Next Generation Mobile Communication Technology (MIMO-OFDMA System and RRM technique)

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Content

- Introduction
- OFDM Basics
- MIMO- Multiple Antenna Scheme
- MIMO-OFDMA System
- MIMO-OFDMA RRM Technique
- Novel MIMO-OFDMA RRM Algorithm
  - Motivation
  - System Model
  - Algorithm Description and Implementation
  - Conclusion
- References

Introduction

- 1G is based on analog system: voice only
- 2G: GSM

  Limits of GSM:

- ➢ limited capacity at the air interface:

  data transmission standardized with only 9.6kbit/s

  advanced coding allows 14.4kbit/s

  not enough for Internet and multimedia applications

  => EDGE (Enhanced Data rate for GSM Evolution)

- ➢ Inappropriateness for aperiodic and non-symmetrical data traffic

  => GPRS (General Packet Radio Service)

  2.5G: Adding Packet Services: GPRS, EDGE

Introduction cont………

- 3G: UMTS
- 3G Architecture:

  Support of 2G/2.5G and 3G Access

  Handover between GSM and UMTS
- 3G Extensions:

  HSDPA(High Speed Downlink Packet Access)

Introduction Cont……..

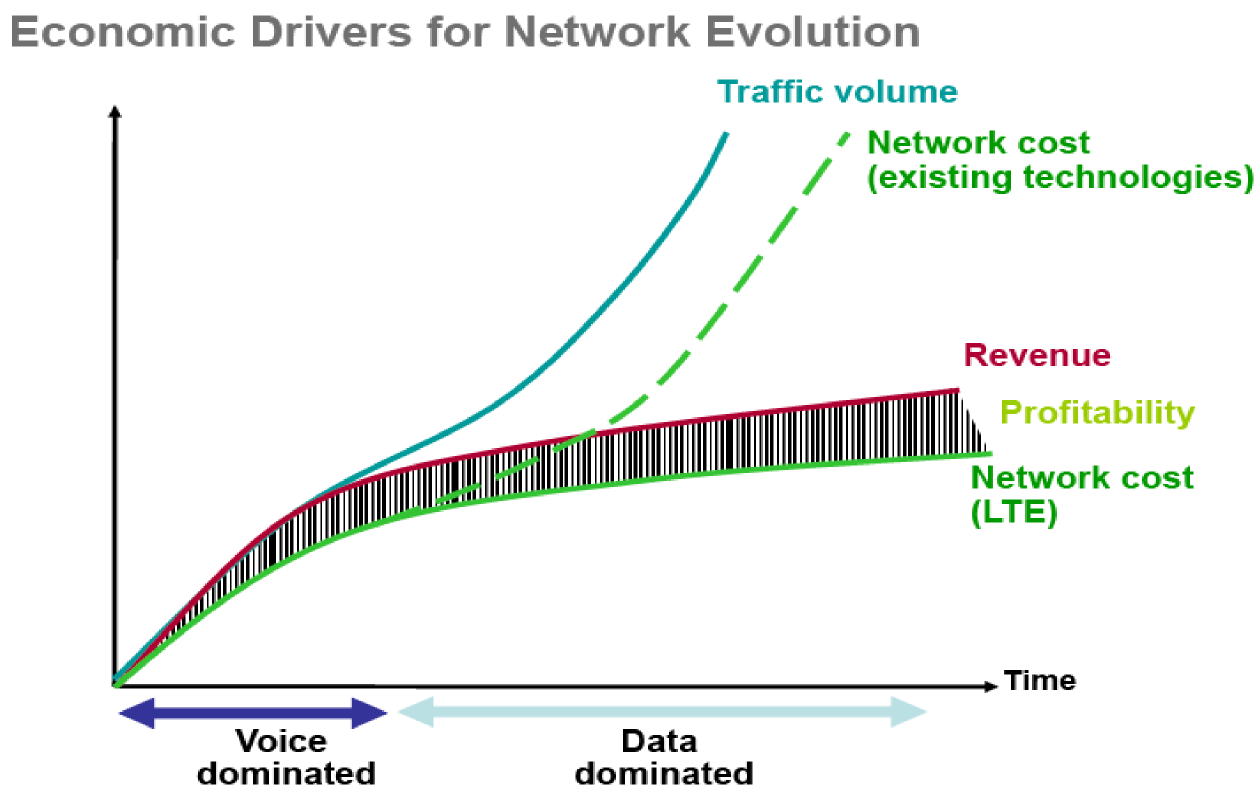
- The HSDPA provides very efficient packet data transmission capabilities, but UMTS should continue to be evolved to meet the ever-increasing demand of new applications and user expectations.
- 10 years have passed since the initiation of the 3G program and it is time to initiate a new program to evolve 3G which will lead to a 4G technology

Introduction Cont…..

The UMTS evolution should target:

- From the application/user perspectives
  - ➢ significantly higher data rates and throughput
  - ➢ lower network latency
  - ➢ support of always on-connectivity.
- From the operator perspectives :
  - ➢ provide significantly improved power and bandwidth efficiencies
  - ➢ facilitate the convergence with other networks/technologies
  - ➢ reduce transport network cost and limit additional complexity.

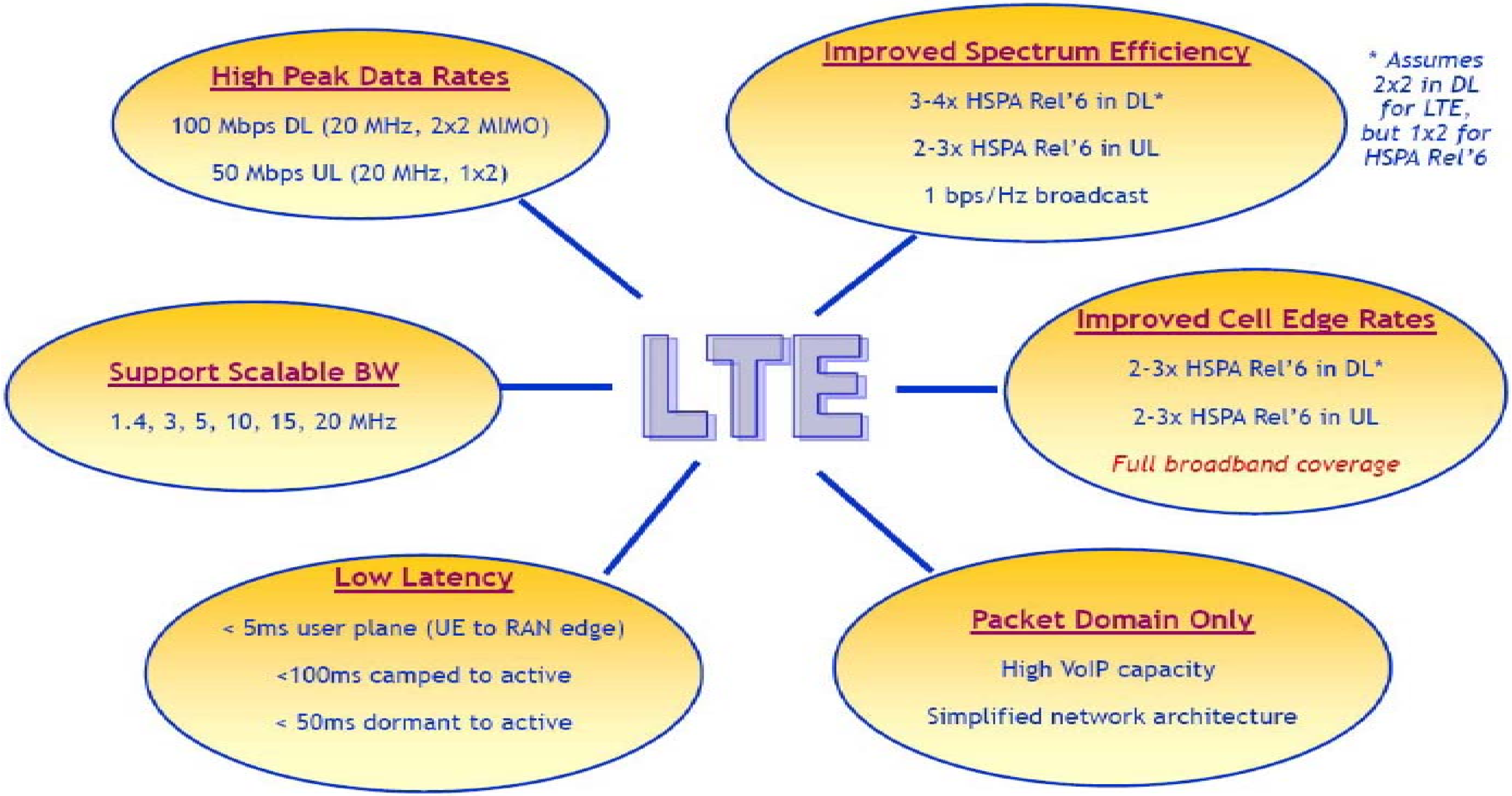
Introduction cont.....



- Led to 3GPP Study: "3GLong-term Evolution(LTE)" for new Radio Access and " System Architecture Evolution" (SAE) for Evolved Network.

Introduction Cont……

LTE Requirements and Performance Target



Introduction Cont..

- **Key Features of LTE to Meet Requirements**

❖ Selection of Orthogonal Frequency Division Multiplexing (OFDM) for the air interface

➢ less receiver complexity

➢ Robust to frequency selective fading and inter-symbol interference(ISI)

➢ Access to both time and frequency domain allows additional flexibility in scheduling (including interference coordination)

Introduction Cont..

- **Key Features of LTE to Meet Requirements**

➢ Scalable OFDM makes it straight forward to extend to different transmission band widths

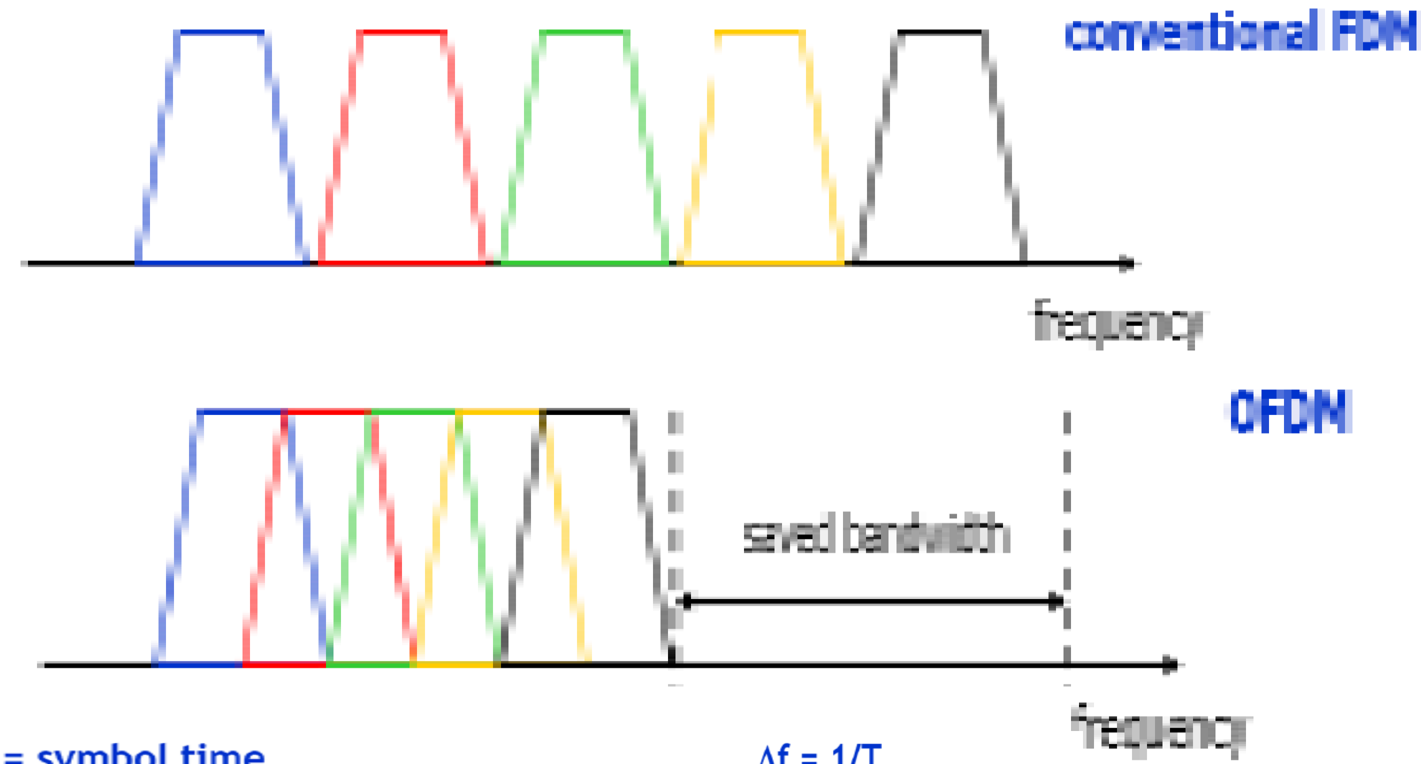
❖ Integration of MIMO techniques

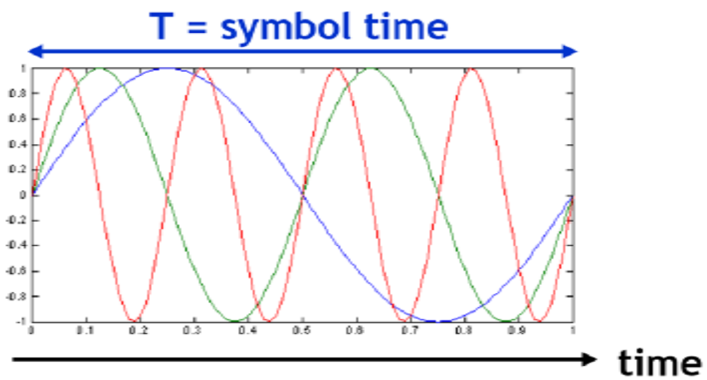
❖ Simplified network architecture reduction in number of logical nodes and clean separation of user and control plane

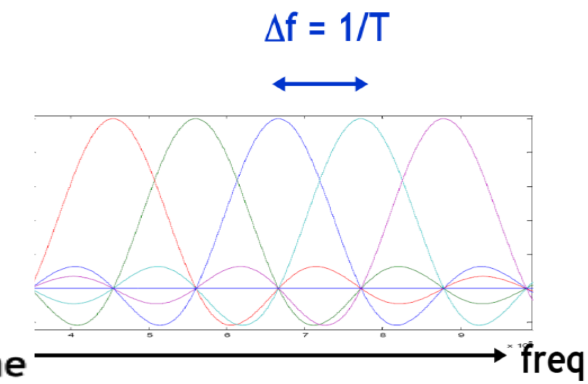
OFDM Basics

- OFDM: Orthogonal Frequency Division Multiplexing
- FDM/FDMA : carriers are separated sufficiently in frequency so that there is minimal overlap to prevent cross-talk
- OFDM: still FDM but carriers can actually be orthogonal (no cross-talk) while actually over lapping and specially designed to saved bandwidth.

OFDM Basics cont……………..

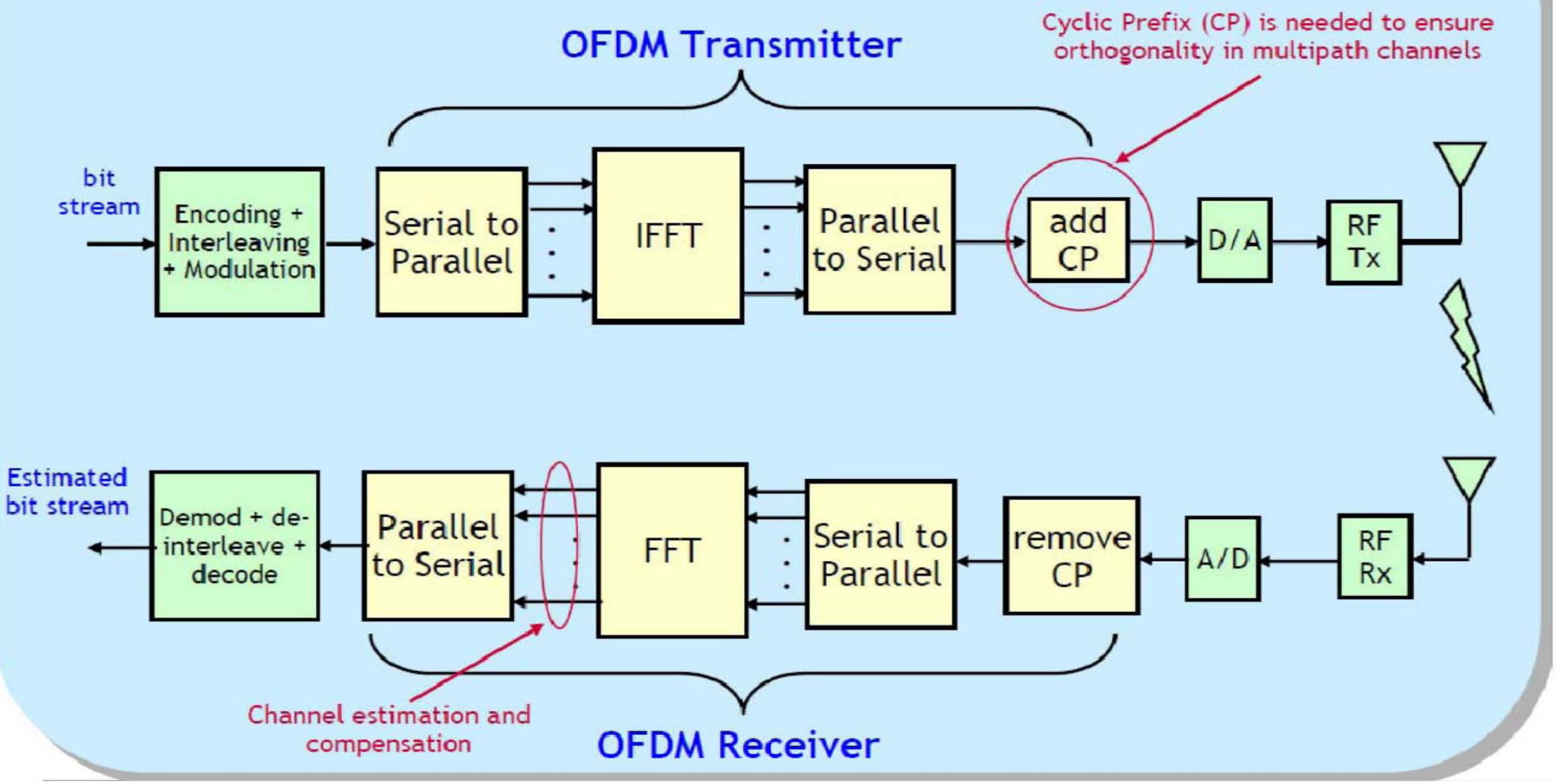




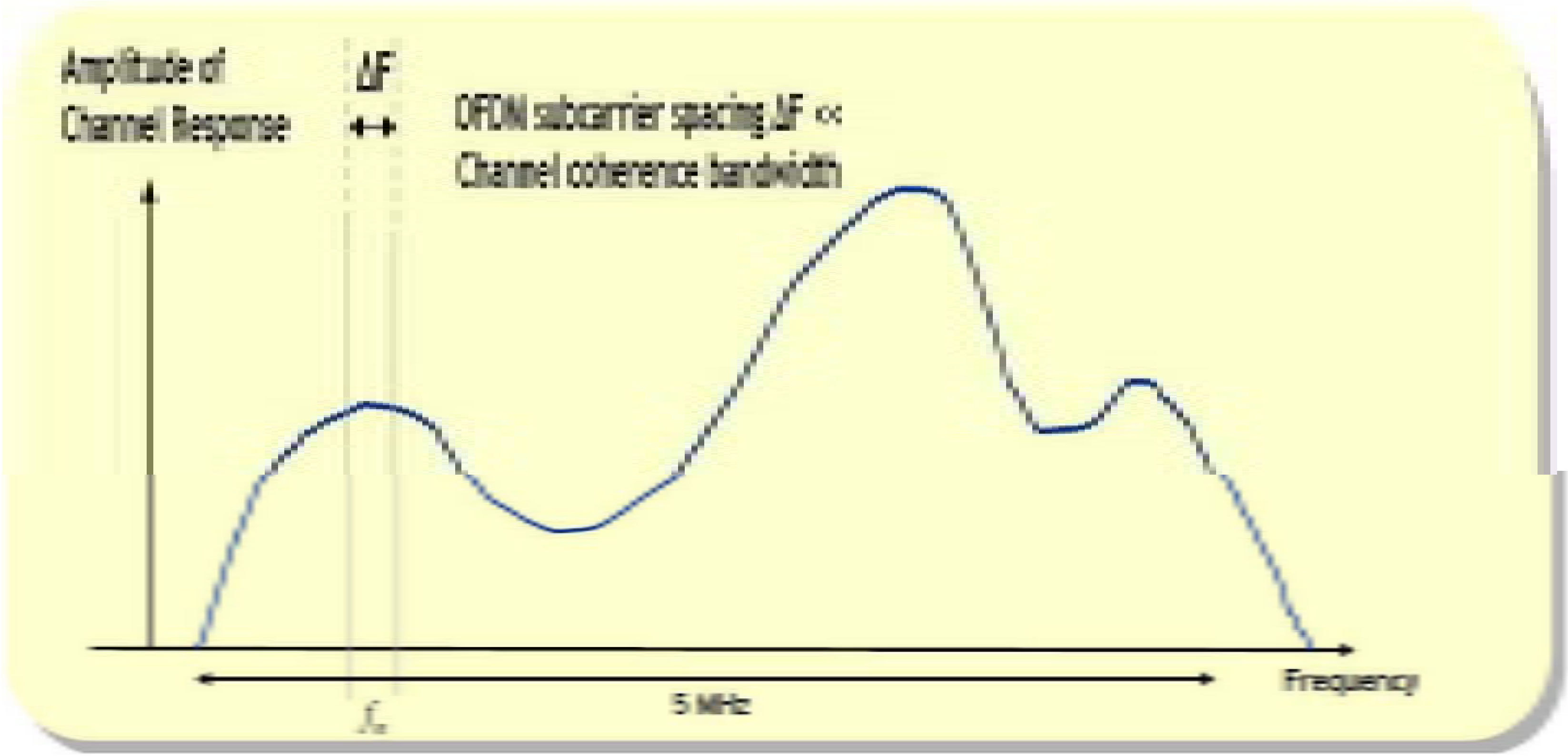


OFDM Basics cont……………..

- Modulating the symbols onto subcarriers can be done very efficiently in baseband using the **FFT** algorithm



OFDM Basics cont……………..



- can avoid to send symbols where channel frequency response is poor based on frequency selective channel knowledge

OFDM Basics cont……………..

OFDMA Concept

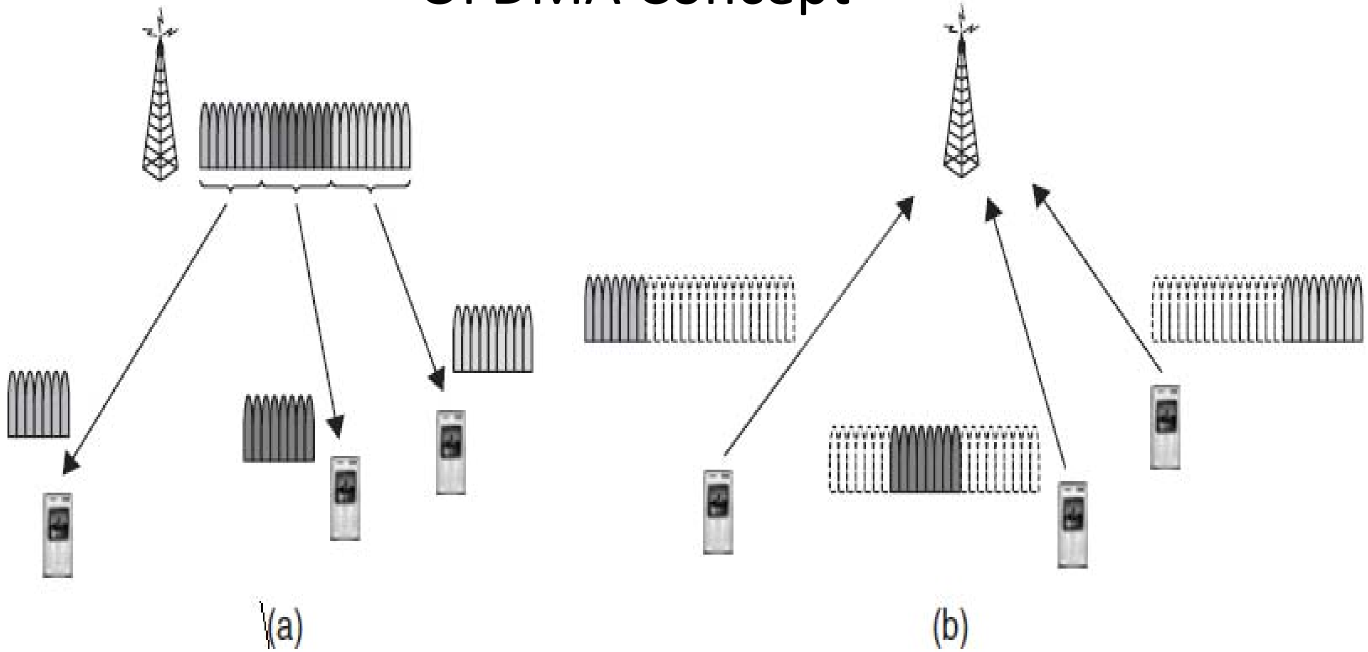
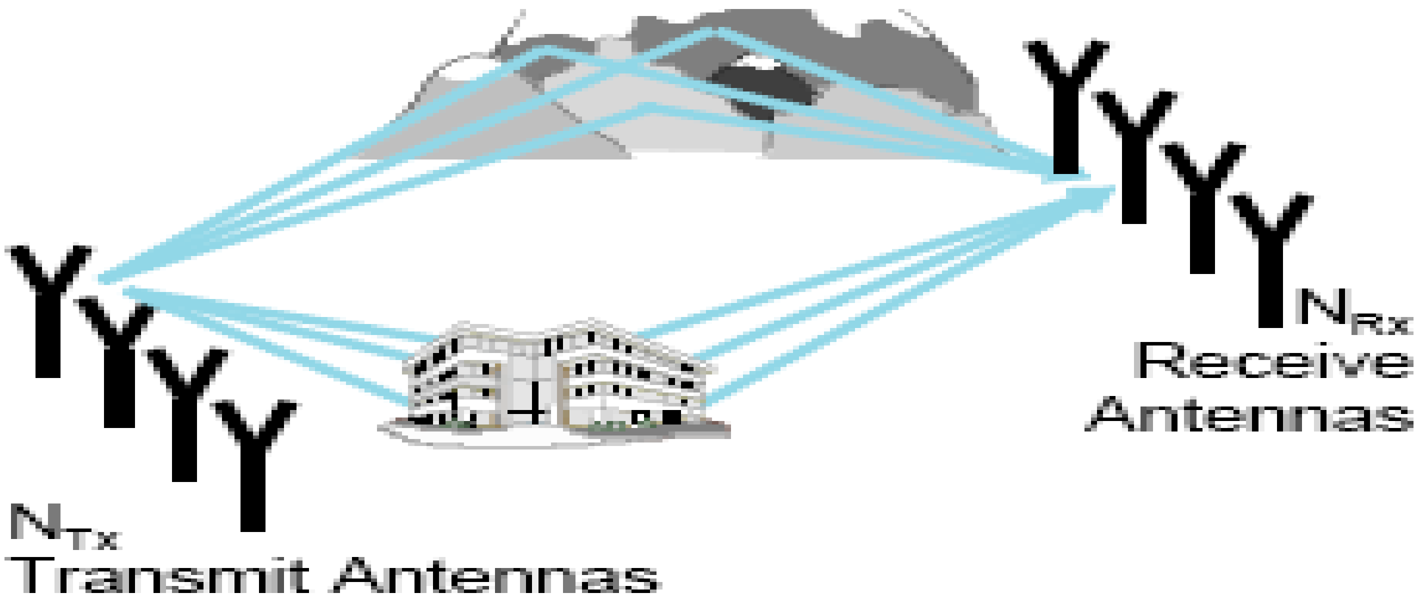


Figure: OFDM as a user-multiplexing/multiple-access scheme: (a) downlink and (b) uplink

MIMO- Multiple Antenna Schemes

- The transmitting end as well as the receiving end is equipped with multiple antenna elements.
- Transmission of several independent data streams in parallel over uncorrelated antennas .



MIMO-Mode of operation

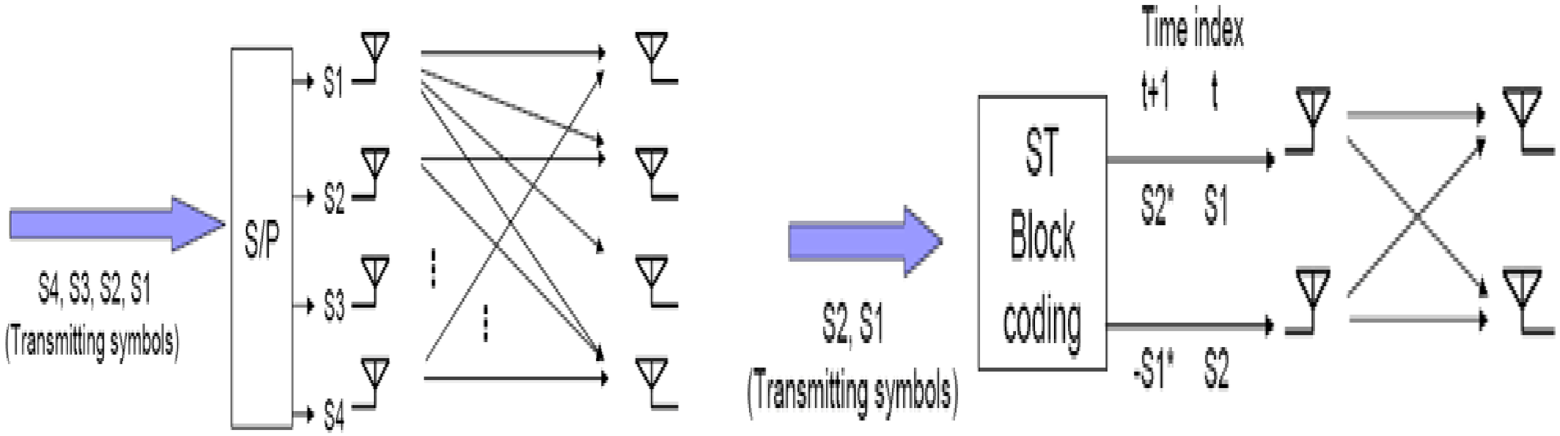


Figure : Spatial multiplexing and spatial diversity mode

- *Spatial multiplexing* :used to increase the data rate
- *spatial diversity mode:* to maximize range or reliability

MIMO-Mode of operation cont..

- Theoretical maximum rate increase factor = Min (N_{Tx} , N_{Rx}) in a rich scattering environment and no gain in a line-of-sight environment.

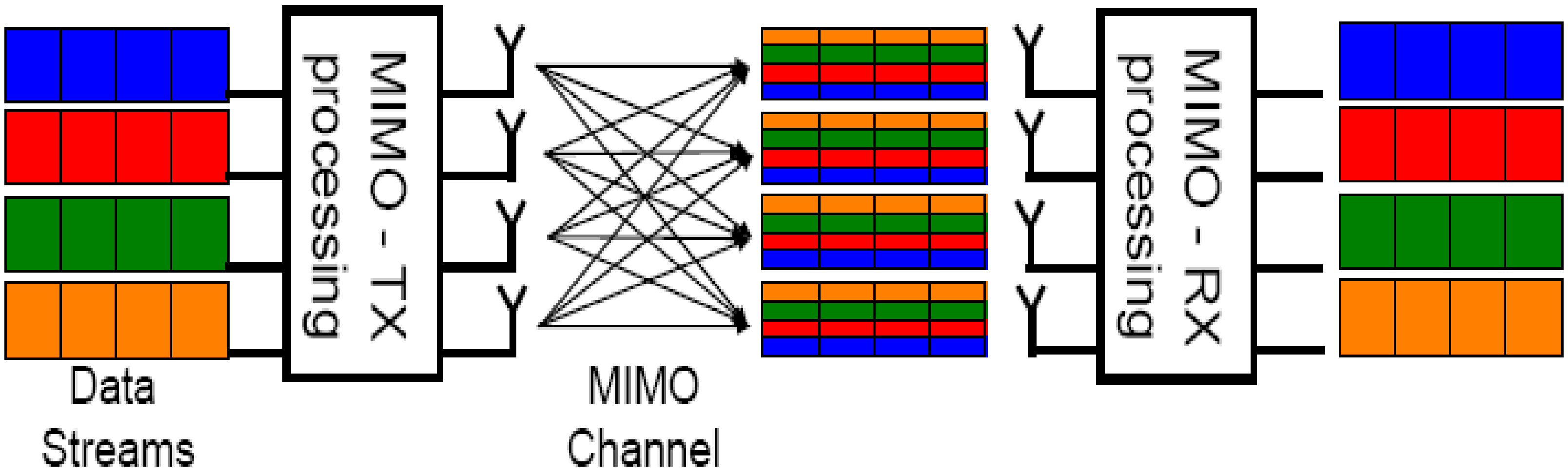
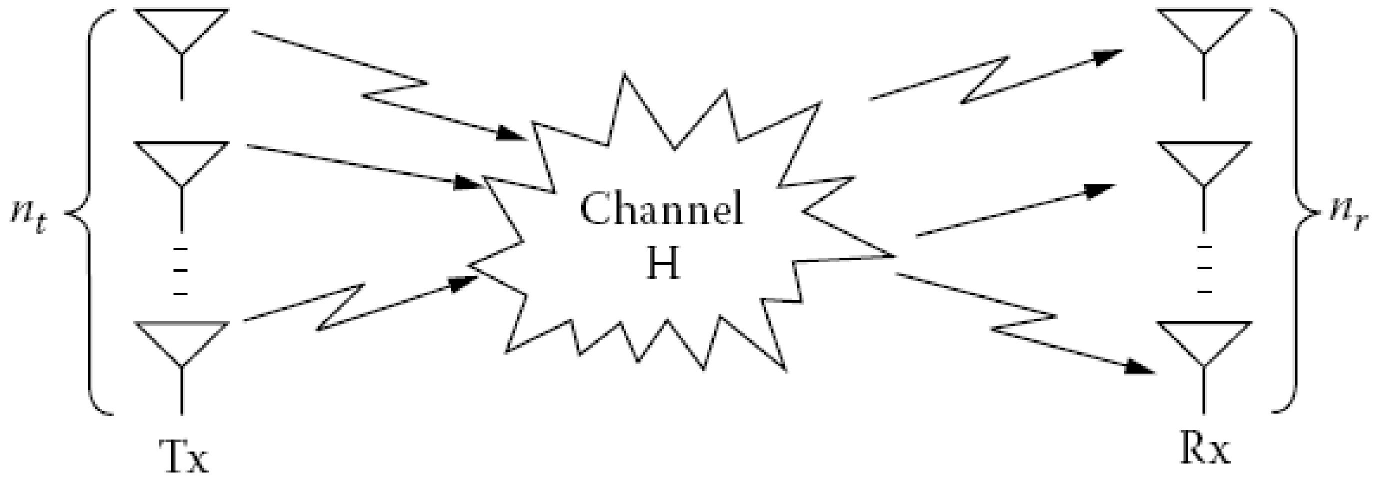


Figure: Basic operation of MIMO System

MIMO Cont….

- MIMO Channel Matrix



$$H(\tau,t)=\begin{bmatrix} h_{1,1}(\tau,t) & h_{1,2}(\tau,t)\ldots\ldots\ldots h_{1,n_t}(\tau,t) \\ h_{2,1}(\tau,t) & h_{2,2}(\tau,t)\ldots\ldots\ldots h_{2,n_t}(\tau,t) \\ \vdots & \vdots \qquad\qquad\qquad \vdots \\ h_{n_r,1}(\tau,t) & h_{n_r,2}(\tau,t)\ldots\ldots\ldots h_{n_r,n_t}(\tau,t) \end{bmatrix}$$

$$y(t)=H(\tau,t)\otimes s(t)+u(t)$$

MIMO-OFDMA

- OFDMA eliminates intra-cell interference (ICI), ISI, IFI and this is more resistive for frequency selective fading and MIMO system is used to provide diversity and it offers better resistance against fading. So combination of both MIMO and OFDMA provides better quality and capacity.
- MIMO OFDMA based cellular systems are currently being standardized by:

➢ 3GPP for LTE

➢ IEEE for WiMAX

- In parallel several research projects e.g. WINNER, MASCOT, SURFACE, are investing advanced MIMO-OFDMA transmission scheme for operating band width up to 100MHz.

MIMO-OFDMA cont…

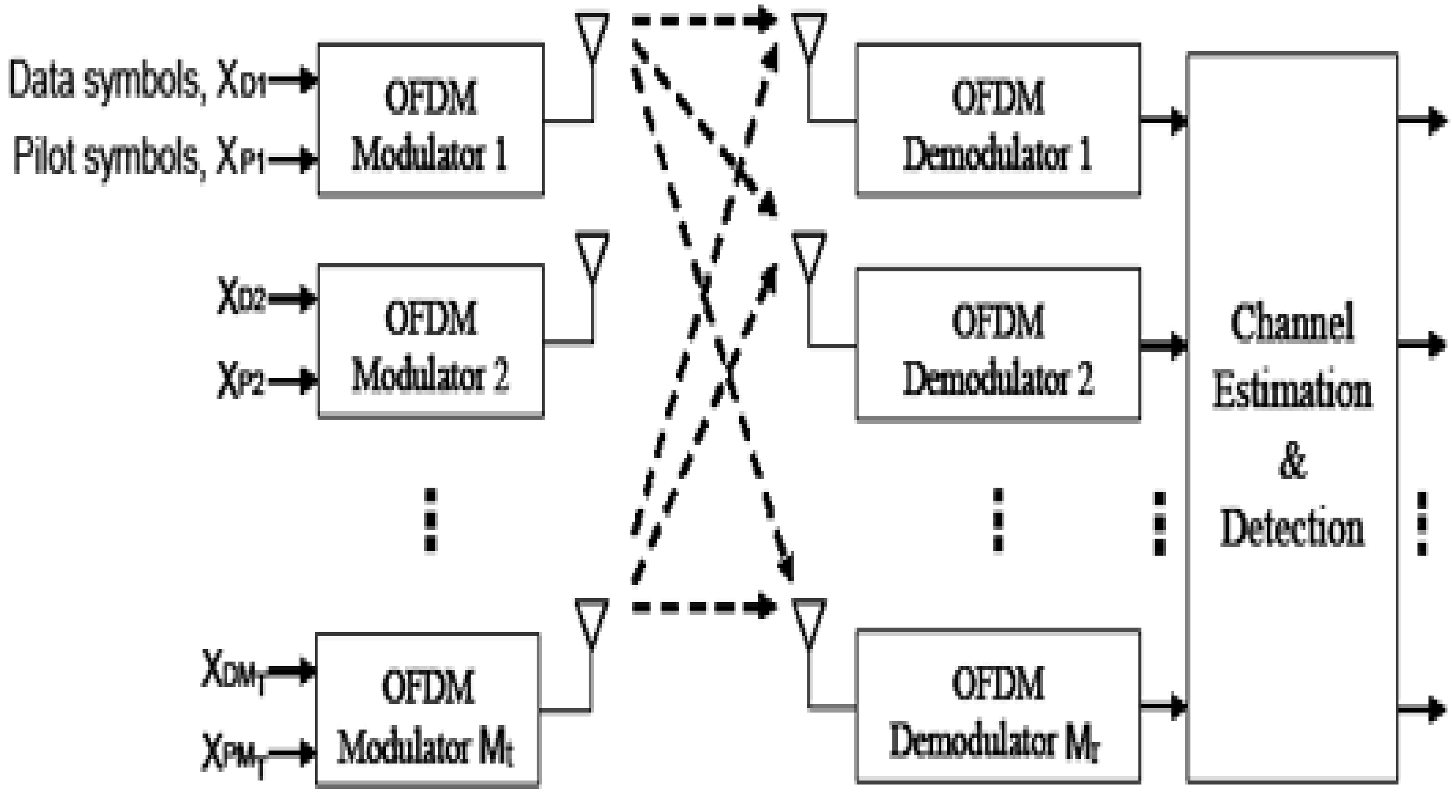


Figure: MIMO-OFDMA Block Diagram

MIMO-OFDMA Radio Resource Management (RRM)

- The problem of assigning the subcarriers, bits, time slots, and power to the different users in an MIMO- OFDMA system has been an area of active research over the past few years.
- Concept of adaptive modulation and coding in addition with multiuser diversity and proportional fair scheduling improve system performance.

MIMO-OFDMA Radio Resource Management (RRM) cont..

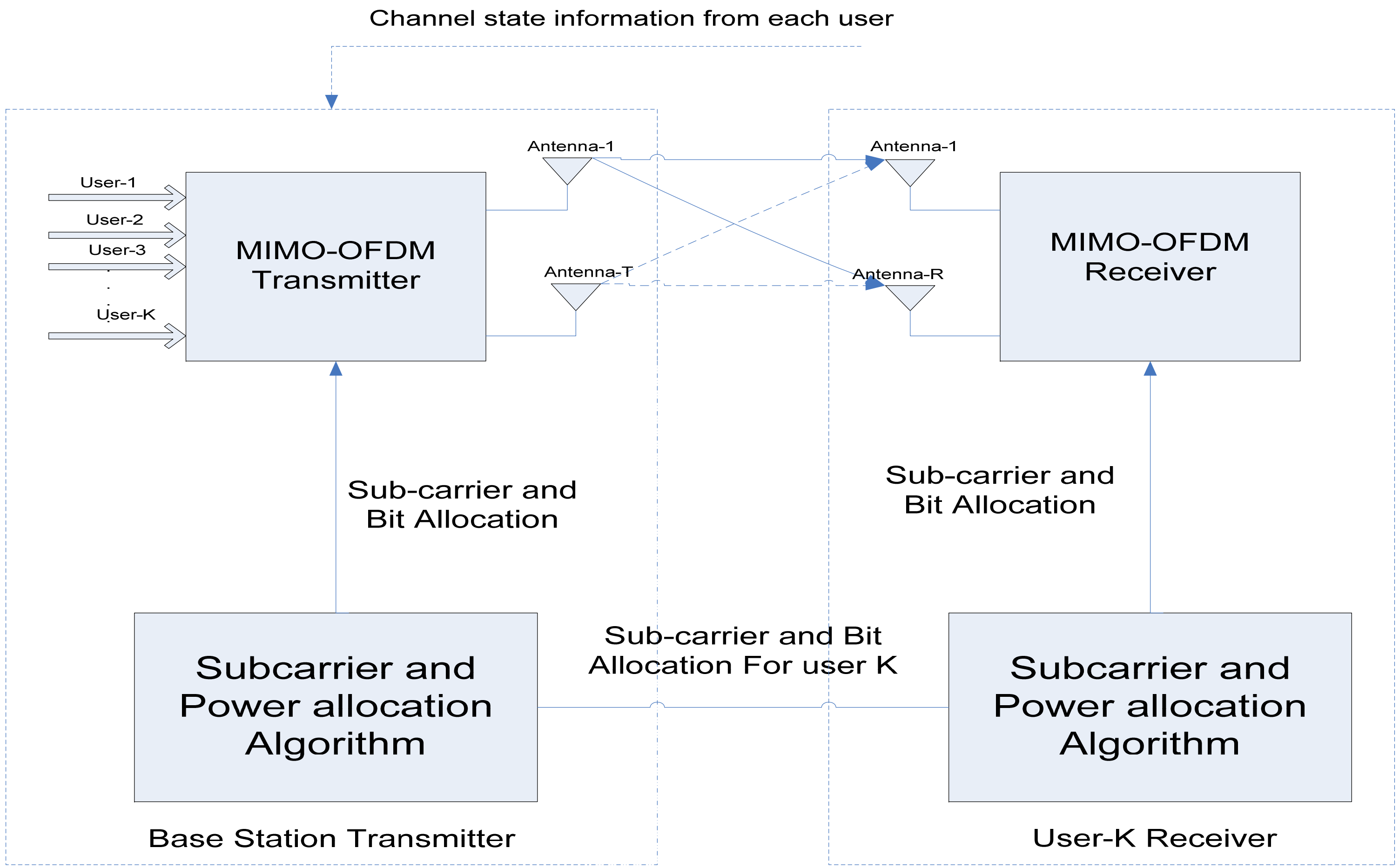


Figure: MIMO-OFDMA downlink block diagram

MIMO- OFDMA Channel Matrix

For a subcarrier *n* and user *k*

$$\overline{\overline{H}}_{k,n} = \begin{pmatrix} h_{1,1} & h_{1,2} & \cdots & h_{1,N_R} \\ h_{2,1} & . & & . \\ & & . & . \\ h_{N_T,1} & & \cdots & h_{N_T,N_R} \end{pmatrix}$$

Overall channel matrix

$$\overline{\overline{H}} = \begin{pmatrix} \overline{\overline{H}}_{1,1} & \overline{\overline{H}}_{1,2} & & \cdots & & \overline{\overline{H}}_{1,N} \\ \overline{\overline{H}}_{2,1} & . & & & & \overline{\overline{H}}_{2,N} \\ & & . & & & . \\ & & & \overline{\overline{H}}_{k,n} & & . \\ & & & & . & . \\ \overline{\overline{H}}_{K,1} & & & \cdots & & \overline{\overline{H}}_{K,N} \end{pmatrix}$$

Eigen value of $\overline{\overline{H}}_{k,n} \cdot \overline{\overline{H}}_{k,n}^{H}$ is $\left\{\lambda_{k,n}^{(i)}\right\}_{i=1,\ldots,M_{k,n}}$

number of channel elements are $K \times N \times N_T \times N_R$

Novel MIMO-OFDMA RRM Algorithm

Motivation

- All of the aforementioned approaches
  - focused on the physical layer transmission optimization for MIMO-OFDMA.
  - based on the only channel state information (CSI) at the transmitter.
  - resource allocation algorithm are not able to increase spectrum efficiency with maintaining required QoS
  - users priority is not considered
- There are no power, subcarrier, modulation level allocation algorithm which can consider both priority of user and channel information to increase QoS and capacity of the system.

System Model

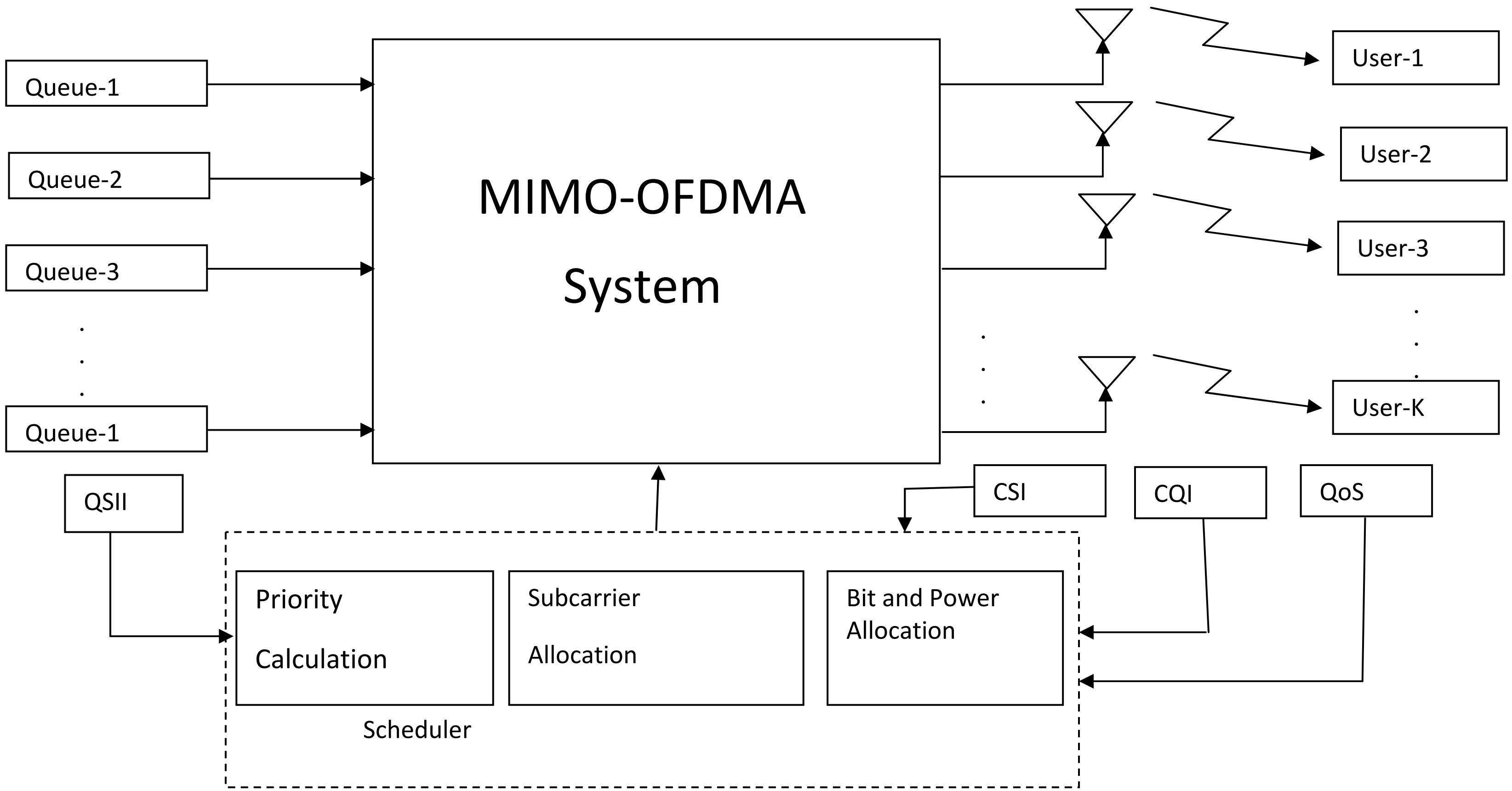


Figure: System model of purposed algorithm

System Model cont…

- MIMO channel can be transformed in to L parallel SISO eigen-mode sub-channel by using singular value decomposition technique (SVD)
- The signal to noise ration on the l_{th} sub channel of the n_{th} subcarrier can be expressed as:

$$SNR_l^n = \frac{P_l^n \left(\lambda_l^n\right)^2}{N_o B}$$

- This scheduling algorithm allocates resources dynamically based on user's QoS requirements, queuing status observed at the MAC layer and CSI observed at the physical layer.

Algorithm Description

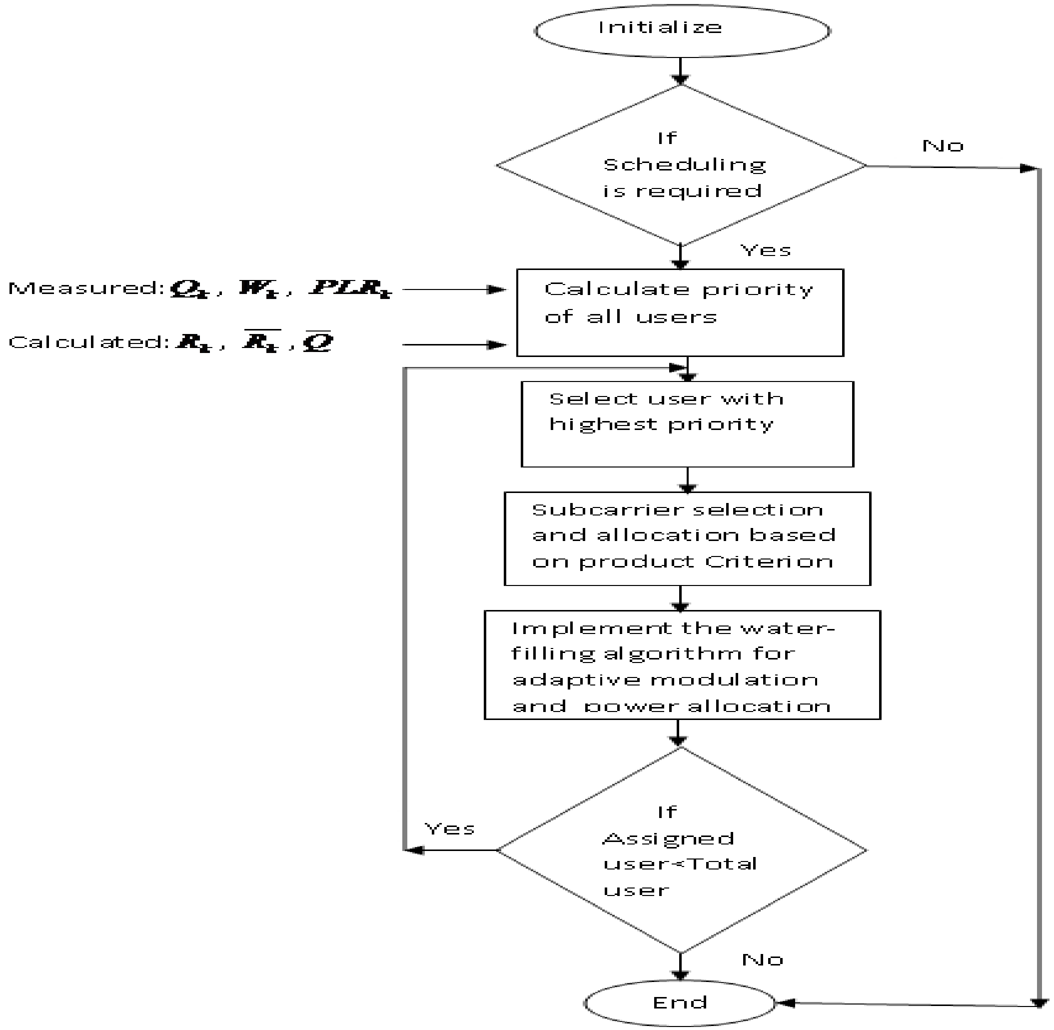


Fig: Algorithm of purposed scheduling technique

Priority Calculation

- *CSI factor:* $$f_1\left(CQI_k(t)\right) = \frac{\min\left(R_k(t), {Q_k(t)}\big/{T_s}\right)}{\overline{R_k}(t)}$$
- *QoS factor:* $$f_2\left(QoS_k(t)\right) = \frac{PLR_k}{PLR_{req,k}} \frac{W_k(t)}{W_{\max,k}}$$
- *QSI factor :* $$f_3\left(QSI_k(t)\right) = \frac{Q_k(t)}{\overline{Q}(t)}$$
- *Priority factor :* $$\mu_k(t) = f\left(CQI_k(t), QoS_k(t), QSI_k(t)\right)$$ $$= f_1\left(CQI_k(t)\right).f_2\left(QOS_k(t)\right).f_3\left(QSI_k(t)\right)$$ $$= \frac{\min\left(R_k(t)\right), Q_k(t)/T_s}{\overline{R_k}(t)} \frac{PLR_k}{PLR_{req,k}} \frac{W_k(t)}{W_{\max,k}} \frac{Q_k(t)}{\overline{Q}(t)}$$

Implementation Parameters

Parameters	Value
Number of transmit antenna (N)	4
Number of receive antenna (M)	2
System Band width	5MHz
Sub-channel Band Width	15KHz
Scheduling period	1ms
Target BER for water-filling algorithm	10^-6
BS height	30m
Total transmit power	20W
Noise density	3.9811e-21

Implementation of Algorithm

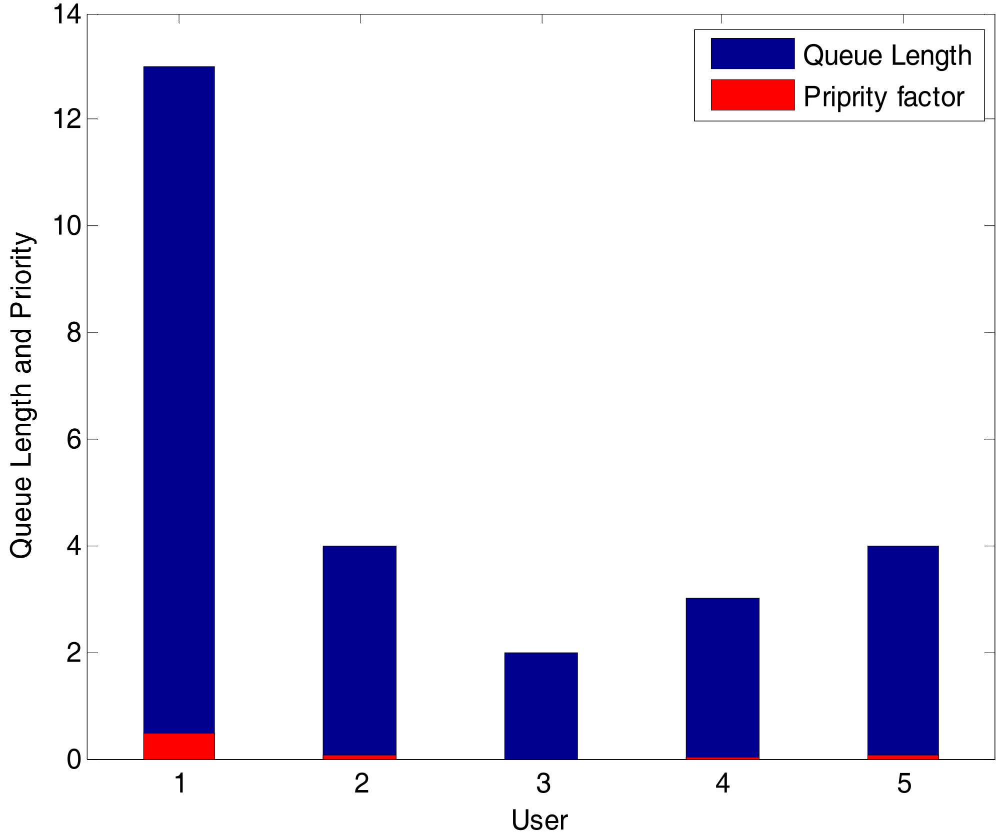


Figure : Queue length and priority factor of the different user.

Subcarrier Allocation

- subcarrier for each user is uniformly distributed
- the subcarrier allocation for the user is done by product-criterion

$$k_n^{(p)} = \arg\max_k \prod_{i=1}^{M_{kn}} \lambda_{kn}^{(i)}$$

- The over all subcarrier allocation for each user is based on the priority of the user and product criterion.

Subcarrier Allocation cont..

$$\begin{bmatrix} 8 & 30 & 15 & 29 & 10 & 23 \\ 20 & 24 & 18 & 3 & 32 & 26 \\ 6 & 5 & 7 & 21 & 19 & 9 \\ 17 & 2 & 16 & 25 & 11 & 13 \\ 4 & 27 & 1 & 28 & 31 & 22 \end{bmatrix}$$

An example of subcarrier distribution among user when number of subcarrier are 30

Power and Bit Allocation

- Power and bit allocation among users and subcarriers is done by water-filling algorithm
- This algorithm allocates bit and power adaptively
- allocation of subcarrier, bit and power for each user repeats for every scheduling period.

Power and Bit Allocation cont..

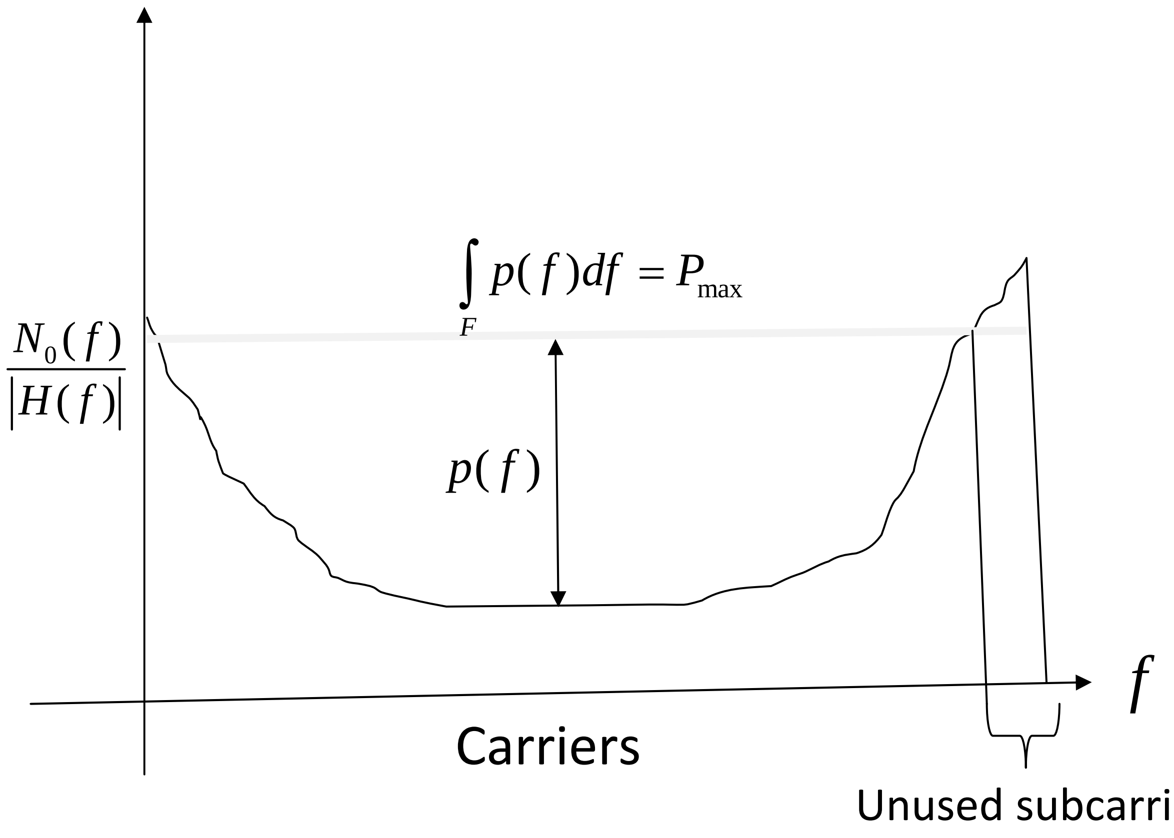


Figure: Basic concept of water filling algorithm

The principle of this method is very similar to pouring process of liquid in to a bowl .

Implementation of Algorithm cont..

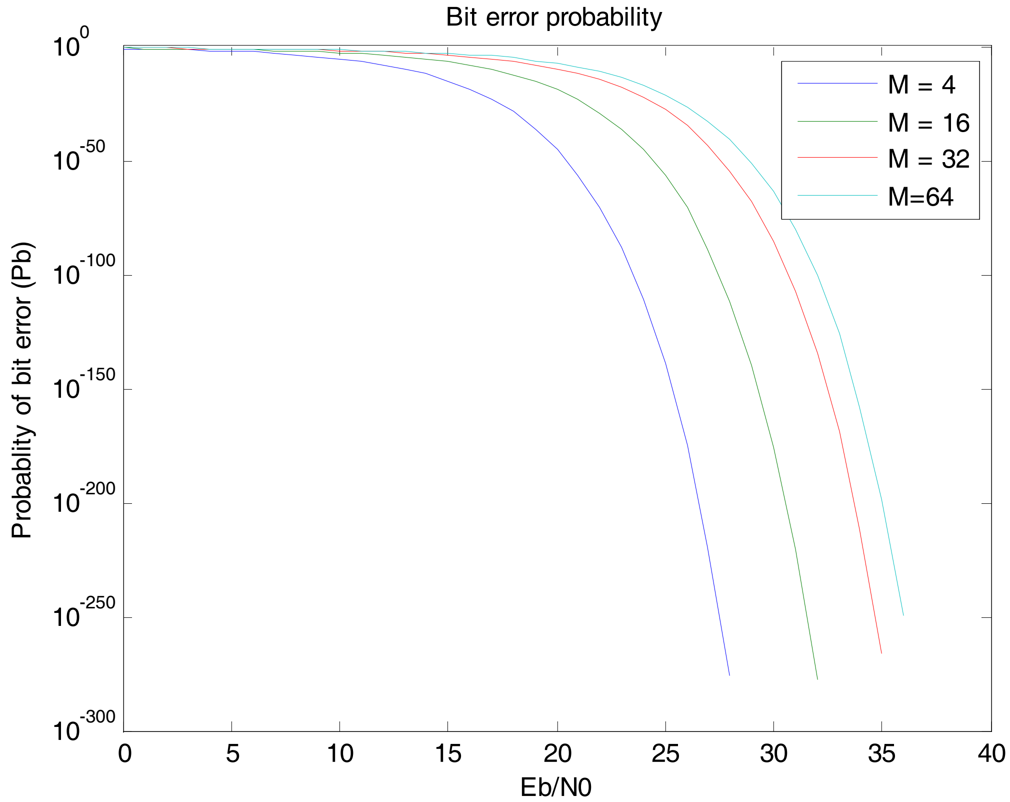


Figure : Adaptive modulation for Gaussian channel

Implementation of Algorithm cont..

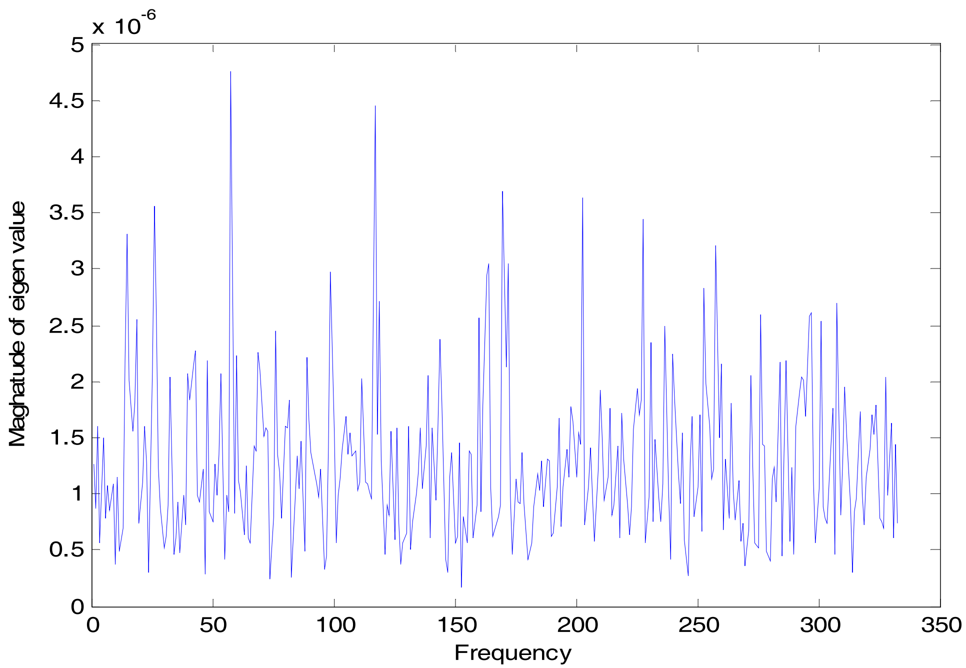


Figure : Response of a user on different subcarrier.

Implementation of Algorithm cont..

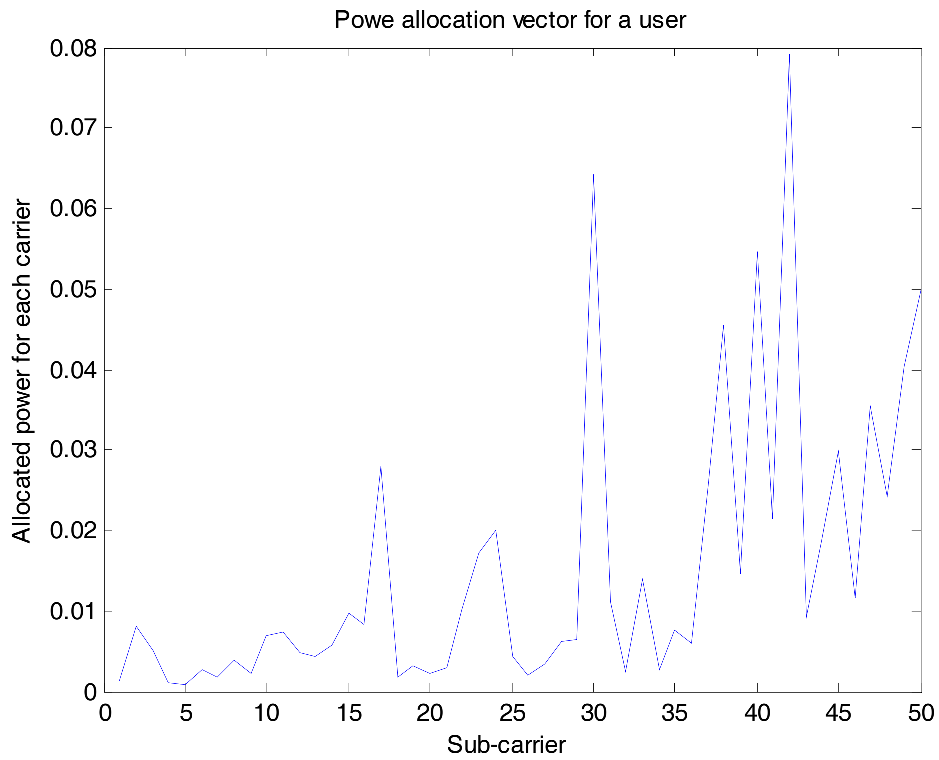


Figure : Power distribution for a user on different subcarrier at a particular time instant

Implementation of Algorithm cont..

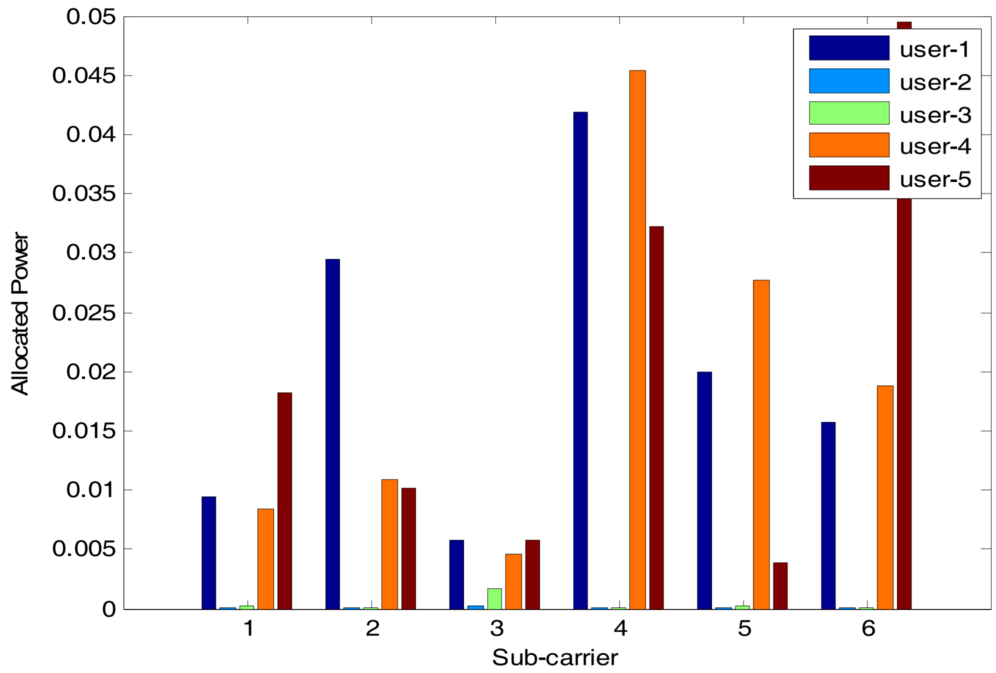


Figure : Power allocation level for each user on different subcarrier for single SISO sub-channel

Implementation of Algorithm cont..

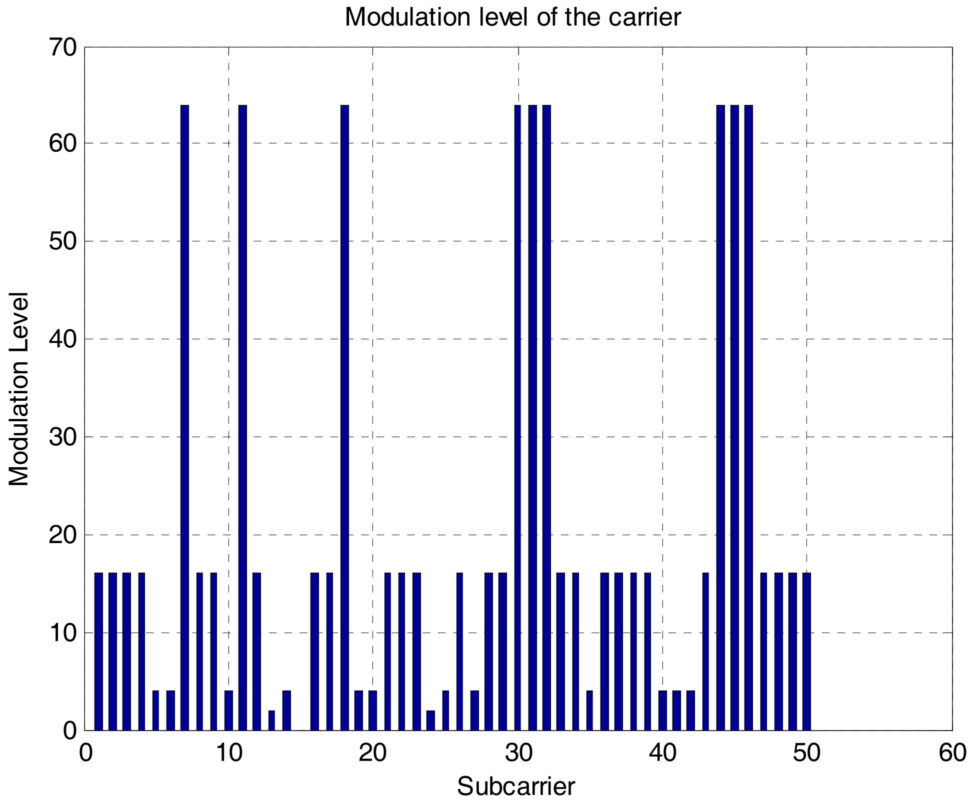


Figure : Adaptive modulation level for a user on different subcarrier

Implementation of Algorithm cont..

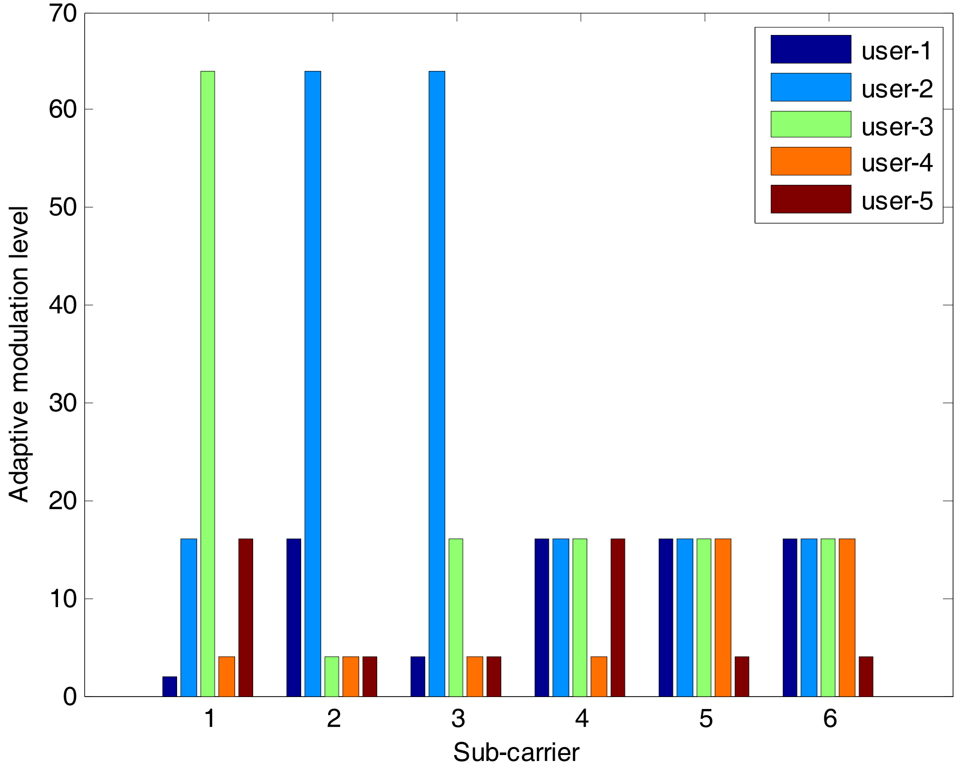


Figure : Adaptive Modulation for different user on different subcarrier

Implementation of Algorithm cont..

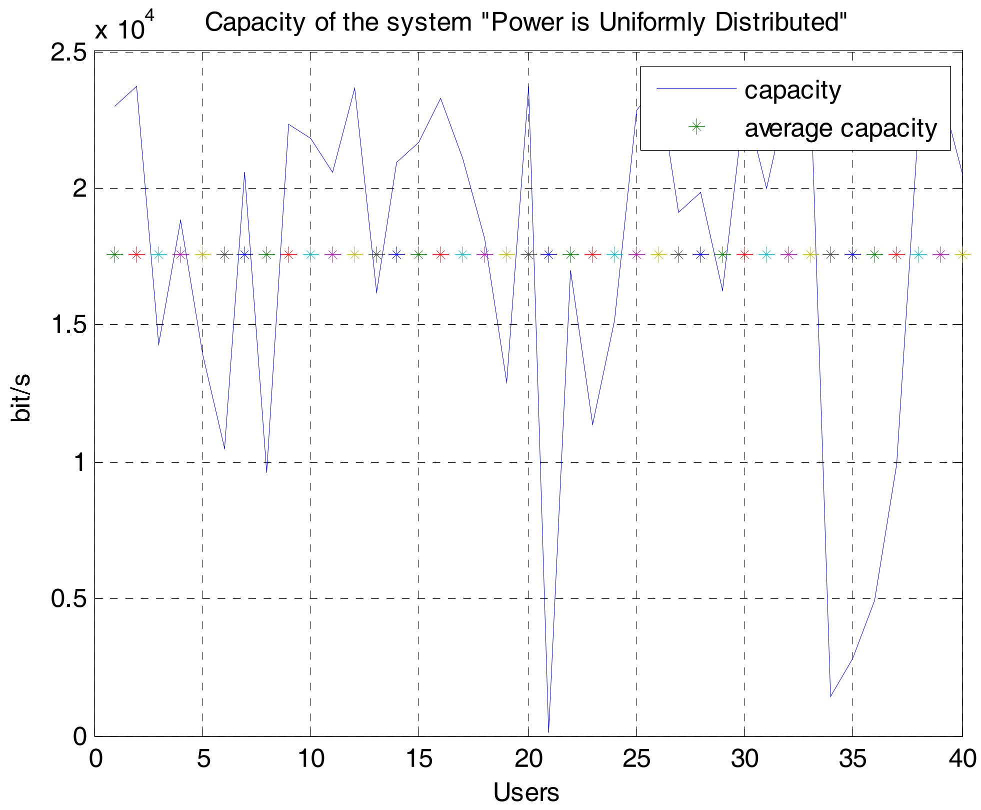


Figure : Capacity that the system can support when power is uniformly distributed

Implementation of Algorithm cont..

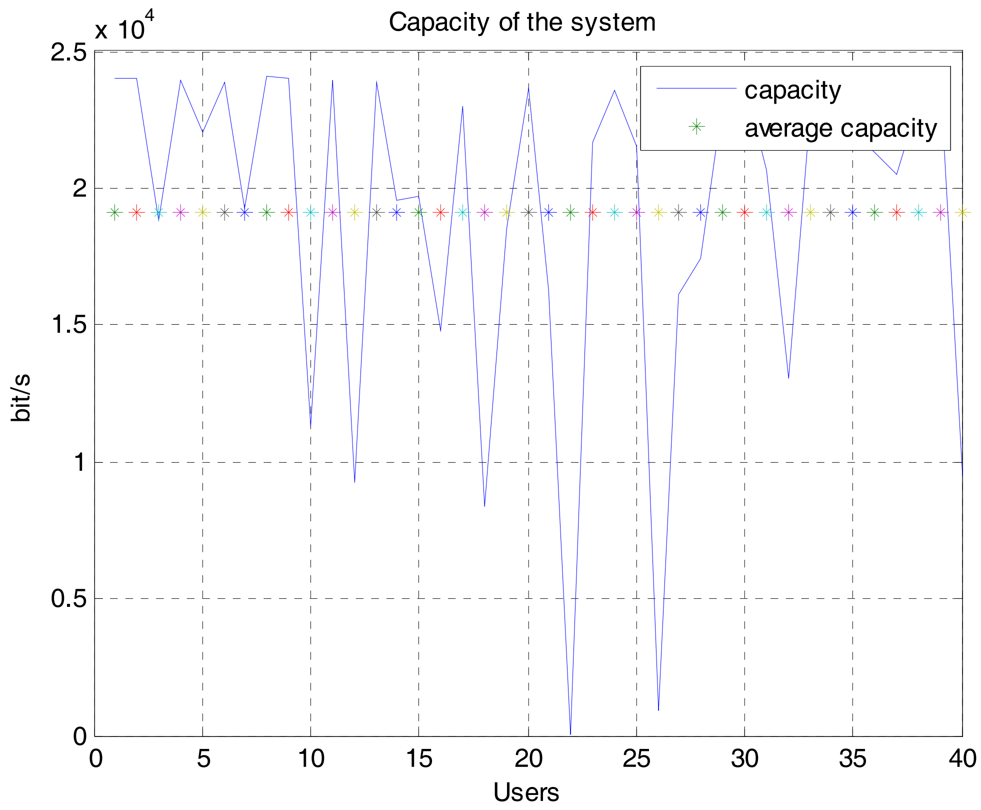


Figure : Capacity that the system can support when adaptive power allocation is used

Implementation of Algorithm cont..

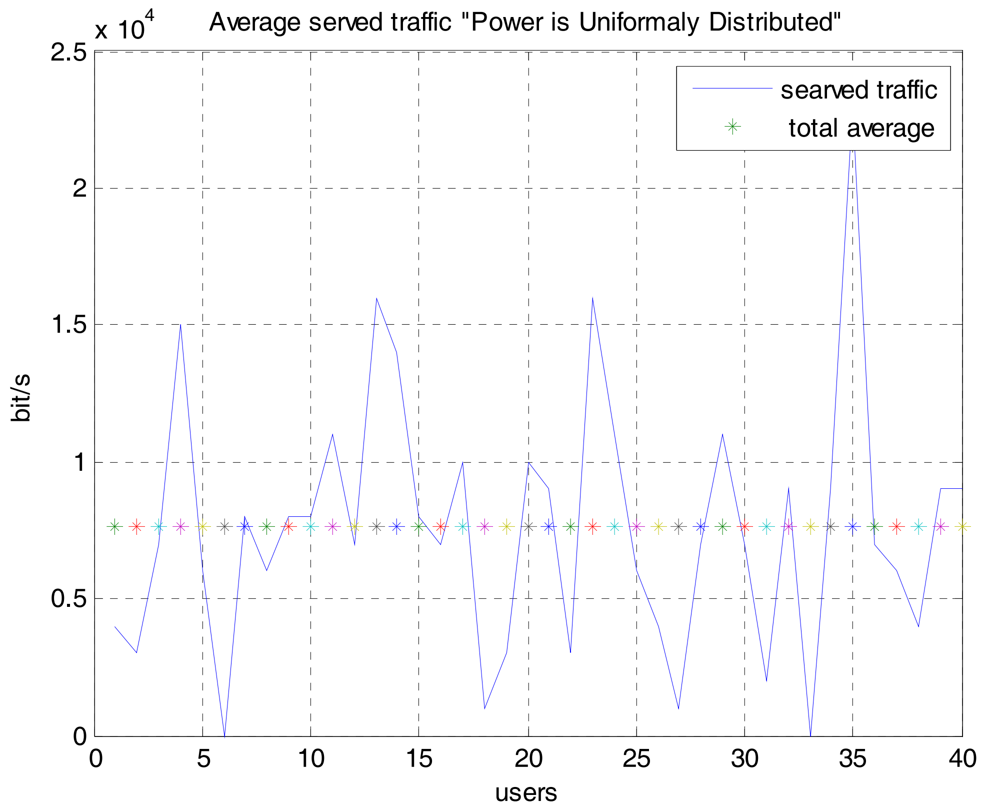


Figure : Average served traffic of the user when power is uniformly distributed

Implementation of Algorithm cont..

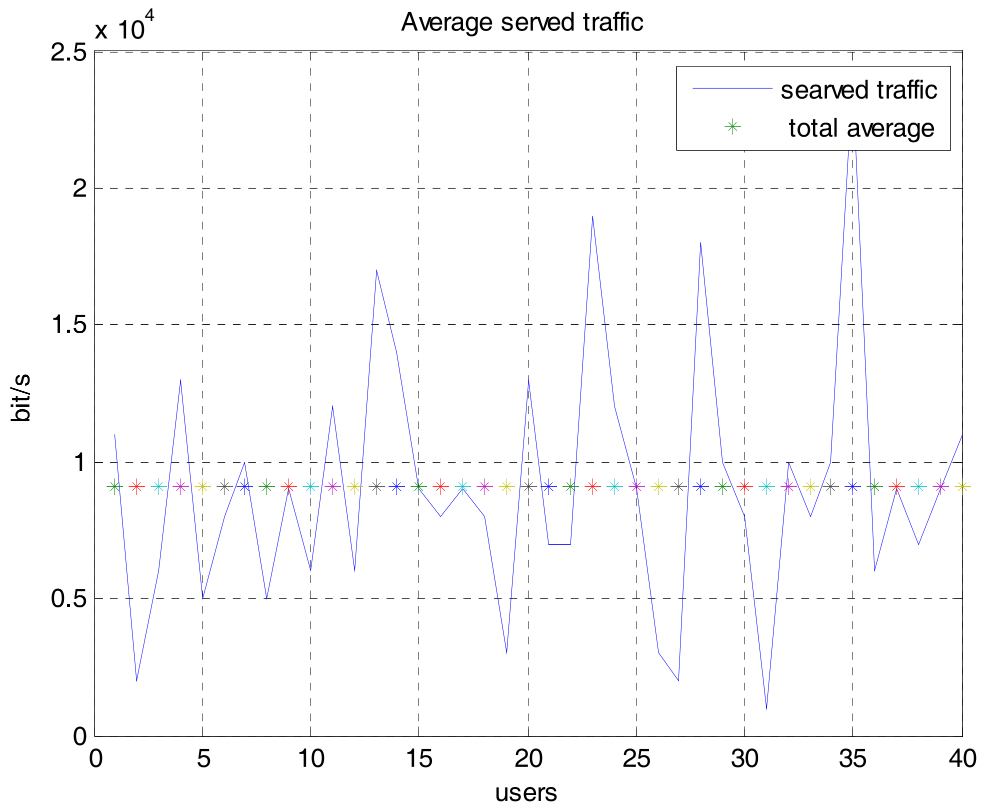


Figure : Average served traffic when power is adaptively controlled

Implementation of Algorithm cont..

- By considering the adaptive modulation and adaptive power allocation with priority of the user
- ➢ maximum (theoretical) capacity of the system is increased by 10.33%.
- ➢ served data rate of the system is increased by 20.37%
- This algorithm guarantee the required QoS of the user because adaptive modulation and power allocation algorithm is executed for required bit error probability.
- subcarrier allocation is also done by considering priority of the user i.e. all the users gets equal QoS.

Conclusion

- MIMO OFDMA based cellular systems are currently being standardized by: 3GPP for LTE and IEEE for WiMAX.
- Required QoS for each user is guaranteed by considering the priority factor of the users and required BER.
- Adaptive power allocation bit loading is implemented.
- capacity of purposed algorithm is increased dramatically compared to other existing algorithm.

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Thank You for Attention!!!