LAYERED STEERED SPACE TIME CODES IN MULTI-USER SYSTEMS

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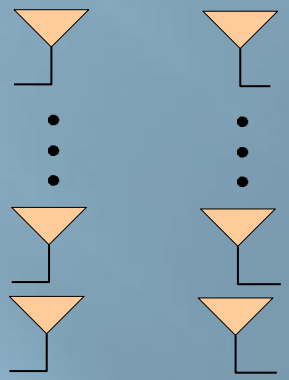
Outline

- Introduction
- Multi Antenna Systems
- Literature Survey
- LSSTC System Model
- Scheduling criteria
- Conclusions

MIMO : Multiple Input Multiple Output

- MIMO increases capacity
  - MIMO uses independent channel fading and multipath propagation to increase capacity.
  - No extra bandwidth is required
- MIMO improves the QOS
  - Multiple independent samples of the same signal at the receiver give rise to “diversity”.



In this work we study scheduling criteria for multi-user multiple input multiple-output (MIMO) systems called the Layered Steered Space-Time Codes (LSSTC) that combines the benefits of vertical Bell Labs space-time (VBLAST) scheme, space-time block codes (STBC), and beamforming.

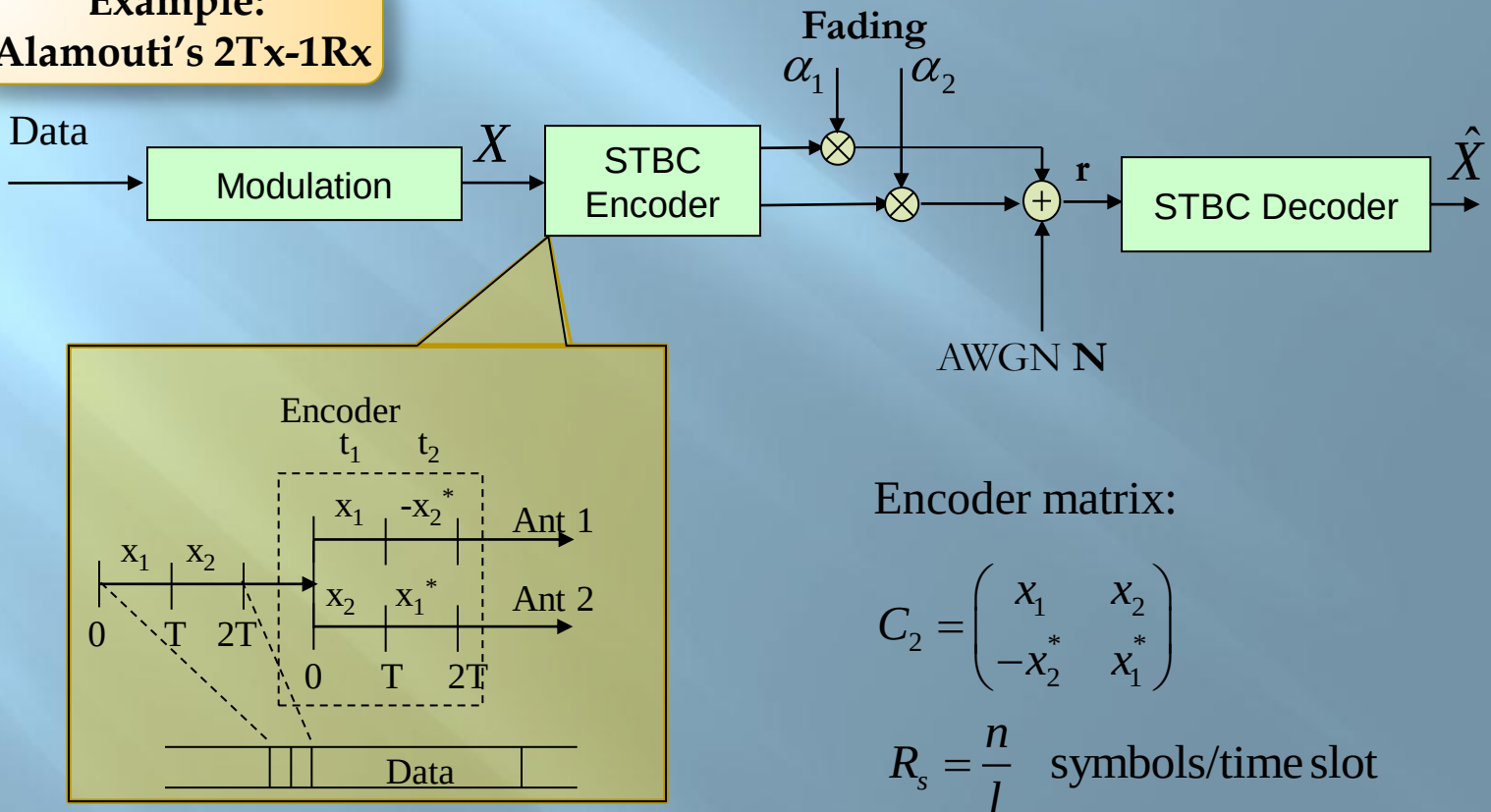
Multi Antenna Systems

STBC

- *STBC* provides redundancy or diversity in time and space
  - Use more than one copy of the same signal.
  - If one copy is in a fade, it is unlikely that all the others will be too.

  → gives rise to diversity gain, dec. the fluctuations in SNR, & min P_e

Example: Alamouti's 2Tx-1Rx



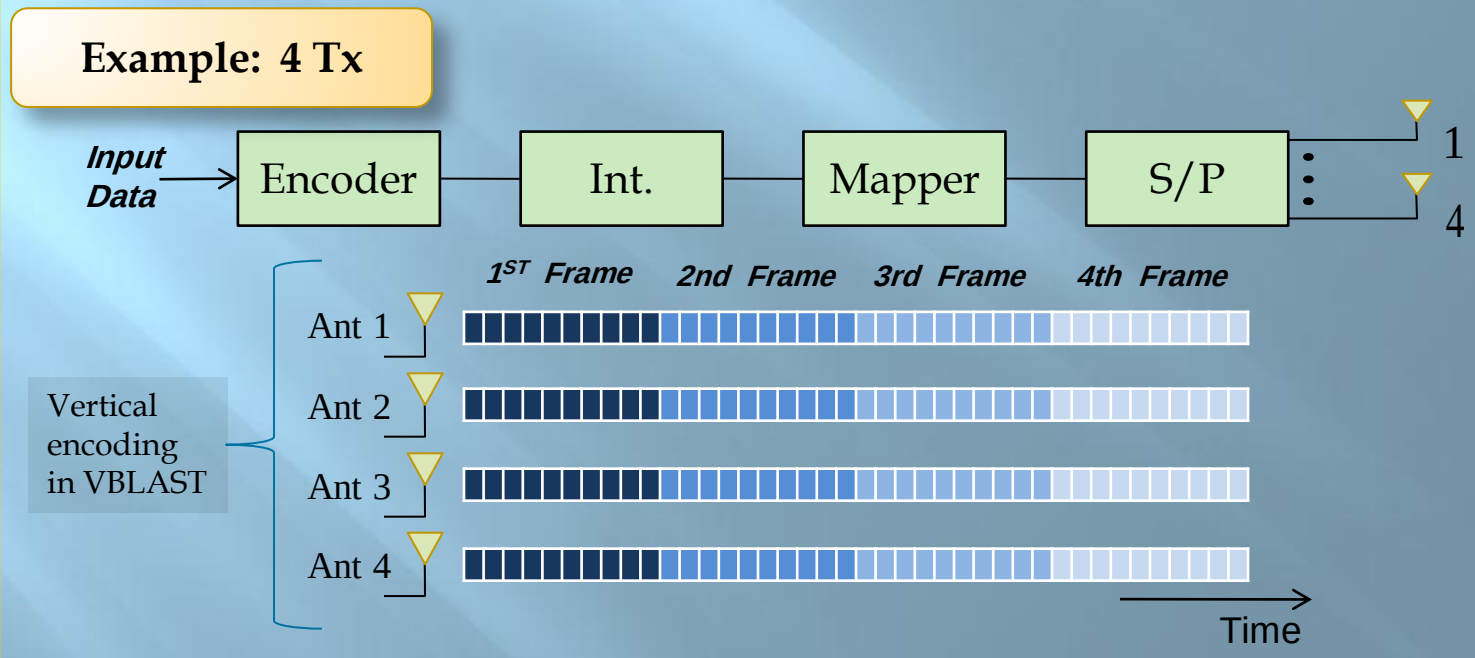
Encoder matrix:

$$C_2 = \begin{pmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{pmatrix}$$

$$R_s = \frac{n}{l} \quad \text{symbols/time slot}$$

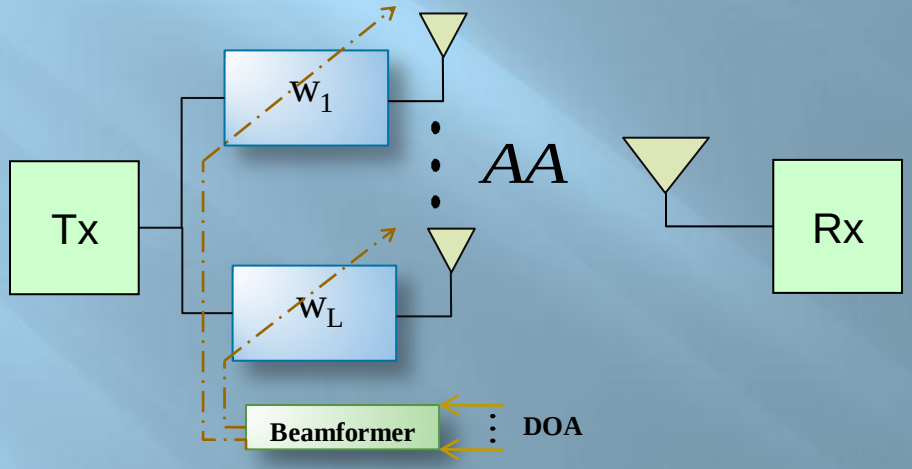
VBLAST

- ***VBLAST*** provides parallel data streams
  - Improves the system spectrum efficiency because of spatial multiplexing
  - Condition of operation: $N_R \geq N_T$



Beamforming

- ***Beamforming*** focuses the energy from the antenna
  - Enables a high gain steerable antenna
  - Focuses the energy towards one direction and increases the SNR in that direction.



Literature Survey

- [Wolniansky et al, 1998] proposed VBLAST, in which parallel data streams are sent via the transmit antennas at the same frequency.
- In [Alamouti, 1998] STBC was presented. It was shown that STBC with two Tx and one Rx antennas provide the same diversity order as MRRC with one Tx and two Rx antennas.
- In [Tao et al, 2001] a combination of BLAST and STC was implemented which they called generalized layered space-time coding (GLST). This scheme was studied further with comparing many detection algorithms in [Mohammad et al, 2004] and called it MLSTBC, in which, the Tx antennas were grouped in VBLAST layers. each layer is encoded by STBC.

Literature Survey (Cont'd)

- Recently, beamforming, has been combined with MLSTBC in [El-Hajjar et al, 2007] to produce a hybrid system called the layered steered space time codes (LSSTC), this system has the advantages of its elementary systems.

- On the other hand, In multiuser systems, scheduling can be used to increase the system capacity as in [Heath et al, 2001] , where it was shown that the independence of fading among users results in multiuser diversity.

LSSTC System Model

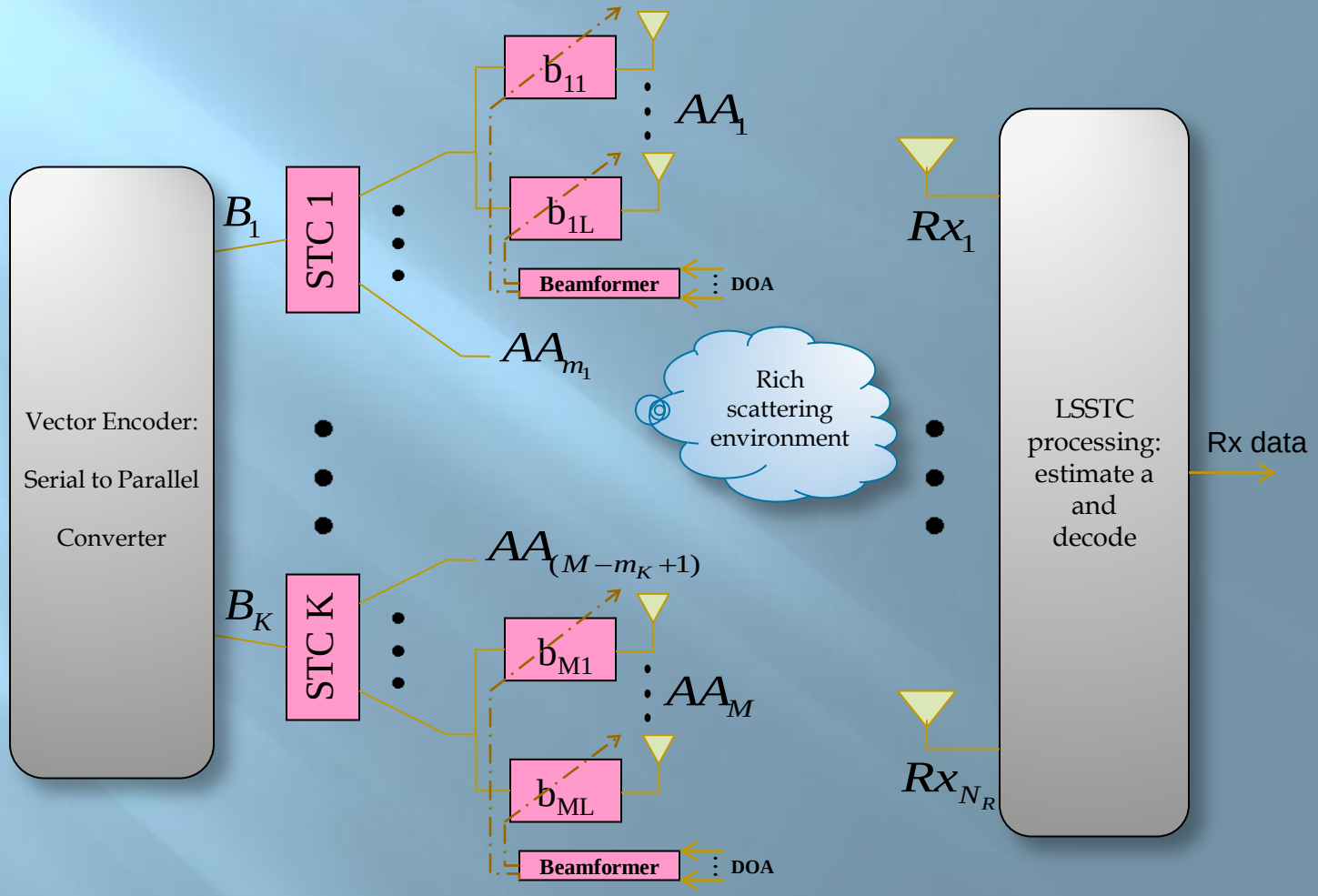


Figure 1:Block diagram of a single user LSSTC system.

Problem Statement

The objectives of this work is to investigate LSSTC in a multi-user environment.

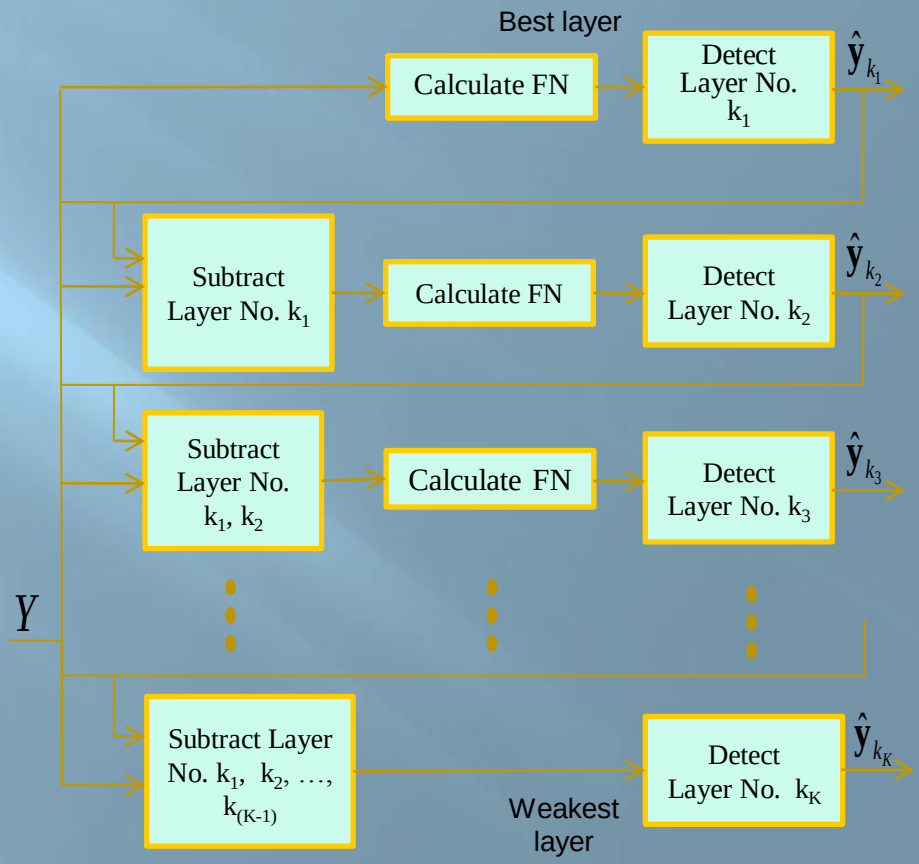
- Multiuser scheduling is discussed with comparing several scheduling criteria to schedule users with LSSTC receivers.

- Some numerical results will be presented to validate our analysis.

Receiver of LSSTC

- The steps of post-ordered SGIC proposed in [Ghad04, Meixia01] are:

1. Ordering: choose the best layer with highest squared FN.
2. Nulling: null out interference and keep desired layer.
3. Slicing: estimate the detected layer.
4. Canceling: subtract the detected layer from received vector.
5. The last steps are repeated until all layers are detected.



General block diagram of a LSSTC receiver

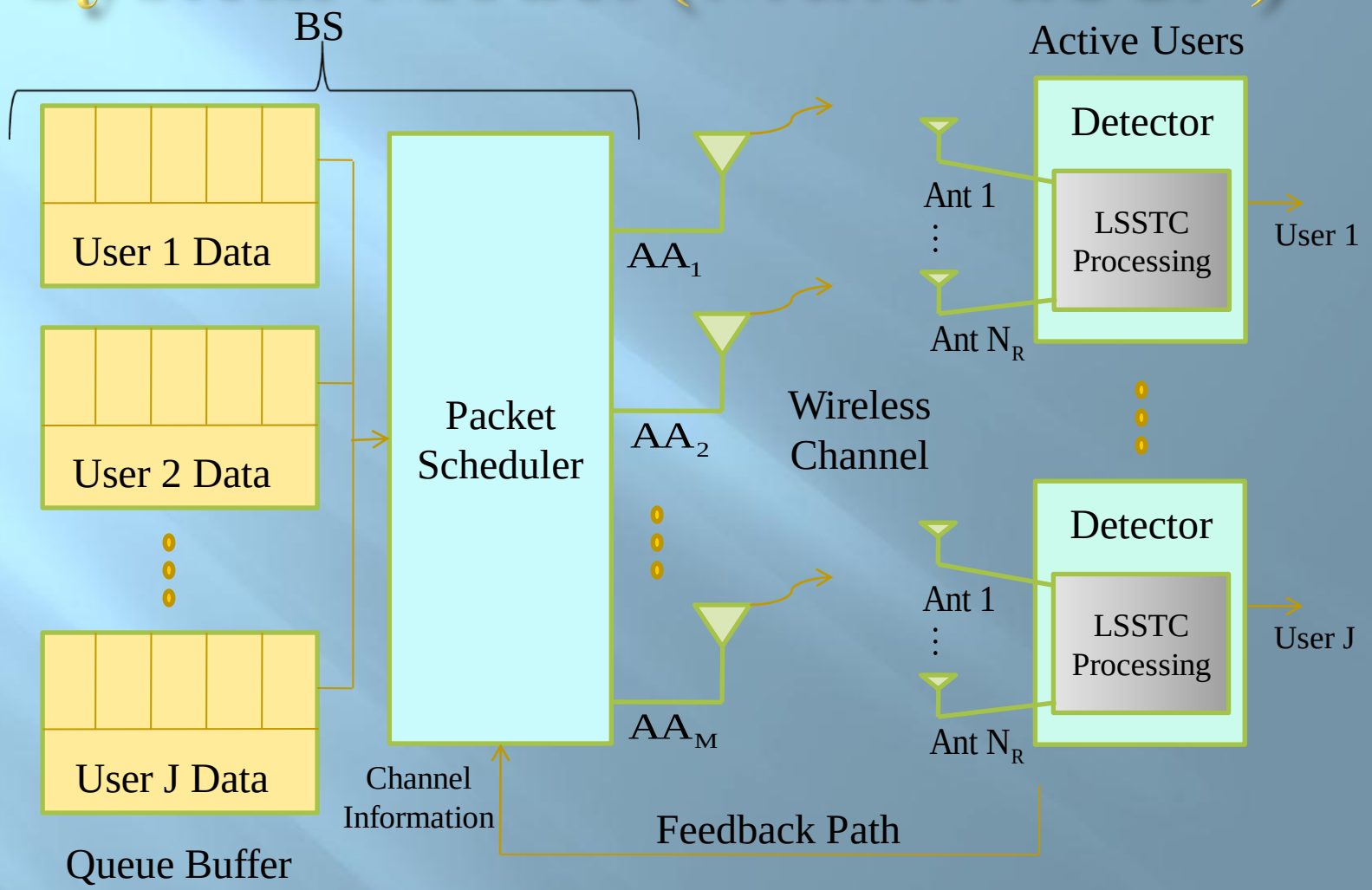
Capacity of LSSTC

- The following formula was obtained for the instantaneous capacity of LSSTC

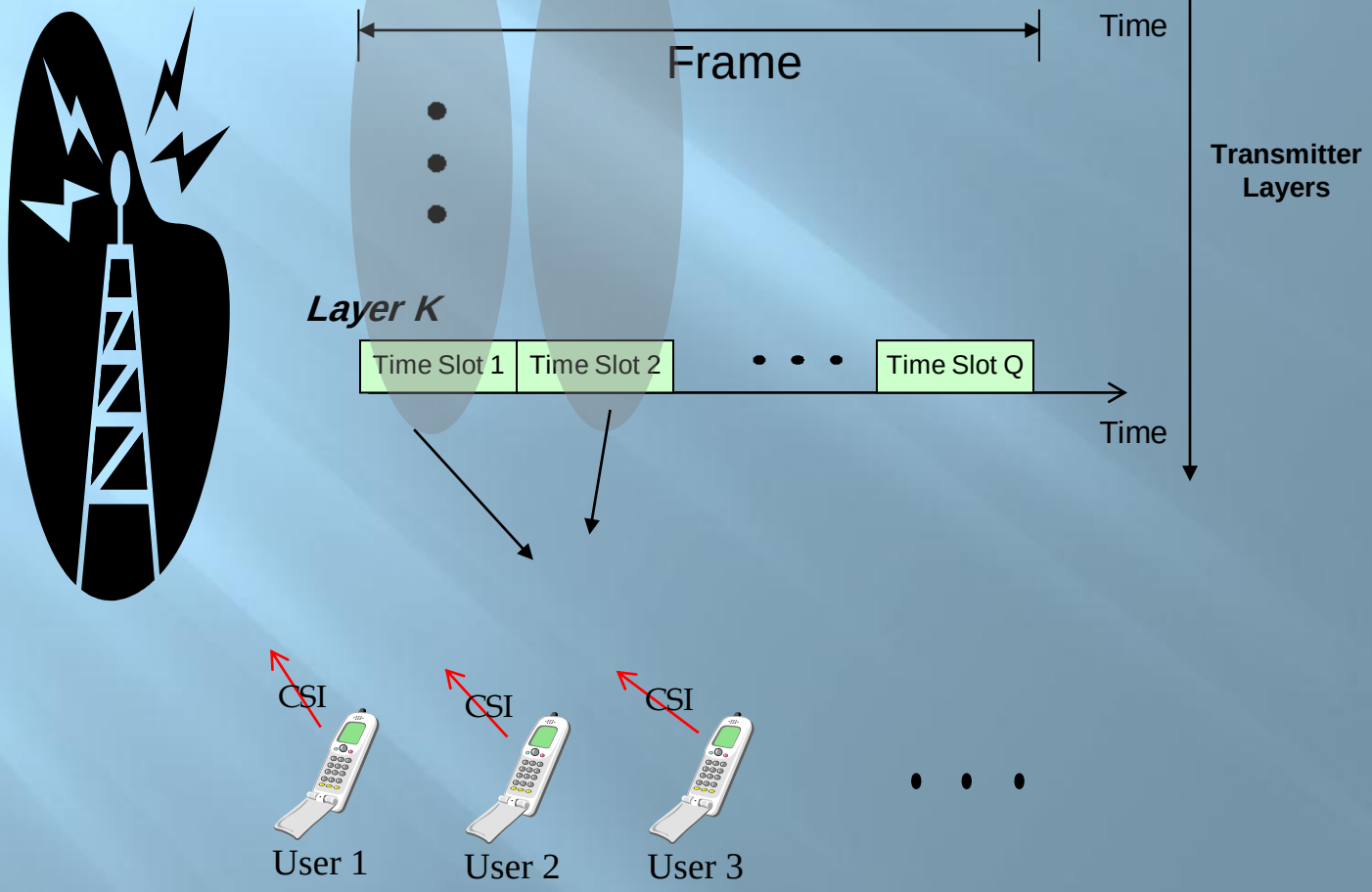
$$C_{LSSTC} = K \cdot R_s \cdot \min_{k=1,2,\ldots,K} \left\{ \log_2 \left(1 + \frac{L^2 \cdot P_T}{M \cdot N_0} \| \mathbf{H}_{PP,k} \|^2 \right) \right\}$$

where $\mathbf{H}_{PP,k}$ is the Post-Processing (PP) matrix corresponding to the k^{th} layer after nulling out the interference from the yet to be detected layers.

System Model (Multi-user)



Frame Structure



Scheduling for packet data

- **Scheduling** is a method of allowing multiple users to share a common resource (such as band width) to optimize a measure of goodness like SER, delay, etc.

- **Common scheduling algorithms:**

1. Round robin Scheduling (RR): routes the transmission of packets equally across users.(used in TDMA)
2. Greedy Scheduling: routes each transmission to the user with the best CSI.
3. Proportional Fair (PF): assigns a user for transmission when its instantaneous channel capacity is high relative to its average channel condition.
4. Opportunistic Round Robin (ORR): routes the transmission to the best user and after that he will be excluded from competition of the coming time slots of the frame.

Scheduling criteria

- It is the condition considered by the scheduling algorithm to differentiate between users.

- The following have been used:

1) MaxSNR: Max. FN of **H**
2) $\text{MaxSNR}_{\text{WL}}$: Max. FN of the worst layer
3) MinES: Min. eigenspread of $\mathbf{HH}^{H}$
4) MaxMinSV: Max. min. singular value of **H**
5) MaxLSSTCCap: Max. LSSTC capacity

More on MaxLSSTCCap

- The scheduler selects the user with

$$\max_{k=1,2,\ldots,J} \left\{ C_{LSSTC}^{(k)} \right\}$$

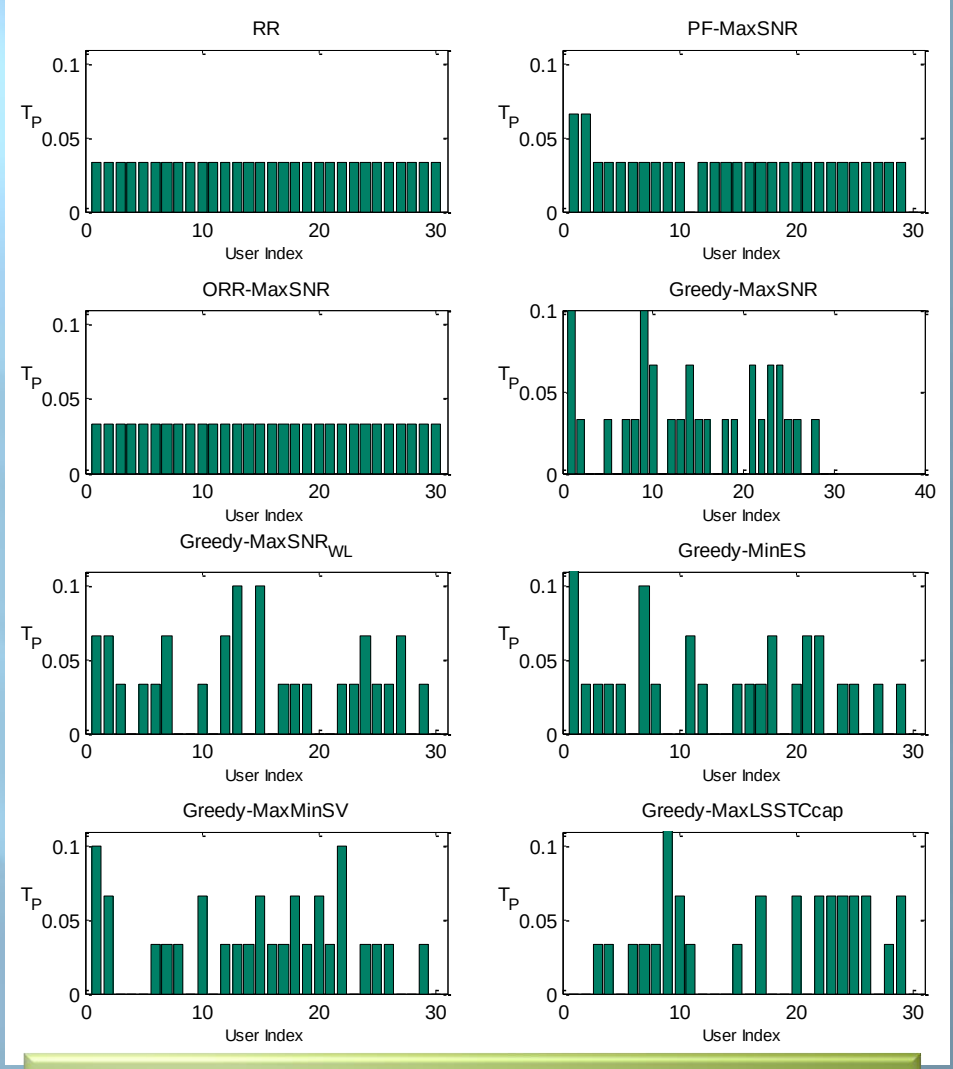
or

$$\max_{k=1,2,\ldots,J} \left\{ K \cdot R_s \cdot \min_{i=1,2,\ldots,K} \left\{ \log_2 \left(1 + \frac{L^2 \cdot P_T}{M \cdot N_0} \| \mathbf{H}_{PP,i}^{(k)} \|^2 \right) \right\} \right\}$$

which is equivalent to

$$\max_{k=1,2,\ldots,J} \min_{i=1,2,\ldots,K} \| \mathbf{H}_{PP,i}^{(k)} \|^2$$

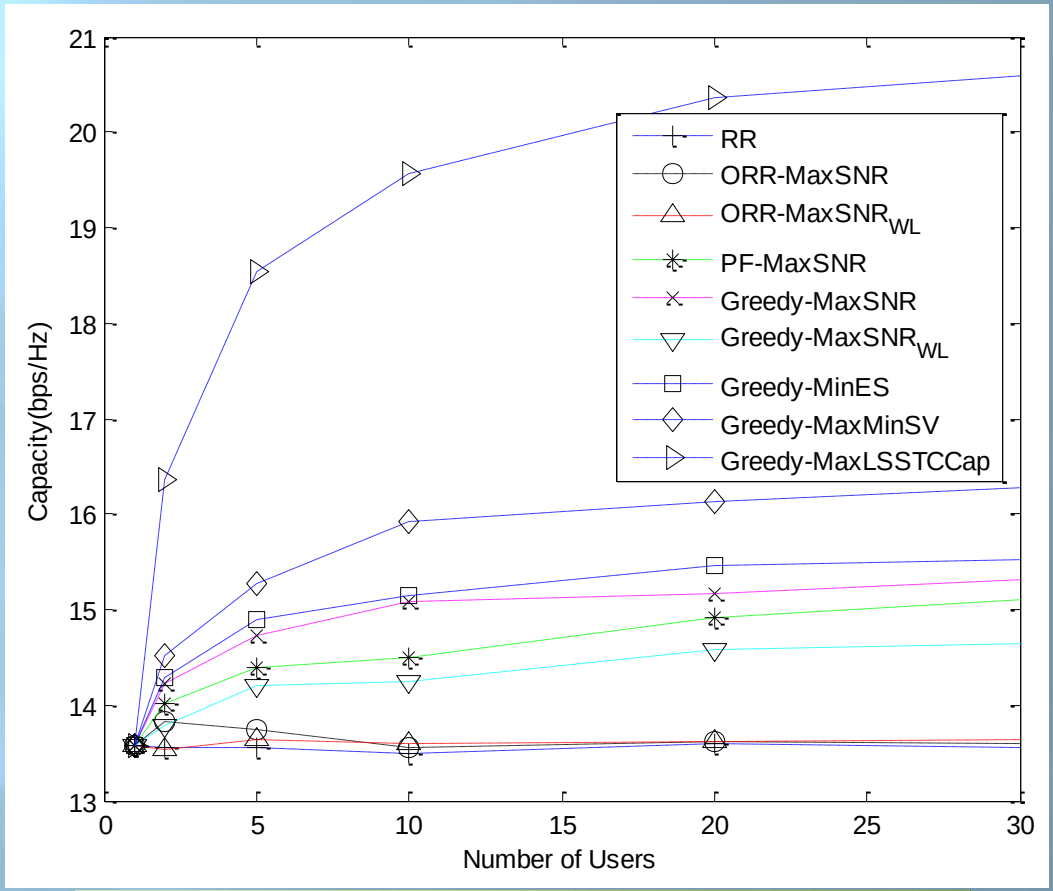
Simulation Results



16 x 4
K = 4
L = 2
m_k = 2
J = 30
Q= 30

Percentage of time the user takes the channel (T_P) using several algorithm-criteria configurations

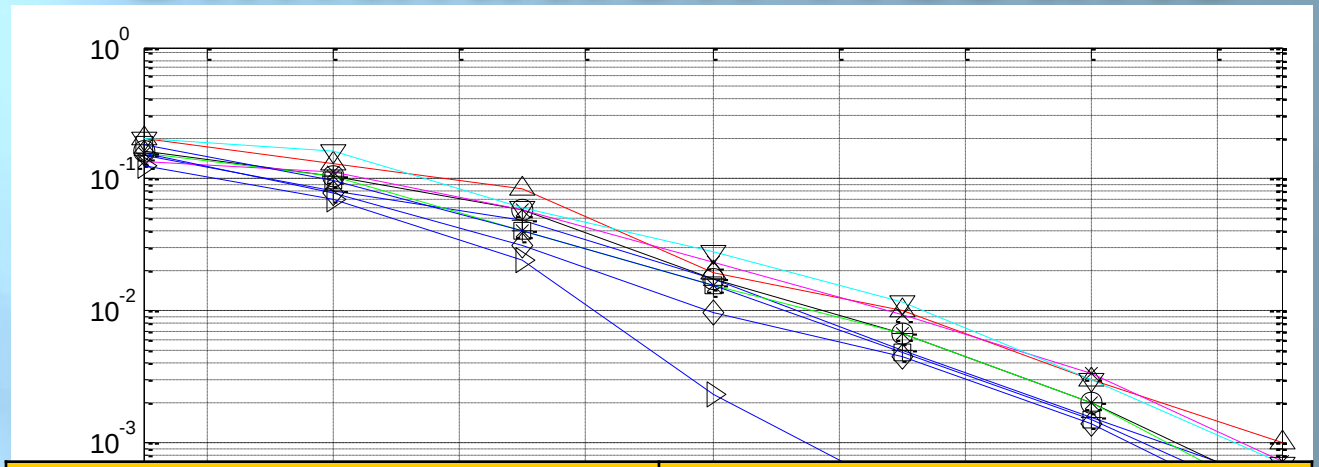
Simulation Results



16 x 4
K = 4
L = 2
$m_k = 2$

Capacity vs. number of users at 10% Outage probability and 15 dB SNR

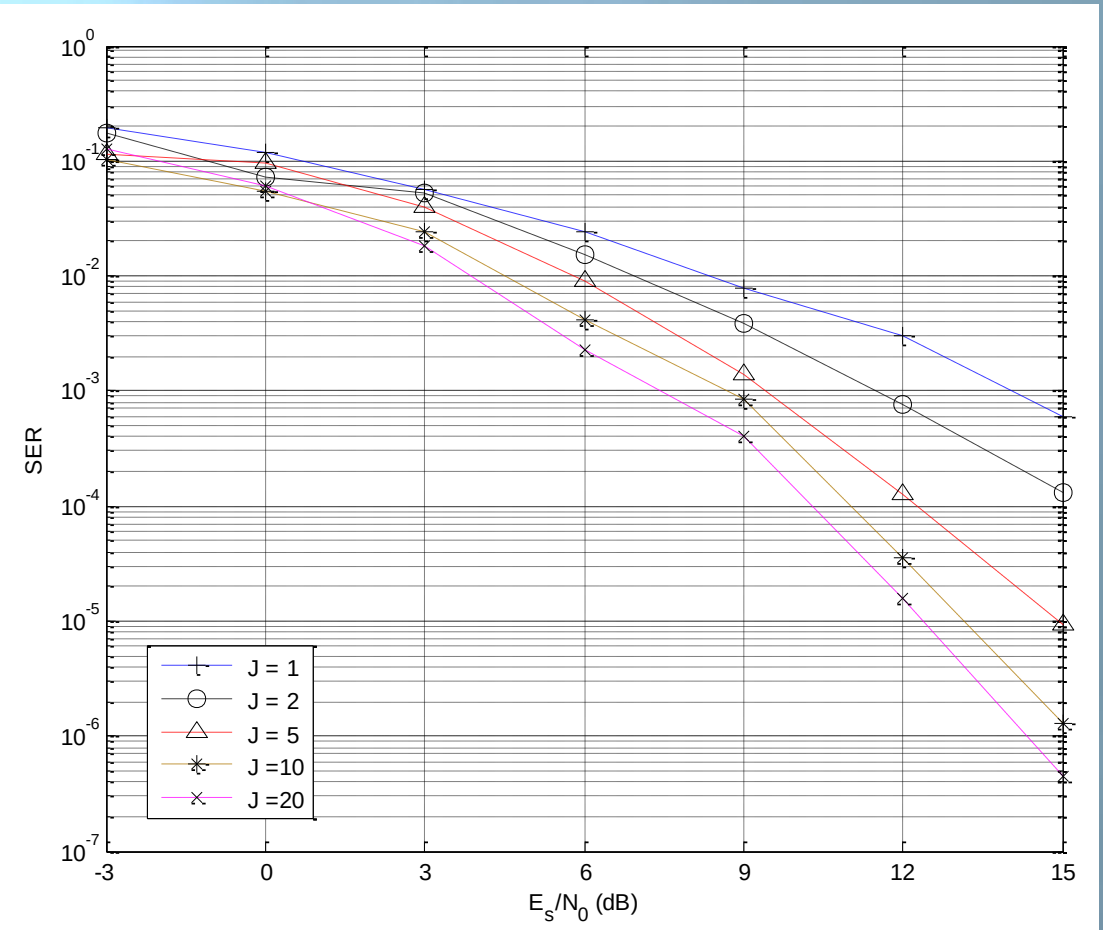
Simulation Results



Configuration	Gain over RR @ SER of 10^{-3}
Greedy-MaxLSSTCCap	7.5 dB
Greedy-MaxMinSV	2.4 dB
Greedy-MinES	2.2 dB
Greedy-MaxSNR	1.9 dB
PF-MaxSNR	1.8 dB
Greedy-MaxSNR$_{WL}$	1.7 dB
ORR-MaxSNR$_{WL}$	0.8 dB
ORR-MaxSNR	0.6 dB

16 x 4
K = 4
L = 2
m_k = 2
J = 20
Q= 30

Simulation Results



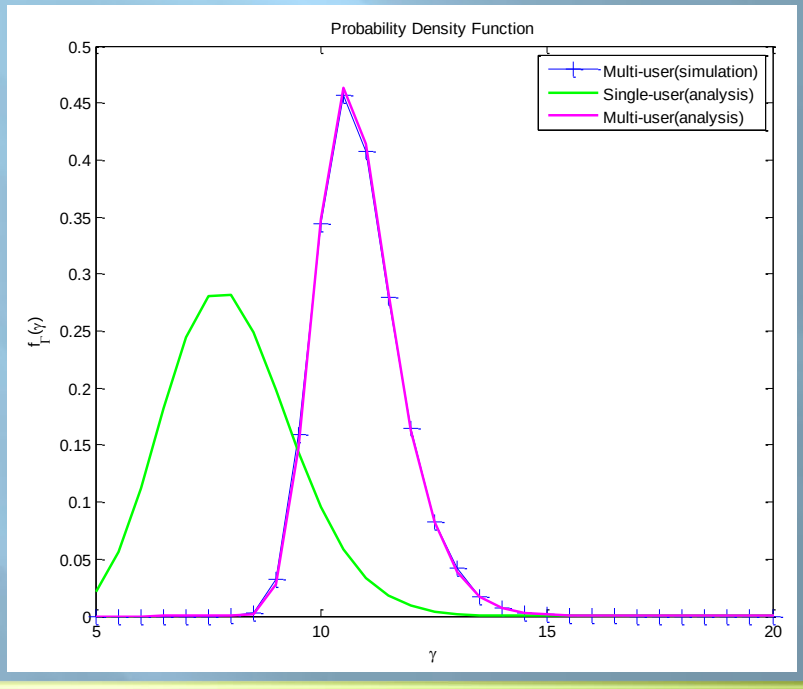
16 x 4
K = 4
L = 2
m_k = 2
Q= 30

SER versus E_s/N_0 with different number of users using the MaxLSSTCCap criterion

Simulation Results

- Using order statistics theory, we have found the PDF the maximum pre-processing SNR:

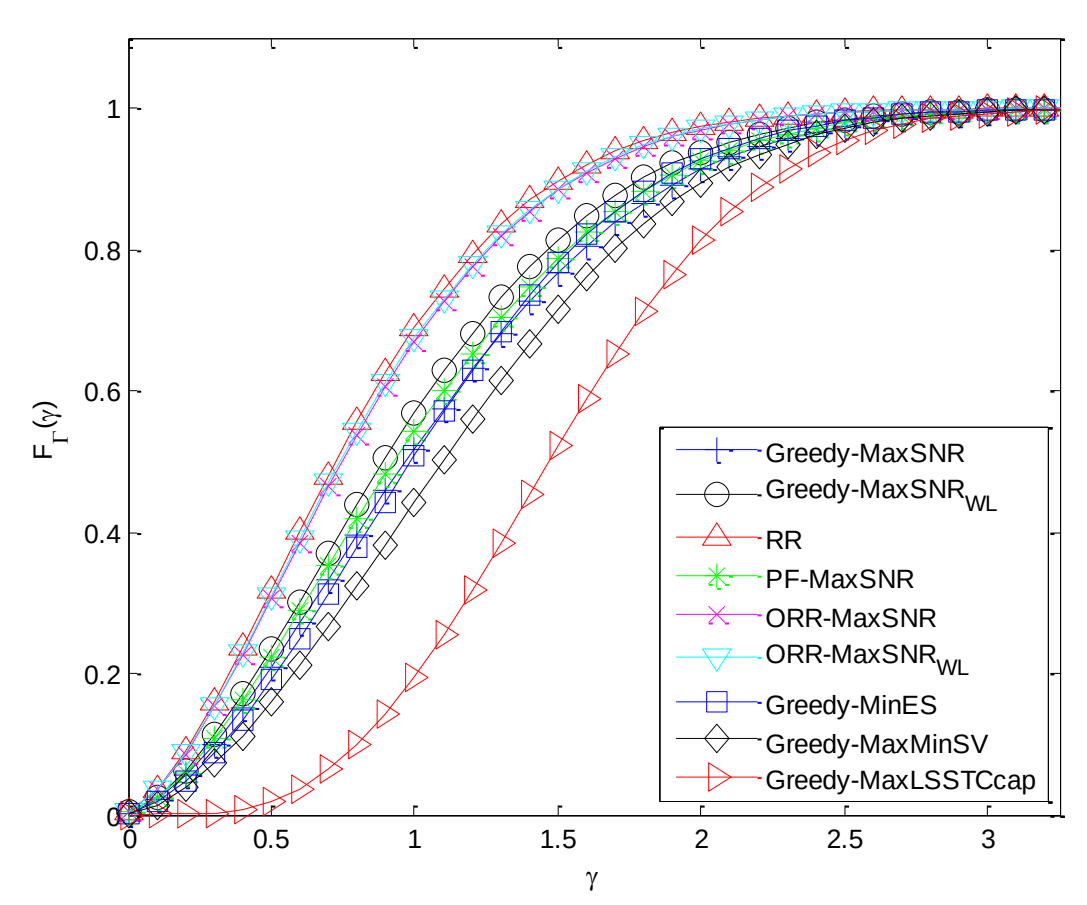
$$g_{\Gamma}(\gamma) = \frac{J}{\overline{\gamma}\cdot(m-1)!}\left(\frac{\gamma}{\overline{\gamma}}\right)^{m-1} exp\left(-\frac{\gamma}{\overline{\gamma}}\right)\left(1-exp\left(-\frac{\gamma}{\overline{\gamma}}\right)\sum_{k=0}^{m-1}\frac{1}{k!}\left(\frac{\gamma}{\overline{\gamma}}\right)^{k}\right)^{J-1}$$



PDF of the maximum pre-processing SNR (Greedy-MaxSNR)

16 x 4
K = 4
L = 2
m_k = 2
J = 20
Q= 30

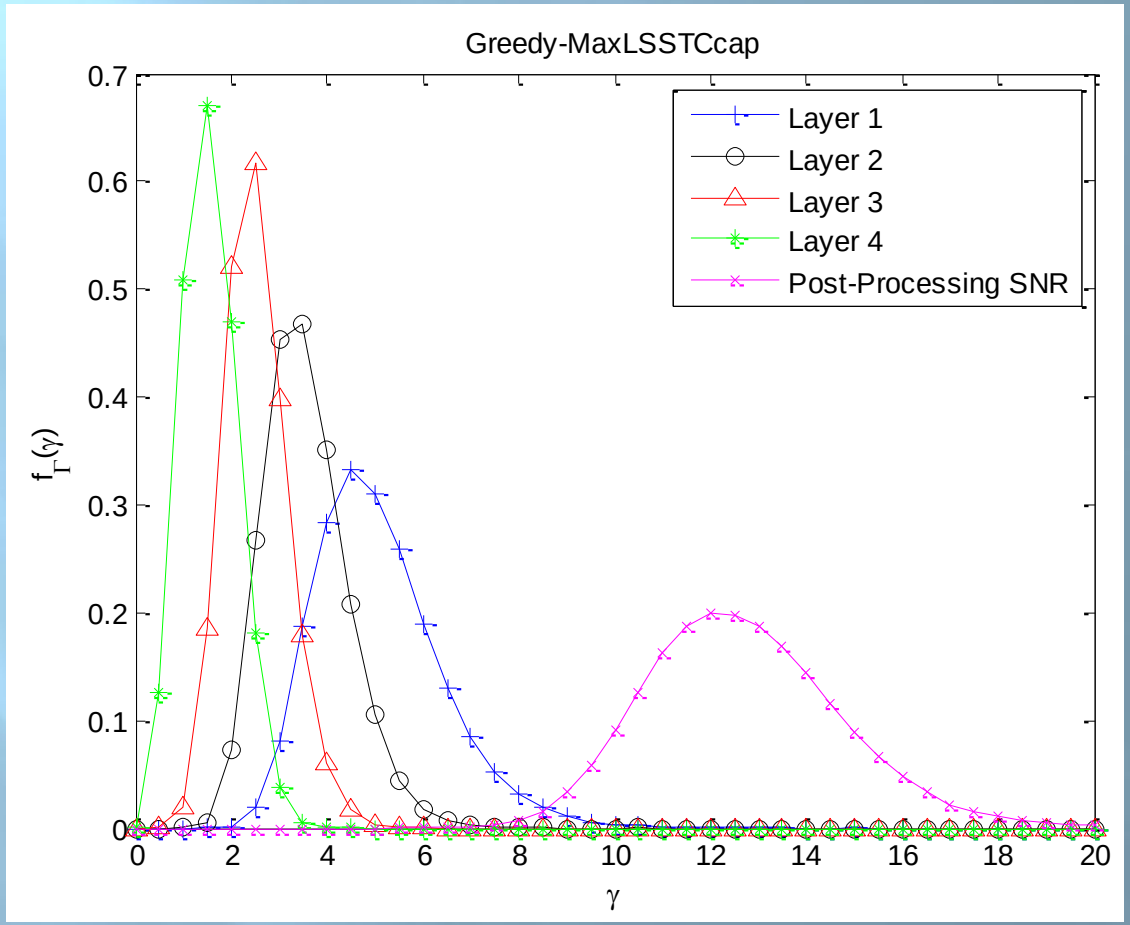
Simulation Results



16 x 4
K = 4
L = 2
m_k = 2
J = 20
Q= 30

PDF of the post-processing SNR corresponding to the weakest layer of the scheduled user using several algorithm-criteria configurations

Simulation Results



16 x 4
K = 4
L = 2
$m_k = 2$
J = 20
Q= 30

PDF of the post-processing SNR of the scheduled user according to the MaxLSSTCCap criterion

Conclusions

1. Multi-user LSSTC was investigated in this work. It was shown that it can support high data rates due to VBLAST. Also, it has superior performance, especially in the high SNR regime due to STBC.

2. Multi-user LSSTC can be added to the existing and evolving wireless communication systems, that employ MIMO such as the long-term evolution (LTE) or WiMAX, seamlessly and with quite low cost.

3. As seen from the numerical results, LSSTC can result in a huge drop in the SER at a quite high bandwidth efficiency. The proposed system can result in a SER as small as 10^{-6} at an SNR of 15 dB. Which makes it a highly efficient and reliable.

4. Multi-user LSSTC was investigated. We found that the most suitable scheduling criteria for LSSTC is the MaxLSSTCCap.

Thank you