{\infty} x_k(i) \cdot c_k(i) \cdot s_k(t - iT - \tau_k)$$

    - $x_k(i)$ is the i^{th} input symbol of the k^{th} user
    - $c_k(i)$ is the real, positive channel gain
    - $s_k(t)$ is the signature waveform containing the PN sequence
    - τ_k is the transmission delay; for synchronous CDMA, $\tau_k=0$ for all users

MUD CONCEPTS AND TECHNIQUES : (2/5)



MUD CONCEPTS AND TECHNIQUES : (3/5)



MUD CONCEPTS AND TECHNIQUES : (4/5)

- Received signal at baseband
  - K number of users
  - $z(t)$ is the complex AWGN

$$y(t) = \sum_{k=1}^{K} u_k(t) + z(t)$$

- Sampled output of the matched filter for the kth user:

$$\begin{aligned} y_k &= \int_0^T y(t) s_k(t)\,dt \\ &= c_k x_k + \sum_{j \neq k}^{K} x_j c_j \int_0^T s_k(t) s_j(t)\,dt + \int_0^T s_k(t) z(t)\,dt \end{aligned}$$

  - 1st term - desired information
  - 2nd term - MAI
  - 3rd term – noise

MUD CONCEPTS AND TECHNIQUES : (5/5)

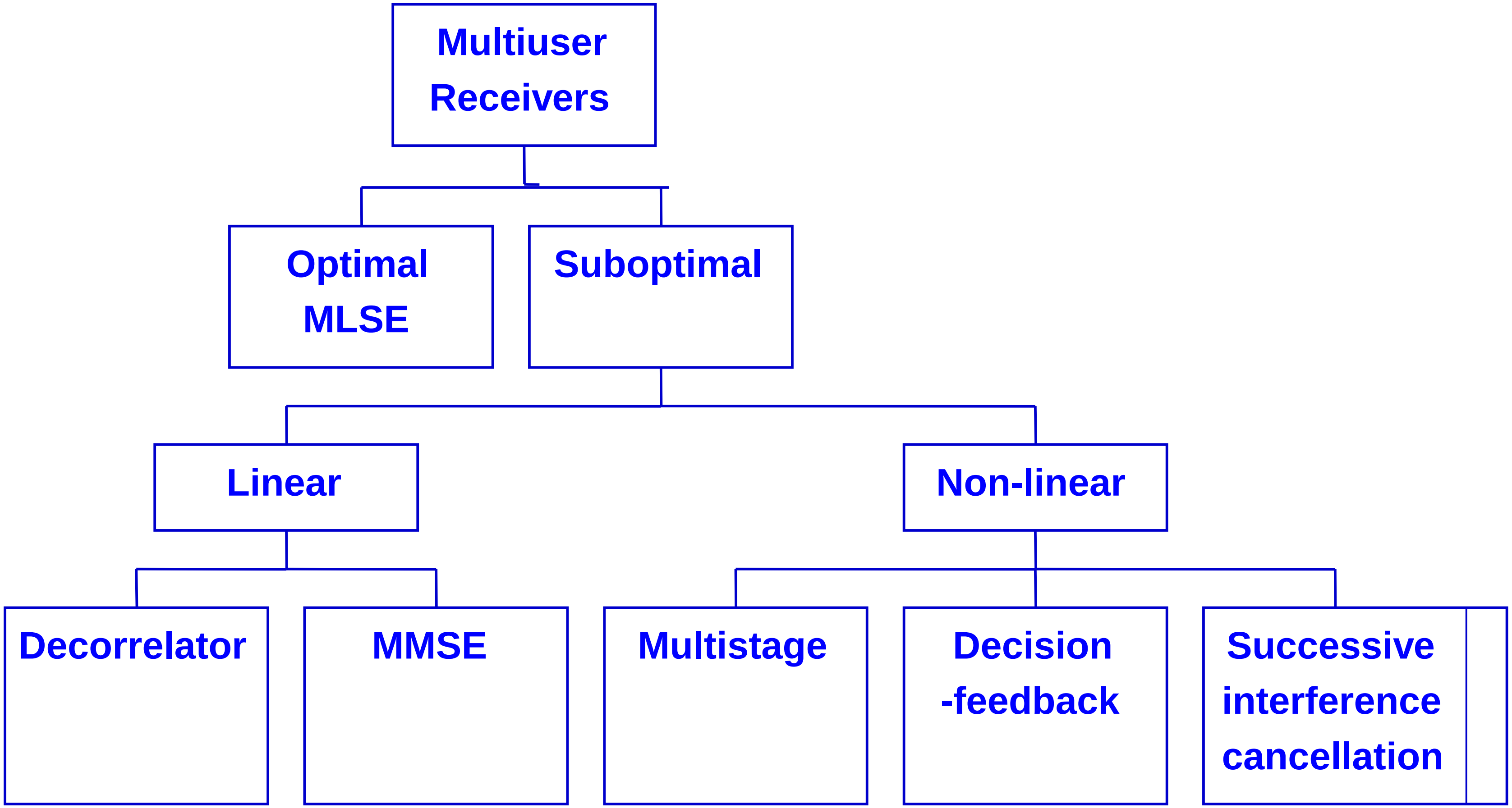
- Assume two-user case (K=2), and

$$r = \int_0^T s_1(t) s_2(t) dt$$

- Outputs of the matched filters are:

$$y_1 = c_1 x_1 + r c_2 x_2 + z_1 \qquad y_2 = c_2 x_2 + r c_1 x_1 + z_2$$

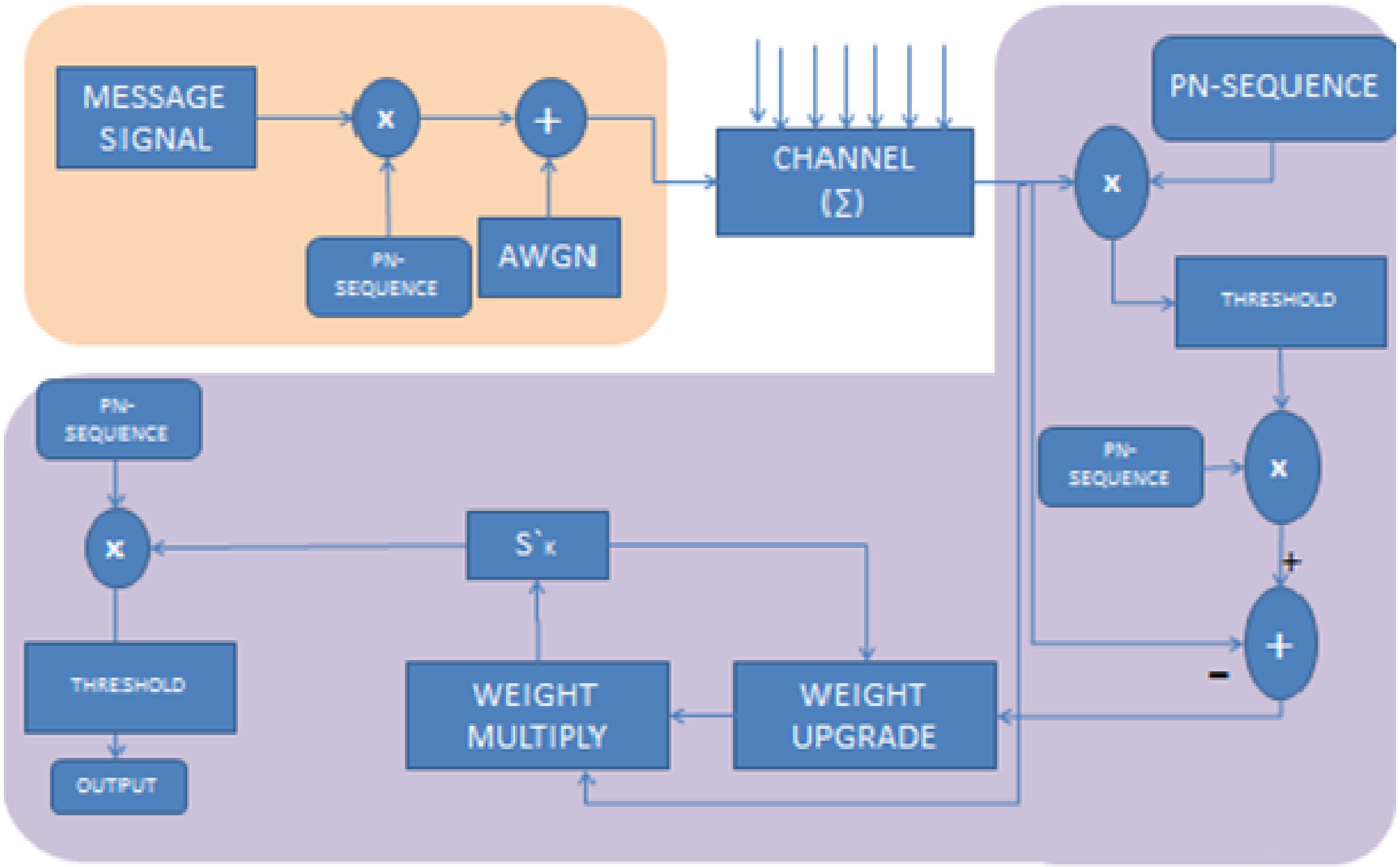
MUD ALGORITHM :



SUCCESSIVE INTERFERENCE CANCELLATION :

- Multistage interference Cancellation approaches
  - Serial (or successive) Interference Canceller (SIC)
    - » sequentially recovers users (recover one user per stage)
    - » data estimate in each stage is used to regenerate the interfering signal which is then subtracted from the original received signal
    - » Detects and removes the strongest user first

SUCCESSIVE INTERFERENCE CANCELLERS : (1/2)



SUCCESSIVE INTERFERENCE CANCELLERS : (2/2)

Detected symbol for user k:

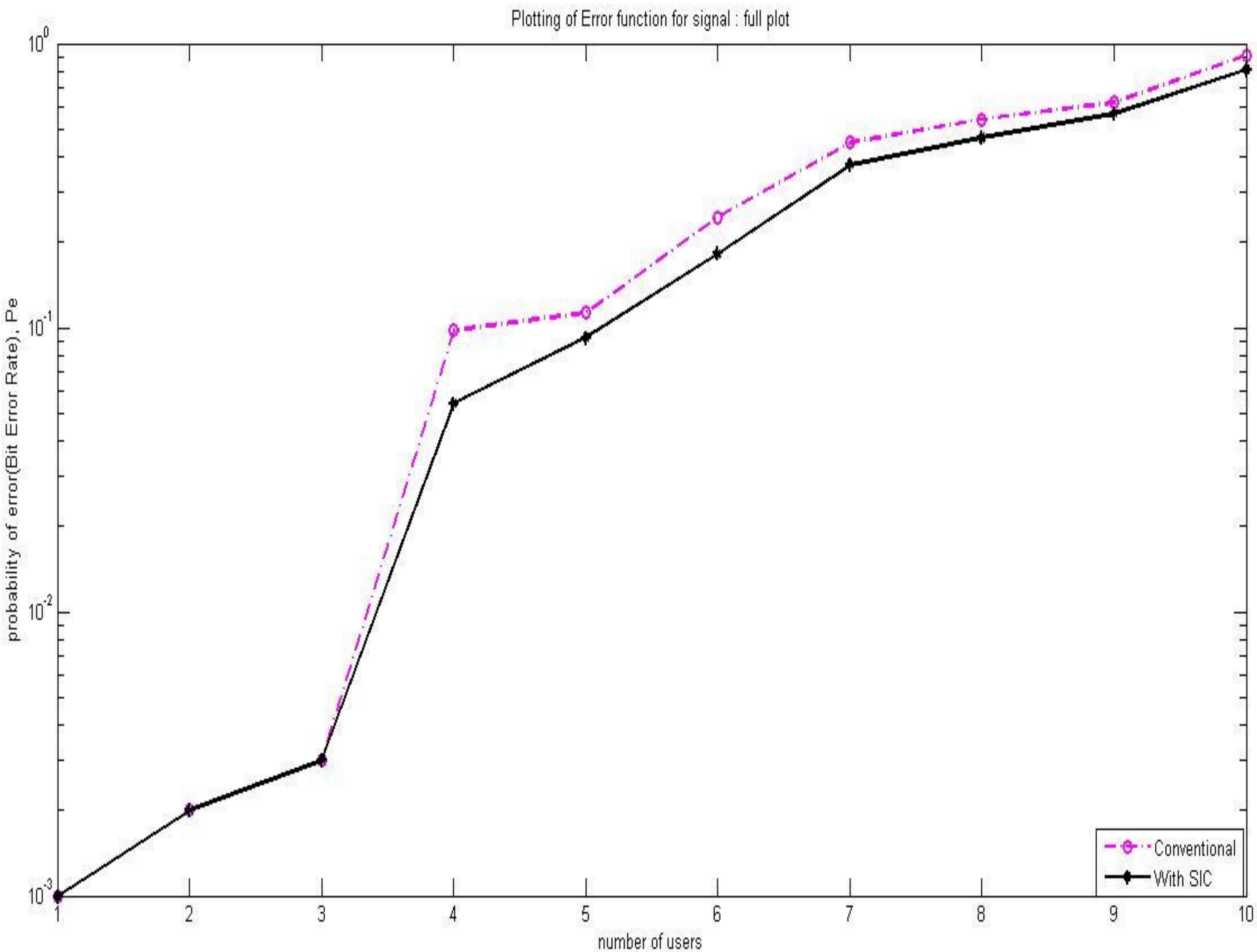
$$\hat{x}_k = \operatorname{sgn}(y_k)$$

If user 1 is much stronger than user 2 (the near/far problem), the MAI term rc_1x_1 present in the signal of user 2.
Decision is made for the stronger user 1: .Subtract the estimate of MAI from the signal of the weaker user.

$$\begin{aligned} \hat{x}_1 &= \operatorname{sgn}(y_1) \\ \hat{x}_2 &= \operatorname{sgn}(y_2 - rc_1\hat{x}_1) \\ &= \operatorname{sgn}(c_2x_2 + rc_1(x_1 - \hat{x}_1) + z_2) \end{aligned}$$

All MAI can be subtracted from user 2 signal provided estimate is correct. MAI is reduced and near/far problem is alleviated.

BER V/S NUMBER OF USERS COMPARISION RESULT BEWEEN CONVENTIONAL & SIC CDMA SYSTEM :



CONCLUSION :

- The inclusion of SIC in a CDMA receiver can significantly improve its performance relative to that of conventional CDMA receiver where no interference cancellation is attempted.
- It achieves better result with regards to BER and capacity performance.
- It suffers mightily from a high processing delay.

FUTURE WORK :

- While doing practical implementation, problem occurred due to processing delay, sensitivity and robustness.

- For delay, one of the way is to limit the number of cancellation also Group wise SIC (GSIC) has proposed to deal with delay.

Any Questions?

Thank you!!!